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Science and Technology Issues in the 117th Congress

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SUMMARY

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The federal government supports scientific and technological advancement directly by funding and performing research and development, and indirectly by creating and maintaining policies that encourage private sector efforts. Additionally, the federal government regulates many aspects of S&T activities. This report briefly outlines a key set of science and technology policy issues that may come before the 117th Congress.

Many of these issues carry over from previous Congresses, and represent areas of continuing Member interest. Examples include policies on taxation, trade, intellectual property, commercialization of basic scientific research and other overarching issues that affect scientific and technological progress. Other issues may represent new or rapidly evolving areas affected by the threats of pandemic diseases, climate change, and malicious cyber activities, among others. Examples covered in this report include infectious disease modeling and forecasting, digital contact tracing and digital exposure notification, hydrogen pipelines, and expansion of emerging information and communications technologies such as 5G.

These and other S&T-related issues that may come before the 117th Congress are grouped into 10 categories.

- Overarching S&T Policy Issues,
- Agriculture,
- Biotechnology and Biomedical Research and Development,
- Climate Change and Water,
- Defense,
- Energy,
- Homeland Security,
- Information Technology,
- Physical and Material Sciences, and
- Space.

Each of these categories includes concise analysis of multiple policy issues. The material presented in this report should be viewed as illustrative rather than comprehensive. Each section identifies CRS reports, when available, and the appropriate CRS experts to contact for further information and analysis.

Contents

Contacts

Overarching Science and Technology Policy Issues

This section provides an overview of the federal science and technology (S&T) policymaking enterprise, followed by discussion of several issues that the enterprise currently addresses. These issues include federal funding for research and development; the adequacy of the science and engineering workforce; the role of tax incentives in promoting advancement of science and technology; federal scientific integrity policies; technology transfer from federal laboratories; research and development security; the role of technical standards in federal trade policy; and intellectual property law.

Federal Science and Technology Policymaking Enterprise

The federal S&T policymaking enterprise is composed of an extensive and diverse set of stakeholders in the executive, legislative, and judicial branches. The enterprise fosters, among other things, the advancement of scientific and technical knowledge; science, technology, engineering, and mathematics (STEM) education; the application of S&T to achieve economic, national security, and other societal benefits; and the use of S&T to improve federal decisionmaking.

Federal responsibilities for S&T policymaking are highly decentralized. Many House and Senate committees have jurisdiction over important elements of S&T policy. In addition, congressional appropriations committees provide funding for federal agency S&T programs. Congress also enacts laws to establish, refine, and eliminate programs, policies, regulations, regulatory agencies, and regulatory processes that affect science, technology, and engineering research and development (R&D) or rely on S&T data and analysis. However, congressional authorities related to S&T policymaking are diffuse. In addition, there are dozens of informal congressional caucuses in areas of S&T policy such as R&D, specific S&T disciplines, and STEM education.

The President formulates annual budgets, policies, and programs for consideration by Congress; issues executive orders and directives; and directs the executive branch departments and agencies responsible for implementing S&T policies and programs. The Office of Science and Technology Policy (OSTP), in the Executive Office of the President, advises the President and other Administration officials on S&T issues.

Executive agency S&T responsibilities are also diffuse. Some agencies have broad S&T responsibilities (e.g., the National Science Foundation). Others use S&T to meet a specific federal mission (e.g., defense, energy, health, space). Regulatory agencies have S&T responsibilities in areas such as nuclear energy, food and drug safety, and environmental protection.

Federal court cases and decisions often affect U.S. S&T policy. Decisions can have an impact on the development of S&T (e.g., decisions regarding the U.S. patent system); S&T-intensive industries (e.g., the break-up of AT&T in the 1980s); and the admissibility of S&T-related evidence (e.g., DNA samples).

For Further Information

John F. Sargent Jr., Specialist in Science and Technology Policy

CRS Report R43935, *Office of Science and Technology Policy (OSTP): History and Overview*, by John F. Sargent Jr. and Dana A. Shea

Federal Funding for Research and Development

The federal government has long supported the advancement of scientific knowledge and technological development through investments in R&D, which have led to scientific breakthroughs and new technologies, from jet aircraft and the internet to communications satellites and defenses against disease. Federal R&D funding seeks to address a broad range of national interests, including national defense, health, safety, the environment, and energy security; advance knowledge generally; develop the scientific and engineering workforce; and strengthen U.S. innovation and competitiveness.

Between FY2008 and FY2013, federal R&D funding fell from $140.1 billion to $130.9 billion in current dollars, a reduction of $9.3 billion (6.6%). The decline was a reversal of sustained growth in federal R&D funding for more than half a century, and stirred debate about the potential long-term effects on U.S. technological leadership, innovation, competitiveness, economic growth, and job creation. From FY2013 to FY2017, federal funding grew, rising to an all-time current dollar high of $155.0 billion in FY2017.

A change in R&D accounting by the Office of Management and Budget to exclude certain late-stage development activities (primarily at the Department of Defense and NASA) from total federal R&D calculations obscures comparison of funding levels for FY2018 and later years to funding from FY2017 and earlier years. As calculated by OMB, current dollar federal R&D funding was $135.8 billion in FY2018, $140.1 billion in FY2019, and $156.0 billion in FY2020. Concerns by some about the adequacy of federal R&D funding have been exacerbated by increases in the R&D investments of other nations (China, in particular); globalization of R&D and manufacturing activities; and trade deficits in advanced technology products, an area in which the United States previously ran trade surpluses (most recently in 2001). In addition, R&D funding decisions may be affected by differing perspectives on the appropriate role of the federal government in advancing science and technology.

As the 117th Congress undertakes the appropriations process it may consider two overarching issues: (1) the level of federal R&D investment and (2) how available funding will be prioritized and allocated. Low or negative growth in the federal government's overall R&D investment may require movement of resources across disciplines, programs, or agencies to address priorities. Congress continues to play a central role in defining the nation's R&D priorities as it makes decisions with respect to the size and distribution of aggregate, agency, and programmatic R&D funding.

For Further Information

John F. Sargent Jr., Specialist in Science and Technology Policy

CRS Report R46341, *Federal Research and Development (R&D) Funding: FY2021*, coordinated by John F. Sargent Jr.

CRS Report R45715, *Federal Research and Development (R&D) Funding: FY2020*, coordinated by John F. Sargent Jr.

Adequacy of the U.S. Science and Engineering Workforce

The adequacy of the U.S. science and engineering (S&E) workforce has been an ongoing concern of Congress for more than 70 years. Scientists and engineers are widely believed to be essential to U.S. technological leadership, innovation, manufacturing, and services, and thus vital to U.S. economic strength, national defense, and other societal needs. Congress has enacted many programs to support the education and development of scientists and engineers. Congress has also

undertaken broad efforts to improve science, technology, engineering, and math skills to prepare a greater number of students to pursue S&E degrees. In addition, some policymakers have sought to increase the number of foreign scientists and engineers working in the United States through changes in visa and immigration policies.

Most experts agree that there is no authoritative definition of which occupations comprise the S&E workforce. Rather, the selection of occupations included in any particular analysis of the S&E workforce may vary depending on the objective of the analysis. The policy debate about the adequacy of the U.S. S&E workforce has focused largely on professional-level computer occupations, mathematical occupations, engineers, and physical scientists. Accordingly, much of the analytical focus has been on these occupations. However, some analyses may use a definition that includes some or all of these occupations, as well as life scientists, S&E managers, S&E technicians, social scientists, and related occupations.

Many policymakers, business leaders, academics, S&E professional society analysts, economists, and others hold differing views with respect to the adequacy of the S&E workforce and related policy issues. These issues include the question of the existence of a shortage of scientists and engineers in the United States, what the nature of any such shortage might be (e.g., too few people with S&E degrees, mismatches between skills and needs), and whether the federal government should undertake policy interventions or rely upon market forces to resolve any shortages in this labor market. Among the key indicators used by labor economists to assess the existence of occupational labor shortages are employment growth, wage growth, and unemployment rates.

For Further Information

John F. Sargent Jr., Specialist in Science and Technology Policy

CRS Report R43061, *The U.S. Science and Engineering Workforce: Recent, Current, and Projected Employment, Wages, and Unemployment*, by John F. Sargent Jr.

Tax Incentives for Technological Innovation

The 117th Congress may consider new federal policies to promote technological innovation, considered a key contributor to long-term economic growth.

In general, companies are unlikely to invest as much in R&D as the resulting social benefits might warrant because aggregate social benefits are often not realized as direct monetary returns on R&D investment to companies. Economists regard underinvestment in R&D as a market failure, which can be remedied through various kinds of government intervention.

One way many governments address this issue is to provide tax incentives for business R&D investment. The federal government offers two such incentives. One is a research tax credit under Section 41 of the Internal Revenue Code (IRC), and the other is an expensing allowance for the full amount of qualified expenses under Section 174. There are two options for the credit: (1) 20% of qualified expenses above a base amount, or (2) 14% of qualified expenses above a different base amount. Section 174 expensing is scheduled to expire at the end of 2021, and starting in 2022, qualified research costs would have to be amortized over five years.

The loss of an expensing option for research expenses is likely to raise the user cost of capital for R&D investments and reduce cash flow for firms investing in R&D. Critics of the current research tax credit argue that it should be altered in two ways. First, they say the credit's rate should be increased so it might stimulate large, sustained increases in business R&D. Second, in recognition of the key role played by young, small firms in the innovation process, critics

advocate making the credit fully refundable for small research-intensive startup firms in their early years, when many of them are likely to have operating losses, and thus no tax liability.

For Further Information

Gary Guenther, Analyst in Public Finance

CRS Report RL31181, *Research Tax Credit: Current Law and Policy Issues for the 114th Congress*, by Gary Guenther

CRS Report R44829, *Patent Boxes: A Primer*, by Gary Guenther

Federal Scientific Integrity Policies

The results of research and development (R&D) help inform the decisions that policymakers and the public reach on a wide range of issues, including human health and safety, the environment, agriculture, energy, and transportation. For example, scientific information is essential to the review and approval of drugs and medical devices and the setting of air quality standards. There is broad agreement among policymakers and the scientific and engineering community about ensuring the integrity of the conduct, communication, and management of R&D, and its use in policy development and decisionmaking. However, some policymakers and others allege that presidential administrations of both parties have violated principles of scientific integrity.

Assertions of such violations include weighting the membership of federal advisory committees toward a particular viewpoint or constituency, targeting individual scientists for harassment or adverse actions, appointing agency officials with significant conflicts of interest or antagonistic views toward an agency's mission or neutrality to science, improperly editing scientific documents, and using the budget process to impede the implementation or formulation of science-based policies.

Following the guidance of a 2010 memorandum issued by the Office of Science and Technology Policy, more than 20 federal departments and agencies have developed and implemented scientific integrity policies. There is, however, no uniform definition of scientific integrity across the federal government. Some experts have expressed concern over the variation in scope and specificity of federal agency scientific integrity policies and recommended that Congress enact scientific integrity legislation that would create a clear set of standards and mechanisms for enforcement. The 117th Congress may consider such legislation. Additionally, Congress may consider how agencies report and address alleged violations as well as potential strategies for and improvements to interagency coordination of scientific integrity policies.

Further Information

Marcy E. Gallo, Analyst in Science and Technology Policy

CRS Report R46614, *Federal Scientific Integrity Policies: A Primer*, by Marcy E. Gallo

Technology Transfer from Federal Laboratories

On an annual basis, approximately one-third of the federal government's research and development (R&D) spending has been obligated to federal laboratories, including federally funded research and development centers, in support of agency mission requirements. The technology and expertise generated by federal laboratories often has application beyond the immediate goals or intent of the original R&D. Over the years, Congress has established various mechanisms—primarily through the Stevenson-Wydler Technology Innovation Act of 1980 (P.L.

96-480) and subsequent legislation—to facilitate the transfer of technology and research from federal laboratories to the private sector where it can be further developed and commercialized.

Congress is broadly interested in promoting the transfer of technology to address societal needs, promote economic growth, and enhance national welfare and security. Technology transfer from federal laboratories can occur in many forms. In some instances, it can occur through formal partnerships and joint research activities between federal laboratories and private firms, including through cooperative research and development agreements. In other cases, it can occur when the federal government licenses its patent rights to a private firm.

Despite efforts to increase the effectiveness and frequency of technology transfer from federal laboratories to the private sector, critics of current mechanisms maintain that working with federal laboratories continues to be difficult and time-consuming. Proponents of current mechanisms assert that federal laboratories are open and receptive to collaborating with private firms, but it remains up to those firms to take advantage of federal laboratory technologies and capabilities.

In April 2019, the National Institute of Standards and Technology released a green paper, titled "Return on Investment Initiative for Unleashing American Innovation," proposing various strategies and actions to accelerate and improve the transfer of technology to the private sector. Several of the proposed actions, including additional mechanisms for collaborating with the private sector and modifying federal technology transfer policies and practices, would require congressional approval and additional legislative authority to implement. The 117th Congress may consider the actions contained in the green paper or other efforts to improve technology transfer.

Further Information

Marcy E. Gallo, Analyst in Science and Technology Policy

CRS Report R44629, *Federally Funded Research and Development Centers (FFRDCs): Background and Issues for Congress*, by Marcy E. Gallo.

R&D Security

The federal government invests extensively in science and engineering R&D to achieve national objectives, including economic competitiveness and national security. Many in Congress are concerned about security vulnerabilities in the U.S. R&D enterprise and are interested in protecting it against compromise by foreign competitors and potential military adversaries.

In general, U.S. policy for federally funded basic and applied research is to encourage openness and broad dissemination of results (see National Security Decision Directive NSDD-189, 1985). When openness would present a national security concern, however, the federal government can use restrictions such as classification and export controls to prevent certain nations (e.g., Russia, China, Iran, and North Korea) and their proxies from accessing certain results and technologies. Some emerging fields may not yet be subject to these controls, so Congress enacted a provision in the Export Control Reform Act of 2018 (50 U.S.C. §4817) requiring the Bureau of Industry and Security of the Department of Commerce to "establish appropriate controls, including interim controls, on the export, reexport, or transfer (in country) of emerging and foundational technologies." Some Members may be interested in strengthening these protections.

Recently Congress has also focused on the security of U.S. R&D that is significant for economic competitiveness, in light of organized efforts, both licit and illicit, by China and other nations to access economically important U.S. R&D outputs to aid their defense and commercial sectors. Classification and export controls were not designed to address commercial aspects of the R&D

security threat. U.S. law enforcement and counterintelligence agencies have highlighted China's strategy of using espionage, intellectual property theft, direct and venture capital investment and financial subsidies, corporate acquisitions, forced technology transfer, and talent recruitment to gain access to U.S. R&D outputs.

Many in Congress have been concerned with co-option of U.S. citizen researchers through foreign talent recruitment programs (such as China's Thousand Talents program) and the use of foreign nationals at U.S. universities and other institutions—such as students, faculty, visiting scholars, and postdoctoral researchers—to acquire and report on research activities, progress, and results. It has considered policy options to address these concerns, such as increasing threat awareness among U.S. academic researchers, strengthening disclosure requirements for U.S. researchers with foreign ties, and changing policies for foreign students at U.S. universities.

The 117th Congress may continue to monitor threats to the security of U.S. R&D, conduct oversight to examine the progress of ongoing efforts to address those threats, and consider additional measures that may enhance the ability of the United States to protect the results of federally funded R&D.

For Further Information

Daniel Morgan, Specialist in Science and Technology Policy

John F. Sargent, Jr., Specialist in Science and Technology Policy

Karen Sutter, Specialist in Asian Trade and Finance

Jill H. Wilson, Analyst in Immigration Policy

The Role of Technical Standards in U.S. Trade Policy

Industrial, technical, and agricultural standards, which often aim to achieve legitimate public policy objectives, can become non-tariff trade barriers and limit economic opportunities for U.S. exporters, depending on how those standards are designed and implemented. These issues are becoming more central as trade expands and supply chains become more globally integrated. Local or national standards that deviate significantly from recognized international standards or favor domestic firms may make it difficult for U.S. firms to enter particular overseas markets. The United States has historically promoted non-discriminatory and transparent standards through its trade agreements, including through the Technical Barriers to Trade (TBT) agreement in the World Trade Organization (WTO) and participation in international standards-setting institutions.

As countries make new breakthroughs in fields such as information and communications technology, pharmaceuticals, and advanced manufacturing, the landscape of standards-setting is becoming more competitive. U.S. partners and competitive rivals are actively pursuing domestically-driven standardization strategies at the international level that may give their firms an edge in certain strategic industries of interest to Congress, including fifth-generation wireless technology (5G), machine learning, and "Internet of Things" protocols. The Chinese government is pursuing an ambitious push to set international standards across a range of emerging technologies as part of its forthcoming China Standards 2035 initiative. Additionally, China's representation in the leadership and administrative staff of international standards-setting organizations is growing. The European Union (EU) is pursuing the concept of "digital sovereignty," often through new rules and technological standards based on EU values, such as "ethical AI" or the EU's fundamental right to privacy.

The U.S. standards-setting process is traditionally bottom-up, fed by industry innovation, rather than top-down as in China or the EU. Some experts argue that without clear U.S. leadership in

establishing international standards or providing sound U.S. alternatives that can be widely adopted and supported by other countries, as well as more active U.S. government involvement in standards-setting bodies as a national policy priority, other countries may imitate EU or Chinese standards and regulations. This could create additional burdens for U.S. firms serving foreign markets. Increased U.S. involvement in international standard setting could serve as an avenue for ensuring the long-term competitiveness of U.S. firms, particularly in emerging technology sectors. As competition in international standards-setting bodies has intensified, some Members of Congress have expressed concern about the competitiveness of United States' approach and processes.

For Further Information

Michael D. Sutherland, Analyst in International Trade and Finance

Rachel F. Fefer, Analyst in International Trade and Finance

Intellectual Property Law

Intellectual property (IP) rights, including patents and copyrights, play a critical role in encouraging innovation, creativity, and the dissemination of knowledge. Given activity on IP issues during the prior Congress, the 117th Congress may consider legislation in several IP-related areas.

Patents grant inventors the exclusive right to make, use, sell, and import their patented inventions for a term of years. Patents play a particularly significant role in certain industries, such as information technology and pharmaceuticals. Many recent bills have sought to increase competition and reduce drug prices by limiting certain alleged pharmaceutical patenting practices (e.g., patent "evergreening," "thickets," and "pay-for-delay" settlements). Following Supreme Court decisions restricting patent availability in fields such as software and biomedical treatments, the types of inventions that may be patented ("patent-eligible subject matter") has also received congressional attention.

Copyrights grant authors of original creative works (e.g., books, music, computer code) the exclusive right to reproduce, perform, and sell their works. Changes to the Digital Millennium Copyright Act of 1998 (DMCA) is one area of potential copyright-related legislative action. Among other things, the DMCA creates safe harbors to copyright liability for online intermediaries. Whether the DMCA's attempted balance between copyright holders and online service providers requires updating has been the subject of congressional hearings. Implementation of the CASE Act—originally introduced as H.R. 2426 in the 116th Congress and subsequently enacted under the Consolidated Appropriations Act, 2021 (P.L. 116-260)—established an administrative forum to resolve certain lower-value copyright disputes, and as such is another area of potential congressional interest.

Patent rights have also been of interest to Congress during the Coronavirus Disease 2019 (COVID-19) pandemic. Specifically, how patent rights affect affordability and access to COVID-19 medical countermeasures (e.g., vaccines and treatments), especially those developed using federal funds, was a topic of interest at several congressional hearings in the 116th Congress. Another emerging issue is how copyright laws should adapt, if at all, to the increased use of webcasting and e-book lending during the pandemic. For example, schools, libraries, and religious groups have raised concerns about potential copyright liability for uses of copyrighted works that would be permitted in person, yet may infringe copyrights when conducted over the internet.

For Further Information

Kevin Hickey, Legislative Attorney

Kevin Richards, Legislative Attorney

CRS Report R46525, *Patent Law: A Handbook for Congress*, by Kevin T. Richards

CRS Report R45666, *Drug Pricing and Intellectual Property Law: A Legal Overview for the 116th Congress*, coordinated by Kevin J. Hickey

CRS Report R46679, *Drug Prices: The Role of Patents and Regulatory Exclusivities*, coordinated by Erin H. Ward

CRS Report R46741, *Drug Pricing and Intellectual Property: The Legislative Landscape for the 117th Congress*, by Kevin J. Hickey, Kevin T. Richards, and Erin H. Ward

CRS Report R45918, *Patent-Eligible Subject Matter Reform in the 116th Congress*, by Kevin J. Hickey

CRS Legal Sidebar LSB10367, *The CASE Act of 2019: Establishing a Small-Claims Process for Copyright Disputes*, by Kevin J. Hickey

CRS In Focus IF11478, *Digital Millennium Copyright Act (DMCA) Safe Harbor Provisions for Online Service Providers: A Legal Overview*, by Kevin J. Hickey

CRS Legal Sidebar LSB10422, *COVID-19 Medical Countermeasures: Intellectual Property and Affordability*, by Kevin J. Hickey

CRS Legal Sidebar LSB10440, *Webcasting in the Time of COVID-19: Copyright Implications of Remote Worship & Distance Learning*, by Kevin T. Richards

CRS Legal Sidebar LSB10453, *COVID-19 and Libraries: E-Books and Intellectual Property Issues*, by Kevin T. Richards

Agriculture

The federal government funds billions of dollars of agricultural research annually. The 117th Congress may consider issues related to funding this research as well as specific issues related to climate change science at the United States Department of Agriculture (USDA). Other issues of topical interest include the operations of two USDA research agencies following their relocation in 2019; the regulation of agricultural biotechnology; the National Bio and Agro-defense Facility (NBAF); and cell-cultured meat.

Agricultural Research Funding

The USDA Research, Education, and Economics (REE) mission area consists of four agencies: the Agricultural Research Service (ARS), the Economic Research Service (ERS), the National Agricultural Statistics Service (NASS), and the National Institute of Food and Agriculture (NIFA). Additionally, REE's Office of the Chief Scientist (OCS) coordinates research programs and activities across the department.

REE has the primary federal responsibility of advancing scientific knowledge for agriculture. Its agencies conduct and fund research that spans the biological, physical, and social sciences related broadly to agriculture, food, and natural resources. The REE mission area received approximately $3.4 billion in FY2020 discretionary appropriations, and is authorized to receive approximately

$215 million of mandatory funding per year. USDA administers nearly half of this federal funding to states and local partners, primarily through grants.

The most recent farm bill (P.L. 115-334), the Agriculture Improvement Act of 2018, enacted in December 2018, reauthorizes many existing USDA research and education programs, and authorizes new programs, through FY2023. Congress has not yet appropriated funding for some of the new programs. For example, the 2018 farm bill authorized the Agriculture Advanced Research and Development Authority (AGARDA) pilot program. AGARDA is intended to operate under OCS to address long-term and high-risk research challenges in the agriculture and food sectors. It is modeled on federal advanced research entities like the Defense Advanced Research Projects Agency (DARPA) and the Advanced Research Projects Agency—Energy (ARPA-E). AGARDA has not received an appropriation, and USDA has not established it.

The 117th Congress may consider reviewing AGARDA and other new programs established in the 2018 farm bill that have not yet received appropriations. The 2018 farm bill expires in 2023, and Congress may begin to consider new programs or revisions to existing programs for the next farm bill.

For Further Information

Genevieve Croft, Analyst in Agricultural Policy

CRS Report R40819, *Agricultural Research: Background and Issues*, by Genevieve K. Croft

CRS In Focus IF11319, *2018 Farm Bill Primer: Agricultural Research and Extension*, by Genevieve K. Croft

CRS Report R45897, *The U.S. Land-Grant University System: An Overview*, by Genevieve K. Croft

CRS Report R45715, *Federal Research and Development (R&D) Funding: FY2020*, coordinated by John F. Sargent Jr.

Climate Change Science at USDA

The 117th Congress may be interested in research to address climate change and how USDA is carrying out plans to address the needs of agricultural producers in the context of changing climatic conditions. Some farmers and agricultural groups have called on USDA to increase its engagement in helping farmers adapt to changing climatic conditions, which may include increased instances of drought and extreme rainfall; historically unseasonable temperatures; and changes in the dates of first and last frost. Agricultural research can identify best management practices under different environmental conditions.

Some Members of Congress have raised concerns that, in recent years, USDA has not publicized its climate change research and has not finalized or publicly released its 2017 *USDA Climate Resilience Science Plan*. This plan identifies the science that USDA needs to pursue to meet national needs. Some stakeholders have expressed concern that USDA is not meeting its responsibilities to agricultural producers, who need this information to succeed under existing and future climatic conditions. The 117th Congress may consider reviewing whether USDA research programs and policies are meeting concerns about food security and production related to climatic changes.

For Further Information

Genevieve Croft, Analyst in Agricultural Policy

CRS Report R46454, *Climate Change Adaptation: U.S. Department of Agriculture*, coordinated by Genevieve K. Croft

ERS and NIFA Operations Following Their Relocation

In October 2019, USDA relocated the majority of NIFA and ERS staff positions from their headquarters in Washington, DC, to Kansas City, MO. About 75% of employees in these positions (approximately 300, of about 400 whose positions were relocated) declined to relocate, and left the agencies. NIFA administers approximately $1.7 billion in extramural agricultural research and extension funding. ERS conducts its own economic and statistical analyses on topics of interest to Congress, agricultural producers, and agriculture and food stakeholder groups.

Media reports indicate that ERS and NIFA have experienced challenges in recruiting and retaining new employees since their relocation. In 2020, the NIFA director departed the agency after less than two years of a six-year term. The 117th Congress may be interested in continuing oversight of how NIFA and ERS are meeting their responsibilities now, with reduced workforces, and in the future, as new staff are hired to work in Kansas City. The House Committee on Appropriations, in its FY2021 agriculture appropriations bill report (H.Rept. 116-446), requested that the National Academies of Sciences, Engineering, and Medicine conduct a symposium to review the effects of the relocation on the agencies. The Senate Committee on Appropriations did not request such a review in its FY2021 agriculture appropriations draft report.

For Further Information

Genevieve Croft, Analyst in Agricultural Policy

CRS In Focus IF11527, *Relocation of the USDA Research Agencies: NIFA and ERS*, by Genevieve K. Croft

Regulation of Agricultural Biotechnology

The 117th Congress may provide oversight of issues regarding the labeling of bioengineered foods and the regulation of agricultural biotechnology in light of recent innovations in gene editing.

In 2016, Congress enacted P.L. 114-216, mandating the establishment of a national standard for the mandatory labeling of foods containing *bioengineered* ingredients, which consumers may recognize as *genetically engineered (GE)* or *genetically modified organisms (GMOs)*. USDA finalized the National Bioengineered Food Disclosure Standard (the Standard) in December 2018. Voluntary compliance began in January 2020, and mandatory compliance begins in January 2022. The 117th Congress may choose to monitor implementation of the new Standard in accordance with its oversight authority. Areas of interest may include consumer perceptions about labeling a food as *bioengineered*; the emerging views of food manufacturers, retailers, and importers on the Standard; and how the Standard aligns with international labeling requirements.

The emergence of new biotechnology tools (e.g., genome editing), a 2020 update to the USDA plant biotechnology regulations, and a proposed change in the regulation of genetically engineered agricultural animals have raised concerns among some stakeholders. In May 2020, USDA finalized the SECURE Rule for its regulation of GE organisms under the Plant Protection Act (7 U.S.C. §7701 et seq.). This new rule exempts certain categories of modified plants, including those consistent with many genome-edited plants, because they are "unlikely to pose an increased plant pest risk compared to conventionally bred plants." While some producer groups viewed the new rule as supportive of innovation, some consumer and exporter groups criticized it as providing too little oversight and transparency. In December 2020, USDA issued an Advanced

Notice of Proposed Rulemaking, proposing to transfer the regulation of agricultural animals produced or modified with genetic engineering from the Food and Drug Administration to USDA. Congress could consider whether to retain or revisit the 1986 framework that governs U.S. biotechnology regulation (i.e., the Coordinated Framework for the Regulation of Biotechnology), as plants and animals developed with new biotechnology tools become more common, and as federal agencies reconsider their roles and responsibilities in protecting health and the environment without impeding innovation.

For Further Information

Genevieve Croft, Analyst in Agricultural Policy

CRS Report R46737, *Agricultural Biotechnology: Overview, Regulation, and Selected Policy Issues*, by Genevieve K. Croft

CRS Report R46183, *The National Bioengineered Food Disclosure Standard: Overview and Select Considerations*, by Genevieve K. Croft

CRS In Focus IF11573, *USDA's SECURE Rule to Regulate Agricultural Biotechnology*, by Genevieve K. Croft and Tadlock Cowan

The National Bio and Agro-defense Facility

USDA and DHS are coordinating for the eventual transfer of operational responsibility of the National Bio and Agro-defense Facility (NBAF) from DHS to USDA. NBAF is designed to replace the Plum Island Animal Disease Center (PIADC) in New York and serve as a state-of-the-art biocontainment facility for federal research on high-consequence foreign animal diseases (e.g., transboundary and zoonotic diseases). NBAF, located in Manhattan, KS, is expected to be the first facility in the United States to provide biosafety level 4 (BSL-4) laboratories capable of housing large livestock.

USDA managed PIADC and conducted research there until 2003, at which time Congress transferred management to the newly established DHS. Following this change, USDA has continued to conduct research at the facility. In 2007, DHS announced its intention to establish a new facility to replace the outdated PIADC. Congress appropriated funds to construct this new facility (NBAF), and directed DHS to be responsible for its construction. In 2018, DHS announced its intention to transfer NBAF ownership and management to USDA (through the Agricultural Research Service and the Animal and Plant Health Inspection Service) upon completion of construction and commissioning. USDA had expected completion of the facility would occur in 2022, but reported in September 2020 that construction has been delayed by approximately 2.5 months due to the COVID-19 pandemic. The 117th Congress may be interested in the joint planning between USDA and DHS for managing this transfer, in USDA's planning for continued research and operations, as well as any future research coordination between the two agencies. Additional areas of interest to Congress may include the ongoing construction, equipping, staffing, and operations of NBAF.

For Further Information

Genevieve Croft, Analyst in Agricultural Policy

CRS In Focus IF11492, *National Bio and Agro-Defense Facility: Purpose and Status*, by Genevieve K. Croft

Cell-Cultured Meat

Cell-cultured meat is grown in laboratories from animal cell-cultures. First developed in the early 2000s, improved technological efficiencies and reduced production costs have allowed cell-cultured meat companies to scale up and, in some instances, move closer to commercial viability. Some believe their products could be sold within a few years in certain markets and become widely available in 10 years.

A debate surfaced in early 2018 about which federal agency—the Department of Health and Human Services' (HHS) Food and Drug Administration (FDA) or the U.S. Department of Agriculture's (USDA) Food Safety and Inspection Service (FSIS)—would have regulatory jurisdiction over cell-cultured meat. Currently, FSIS regulates meat and poultry, catfish, and egg products. FDA regulates game-meat, fish and seafood, processed meat products (containing 2%-3% meat), and shell eggs.

FDA and FSIS often share overlapping responsibilities for some food products and have developed "memoranda of understanding" to facilitate communication and division of responsibilities between the two agencies. In February 2019, in the conference report accompanying the Consolidated Appropriations Act, 2019 (H.J.Res. 31), Congress directed FDA and USDA to establish a formal agreement that would delineate each agency's responsibilities for regulating cell-cultured meat. In response, in March 2019, FDA and USDA issued a joint Memorandum of Understanding (MOU) outlining the regulatory roles for each agency.

Under the MOU, FDA is to issue regulations or guidance on inspections for entities involved in cell collection, cell lines, and the differentiation process. FDA is to ensure that entities follow current Good Manufacturing Practices and preventive control regulations that ensure the substances leaving the culturing process are safe and not adulterated. At the point of harvest, FDA will transfer oversight to USDA. Entities harvesting cells for human food will be subject to FSIS regulations on sanitation, Hazard Analysis and Critical Control Point verification, and testing to ensure the product is unadulterated, wholesome, and properly labeled under the Federal Meat Inspection Act and the Poultry Products Inspection Act. To ensure label accuracy, FSIS is to provide guidance and prior approval of labels for cell-cultured meat and poultry products. Throughout the cell-cultured meat production process, the MOU affirms that FDA and USDA are to share information and collaborate on regulation.

During the 116th Congress, three bills were introduced in the House and Senate that would have addressed the regulatory framework that FDA and USDA issued in the March 2019 MOU. These were the Cell-Cultured Meat and Poultry Regulation Act of 2019 (S. 1056), and the Food Safety Modernization for Innovative Technologies Act (S. 3053 and H.R. 5728). The bills were referred the Senate Committee on Agriculture, Nutrition, and Forestry, and the House Committee on Agriculture and the House Committee on Energy and Commerce.

For Further Information

Joel L. Greene, Analyst in Agricultural Policy

CRS In Focus IF10947, *Regulation of Cell-Cultured Meat*, by Joel L. Greene and Sahar Angadjivand

Biotechnology and Biomedical Research and Development

Advances in biotechnology and biomedical research and development underpin improvements in medications and treatments. Some issues that the 117th Congress may face related to these areas include advanced gene genomic editing, the bioeconomy, National Institutes of Health research, the role the Food and Drug Administration in approving new medicines and laboratory tests, and issues related to stem cell-based medicine and infectious disease modelling.

CRISPR: Advanced Genome Editing

Researchers have long searched for a reliable and simple way to make targeted changes to the genetic material of humans, animals, plants, and microorganisms. To that end, scientists developed a gene editing tool known as CRISPR—clustered regularly interspaced short palindromic repeated DNA sequences—that offers substantial improvement over previous technologies. The characteristics of CRISPR—easier to use, more precise, fewer unintended edits, and less costly—have led many in the scientific and business communities to predict significant advances across a broad range of areas—from medicine and public health to agriculture and the environment.

While CRISPR offers a number of potential benefits, its use is also associated with risks and ethical concerns. For example, in 2018 a Chinese researcher used CRISPR to create the first genetically engineered human babies—renewing debate on the ethics of genetic engineering and its potential applications in human embryos, especially those that alter heritable traits. Additionally, some researchers are using CRISPR to reduce or eliminate mosquito populations that serve as the primary vector for the transmission of malaria. While this has the potential to save lives and substantially reduce medical costs, a 2016 report, "Gene Drives on the Horizon," from the National Academies of Sciences, Engineering, and Medicine indicates that existing mechanisms may be inadequate to assess the potential immediate and long-term environmental and public health consequences associated with such a use of the technology.

In the 117th Congress, policymakers may examine the potential benefits and risks associated with the use of CRISPR gene editing, including the ethical and social implications of CRISPR-related biotechnology products. Congress may also consider whether and how to address CRISPR gene editing and future biotechnology products with respect to regulation, research and development, and economic competitiveness, including potentially harmonizing CRISPR-related policies of the United States with those of other countries.

For Further Information

Marcy E. Gallo, Analyst in Science and Technology Policy

John F. Sargent Jr., Specialist in Science and Technology Policy

Amanda K. Sarata, Specialist in Health Policy

Genevieve Croft, Analyst in Agricultural Policy

CRS Report R44824, *Advanced Gene Editing: CRISPR-Cas9*, by Marcy E. Gallo et al.

CRS Report R46737, *Agricultural Biotechnology: Overview, Regulation, and Selected Policy Issues*, by Genevieve K. Croft

Bioeconomy

Advances in the biological sciences—driven, in large part, by the integration of biology with the physical sciences, engineering, and computational sciences—are likely to stimulate economic growth and address societal challenges (e.g., food security and climate change). The McKinsey Global Institute estimates the direct economic impact of bio-based products, services, and processes (e.g., bio-plastics and genetically engineered crops)—often referred to as the bioeconomy—at between $2 trillion and $4 trillion per year globally over the next 10 to 20 years. With nearly 60 countries pursuing bioeconomy-related policies (e.g., increased research and development funding, infrastructure investments, and tax subsidies), some aggressively so, U.S. competitiveness and leadership in the future bioeconomy is uncertain.

Policy considerations for strengthening the role of the United States in the global bioeconomy include the development and implementation of a national bioeconomy strategy; increased funding for bioeconomy-related research and development; the development of a bioeconomy workforce; facilitating demand for bio-based products; and efforts to improve public engagement, awareness, and acceptance of the bioeconomy and bio-based products and services. In addition to examining these policy considerations, the 117th Congress might address risks associated with the bioeconomy, including the misuse of bioeconomy technologies and products, the theft of bioeconomy-related intellectual property, and the accuracy and integrity of federal biological databases and information.

For Further Information

Marcy E. Gallo, Analyst in Science and Technology Policy

National Institutes of Health (NIH) and Biomedical Research

The National Institutes of Health (NIH) is the lead federal agency for medical, health, and behavioral research. The agency has been provided with over $40 billion in regular appropriations for each of FY2020 and FY2021 for basic, clinical, and translational research in NIH laboratories as well as in research institutions nationwide. NIH represents about one fifth of total federal research and development spending, and half of non-Department of Defense research and development funding. From FY2016 through FY2020, NIH has seen funding increases of over 5% each year. NIH also received over $4.5 billion in coronavirus emergency appropriations in FY2020 and FY2021.

NIH is a large and complex organization made up of 27 institutes and centers (ICs). Each research IC sets its own research priorities and manages its research programs in coordination with the Office of the Director (OD). Congress provides separate appropriations to each research IC and to OD. Funding levels vary widely among the ICs—for example, the National Cancer Institute (NCI) has the highest regular enacted funding level at $6.6 billion for FY2021 and the John E. Fogarty International Center (focus on global health) has the lowest funding level at $84.0 million for FY2021. IC funding levels reflect congressional priorities and inform the overall research direction of the agency. Aside from setting funding levels for individual IC accounts, Congress has not designated funding for specific disease or research areas, except in a few cases.

NIH has played a major role in the federal response to the COVID-19 pandemic. The agency has supported related research, including major vaccine, treatment and diagnostic development projects, and published and maintained treatment guidelines for patients. The National Institute of Allergy and Infectious Diseases (NIAID) Director, Dr. Anthony Fauci, developed a significant public profile as a source of health information. Other recent policy issues at the agency include the role of NIH-funded research in the development of certain pharmaceutical drugs and

subsequent pricing of those drugs; and undue foreign influence in NIH research, whereby foreign governments facilitate the transfer of research and proprietary information from NIH-funded projects to foreign institutions. In addition, new restrictions on human fetal tissue research by the Trump Administration has drawn some congressional attention.

For Further Information

Kavya Sekar, Analyst in Health Policy

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CRS Report R44129, *Human Fetal Tissue Research: Frequently Asked Questions*

CRS Report R44720, *The 21st Century Cures Act (Division A of P.L. 114-255)*

The Food and Drug Administration (FDA): Medical Product Innovation

The Food and Drug Administration (FDA) regulates the safety of foods, cosmetics, and radiation-emitting products; the safety and effectiveness of medical products (i.e., drugs, biologics, and medical devices); and public health aspects of tobacco products. To keep pace with changes in science and emerging safety and security issues, FDA's regulatory pathways have been subject to modifications through legislation and administrative action.

The 21st Century Cures Act (P.L. 114-255), which FDA is in the process of implementing, modified drug and device regulatory pathways to support innovation. The FDA Reauthorization Act (P.L. 115-52) further modified regulatory pathways to expedite generic drug approval and competition. It also reauthorized medical product user fees for five years, which are set to expire at the end of FY2022. User fee legislation historically has been used to address related FDA policy concerns, and the 117th Congress may consider additional modifications to the agency's regulatory framework, along with reauthorization of the medical product user fee programs.

In light of regulatory and supply chain issues highlighted by the COVID-19 pandemic, the 117th Congress may consider legislation to further support development and approval of medical countermeasures (e.g., vaccines) for emerging infectious diseases, as well as to encourage use of advanced manufacturing technologies to prevent medical product supply chain disruptions and shortages.

Congress also may consider legislation related to medical devices, which are increasingly connected to the internet, hospital networks, and other devices. While this allows for more accurate disease diagnoses and enhanced health care delivery, the broad scope and rapidly evolving domain of *digital health*—comprising software as a medical device (SaMD), cybersecurity, health information technology (IT), and telemedicine, among other things—can create regulatory challenges for FDA. To address some of these challenges, FDA launched the Digital Health Center of Excellence to foster partnerships, knowledge sharing, and innovative regulatory approaches. Some of FDA's regulatory approaches—e.g., a precertification pilot program for SaMD—may require additional statutory authority.

For Further Information

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Regulation of Laboratory-Developed Tests

Regulation of laboratory-developed tests (LDTs)—a class of in vitro diagnostic (IVD) devices that is designed, manufactured, and used within a single laboratory—has been debated for many years, driven in part by an increase in the number and complexity of LDT genetic tests. The Food and Drug Administration (FDA) has traditionally exercised enforcement discretion over LDTs, meaning that most have not undergone FDA premarket review; regardless, FDA has asserted authority over certain LDTs that it considers to be higher risk. In 2014, FDA published draft guidance outlining a comprehensive risk-based regulatory framework for LDTs. This was never finalized, although FDA published a discussion paper summarizing the comments received on the draft guidance, and presenting a modified proposed framework for an approach to LDT oversight.

The COVID-19 pandemic has highlighted issues around current FDA regulation of LDTs. Specifically, although FDA generally exercises enforcement discretion over LDTs, most COVID-19 LDTs had nevertheless been subject to Emergency Use Authorization (EUA) requirements in the same way as other medical products, including other IVDs. To ease testing capacity issues, FDA issued guidance which exempted certain subsets of COVID-19 LDTs from EUA requirements entirely, and allowed others to be used clinically while the EUA submission was under consideration by FDA. In August 2020, HHS announced that FDA was prohibited from requiring premarket review of any kind for all LDTs without first undergoing notice-and-comment rulemaking. Pursuant to this announcement, FDA has halted review of COVID-19 LDT EUA submissions, except for those voluntarily submitted to the agency.

Two bills addressing LDT regulation were introduced early in 2020 in response to the longstanding debate and spurred by the COVID-19 pandemic: the VALID Act (H.R. 6102, S. 3404) which would have established a comprehensive regulatory scheme for all in vitro clinical tests, and the VITAL Act (S. 3512), which would exclude LDTs from regulation by the FDA.

For Further Information

Amanda Sarata, Specialist in Health Policy

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Stem Cells and Regenerative Medicine

Stem cells have the unique ability to become many types of cells in the body. Scientists are exploring ways of using stem cells to create regenerative medicine therapies that repair damaged or diseased organs and restore them to normal functioning. Stem cells may either be pluripotent or multipotent. Pluripotent stem cells include embryonic stem cells or reprogrammed adult cells that have the ability to become any of the more than 200 cell types in the adult body. Multipotent stem cells have the capacity to become multiple (but not all) types of cells, usually within a particular organ system such as the blood or nervous system. Most adult stem cells are multipotent stem cells.

Congress has taken action to boost research and development of clinical applications for stem cells, both pluripotent and multipotent. For instance, the 21st Century Cures Act (P.L. 114-255) authorized to be appropriated $30 million for FY2017 through FY2020 for regenerative medicine research and a new designation at FDA for certain regenerative medicine therapies, eligible for expedited review. The term "regenerative medicine therapy" includes cell therapy, therapeutic tissue engineering products, human cell and tissue products, and combination products using any such therapies or product. Clinical trials are underway for stem cell therapies to treat eye diseases, amyotrophic lateral sclerosis (ALS), Parkinson's disease, traumatic brain injury, and others. However, some therapies have shown safety concerns, including potential cancer risks.

There has also been a rise in the number of stem cell clinics offering unapproved and potentially unsafe treatments to consumers. In response, FDA has issued guidance on the regulation of therapies using human cells. FDA has also issued warning letters and taken enforcement actions against certain stem cell clinics offering unapproved treatments. Similarly, the Federal Trade Commission has filed complaints against marketing claims made by stem cell clinics.

The 117th Congress may consider actions to boost research and clinical development of stem cell therapies, while ensuring the safety of such treatments. Policymakers may also consider addressing the rising use of unapproved stem cell treatments.

For Further Information

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CRS Report RL33540, *Stem Cell Research: Science, Federal Research Funding, and Regulatory Oversight*, by Judith A. Johnson and Edward C. Liu

Infectious Disease Modeling and Forecasting

Infectious disease models have played a notable role during the Coronavirus Disease 2019 (COVID-19) pandemic, informing policy responses such as the allocation of scarce resources at the federal and sub-federal levels. These models may be confusing and are easily misunderstood, due to various factors, including inherent scientific uncertainties; availability and quality of the underlying data; differing methodologies and purposes for models; and misunderstandings about how to interpret and use model outputs for decisionmaking. The pandemic highlighted opportunities for innovation and better coordination across agencies; public and private stakeholders have called for expanding research partnerships and supporting innovative techniques—such as the use of artificial intelligence and machine learning—for data management, modeling, and forecasting. In addition, some have called for greater transparency in the ways that models were designed and used to guide key decisions during the COVID-19 response given the amount of discretion inherent in model design.

Models can illuminate the current and future spread of diseases, and the potential impacts of public health interventions. However, the accuracy of model outputs is limited by the quality and completeness of the inputs. Early in a disease outbreak, particularly with a novel pathogen such as the COVID-19 virus, inputs such as transmission characteristics, risk factors, and other features may be unknown. Modelers must estimate inputs in these situations, further affecting the accuracy of outputs. As public health officials and researchers gather more information, models are periodically revised to optimize their usefulness in informing public health decisions.

During the COVID-19 pandemic, the National Institutes of Health (NIH), the Health and Human Services (HHS) Assistant Secretary for Preparedness and Response, the Centers for Disease Control and Prevention (CDC), the Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), and the Department of Defense (DOD) all funded infectious disease modeling and forecasting efforts—generally conducted by nonfederal research institutions. CDC has maintained an "ensemble" forecast that combines over 20 models to estimate new cases, hospitalizations, and deaths. The Government Accountability Office (GAO) reported in May 2020 (GAO-20-372) of a risk for overlap and duplication in agencies' disparate modeling efforts, as well as missed opportunities to improve and enhance such modeling based on experience from prior infectious disease outbreaks.

Recent legislation has addressed infectious disease modeling and forecasting. In 2019, the Pandemic and All-Hazards Preparedness and Advancing Innovation Act (P.L. 116-22) included several relevant provisions, including (1) requiring the development of a multi-faceted public health situational awareness network, in consultation with relevant federal agencies and forecasting and modeling experts among others, that would coordinate and develop standards for the collection and analysis of data in a public health emergency; and (2) a new CDC special hiring authority for certain qualified individuals as specified, including experts in "prediction, modeling, or forecasting." Further, the American Rescue Plan Act of 2021 (P.L. 117-2) provided $500 million to CDC to modernize U.S. infectious disease data and forecasting capabilities. Congress may assess implementation, determine if agencies have adequate resources, and consider new reforms based on experience with the pandemic.

For Further Information

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Climate Change and Water

Science and technology considerations permeate deliberations on climate change and may be grouped into six interrelated topics:

- federal expenditures on climate change S&T;
- climate change science;
- greenhouse gas (GHG)-related technology development and deployment;
- investment in infrastructure;
- anticipating, adapting to, and increasing resilience to the impacts of climate changes; and
- carbon sequestration and utilization technology.

Additionally, Congress may face several issues related to ensuring reliable water quality and quantity. Climate change may affect availability of water for drinking, farming, and industry, as well as the overall health of ecosystems that support commercial fishing, recreation, and flood protection. Congress therefore supports a wide array of water research initiatives related to developing, using, and protecting water supplies and aquatic ecosystems.

Legislation regarding climate change and water were passed in the 116th Congress, providing a new landscape for charting Congress's priorities in these domains in the 117th.

Climate-Related S&T Expenditures and Activities by the Federal Government

According to the most recent report of the Office of Management and Budget, in response to an appropriations directive, federal funding and tax incentives for climate change-related S&T reached almost $17 billion in FY2016. The funding data covered 16 reporting agencies, though some related expenditures may not have been included. Of the S&T total, approximately $6.7 billion, about 42%, were tax incentives for technology deployment. Another 45% funded "clean energy technology," the large majority at the Department of Energy for R&D and deployment programs. Approximately 15% funded climate change-related science, most of which supported satellites and computing infrastructure. From FY2016 through FY2021, CRS estimates that Congress increased appropriations for "clean energy" technology, while decreasing funding for climate change science reported in the U.S. Global Change Research Program (see below). In the Consolidated Appropriations Act, 2021, Congress also extended tax incentives to deploy energy efficiency and clean energy technologies by almost $700 million in FY2021, in addition to approximately $10.3 previously enacted (preliminary CRS estimate based on budget and appropriations documents). The 117th Congress faces the consideration of appropriations for climate change-related programs and incentives.

For Further Information

Jane A. Leggett, Specialist in Energy and Environmental Policy

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Climate Change-Related Science

The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) is due to be published in three volumes through 2021, potentially contributing to renewed congressional examination of climate change science, impacts, and greenhouse gas mitigation technologies. The IPCC assessments, and much of the observations and research on which they are founded, have relied on decades of U.S. federal (and nonfederal) investment in global change science, amounting cumulatively to tens of billions of dollars. The U.S. Global Change Research Program (USGCRP) is an interagency mechanism, required by the Global Change Research Act of 1990 (P.L. 101-606), that coordinates and integrates global change research across 13 government agencies. For FY2019, enacted appropriations for this purpose exceeded $2.2 billion, down from more than $2.5 billion enacted for FY2016.

In 2017, USGCRP published the *Climate Science Special Report, Volume I* (CSSR) that found that human-related emissions of greenhouse gases (GHG) are accumulating in the atmosphere, intensifying the natural greenhouse gas effect, and increasing acidity (decreasing alkalinity) of the oceans. It concluded that the increase in GHG is driving global land and ocean warming and other climate changes that are now unprecedented in the history of modern civilization. It also stated,

> [B]ased on extensive evidence, that it is extremely likely [>95% likelihood] that human activities, especially emissions of greenhouse gases [GHG], are the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.

The 2018 USGCRP report, the *Fourth National Climate Assessment Volume II*, found that human-induced climate change is affecting U.S. communities across the country through extreme weather events and generally warmer temperatures, more variable precipitation, and other observed trends. The report anticipates continued and increasing disruption to infrastructure, economic, and social systems, including economic disparities. Such impacts would not be distributed evenly across the United States and globally. According to its assessment, projected climate change impacts are affecting, and are virtually certain to increasingly affect, the U.S. economy, trade, and other essential U.S. interests. Some stakeholders, including some Members of Congress, consider that the resulting impacts of climate change in the United States and abroad are and would be modest and manageable.

The 117th Congress may examine the scope and priorities for federal climate change science, including the data and methods that increasingly support attribution of many observed changes and extreme weather events to human-related GHG emissions and are used to project climate change and understand associated uncertainties. Congress may express its priorities for further scientific research. In light of the state of climate science, Congress may consider options for

appropriations levels and distribution among federal climate-related science programs. For example, deliberations may concern the balance between observations and analysis, between science to increase knowledge and to support private and public decisionmaking, and between physical and social sciences, as well as public access to federally supported information.

For Further Information

Jane A. Leggett, Specialist in Energy and Environmental Policy

CRS Report R45086, *Evolving Assessments of Human and Natural Contributions to Climate Change*, by Jane A. Leggett

GHG-Related Technology Research, Development, Demonstration, and Deployment

A large majority of federal climate change-related expenditures is aimed at advancing "clean energy," with additional programs aimed at technologies for agriculture, forestry, and industrial sources of greenhouse gases. Most human-related GHG emissions come from production, distribution, and combustion of fossil fuels, particularly for electricity generation and transportation, and are primarily emitted as carbon dioxide (CO_2) and methane (CH_4). Most scientists agree that halting GHG-induced climate change would require eventually reducing net GHG emissions to near zero; the total amount of change would depend in large part on the cumulative emissions on that pathway.

Many analysts see a decades-long path to stabilizing climate change as involving greater advance and deployment of efficiency improvements, decarbonization, and electrification of the world's economies, along with additional options in multiple sectors. Many options could potentially provide additional security and health benefits, while their costs may depend on public and private investments in research, development, demonstration, and deployment (RDD&D), as well as efforts to facilitate transitions in businesses, employment, and communities. Some see potential carbon capture, utilization, and sequestration (CCUS) technologies as key to preventing CO_2 emissions while preserving a large place for coal and other fossil fuels in the energy economy (see below). Still others advocate for developing direct CO_2 removal from the atmosphere or geoengineering technologies, along with international governance regimes, to intentionally and directly modify the climate, particularly should the climate change rapidly and adversely. The capacity to reduce GHG emissions to near zero at affordable costs, while maintaining U.S. economic growth and security, and alleviating energy poverty, would depend on deployment of existing and demonstrated technologies supplemented by technological breakthroughs.

Members may deliberate on the appropriate degree and means of federal support for advancing and deploying new technologies. Choices the 117th Congress may address include:

- whether any policies should be neutral or favor selected technologies (or fuels);
- where federal intervention in the technology pipeline, through RDD&D, can be most cost efficient and complement, not "crowd out," private investment;
- whether policies are most effective when aimed at pushing the supply of selected technologies or incentivizing demand for low- or no-GHG technologies, or in combination; and
- how best to engage with the private sector and research institutions in partnerships on RDD&D.

RDD&D funding has not been evenly distributed across technology types, and those funded include mature, commercialized technology types as well as emerging or novel technology types. Research has been intended to advance fossil fuel combustion, renewable energy, biofuels, efficiency, storage, vehicles and their fuels, nuclear energy, the electricity grid, and direct capture of carbon dioxide from the atmosphere. It also supports development of new technologies and practices for agriculture, industry, and additional sectors. Some incentives focus on "supply-push" of technologies (e.g., R&D funding), while others emphasize "demand-pull" (e.g., tax incentives for purchasers). Numerous examples suggest that coordinated use of both supply and demand side policies could be most effective. Technologies with less associated pollution can produce public health benefits in addition to climate benefits, while shifts in the energy economy can pose transitional challenges to workers and communities. The magnitude of federal expenditures for climate change technologies, the performance of federally supported programs, and priorities for policy tools and technologies may be topics for Congress, particularly in light of budget objectives.

For Further Information

Jane A. Leggett, Specialist in Energy and Environmental Policy

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CRS Report R42566, *Alternative Fuel and Advanced Vehicle Technology Incentives: A Summary of Federal Programs*, by Lynn J. Cunningham et al.

CRS Report R45010, *Public-Private Partnerships (P3s) in Transportation*, by William J. Mallett

CRS In Focus IF10979, *Greenhouse Gas Emissions and Sinks in U.S. Agriculture*, by Renée Johnson

Climate Change and Infrastructure

Leaders in both chambers of Congress express interest in federal investment in the nation's infrastructure. In evaluating options for infrastructure, two types of linkages with climate change may be considered simultaneously (along with numerous other factors) to optimize investments: infrastructure effects on long-term GHG emissions and potential effects of climate change on long-term infrastructure-related costs and public health and safety. For example, decisions regarding modernization of the electric grid may take account both of possible future policies to reduce GHG emissions and effects on electricity reliability in the context of more extreme weather events and an average increase in summer cooling demand.

The first linkage between climate change and infrastructure investment arises from the foundation that infrastructure sets for certain technological choices, and consequently, levels of future U.S. GHG emissions (and the costs of reducing them). Long-lived infrastructure may exert influence on emissions for decades into the future; infrastructure can "lock in" or support flexibility for certain technological options. Infrastructure choices could make adaption to new science, technological advances, and policy priorities more or less expensive.

Infrastructure influence on GHG emissions is particularly strong for energy supply, transportation, industry, buildings, and communities. For example, pipeline infrastructure would be critical for deployment of CCUS technologies, particularly for industrial applications. In

transportation, choices among transportation modes, and choices between energy types (e.g., gasoline or biofuels or electricity) would depend in part on the availability of the refueling or charging infrastructure. Similarly, land use decisions—generally made by local governments and maybe influenced by federal funding—affect transportation options, which can have long-term impacts on fossil fuel consumption. For example, land use development patterns designed for private automobiles are often not readily adaptable for installation of mass transit.

A second linkage between climate change and infrastructure investment is the ability of infrastructure to avoid damages of climate changes and become more resilient to extreme weather events that scientists expect to increase in frequency and strength. Because much infrastructure is intended to last for decades, projected climate changes in 2030 or 2050 that seem far off for current decisionmaking may have importance for future adequacy, safety, operating costs, and maintenance of investments. Some federal (including military) infrastructure has been severely damaged in recent extreme weather events, while nonfederal water, energy, transportation, urban, and other systems have been disrupted or experienced sustained damage. Congress may consider the merits of federal technical specifications or incentives to harden or increase the resiliency of long-lived infrastructure financed by the federal government, potentially providing model code or demonstrations to other decisionmakers. Policy choices could, on the one hand, increase near-term costs of building infrastructure; on the other hand, climate-related benefits could include avoiding future losses to life, damages to human health (including mental health), and higher federal outlays that could occur with projected climate change.

For Further Information

Jane A. Leggett, Specialist in Energy and Environmental Policy

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CRS Report R40147, *Infrastructure: Green Building Overview and Issues*, by Eric A. Fischer and Danielle A. Arostegui

Science and Technology for Adaptation and Resilience

Congress may review federal programs and funding for S&T to support adaptation or resilience to observed and projected climate change in light of recent scientific assessments and federal outlays for relief and recovery following extreme weather events, some of which have been statistically linked to GHG-induced climate change. Some issues related to infrastructure technology are discussed above, and there are additional science and technology issues associated with adaptation and resilience. For example, technological R&D needs may include new crop seed varieties suited to emerging climate conditions, better means to manage floodwaters, advanced air conditioning technologies for buildings, wildfire management techniques, and others. Further advances in climate forecasting, particularly at the local scale, could assist

assessment of vulnerabilities and preparation for opportunities and risks. Increased research on and improved forecasting of human behavior could assist adaptation and resilience.

Congress may address the federal role in supporting S&T that can facilitate effective state, local, and private decisionmaking on adaptation and resilience to climate change. Federal roles, in addition to funding for S&T, may include easing public access to scientific research, climate and seasonal projections, impact assessments, and adaptation decision tools, as well as training to make productive use of them. Congress may examine whether federal financial support for disaster recovery encourages or discourages incorporation of vulnerabilities and adaptation in private, state, and local adaptation decisionmaking, for example regarding flood risk mitigation or agricultural risks. Congress may also review efforts already begun to incorporate climate change projections into federal agency management of federal personnel, lands and waters, infrastructure, and operations. The effectiveness of agency actions to promote adaptation and resilience would depend on the adequacy and appropriate use of scientific information and available technologies.

For Further Information

Jane A. Leggett, Specialist in Energy and Environmental Policy

CRS Report R43915, *Climate Change Adaptation by Federal Agencies: An Analysis of Plans and Issues for Congress*, coordinated by Jane A. Leggett

CRS Report R46454, *Climate Change Adaptation: U.S. Department of Agriculture*, coordinated by Genevieve K. Croft

CRS Report R45017, *Flood Resilience and Risk Reduction: Federal Assistance and Programs*, by Nicole T. Carter et al.

CRS Report R43407, *Drought in the United States: Causes and Current Understanding*, by Peter Folger

CRS Report R44632, *Sea-Level Rise and U.S. Coasts: Science and Policy Considerations*, by Peter Folger and Nicole T. Carter

CRS In Focus IF10728, *After the Storm: Highway Reconstruction and Resilience*, by Robert S. Kirk

Carbon Capture and Sequestration

Carbon capture and sequestration (or storage)—known as CCS—involves capturing carbon dioxide (CO_2) at its source, storing it underground, or utilizing it for another purpose or product. (CCS is sometimes referred to as CCUS—carbon capture, utilization, and storage.) CCS could reduce the amount of CO_2 emitted from the burning of fossil fuels at large stationary sources. Carbon utilization recently has gained interest within Congress as a means for capturing CO_2 and converting it into potentially commercially viable products, such as chemicals, fuels, cements, and plastics. Direct air capture (DAC), a related emerging technology, is intended to remove atmospheric CO_2 directly from the atmosphere rather than capture the CO_2 emissions from an industrial source. Some view DAC as an important method for achieving "net zero" GHG emissions, given projections for fossil fuel use. Many legislative proposals aimed at supporting CCS also include DAC. In many cases, carbon injection has also occurred for purposes of enhanced oil recovery (EOR), with some permanent CO_2 storage occurring as part of the process.

CCS includes three main steps: (1) capturing CO_2; (2) transporting CO_2; and (3) injecting it into the subsurface. Following injection, the CO_2 would be monitored to verify that it remains underground. Capturing CO_2 is the most costly and energy-intensive step in the process (this is

sometimes referred to as the energy penalty or the parasitic load). Globally, two coal-fired power plants have been retrofit to capture CO_2 in large quantities (i.e., over 1 million tons per year): the Boundary Dam plant in Canada and the Petra Nova plant in Texas (which suspended CCS operations in 2020). Both plants offset some of the capture costs by selling the captured CO_2 to be used for nearby EOR operations.

Emerging technologies for carbon utilization and DAC have been promoted by some CCS advocates. A challenge for utilization is whether the market for products and uses is large enough so that the amount of carbon captured or removed has a measurable effect mitigating climate change. The challenge for DAC is fairly straightforward—how to reduce the cost per ton of CO_2 removed. Since FY2010, Congress has provided more than $6 billion total in annual appropriations for DOE's Fossil Energy Research and Development portfolio (FE R&D), the DOE research arm conducting most federal CCS research activity. Congress provided $740 million to FE R&D in FY2019 and $750 million for FY2020. Several CCS-related bills were introduced in the 116th Congress, with CCS-related provisions in more than 30 measures introduced.

The 115th Congress enacted a tax provision (Title II, Section 41119 of P.L. 115-123, which amended Internal Revenue Code, Section 45Q) to incentivize underground carbon injection, including storage and EOR. The amendment increases the tax credit for underground carbon sequestration, whether associated with EOR or injected solely for geologic sequestration. In 2020, the Internal Revenue Service proposed new regulations that would establish 45Q requirements for secure geologic storage of CO_2, DAC, and utilization for purposes of the tax credit. The 117th Congress may explore how the 45Q tax credit is being implemented and implications for CCS project deployment.

In recent years, proponents of CCS and some Members of Congress have called for increased federal support for building out infrastructure related to CCS. The federal role in development of CCS-related infrastructure and associated legislative options may continue to be of interest in the 117th Congress.

For Further Information

Angela Jones, Analyst in Environmental Policy

Ashley Lawson, Analyst in Energy Policy

CRS Report R44902, *Carbon Capture and Sequestration (CCS) in the United States*, by Peter Folger

CRS In Focus IF11501, *Carbon Capture Versus Direct Air Capture*, by Ashley J. Lawson

CRS Report R46192, *Injection and Geologic Sequestration of Carbon Dioxide: Federal Role and Issues for Congress*, by Angela C. Jones

CRS In Focus IF11345, *Carbon Sequestration Legislation in the 116th Congress*, by Angela C. Jones

CRS In Focus IF11455, *The Tax Credit for Carbon Sequestration (Section 45Q)*, by Angela C. Jones and Molly F. Sherlock

CRS In Focus IF11639, *Carbon Storage Requirements in the 45Q Tax Credit*, by Angela C. Jones

Water

The reliable supply of high quality water in sufficient quantities supports the U.S. population and economy, including public and ecosystem health, agriculture, and industry (e.g., energy production, fisheries, navigation, and manufacturing). Federal research activities and facilities span numerous departments, agencies, and laboratories. The federal government also funds water research through grants to universities and other researchers. In recent years, federal agencies have sponsored prize competitions for water data, science, and technologies and developed cooperative arrangements with various entities. Drinking water contamination and recent droughts, floods, and storms also have increased interest in innovative technologies and practices (including approaches that mimic nature, often referred to as green infrastructure or nature-based infrastructure). The 117th Congress may consider water research and technology topics, which can be broadly divided into water and aquatic ecosystem information, water infrastructure and use, and water quality.

Information on water and aquatic ecosystem information includes observations, forecasts, and associated modeling. Science and research agencies collect data remotely and in situ; they use a wide variety of traditional and new technologies and techniques that inform water-related decisions for infrastructure, agriculture, and drinking water and wastewater services. Some of the water and ecosystem information research topics that may be before the 117th Congress include the following:

- water monitoring infrastructure and science programs, including water quality monitoring, stream gauges, buoys, groundwater assessments, and modeling (i.e., the National Water Model and Next Generation Water Observing Systems);
- water-related weather, climate, and earth system science including storm surge, hurricane, rainfall, and drought forecasts and associated remote sensing investments (see, for example, "Earth-Observing Satellites");
- water conditions in rivers and along coasts (e.g., relative sea-level rise rates);
- altering the operation of existing reservoirs (e.g., using seasonal forecasts for forecast-informed operations);
- monitoring and management of invasive species and harmful algal blooms;
- access to and use of water data (e.g., Integrated Water Availability Assessments); and
- coordination of the federal water science and research portfolio, including partnerships with academic and private entities.

Water infrastructure research includes how to prolong and improve the performance of existing coastal and inland water infrastructure as well as the development of next-generation infrastructure technologies. Some infrastructure and water use research topics include:

- water augmentation technologies and science to support their adoption, including stormwater capture, water reuse, brackish and seawater desalination, as well as groundwater recharge, storage, and recovery;
- technologies and materials for monitoring and rehabilitating aging infrastructure, such as materials selection, construction and repair techniques, and detection technologies (e.g., structural health monitors and leak detection);
- water efficiency technologies and practices; and

- gray and green technologies to enhance infrastructure resilience to droughts, floods, hurricanes, and other natural hazards.

The quality of drinking water, surface water, and groundwater is important for public health, environmental protection, food security, and other purposes. Technologies for preventing contamination and for identifying and treating existing contamination is an ongoing research topic for the federal government. Some research topics include:

- analytical methods and treatment technologies to detect and manage emerging contaminants (e.g., cyanotoxins associated with harmful algal blooms, per- and polyfluoroalkyl substances [PFASs], and microplastics);
- technologies to prevent and manage contamination at drinking water treatment plants and in distribution systems (e.g., real-time monitoring, treatment to minimize disinfection byproducts, and lead pipe corrosion control); and
- innovative technologies and practices to protect water quality (e.g., nature-based or green infrastructure storm water management), including methods for increasing resilience of drinking water systems against natural disasters and protecting drinking water sources for public water system from contamination (e.g., watershed management approaches and nonpoint source pollution management).

For Further Information

Anna E. Normand, Analyst in Natural Resources Policy

Eva Lipiec, Analyst in Natural Resources Policy

Elena H. Humphreys, Analyst in Environmental Policy

Nicole T. Carter, Specialist in Natural Resources Policy

Laura Gatz, Analyst in Environmental Policy

CRS Report R45695, *U.S. Geological Survey (USGS) Streamgaging Network: Overview and Issues for Congress*, by Anna E. Normand

CRS Report R43407, *Drought in the United States: Causes and Current Understanding*, by Peter Folger

CRS Report R45259, *The Federal Role in Groundwater Supply*, by Peter Folger et al.

CRS Report R44632, *Sea-Level Rise and U.S. Coasts: Science and Policy Considerations*, by Peter Folger and Nicole T. Carter

CRS Report R44871, *Freshwater Harmful Algal Blooms: Causes, Challenges, and Policy Considerations*, by Laura Gatz

CRS Report R45998, *Contaminants of Emerging Concern under the Clean Water Act*, by Laura Gatz

CRS Report R45793, *PFAS and Drinking Water: Selected EPA and Congressional Actions*, by Elena H. Humphreys and Mary Tiemann

CRS Report R46416, *Forecasting Tropical Cyclones: Overview and Issues for Congress*, by Eva Lipiec

Defense

Science and technology play an important role in national defense. The Department of Defense (DOD) relies on a robust research and development effort to develop new military systems and improve existing systems. Issues that may come before the 117th Congress regarding the DOD's S&T activities include budgetary concerns and the effectiveness of programs to transition R&D results into fielded products.

Department of Defense Research, Development, Test, and Evaluation

The Department of Defense spends more than $100 billion per year on research, development, testing, and evaluation (RDT&E). In FY2020, enacted RDT&E funding was approximately $109 billion. Roughly 80%-85% of this is spent on the design, development, and testing of specific military systems. Examples of such systems include large integrated combat platforms such as aircraft carriers, fighter jets, and tanks, among others. They also include much smaller systems such as blast gauge sensors worn by individual soldiers. The other 15%-20% of the RDT&E funding is spent on what is referred to as DOD's Science and Technology Program. The S&T Program includes activities ranging from basic science to demonstrations of new technologies in the field. The goal of DOD's RDT&E spending is to provide the knowledge and technological advances necessary to maintain U.S. military superiority.

DOD's RDT&E budget contains hundreds of individual line items. Congress provides oversight of the program, making adjustments to the amount of funding requested for any number of line items. These changes are based on considerations such as whether the department has adequately justified the expenditure or the need to accommodate larger budgetary adjustments.

RDT&E priorities and focus, including those of the S&T portion, do not change radically from year to year, though a few fundamental policy-related issues regularly attract congressional attention. These include ensuring that S&T, particularly basic research, receives sufficient funding to support next generation capabilities; seeking ways to speed the transition of technology from the laboratory to the field; and ensuring an adequate supply of S&T personnel. Additionally, the impact of budgetary constraints, including continuing resolutions, on RDT&E may be of interest to the 116th Congress. Specifically, senior DOD officials have been describing the need to develop and implement a strategy aimed at identifying new and innovative ways to maintain the dominance of U.S. military capabilities into the future, which may require increased investment in RDT&E.

In addition, as U.S. federal defense-related R&D funding's share of global R&D funding has fallen from about 36% in 1960 to about 3% in 2018, some have become concerned about the ability of DOD to direct the development of leading technologies and to control which countries have access to it. Today, commercial companies in the United States and elsewhere in the world are leading development of groundbreaking technologies in fields such as artificial intelligence, autonomous vehicles and systems, and advanced robotics. DOD has sought to build institutional mechanisms (e.g., the Defense Innovation Unit) and a culture for accessing technologies from nontraditional defense contractors. DOD's ability to maintain a technology edge for U.S. forces may depend increasingly upon these external sources of innovation for its weapons and other systems.

For Further Information

John F. Sargent Jr., Specialist in Science and Technology Policy

Marcy E. Gallo, Analyst in Science and Technology Policy

CRS Report R45403, *The Global Research and Development Landscape and Implications for the Department of Defense*, by John F. Sargent Jr. and Marcy E. Gallo

CRS Report R44711, *Department of Defense Research, Development, Test, and Evaluation (RDT&E): Appropriations Structure*, by John F. Sargent Jr.

CRS Report R45110, *Defense Science and Technology Funding*, by John F. Sargent Jr.

CRS Report R46341, *Federal Research and Development (R&D) Funding: FY2021*, coordinated by John F. Sargent Jr.

Energy

Energy-related science and technology issues that may come before the 117th Congress include biofuels; fracking; electricity modernization and decarbonization; hydrogen pipelines; reprocessing of spent nuclear fuel; advances in nuclear energy technology; and offshore energy development technologies.

Biofuels

Biofuels—transportation fuels produced from biomass—are an alternative to conventional fuels. Some see promise in producing fuels from a domestic feedstock that may reduce dependence on foreign energy sources, improve rural economies, and lower greenhouse gas emissions. Others regard biofuels as potentially more harmful to the environment (e.g., air and water quality concerns), more land-intensive, and prohibitively expensive to produce. The debate about biofuels is complex, as policymakers consider numerous factors (e.g., feedstock costs, timeframe to reach commercial-scale advanced biofuel production, environmental impact of biofuels). The debate can be even more complicated because biofuels may be produced using numerous biomass feedstocks and conversion technologies.

Congress supported biofuels for decades, with most of its attention on "first-generation" biofuels (e.g., cornstarch ethanol). Starting in 2002, the farm bills have contained an energy title with several programs to assist biofuel production and R&D. In addition, the DOE Office of Energy Efficiency and Renewable Energy (EERE) supports domestic biofuel production R&D. Congress and the executive branch have debated the amount of USDA and DOE funding for biofuel initiatives. While commercial-scale production of "first-generation" biofuels is well established, commercial-scale production for some advanced biofuels (e.g., cellulosic ethanol) is in its infancy.

In 2007, Congress expanded the main policy support for biofuel production—the Renewable Fuel Standard (RFS), which requires U.S. transportation fuel to contain minimum volumes of different classes of biofuels. The RFS is under scrutiny for various reasons, including concerns about program implementation, advanced biofuel pathway approval, growth of advanced biofuel production, and RFS compliance. These concerns, among others, create uncertainty for some stakeholders.

The 117th Congress may consider whether to modify various biofuel promotional efforts, to establish new biofuel initiatives, or to maintain the status quo. Other topics of congressional interest include the development of a low-carbon fuel standard in lieu of an explicit renewable fuel mandate, and R&D into sustainable fuels for aviation, shipping, and other applications.

For Further Information

Kelsi Bracmort, Specialist in Natural Resources and Energy Policy

CRS Report R43325, *The Renewable Fuel Standard (RFS): An Overview*, by Kelsi Bracmort

CRS Report R46244, *The Renewable Fuel Standard (RFS): Frequently Asked Questions About Small Refinery Exemptions (SREs)*, by Kelsi Bracmort

CRS Insight IN11353, *The 2020 Renewable Fuel Standard (RFS): COVID-19 Impacts*, by Kelsi Bracmort

CRS Report R45943, *The Farm Bill Energy Title: An Overview and Funding History*, by Kelsi Bracmort

Hydraulic Fracturing and Horizontal Drilling

Hydraulic fracturing, or fracking, applied to horizontally drilled wells was one of the key technological advancements at the beginning of the 21st century (along with directional drilling of long horizontal wells) that unlocked natural gas and oil resources from shale and other tight rock formations (also known as unconventional formations). The oil and natural gas released by fracking have catapulted the United States to the lead global producer of both fuels and have made the United States relatively energy independent. Fracking has also made the United States into the fastest growing exporter of both commodities.

As hydraulic fracturing became a more prominent form of production, it also raised environmental concerns. These concerns centered initially on water quality issues, including potential contamination of groundwater and surface waters. Concerns have since incorporated other issues, such as water management practices (both consumption and discharge), methane release, land use changes, endangered species impacts, induced seismicity, and air and noise pollution. Other related concerns have centered on the potential long-term and indirect impacts from a reliance on fossil fuels and the resulting greenhouse gas (GHG) emissions.

To many, fracking has become synonymous with anything related to extraction of natural gas and oil from unconventional formations. However, fracking has been a part of the industry for decades, emerging as an enhanced recovery method to boost production from nearly all traditional wells in conventional formations. In unconventional formations, hydraulic fracturing is not an optional or additional technique but a necessary one for production. Unconventional resource recovery requires creating a huge connected fracture network leading to the wellbore in order to achieve economic oil or gas recovery. Currently, no alternative to hydraulic fracturing in these formations exists; nor does one appear to be on the horizon. During the 2020 presidential election, fracking became a flash point of the debate, and it portends to be an issue in the 117th Congress.

For Further Information

Richard Lattanzio, Specialist in Environmental Policy or Michael Ratner, Specialist in Energy Policy

CRS In Focus IF11036, *U.S. Oil and Natural Gas Transformation and Effects*, by Michael Ratner et al.

CRS Report R43836, *Human-Induced Earthquakes from Deep-Well Injection: A Brief Overview*, by Peter Folger and Mary Tiemann

CRS Report R43152, *Hydraulic Fracturing: Selected Legal Issues*, by Adam Vann, Brandon J. Murrill, and Mary Tiemann

CRS Report R41760, *Hydraulic Fracturing and Safe Drinking Water Act Regulatory Issues*, by Mary Tiemann and Adam Vann

CRS Report R43148, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, by Michael Ratner and Mary Tiemann

CRS Report R42986, *Methane and Other Air Pollution Issues in Natural Gas Systems*, by Richard K. Lattanzio

Electricity Modernization and Decarbonization

Interest in the modernization of the electricity grid to improve its reliability and resilience is increasing; so too is interest in reducing emissions of carbon dioxide from power generation. The two goals are potentially compatible, as a grid that utilizes more zero-carbon emission electricity resources also can benefit from modernization to move electricity more efficiently and could bolster resilience.

To accommodate today's more complex power flows, serve reliability needs, and meet future projected uses, grid modernization is incorporating electronic intelligence capabilities for power control purposes and operations monitoring. The "Smart Grid" is the name given to this evolving intelligent electric power network. Given ideas for a grid based on renewable energy, an electric power system able to potentially shift energy nationally from where it is generated to where it is needed may require a level of real-time monitoring and control that does not currently exist.

Ensuring that the grid is always able to meet electricity needs will likely mean that resources capable of generating power on demand will still be required, and enabling today's natural gas generation fleet to be able to use hydrogen as a power generation fuel is one option. Other potential options may include nuclear power (both fusion and fission), and carbon capture with sequestration and reuse. The projected need for this base load generating capacity may continue even with advances in energy storage (as some utility executives have speculated we would need to store energy on a seasonal basis—not just for hours or days—for goals approaching 100% renewable energy). More affordable hydrogen could address some of the barriers to sustainable energy. While hydrogen as a fuel for electric power generation does not directly result in carbon dioxide emissions, hydrogen is expensive to produce, difficult to transport or store, and existing combustion turbines would need to be modified for its use. All of these preceding areas are subjects of federal R&D, particularly at the Department of Energy.

For Further Information

Richard J. Campbell, Specialist in Energy Policy

CRS Report R45156, *The Smart Grid: Status and Outlook*, by Richard J. Campbell

CRS Report R46436, *Hydrogen in Electricity's Future*, by Richard J. Campbell

Advanced Battery Energy Storage

Advanced battery energy storage (ABES) technology has the potential to revolutionize the nation's electric power industry and the transportation sector. In 2019, plug-in hybrid- and battery-electric vehicles (collectively plug-in electric vehicles or PEVs) made up 2% of all light-duty vehicle sales. If PEV use increases, as estimated by a 2018 study from the National

Renewable Energy Laboratory (NREL), energy load profiles might shift, creating additional energy demand during work hours and a greater overnight demand once residents return home.

PEV batteries today are mostly based on lithium ion technology using liquid cells. These batteries can be charged a number of times due largely to their high energy density and ability to undergo a number of full power charging cycles. However, liquid cells have been associated with fire risk, and the acquisition of cobalt, a mineral commonly used in PEV batteries, from its major source in the Democratic Republic of the Congo has been associated with child labor and miner safety issues. Research on dry lithium ion batteries, recycling of lithium ion battery components, and alternate chemistries have been identified as keys to the greater deployment of PEV batteries.

With PEVs connected to the electric power grid, an opportunity might arise for vehicle batteries to provide energy storage at low energy demand times when grid generation might be high, and EV use might be low. This could help reduce the need for new power plants and reduce overall atmospheric emissions from fossil fuels, if such a regime can be economically implemented.

In 2018, battery storage power capacity accounted for less than 1% of total U.S. large-scale electricity storage, but its share is growing. ABES could not only improve grid reliability but also enhance the attractiveness of wind and solar power, which may lead to lower electricity-related emissions.

Greater electrification of the transportation sector will not only depend on PEV battery capabilities and designs, but on the development of a national and interstate PEV charging infrastructure that will economically enable large vehicles and trucks to begin to switch from fossil fuels. Such a network could address concerns over the range of purely battery-electric vehicles to meet the needs of the public and transportation industry.

In recent years, congressional action on ABES has focused on funding Department of Energy R&D, and on incentives for deployment of PEVs and charging infrastructure.

For Further Information

Melissa N. Diaz, Analyst in Energy Policy

CRS Report R45980, *Electricity Storage: Applications, Issues, and Technologies*, by Richard J. Campbell

CRS Report R45980, *Electricity Storage: Applications, Issues, and Technologies*, by Richard J. Campbell

CRS Report R45747, *Vehicle Electrification: Federal and State Issues Affecting Deployment*, by Bill Canis, Corrie E. Clark, and Molly F. Sherlock

Reprocessing of Spent Nuclear Fuel

Spent fuel discharged from commercial nuclear reactors contains most of the original uranium that was used to make the fuel, along with plutonium and other highly radioactive nuclear materials. A fundamental issue in nuclear policy is whether spent fuel should be "reprocessed" (or "recycled") to extract plutonium and uranium for new reactor fuel, or directly disposed of without reprocessing. Proponents of nuclear power point out that spent fuel still contains substantial energy that reprocessing could recover, and that reprocessing could reduce the long-term hazard of radioactive waste. Reprocessed plutonium could also be used in nuclear weapons, raising proliferation concerns.

In the 1950s and 1960s, the federal government expected that all commercial spent fuel would be reprocessed to make new reactor fuel. Increased concern about weapons proliferation in the 1970s

and the slower-than-projected growth of nuclear power prompted President Carter to halt commercial reprocessing efforts in 1977. Subsequent administrations have had a wide range of policies on the issue.

The George W. Bush Administration proposed that the Department of Energy (DOE) complete a pilot reprocessing plant by the early 2020s. During the Obama Administration, plans for the pilot plant were halted and DOE research was redirected toward development of technology options for a wide range of nuclear fuel cycle approaches. FY2021 DOE funding related to reprocessing and recycling R&D includes $25 million for nuclear material recovery and waste treatment and $20 million for fuel cycle laboratory R&D (P.L. 116-260).

The level of potential controversy over plutonium fuel was illustrated by DOE's now-terminated Mixed Oxide Fuel Fabrication Facility (MFFF) in South Carolina. MFFF would have produced fuel for commercial nuclear reactors using surplus nuclear weapons plutonium, as part of an agreement with Russia to reduce nuclear weapons material. Critics of the project contended that MFFF would have subverted U.S. nonproliferation efforts by encouraging the use of plutonium fuel. Because of the project's steeply rising costs and other controversy, Congress agreed to stop construction in FY2019 (P.L. 115-244).

For Further Information

Mark Holt, Specialist in Energy Policy

CRS Report R42853, *Nuclear Energy: Overview of Congressional Issues*, by Mark Holt

CRS Report RL34234, *Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear Power*, coordinated by Mary Beth D. Nikitin

Advanced Nuclear Energy Technology

All currently operating commercial nuclear power plants in the United States are based on light water reactor (LWR) technology, in which ordinary water cools the reactor and acts as a neutron moderator to help sustain the nuclear chain reaction. DOE has long conducted research and development work on other, non-LWR nuclear technologies that could have advantages in safety, waste management, and cost. Much of the DOE R&D program focuses on small modular reactors (SMRs), defined as having electric generating capacity no greater than 300 megawatts (compared with 1,000 megawatts or more for standard commercial reactors), and microreactors with capacity of about 10 megawatts or below. A growing number of private-sector firms are pursuing commercialization of advanced nuclear technologies.

Non-LWR advanced nuclear energy technologies include high-temperature gas-cooled reactors, liquid metal-cooled reactors, and molten salt reactors, among a wide range of other concepts. Research on advanced reactor coolants, materials, controls, and safety is carried out by DOE's Advanced Reactor Technologies program, which was appropriated $46 million for FY2021 (P.L. 116-260). DOE's Advanced Reactors Demonstration Program in FY2021 is providing $80 million apiece to support two demonstration projects and $40 million to prepare for five future demonstrations.

Private-sector nuclear technology companies contend that a major obstacle to commercializing advanced reactors is that the Nuclear Regulatory Commission's (NRC's) licensing process is based on existing LWR technology. Development of a licensing and regulatory framework that could apply to all nuclear concepts is required by the Nuclear Energy Innovation and Modernization Act (P.L. 115-439), signed into law January 14, 2019. The DOE Advanced Reactor

Demonstration Program includes $15 million in FY2021 for national laboratories to work with NRC in that effort.

Legislation to promote advanced nuclear power technologies, the Nuclear Energy Innovation Capabilities Act of 2017 (NEICA, P.L. 115-248) authorizes the National Reactor Innovation Center (NRIC) "to enable the testing and demonstration of reactor concepts to be proposed and funded, in whole or in part, by the private sector." NRIC was appropriated $30 million for FY2021. NEICA also requires DOE to determine the need for a fast-neutron "versatile" test reactor, for which $45 million was appropriated in FY2021.

For Further Information

Mark Holt, Specialist in Energy Policy

CRS Report R45706, *Advanced Nuclear Reactors: Technology Overview and Current Issues*, by Danielle A. Arostegui and Mark Holt

CRS Report R42853, *Nuclear Energy: Overview of Congressional Issues*, by Mark Holt

Hydrogen Pipelines

Some in Congress have proposed hydrogen as an environmentally friendlier alternative to conventional fossil fuels for vehicles, vessels, and electric power generation. Delivering hydrogen to widely scattered power plants, industrial facilities, and regional distribution centers for vehicular fuel could require the development of an expansive hydrogen pipeline network. The House Select Committee on the Climate Crisis stated in its 2020 *Solving the Climate Crisis* majority staff report,

> To achieve wide use of hydrogen at a reasonable cost, industry will need infrastructure to generate and transport hydrogen.... One option is to generate hydrogen at a small number of large-scale facilities and then distribute it through a pipeline network to individual industrial facilities.

Environmental advocates and other stakeholders likewise have identified hydrogen pipelines as an essential component of a widespread hydrogen fuel strategy.

Shipping hydrogen by pipeline in the United States is not new, but the existing pipeline network is small and located almost entirely along the Gulf Coast. The pipeline network required to support a hydrogen-based U.S. energy strategy would be much larger with much broader geographic reach. Establishing such a network could pose technical challenges due to the chemical characteristics of hydrogen, an issue which has been, and could likely continue to be, the subject of federally-funded research and development.

Hydrogen molecules are the smallest of all molecules, and therefore are more prone than methane (the principal component of natural gas) to leak through joints, microscopic cracks, and seals in pipelines and associated infrastructure. Hydrogen can also permeate directly through polymer (plastic) materials, such as those typically used to make natural gas distribution pipes, four to five times faster than methane does. Both hydrogen and methane are odorless and colorless gases. To reduce the safety risks of methane leaks, odorants are generally added to natural gas in distribution systems to aid in leak detection. Due to differences in end use (e.g., in fuel cells) odorization of hydrogen has distinctive chemical requirements. Research is underway on potential odorants that can be added to hydrogen transportation systems.

The presence of hydrogen can deteriorate steel pipe, pipe welds, valves, and fittings through a variety of mechanisms, particularly embrittlement. Hydrogen embrittlement occurs when the diffusion of hydrogen into a material decreases its ductility. The susceptibility of particular

pipelines depends upon many factors, including hydrogen pressure, concentration, and temperature, as well as the specific properties of the type of steel used and other operating conditions. Pipeline companies may use specialty steels or may modify their infrastructure and put other measures in place to manage embrittlement risks. Nonetheless, the potential for hydrogen embrittlement is an important safety consideration in the design and operation of hydrogen pipelines, or when hydrogen is present in pipelines designed to transport natural gas or other materials.

The House Select Committee on the Climate Crisis report recommended that Congress draft legislation to facilitate the development of hydrogen transportation and related infrastructure, that federal agencies create a hydrogen infrastructure development plan, and that the agencies review and change their regulatory framework to support the plan. The Senate Committee on Appropriations has considered fiscal funding for energy and water development, which would include funding for large-scale hydrogen pipeline research and development.

Executive agencies, such as the Department of Transportation's Pipeline and Hazardous Materials Safety Administration, may fund hydrogen pipeline research under existing research grant programs and may examine hydrogen pipeline technical issues through advisory committees and industry partnerships. Such activities may advance hydrogen pipeline design, operations, or safety research, and the development of standards, which could be incorporated into industry practices or federal pipeline regulations.

For Further Information

Paul W. Parfomak, Specialist in Energy and Infrastructure Policy

CRS Report R46700, *Pipeline Transportation of Hydrogen: Regulation, Research, and Policy*, by Paul W. Parfomak

Offshore Energy Development Technologies

Technological innovations are key drivers of U.S. ocean energy development. They may facilitate exploration of previously inaccessible resources, provide cost efficiencies, address safety and environmental concerns, and enable advances in emerging sectors such as U.S. offshore wind energy. Private industry, universities, and government all are involved in ocean energy R&D. At the federal level, both the Department of Energy (DOE) and the Department of the Interior (DOI) support ocean energy research.

With respect to U.S. offshore oil and gas, developers and federal regulators have focused on exploration and development in deepwater areas and in the Arctic region. Industry interest in expanding deepwater activities, improving safety and efficiency, and reducing costs has prompted improvements in drilling technologies and steps toward automated monitoring and maintenance. For the Arctic, industry R&D has included work on technology to extend the drilling season beyond the periods where sea ice is absent—for example, by developing ice-resistant drilling units—and on oil spill response technologies for Arctic conditions. DOE and DOI undertake and fund Arctic energy R&D, and in 2019 DOE reestablished an Arctic Energy Office. One focus of federal efforts has been on safety improvements to reduce the likelihood of catastrophic oil spills. DOI has revised safety regulations for offshore blowout preventer systems and other well control equipment, as well as for Arctic exploratory drilling. Stakeholders have debated whether these rules' requirements are unnecessarily prescriptive or, conversely, not prescriptive enough to achieve safety aims.

Among renewable ocean energy sources, only wind energy is poised for commercial application in U.S. waters. In December 2016, the first U.S. offshore wind farm, off of Rhode Island, began

regular operations, and in June 2020, a two-turbine offshore pilot project completed construction off the coast of Virginia. In addition to identified resources in the Atlantic region, wind energy has potential in the Great Lakes, offshore of the West Coast and Alaska, and offshore of the Gulf Coast. Identified priorities for offshore wind R&D include (1) technology advancement of the offshore wind plant; (2) improvements of resource and physical site characterization; and (3) technology improvements in installation, operations and maintenance, and supply chain issues for the U.S. market. For offshore wind plant technology advancement, identified opportunities include optimizing performance, reducing costs of support structures, developing mooring and anchoring technologies for floating wind structures in deeper water, and reducing costs and risks of the transmission and distribution of electricity generated from offshore wind. For resource and physical site characterization, identified opportunities include data collection and validation, improving measurement methodologies, and validating analytical models.

For technology improvements, R&D opportunities include the development of innovative deployment strategies, improved machine reliability, advanced maintenance strategies, and development of critical supply chain elements. Such opportunities could reduce costs and risks associated with transporting equipment and the dependence on heavy-lift vessels. A perennial issue for Congress is whether and how to support or incentivize development of offshore wind and other ocean renewables.

For Further Information

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CRS Report R42942, *Deepwater Horizon Oil Spill: Recent Activities and Ongoing Developments*, by Jonathan L. Ramseur

CRS Report R41153, *Changes in the Arctic: Background and Issues for Congress*, coordinated by Ronald O'Rourke

Homeland Security

The federal government spends billions of dollars supporting research and development to protect the homeland. Some of the issues that the 117th Congress may consider include law enforcement access to digital social media and messaging, and use of facial recognition technology. Congress may also consider how the Department of Homeland Security addresses rapidly evolving natural and manmade hazards to critical infrastructure.

Evolving Technology and the Debate over "Lawful Access"

The continual evolution of technology presents ongoing opportunities and challenges for U.S. law enforcement. Some technological advances (e.g., social media) have arguably provided a wealth of information for law enforcement investigators and intelligence analysts. Other changes have presented unique hurdles for law enforcement. While some believe that law enforcement now has access to more information than ever before, others contend that law enforcement investigative capabilities are outpaced by the speed of technological change. These hurdles for law enforcement include strong, end-to-end (or what law enforcement has sometimes called "warrant-proof") encryption; provider limits on data retention; bounds on companies' technological capabilities to provide specific data points to law enforcement; tools facilitating anonymity online; and a landscape of mixed wireless, cellular, and other networks through which

individuals' information constantly pass. As such, law enforcement may have trouble accessing certain information they otherwise may be lawfully authorized to obtain.

The tension between law enforcement capabilities and technological change—including sometimes competing pressures for technology companies to provide data to law enforcement as well as to secure customer privacy—has received congressional attention for several decades. For instance, in the 1990s the "crypto wars" pitted the federal government against technology companies, and this strain was underscored by proposals to build in vulnerabilities, or "back doors," to certain encrypted communications devices as well as to restrict the export of strong encryption code. In addition, Congress passed the Communications Assistance for Law Enforcement Act (CALEA; P.L. 103-414) in 1994 to help law enforcement maintain their ability to execute authorized electronic surveillance as telecommunications providers turned to digital and wireless technology. More recently, there have been questions about whether CALEA should be amended to apply to a broader range of entities that provide communications services.

The debate over lawful access to information originally focused on *data in motion*, or law enforcement's ability to intercept real-time communications. However, more recent technology advances have impacted law enforcement's capacity to access not only real-time communications but stored content, or *data at rest*. Some officials have urged the technology community to develop a means to assist law enforcement in lawfully accessing certain data. At the same time, law enforcement entities have taken their own steps to bolster their technology capabilities. In addition, policymakers have been evaluating whether legislation that would further enable law enforcement access to data may be an appropriate response to current law enforcement concerns involving access to communications and data.

For Further Information

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CRS Report R44481, *Encryption and the "Going Dark" Debate*, by Kristin Finklea

CRS Report R44827, *Law Enforcement Using and Disclosing Technology Vulnerabilities*, by Kristin Finklea

Federal Law Enforcement Use of Facial Recognition Technology

In the course of carrying out their law enforcement duties, various federal law enforcement agencies may use facial recognition technology (FRT) for a variety of purposes. These purposes can include generating investigative leads, identifying victims of crimes, helping sort faces in photos that are part of forensic evidence, and helping verify the identity of inmates before they are released from prison. For instance, the Federal Bureau of Investigation (FBI) operates two programs that support law enforcement use of the technology: (1) the Next Generation Identification–Interstate Photo System (NGI-IPS), largely supporting state and local law enforcement; and (2) the Facial Analysis, Comparison, and Evaluation (FACE) Services Unit, supporting FBI investigations. In addition, border officials use facial recognition for identity verification purposes. For example, U.S. Customs and Border Protection is using FRT to confirm travelers' identities as part of its biometric entry and exit control system for noncitizen travelers into and out of the country.

There are currently no federal laws specifically governing law enforcement use of facial recognition technology. However, guidelines and recommendations regarding law enforcement use of FRT have been produced by the Facial Identification Scientific Working Group (FISWG)—one of the various scientific working groups that support the Organization of Scientific Area Committees for Forensic Science (administered by the National Institute of

Standards and Technology (NIST), which facilitates standards development, including for FRT). FISWG has published a number of FRT-related guidelines and recommendations for forensic science practitioners. In addition, the FBI maintains a Policy and Implementation Guide for the use of its NGI-IPS. Authorized law enforcement users are required to follow these policies as well as certain FISWG standards.

Law enforcement use of FRT has been the subject of ongoing congressional attention. Some of the concerns raised revolve around the accuracy of the technology, including potential race-, gender-, and age-related biases; the process of collecting, retaining, and securing facial images; public notification of the use of facial recognition and other image-capturing technology; and policies or standards governing law enforcement agencies' use of the technology. Some of these concerns have manifested in actions such as federal, state, and city efforts to prohibit or bound law enforcement agencies' use of FRT. In addition, some companies producing facial recognition software have placed new barriers to law enforcement using their technologies.

For Further Information

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CRS Report R46586, *Federal Law Enforcement Use of Facial Recognition Technology*, coordinated by Kristin Finklea

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Critical Infrastructure Security and Resilience

Critical infrastructure (CI) refers to the machinery, facilities, and information that enable vital functions of governance, public health, and the economy. When Congress created the Department of Homeland Security (DHS) in the wake of the 9/11 attacks, it directed the department to identify, prioritize, and protect CI systems and assets.

In recent years, many stakeholders have advocated for an increased focus on the system-wide resilience of CI functions. In 2019, the DHS Cybersecurity and Infrastructure Security Agency (CISA), created by Congress in 2018, identified 55 National Critical Functions, "so vital to the United States that their disruption, corruption, or dysfunction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof."

The COVID-19 pandemic and other recent events have affected CI functions associated with elections, government, education, health care, supply chains, and trade. Taken together, these events demonstrate how the disruption of social relations, economic relations, and public trust can disrupt critical functions—often without direct physical damage to CI systems and assets.

For example, election administration—an essential government function—requires both the integrity of associated CI systems and assets and public confidence in the election process. During the 2020 election cycle, CISA maintained a website to counter the online spread of misinformation, while also assisting state elections administrators in securing systems and assets against physical threats and cyber intrusions. Similarly, authorities responsible for COVID-19 vaccine development and deployment sought to secure R&D facilities and data, manufacturing

infrastructure, and critical supply chains, while also seeking to counter vaccine misinformation and coordinate distribution across multiple levels of government.

In the 117th Congress, the resilience of critical functions of supply—particularly for COVID-19 countermeasures—could continue to attract congressional attention. Congress may also examine the security of the election infrastructure subsector in light of the large increase in remote voting in 2020. More broadly, Congress may exercise oversight over CISA reorganization and CISA's institutionalization of a substantially revised risk management framework.

For Further Information

Brian E. Humphreys, Analyst in Science and Technology Policy

CRS Report R46407, *COVID-19: Remote Voting Trends and the Election Infrastructure Subsector*, by Brian E. Humphreys

CRS Report R45809, *Critical Infrastructure: Emerging Trends and Policy Considerations for Congress*, by Brian E. Humphreys

Information and Communication Technology

The rapid pace of advancements in information and communication technologies presents several issues for congressional policymakers, including those related to cybersecurity; artificial intelligence; "Big Tech" and social media policy and regulation; broadband deployment; public safety networks and emergency alerting; 5G networks; access to broadband networks and net neutrality; federal networking R&D; quantum information science; and the Internet of Things; digital contact tracing and exposure notification for COVID-19 and other contagious diseases.

Cybersecurity

Cybersecurity is not an end state. Rather, it is a risk management process that information technology (IT) system owners and operators use to ensure that data, devices, systems and networks:

- maintain *confidentiality* to only authorized parties;
- preserve the *integrity* of both the data and technology; and
- are *available* when users desire.

Some cybersecurity issues persist across Congresses:

- The *confidentiality* of internet-based communications (i.e., data security and privacy) is continually assessed by Congress. The 116th Congress held hearings; legislation was not passed.
- A way to achieve the *integrity* of technology is through cyber supply chain risk management (C-SCRM). The adoption of fifth-generation mobile technologies (5G) and the associated risks have renewed the focus on C-SCRM. The 116th Congress required the President to produce a strategy on 5G security.
- Because of a proven record of *availability* and meeting the organization's operational needs, many businesses and government agencies run legacy IT systems. However, maintaining these technologies may create gaps where vulnerabilities become pronounced and are exploited by malicious actors. Congress created working capital funds for federal agencies to modernize (and secure) their IT; these funds have not been fully implemented.

Cyber risks continue to evolve. The 116th Congress examined new issues around the use of information and communications technology (ICT) during the COVID-19 pandemic. The rapid adoption of mobile computing technologies for both work and education raised concerns about the resilience of the nation's internet infrastructure, security of computing platforms (e.g., video conferencing services), and the protection of data.

During the 116th Congress, the congressionally authorized Cyberspace Solarium Commission released its report, which included more than 76 legislative proposals to improve the resilience of the nation's cyberspace and deter malicious actors' operations. The FY2021 National Defense Authorization Act (NDAA) contained 26 of the recommendations, including recommendations to improve the cybersecurity workforce, conduct national exercises, improve information sharing, and investigate cyber risks from emerging technologies. The NDAA also extended the authorization for the Commission, which is to continue to track the implementation of remaining recommendations.

For Further Information

Chris Jaikaran, Analyst in Cybersecurity Policy

CRS In Focus IF10559, *Cybersecurity: A Primer*, by Chris Jaikaran

CRS In Focus IF10920, *Cyber Supply Chain Risk Management: An Introduction*, by Chris Jaikaran

CRS In Focus IF11469, *The Cyberspace Solarium Commission: Illuminating Options for Layered Deterrence*, by Chris Jaikaran

CRS In Focus IF10654, *Challenges in Cybersecurity Education and Workforce Development*, by Boris Granovskiy

CRS Report R46536, *Cybercrime and the Law: Computer Fraud and Abuse Act (CFAA) and the 116th Congress*, by Peter G. Berris

CRS Insight IN11497, *Cybersecurity: Recent Policy and Guidance on Federal Vulnerability Disclosure Programs*, by Chris Jaikaran

Artificial Intelligence

In recent years, both the Administration and Congress have been increasingly engaged in supporting artificial intelligence (AI) research and development (R&D), investing in AI technologies, and working to address policy concerns arising from AI development and use. Congressional activities focused on AI increased substantially in the 115th and 116th Congresses, including multiple committee hearings in the House and Senate, the introduction of numerous AI-focused bills, and the passage of AI provisions in legislation, such as numerous AI provisions in the National Defense Authorization Act for Fiscal Year 2021 (H.R. 6395). Activity related to AI could continue in the 117th Congress.

The term AI is generally considered to mean computerized systems that work and react in ways commonly thought to require intelligence, such as the ability to learn, solve problems, and achieve goals under uncertain and varying conditions. It includes multiple methodologies and application areas, such as machine learning, computer vision, natural language processing, robotics, and autonomous vehicles. AI is employed across a variety of sectors, including transportation, health care, energy, agriculture, manufacturing, and finance. Current AI technologies are considered "narrow AI," meaning that they are highly tailored to particular tasks. In contrast, potential future AI systems that exhibit adaptable intelligence across a range of

cognitive tasks, often referred to as "general AI," are unlikely to be developed for at least decades, if ever, according to most researchers.

There are several broad concerns related to AI spanning multiple sectors that Congress could consider in current session. These include

- the impact of AI and AI-driven automation on the workforce, including potential job losses and the need for worker retraining;
- the challenges of educating students in AI and using AI in the classroom;
- the balance of federal and private-sector funding for AI;
- international competition in AI R&D and deployment;
- the development of standards and testing protocols for AI systems;
- the need for and effectiveness of federal coordination efforts in AI; and
- the incorporation of ethics, privacy, security, transparency, and accountability considerations in AI systems, especially for such applications as facial recognition technologies.

There are additional national security concerns about the potential use of AI technologies that Congress could address, such as deep fakes to influence elections and erode public trust; the balance of human and automated decisionmaking in military operations; and public concerns about the use of AI in combat situations.

For Further Information

Laurie A. Harris, Analyst in Science and Technology Policy

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CRS In Focus IF10608, *Overview of Artificial Intelligence*, by Laurie A. Harris

CRS In Focus IF11333, *Deep Fakes and National Security*, by Kelley M. Sayler and Laurie A. Harris

Big Tech and Social Media Policy and Regulation

Internet policy and regulation has attracted strong congressional interest since the mid-1990s. In addition to net neutrality, broadband deployment, and the digital divide (treated elsewhere in this report), the 117th Congress may address issues related to content providers (also known as edge providers), or those that provide content, applications, or services over the internet. These issues include antitrust actions, social media content moderation practices, the use of algorithms by content providers, and foreign-owned content providers that operate in the United States.

Congressional interest in antitrust has focused on "Big Tech"—Alphabet (Google's parent company), Amazon, Apple, Facebook, and Microsoft. Some Members of Congress have expressed concern that these companies obtain and maintain market dominance using anticompetitive conduct and have questioned whether current antitrust laws are sufficient.

Congressional interest in content moderation strategies among social media companies—such as Facebook and Twitter—has, in recent years, focused largely on Section 230 of the Communications Act of 1934. Section 230 protects interactive computer service providers and their users from liability from publishing, and in some instances restricting access to, another's

content. Some Members of Congress have stated that Section 230 should be amended to allow social media companies to be held liable for hosting or removing certain content.

The 117th Congress may address these issues and others related to content providers. The 116th and 117th Congresses have held multiple committee hearings and introduced numerous bills related to these issues, including bills to amend antitrust laws and Section 230, to require foreign-owned software to include a disclaimer to consumers, and to ban the use of TikTok—an application from a Chinese-owned social media company—on government-issued devices. Activity related to Big Tech and social media is likely to continue in the 117th Congress, which may introduce similar or new bills to address these issues.

For Further Information

Valerie Brannon, Legislative Attorney

Clare Cho, Analyst in Industrial Organization and Business

Patricia Moloney Figliola, Specialist in Internet and Telecommunications Policy

Jason Gallo, Section Research Manager Science and Technology Policy

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CRS Report R45650, *Free Speech and the Regulation of Social Media Content*, by Valerie C. Brannon

CRS Report R45713, *Terrorism, Violent Extremism, and the Internet: Free Speech Considerations*, by Victoria L. Killion

CRS Report R46739, *Mergers and Acquisitions in Digital Markets*, by Clare Y. Cho

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CRS Legal Sidebar LSB10544, *The Google Antitrust Lawsuit: Initial Observations*, by Jay B. Sykes

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CRS Report R46207, *Competition on the Edge of the Internet*, by Clare Y. Cho

CRS Report R46543, *TikTok: Technology Overview and Issues*, by Patricia Moloney Figliola

Broadband Deployment and the Digital Divide

Broadband internet service is delivered through a variety of technologies and allows users to send and receive data at volumes and speeds that support a wide range of applications. Broadband technologies are currently being deployed throughout the United States, primarily by the private sector. Although the overall number of broadband subscribers continues to grow, many rural, tribal, and low-income areas are underserved—both in terms of deployment and the speed of service—relative to higher-income urban and suburban areas. This gap is what is termed the "digital divide." Many policymakers, particularly in light of the COVID-19 pandemic, believe

that disparities in broadband access may exacerbate adverse economic and social conditions for those unable to adequately work or attend school remotely, and assert that the federal government should play a more active role to address this gap.

The 117th Congress may consider a range of broadband-related issues as it attempts to address the digital divide. These include continued funding for the Rural Utilities Service's broadband programs and oversight of the Universal Service Fund; infrastructure legislation that includes funds and incentives for broadband buildout; the adequacy of the currently established benchmark broadband speed; the optimal level of broadband data granularity for mapping; how new broadband technologies may increase coverage; the role of municipalities as broadband providers; and whether broadband should be classified as a public utility.

Support to address the digital divide could include supply-side subsidies, grants, and tax incentives; demand-side incentives such as assistance to low-income households to obtain broadband access and devices; and streamlining broadband deployment regulation.

For Further Information

Colby Leigh Rachfal, Analyst in Telecommunications Policy

CRS Report R46613, *The Digital Divide: What Is It, Where Is It, and Federal Assistance Programs*, by Colby Leigh Rachfal and Angele A. Gilroy

CRS Report R46307, *State Broadband Initiatives: Selected State and Local Approaches as Potential Models for Federal Initiatives to Address the Digital Divide*, by Colby Leigh Rachfal

CRS Report R46501, *Rural Digital Opportunity Fund: Requirements and Selected Policy Issues*, by Colby Leigh Rachfal

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CRS Report R46108, *Demand for Broadband in Rural Areas: Implications for Universal Access*, by Brian E. Humphreys

Deployment of the FirstNet Network

The Middle Class Tax Relief and Job Creation Act of 2012 (P.L. 112-96) authorized the Federal Communications Commission (FCC) to allocate spectrum to public safety use. The act also created the First Responder Network Authority (FirstNet), an independent agency in the Department of Commerce. Congress authorized FirstNet to establish a new, nationwide broadband network for public safety, and provided $7 billion in funding for the network, to enhance communications for public safety agencies at all levels of government.

Congress authorized FirstNet to enter into a public-private partnership to deploy the network. Through a competitive bidding process, FirstNet selected AT&T as its partner. AT&T has been deploying the network as specified in its contract and in state-specific plans, with 80% of the network buildout completed. The FirstNet network supplements legacy voice systems by providing advanced data and voice capabilities, public safety applications, and deployable assets that can restore communications after disasters. Agencies are subscribing to and using the network in emergencies, including the COVID-19 pandemic and wildfires. A remaining challenge for public safety agencies is maintaining traditional land mobile radio systems, while integrating new and emerging cellular technologies (e.g., FirstNet).

An ongoing concern for policymakers has been the transparency related to the buildout of the FirstNet network. The FirstNet/AT&T contract and state plans contain detailed information on

deployment; however, both are deemed proprietary and not available for public review. The Government Accountability Office (GAO) called for a more reliable master schedule to gauge progress; greater communication with public safety stakeholders; and measuring user satisfaction. Additionally, some stakeholders have advocated for greater interoperability between FirstNet and other systems. While this could increase coverage and coordination between agencies, it may also affect the financial viability of the FirstNet network. Given the federal investment in the project and the importance of the network, the 117th Congress may consider continuing its oversight of FirstNet.

For Further Information

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CRS Report R45179, *The First Responder Network (FirstNet) and Next-Generation Communications for Public Safety: Issues for Congress*, by Jill C. Gallagher

5G Telecommunications

Wireless providers around the world are upgrading to fifth-generation (5G) telecommunications networks to meet growing demands for mobile data and to support new applications. 5G promises faster speeds, more bandwidth, and less lag time. 5G networks are expected to support new services for consumers (e.g., virtual reality applications) and new systems for industrial users (e.g., industrial control systems). When fully deployed, 5G is expected to accelerate development of the Internet of Things (IoT)—systems of interconnected devices (e.g., smart homes, smart factories)—and emerging technologies (e.g., remote surgery).

Many experts anticipate that 5G, like 4G, will generate significant economic gains. According to a study by Accenture, 5G could potentially create up to 3 million U.S. jobs and increase U.S. gross domestic product by $500 billion.

Congress has streamlined rules to speed deployment of 5G infrastructure, supported the allocation of spectrum for 5G networks, and invested in R&D on 5G technologies. It supported policies to ensure the security of 5G networks and to strengthen the U.S. position in the global 5G market by supporting software-based technologies that capitalize on U.S. strengths in software development. To address security concerns, it restricted the use of equipment made by the Chinese companies Huawei and ZTE, supported policies encouraging allies to do the same, and authorized funding for the replacement of Huawei equipment in U.S. networks.

The 117th Congress may continue to examine policies and programs that:

- Make additional spectrum available for 5G and incentivize U.S. commercial investment in 5G networks and technologies;
- Ensure the security of global 5G networks and supply chains through policies and programs that support the removal of untrusted 5G equipment in U.S. and foreign networks, and promote the use of open architecture, interoperable technologies in telecommunication networks globally;
- Strengthen U.S. competitiveness in the global 5G market through R&D, investment in software-based network technologies, and promoting U.S. participation and leadership in 5G and 6G standards development; and
- Ensure that U.S. 5G companies have equal access to foreign markets and encourage the Administration to take action against countries and companies engaged in trade practices perceived as unfair.

A continuing challenge facing Congress is balancing competing interests, such as the interests of telecommunications carriers and the government seeking to speed 5G deployment to achieve economic gains; security and intelligence officials striving to ensure the security of networks in the United States and abroad; spectrum users, including incumbent and federal users that may be affected by reallocation of spectrum for 5G; U.S. suppliers affected by trade restrictions; localities seeking to protect constituent needs and interests; and consumer groups striving to ensure the privacy and security of data transmitted over 5G networks and IoT devices.

For Further Information

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CRS Report R45485, *Fifth-Generation (5G) Telecommunications Technologies: Issues for Congress*, by Jill C. Gallagher and Michael E. DeVine

Access to Broadband Networks and the Net Neutrality Debate

Determining the appropriate framework to ensure an open internet is fundamental to the policy debate over broadband access. A central question of the debate is what, if any, steps are necessary to ensure that content, services, and applications providers, as well as consumers, have unfettered access to the internet. The move to place restrictions on the owners of the networks that compose and provide access to the internet, to ensure equal access and nondiscriminatory treatment, is referred to as "net neutrality." While there is no single accepted definition of "net neutrality," most agree that any such definition should include the general principles that owners of the networks that compose and provide access to the internet (i.e., broadband internet access providers) should not control how consumers lawfully use that network, and should not be able to discriminate against content provider access to that network.

Some policymakers contend that specific regulatory guidelines are necessary to protect the marketplace from potential abuses which could threaten the net neutrality concept. Others contend that existing laws and policies are sufficient to deal with potential anti-competitive behavior and that additional regulations would have negative effects on the expansion and future development of the internet. Broadband regulation and the authority of the Federal Communications Commission (FCC) to implement any regulation are issues of growing importance in the debate over broadband access. The FCC's past actions to change net neutrality rules and the likelihood that this issue could be revisited under a newly comprised FCC have reopened the debate over what the appropriate framework should be and whether Congress should enact legislation to establish this framework.

For Further Information

Patricia Moloney Figliola, Specialist in Internet and Telecommunications Policy

CRS Report 46780, *Overview of the Universal Service Fund and Selected Broadband Programs*, by Patricia Moloney Figliola (Coordinator)

CRS Report R40616, *The Federal Net Neutrality Debate: Access to Broadband Networks*, by Patricia Moloney Figliola

Networking and Information Technology Research and Development Program

The Networking and Information Technology Research and Development (NITRD) Program is the United States' primary source of federally-funded information technology (IT) research and

development in the fields of computing, networking, and software. The program evolved from the High-Performance Computing and Communications (HPCC) Program, which originated with the HPCC Program Act of 1991 (P.L. 102-194); it coordinates the activities of multiple agencies conducting multi-disciplinary, multi-technology, and multi-sector R&D needs. The 23 NITRD member agencies invest over $6 billion annually in basic and applied R&D programs.

Proponents of federal support of IT R&D assert that it has produced positive outcomes for the country and played a crucial role in supporting long-term research into fundamental aspects of computing. Such fundamentals may provide broad practical benefits, but generally take years to realize. Additionally, the unanticipated results of research are often as important as the anticipated results. Another aspect of government-funded IT research is that it often leads to open standards, something that many perceive as beneficial, encouraging deployment and further investment. Industry, on the other hand, is more inclined to invest in proprietary products and tends to diverge from a common standard when there is a potential competitive or financial advantage to do so.

Supporters believe that the outcomes achieved through the various funding programs create a synergistic environment in which both fundamental and application-driven research are conducted, benefitting government, industry, academia, and the public. Critics, however, assert that the government, through its funding mechanisms, may be picking "winners and losers" in technological development, a role more properly residing with the market. For example, the size of the NITRD Program could encourage industry to follow the government's lead on research directions rather than selecting those directions itself.

The NITRD Program is funded through appropriations to its individual agencies; therefore, it will be part of the continuing federal budget debate in the 117th Congress.

For Further Information

Patricia Moloney Figliola, Specialist in Internet and Telecommunications Policy

CRS Report RL33586, *The Federal Networking and Information Technology Research and Development Program: Background, Funding, and Activities*, by Patricia Moloney Figliola

Quantum Information Science

Quantum information science (QIS), which combines elements of mathematics, computer science, engineering, and physical sciences, has the potential to provide capabilities far beyond what is possible with the most advanced technologies available today. Although much of the press coverage of QIS has been devoted to quantum computing, there is more to QIS. Many experts divide QIS technologies into three application areas: sensing and metrology, communications, and computing and simulation.

The government's interest in QIS dates back at least to the mid-1990s, when the National Institute of Standards and Technology and the DOD held their first QIS workshops. QIS was first mentioned in the FY2008 budget of what is now the Networking and Information Technology Research and Development Program and has been a component of the program since then. QIS is a component of the National Strategic Computing Initiative (Executive Order 13702), which was established in 2015. In its "National Strategic Overview for Quantum Information Science," the National Science and Technology Council (NSTC) identified policy opportunities that include—

- choosing a science-first approach to QIS,
- creating a "quantum-smart" workforce,
- deepening engagement with the quantum industry,

- providing critical infrastructure,
- maintaining national security and economic growth, and
- advancing international cooperation.

The United States is not alone in its increasing investment in QIS R&D. QIS research is also being pursued at major research centers worldwide, with China and the European Union having the largest foreign QIS programs. Further, even without explicit QIS initiatives, many other countries, including Russia, Germany, and Austria, are making strides in QIS R&D.

In another report, the NSTC stated that creating a cohesive and effective U.S. QIS R&D policy would require a collaborative effort in five policy areas: institutional boundaries; education and workforce training; technology and knowledge transfer; materials and fabrication; and the level and stability of funding. These areas continue to be salient in 2021 and may provide context for developing legislation in the 117th Congress.

For Further Information

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CRS Report R45409, *Quantum Information Science: Applications, Global Research and Development, and Policy Considerations*, by Patricia Moloney Figliola

The Internet of Things

The Internet of Things (IoT) may continue to be a focal point of wide-reaching debates during the 117th Congress. The term refers to networks of "smart" objects with two features: internet connectivity and an internet address. Such objects can form systems that communicate among themselves, allowing automated and remote control of many independent processes. The IoT has become increasingly embedded in homes and communities, factories and cities, and nearly every sector of the economy, both domestically and globally. These may include objects such as—

- self-driving cars,
- aerial vehicles,
- home appliances,
- medical devices,
- electric grids,
- transportation infrastructure,
- precision farming,
- manufacturing equipment, and
- building systems.

An increasing number of these systems require access to radio frequency (RF) spectrum to connect to the internet. The deployment of 5G wireless technologies is likely to increase along with the IoT, potentially substantially expanding the opportunities for growth in use of IoT devices. Although the full extent of IoT impacts remains uncertain, some economic analyses predict that it will contribute trillions of dollars to economic growth in coming years.

The federal government may play an important role in enabling the IoT, including R&D policy and investment, standards, regulation, and support for testbeds and demonstration projects.

Numerous agencies have regulatory, sector-specific, and other mission-related responsibilities related to the IoT, such as the Departments of Commerce, Health, Energy, Transportation, and Defense; the National Science Foundation; the Federal Communications Commission; and the Federal Trade Commission. Its growth will likely depend on changes in—and coordination among—many government departments and agencies. The range of issues that might be of interest to Congress include:

- Security of objects and the networks;
- Data privacy;
- IoT security and connectivity standards;
- Transition to the latest internet protocol (IPv6) and the growth of 5G wireless;
- Energy management for objects; and
- The role of the federal government in the development of standards and regulation.

For Further Information

Patricia M. Figliola, Specialist in Internet and Telecom Policy

CRS Report R44227, *The Internet of Things: Frequently Asked Questions*, by Patricia Moloney Figliola

Digital Contact Tracing and Digital Exposure Notification

"Contact tracing" is a public health measure used to control disease spread. Trained public health workers assist patients with an infectious disease to recall their close contacts within a given timeframe, notify them of potential exposure, and provide advice to patients and contacts. Given the scale of the COVID-19 pandemic, some public health authorities are automating part of the tracing process with smartphone applications (apps). Some apps take advantage of Bluetooth signals to track individuals' proximity to one another, otherwise known as "digital exposure notification (DEN)." Bluetooth allows short-range wireless communications between electronic devices. Apps may also be used by public health authorities to enable "digital contact tracing" (DCT), which may also use location data. Many countries deployed nationwide apps, but the United States took a decentralized approach, with states engaging the private sector to develop tracing tools.

In April 2020, Apple and Google, which develop the iOS and Android mobile phone operating systems, respectively, announced a partnership to develop a protocol to support the development of digital exposure notification apps that use a smartphone's Bluetooth signal. The protocol is to work on both operating systems, which account for nearly the entire share of the U.S. mobile phone market. It was released to developers in May 2020. More recently, in September 2020, Google and Apple began allowing U.S. health agencies to offer exposure notifications without having to build their own apps. That tool, called Exposure Notifications Express, is part of newer iOS versions. Now, iPhone users just have to turn notifications on in the settings menu. Google took a different path, developing a generic app that it customizes for each state.

Discussion of U.S. digital contact tracing has identified a number of challenges related to its use, including Bluetooth limitations, app effectiveness versus personal privacy, interoperability, and coverage. Each poses a different challenge to effective use of digital tracing capabilities.

Further Information

Patricia Moloney Figliola, Specialist in Internet and Telecommunications Policy

CRS In Focus IF11609, *Contact Tracing for COVID-19: Domestic Policy Issues*, by Kavya Sekar and Laurie A. Harris

CRS Legal Sidebar LSB10511, *COVID-19: Digital Contact Tracing and Privacy Law*, by Eric N. Holmes and Chris D. Linebaugh

Physical and Material Sciences

Congress has demonstrated an interest in the National Science Foundation—particularly in funding levels and the prioritization and direction of such funding. Additionally, funding and oversight issues relating to the multiagency initiative for research and development in the emerging field of nanotechnology may be of interest during the 117th Congress.

National Science Foundation

The National Science Foundation (NSF) supports basic research and education in the nonmedical sciences and engineering and is a primary source of federal support for U.S. university research. It is also responsible for the largest share of the federal science, technology, engineering, and mathematics (STEM) education effort, both by number of programs and by total investment. Enacted funding for NSF in FY2021 is $8.5 billion.

Congress has a long-standing interest in NSF's funding levels and the prioritization and direction of such funding. At several times in NSF's history, some policymakers have pursued authorization of large increases in the NSF budget over a defined period of time (e.g., a doubling over seven years). Advocates of large funding increases assert that steep and fast increases in NSF funding are necessary to ensure U.S. competitiveness, particularly in rapidly evolving technical fields such as artificial intelligence. Other analysts argue that steady, reliable funding increases over longer periods of time are less disruptive to the U.S. scientific and technological enterprise. Alternatively, some policymakers seek no additional increases in NSF funding in light of the federal deficit and spending caps. Actual appropriations have rarely reached authorized levels. After nearly a decade of flat funding (on average, after adjusting for inflation), NSF's budget has increased slowly since FY2019.

Congress has typically given NSF considerable discretion in allocating its funding to specific fields of research. From time to time, however, analysts and legislators have debated proposals to prioritize NSF funding for the physical sciences and engineering over funding for the social, behavioral, and economic sciences, or to expand support for multidisciplinary research. In addition, while some policymakers strongly support NSF's focus on basic research, others prefer to direct federal funding to research with a more applied or mission-oriented focus.

Policy issues that the 117th Congress may continue to address include

- NSF's selection, funding, and management of large-scale research facilities and mid-scale projects;
- the adequacy of NSF funding and support for "industries of the future," including artificial intelligence and quantum information science; and
- oversight of NSF's planning for the Arecibo Observatory in Puerto Rico, site of the December 2020 collapse of a 57-year-old 305-meter radio telescope.

Other long-standing, NSF-oriented policy issues focus on the balance between scientific independence and accountability to taxpayers; the geographic distribution of grants; NSF's role in broadening participation by underrepresented groups in STEM fields; support for various STEM

education programs; and the collection and dissemination of data about the U.S. scientific and technological enterprise.

For Further Information

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CRS Report R46341, *Federal Research and Development (R&D) Funding: FY2021*, coordinated by John F. Sargent Jr.

CRS Video WVB00272, *FY2020 Federal Research and Development Funding: National Science Foundation*, by Laurie A. Harris

Nanotechnology and the National Nanotechnology Initiative

Nanoscale science, engineering, and technology—commonly referred to collectively as nanotechnology—is believed by many to offer extraordinary economic and societal benefits. Nanotechnology R&D is directed toward the understanding and control of matter at dimensions of roughly 1 to 100 nanometers (a nanometer is one-billionth of a meter). At this size, the properties of matter can differ in fundamental and potentially useful ways from the properties of individual atoms and molecules and of bulk matter.

Many current applications of nanotechnology are evolutionary in nature, offering incremental improvements in existing products and generally modest economic and societal benefits. For example, nanotechnology is being used in automobile bumpers, cargo beds, and step-assists to reduce weight, increase resistance to dents and scratches, and eliminate rust; in clothes to increase stain- and wrinkle-resistance; and in sporting goods to improve performance. Other nanotechnology innovations play a central role in current applications with substantial economic value.

For example, nanotechnology is a fundamental enabling technology in nearly all semiconductors and is key to improvements in chip speed, size, weight, and energy use. Similarly, nanotechnology has substantially increased the storage density of nonvolatile flash memory and computer hard drives. In the longer term, some believe that nanotechnology may deliver revolutionary advances with profound economic and societal implications, such as detection and treatment of cancer and other diseases; clean, inexpensive, renewable power through energy transformation, storage, and transmission technologies; affordable, scalable, and portable water filtration systems; self-healing materials; and high-density memory devices.

The development of this emerging field has been fostered by sustained public investments in nanotechnology R&D. In 2001, President Clinton launched the multi-agency National Nanotechnology Initiative (NNI) to accelerate and focus nanotechnology R&D to achieve scientific breakthroughs and to enable the development of new materials, tools, and products. More than 60 nations subsequently established programs similar to the NNI.

Cumulatively through FY2020, Congress appropriated approximately $29.4 billion for nanotechnology R&D; President Trump requested $1.7 billion in funding for FY2021. In 2003, Congress enacted the 21st Century Nanotechnology Research and Development Act (P.L. 108-153), providing a legislative foundation for some of the activities of the NNI, establishing programs, assigning agency responsibilities, and setting authorization levels through FY2008. Legislation was introduced in the 114th and 115th Congress to amend and reauthorize the act though none was enacted into law. The 117th Congress may continue to direct its attention primarily to three topics that may affect the realization of nanotechnology's hoped-for potential: R&D funding; U.S. competitiveness; and environmental, health, and safety concerns.

For Further Information

John F. Sargent Jr., Specialist in Science and Technology Policy

CRS Report RL34511, *Nanotechnology: A Policy Primer*, by John F. Sargent Jr.

Space

Congress has historically had a strong interest in space policy issues. Space topics that may come before the 117th Congress include the funding and oversight of the National Aeronautics and Space Administration (NASA) and issues related to the commercialization of space and to Earth-observing satellites.

NASA

Spaceflight has attracted strong congressional interest since the establishment of NASA in 1958. Issues facing the 117th Congress include the goals and strategy of NASA's human spaceflight program, the relationship between NASA and the commercial space sector, and the priority to be placed on NASA's Earth Science program. Congress may address these and other topics through NASA reauthorization legislation and the annual appropriations process.

As directed by the NASA Authorization Act of 2010 (P.L. 111-267), NASA is pursuing a two-track strategy for human spaceflight. First, for crew transport to low Earth orbit, NASA has been supporting the development of commercial capabilities. After years of reliance on Russian spacecraft following the end of the space shuttle program in 2011, in 2020 a NASA-contracted U.S. commercial spacecraft carried a crew to the International Space Station (ISS) for the first time. A second commercial crew transport provider is expected to begin operational flights in 2021.

Second, for human exploration beyond Earth orbit, NASA is developing a crew capsule called Orion and a heavy-lift rocket called the Space Launch System (SLS). These are now part of the Artemis program, established by the Trump Administration with a goal of landing humans on the Moon in 2024. The first test flight of Orion and the SLS is scheduled for 2021; the first test flight with a crew on board is scheduled for 2023. The progress of Orion and the SLS, the development of other components of Artemis (such as the Human Landing System), and the 2024 target date for a lunar landing may all draw attention in the 117th Congress.

The relationship between NASA and the commercial space sector continues to evolve. Rather than acquiring government-owned systems, NASA increasingly contracts for commercial services, including crew and cargo transport to the ISS, the Human Landing System, and a planned sequence of robotic lunar landers. Some in Congress would prefer a more traditional government-owned approach, especially for systems affecting the safety of astronauts. A related topic is the future of the ISS, which NASA has proposed to transition after 2025 to a combination of public-private partnerships and commercial service contracts.

NASA's Earth Science program, in which climate research is a major focus, may be of particular interest in the 117th Congress. In recent years, Congress repeatedly did not follow Trump Administration proposals to terminate certain Earth Science space missions. While the Biden Administration is likely to view climate-related programs more favorably, Congress may continue to debate the priority of the Earth Science program relative to NASA's other responsibilities.

For Further Information

Daniel Morgan, Specialist in Science and Technology Policy

CRS Report R43419, *NASA Appropriations and Authorizations: A Fact Sheet*, by Daniel Morgan

CRS In Focus IF11643, *Artemis: NASA's Program to Return Humans to the Moon*, by Daniel Morgan

Commercial Space

Since the earliest days of spaceflight, U.S. companies have been involved as contractors to government agencies. Increasingly, though, space is becoming commercial. A majority of U.S. satellites are now commercially owned, providing commercial services, and launched by commercial launch providers. Congressional and public interest in space is also becoming more focused on commercial activities, such as companies developing reusable rockets or collecting business data with fleets of small Earth-imaging satellites.

Some observers have identified a distinct "new space" sector of relatively new companies focused on private spaceflight at low cost. One factor driving this trend is NASA's reliance on commercial providers for access to the ISS, but "new space" companies are also focused on other markets. These include the launch of national security satellites for the Department of Defense (DOD), the launch of commercial satellites for U.S. and foreign companies, the provision of commercial services such as Earth imaging and satellite communications, and even space tourism.

Multiple federal agencies regulate the commercial space industry, based on statutory authorities that were enacted separately and have evolved over time. The Federal Aviation Administration licenses commercial launch and reentry vehicles (i.e., rockets and spaceplanes) as well as commercial spaceports. The National Oceanic and Atmospheric Administration (NOAA) licenses commercial Earth remote sensing satellites. The Federal Communications Commission licenses commercial satellite communications. The Departments of Commerce and State license exports of space technology. During the Trump Administration, several of these agencies made significant changes in their regulations affecting commercial space. The 117th Congress may examine the implementation of these regulatory changes and consider whether additional legislation is required. Related ongoing efforts, such as the proposed reorganization of space offices in the Commerce Department and the shift from DOD to civil responsibility for space situational awareness (e.g., issuing alerts when orbiting satellites may be about to collide), are also likely to attract congressional attention.

How the federal government makes use of commercial space capabilities continues to evolve. NASA used to own and operate the space shuttles that contractors built for it, but since 2012 it has contracted with commercial service providers to deliver cargo into orbit using these providers' spacecraft. DOD has its own satellite communications capabilities; it also procures communications bandwidth from commercial satellite companies. Agencies are considering a host of new opportunities, including acquisition of weather data from commercial satellites, acquisition of science data from commercial lunar landers, and expanded commercial utilization of the ISS for technology development and demonstration as well as other purposes. The 117th Congress may address these developments primarily through oversight of agency programs and decisions on agency budgets.

For Further Information

Daniel Morgan, Specialist in Science and Technology Policy

CRS Report R45416, *Commercial Space: Federal Regulation, Oversight, and Utilization*, by Daniel Morgan

Earth-Observing Satellites

The constellation of civil Earth-observing satellites launched and operated by the U.S. government performs a wide range of observational and data collecting activities. These activities include measuring the change in mass of polar ice sheets, wind speeds over the oceans, land cover change, as well as the more familiar daily measurements of key atmospheric parameters that enable modern weather forecasts and storm prediction. Satellite observations of the Earth's oceans and land surface help with short-term seasonal forecasts of El Niño and La Niña conditions, which are valuable to U.S. agriculture and commodity interests; identification of the location and size of wildfires, which can assist firefighting crews and mitigation activities; as well as long-term observational data of the global climate, which are used in predictive models that help assess the degree and magnitude of current and future climate change.

Congress continues to be interested in the performance of NASA, NOAA, and the U.S. Geological Survey (USGS) in building and operating U.S. Earth-observing satellites. NASA's Earth-observing satellites are primarily for research purposes, but some of the data they provide are also used operationally. Congress has often taken an interest in the relationship between NASA's Earth Science research program and the operational programs at NOAA and USGS. Congress is also particularly interested in the agencies' ability to keep to budgets and time schedules so that critical space-based observations are not missed due to delays and cost overruns.

NOAA launched two Geostationary Operational Environmental Satellite weather satellites, GOES-16 and GOES-17 in 2016 and 2017, respectively. GOES-17 experienced an issue with one of its key imaging instruments after launch, the Advanced Baseline Imager (ABI), which impairs its functionality. NASA and NOAA, and the Department of Commerce, each separately launched investigations into the cause of the impairment and possible solutions. Despite the ABI issue, GOES-17 is expected to provide more and better data than currently available. The satellites represent the first two in a series of four Earth-orbiting weather satellites planned by NOAA through 2036.

NOAA expects to launch the next two satellites (GOES-T and GOES-U) in fiscal years 2022 and 2024. NOAA's polar-orbiting satellites program continues its congressionally approved restructuring, with NOAA on schedule to launch three additional Joint Polar Satellite System (JPSS) satellites: JPSS-1, JPSS-2, and JPSS-3 in 2023, 2026, and 2031, respectively. The 117th Congress may continue to require updates on satellite design, construction, and operations budget and timelines, as indicated in explanatory language associated with recent annual appropriations legislation. Congress may also provide oversight of NOAA's partnerships with NASA, other agencies, and the commercial sector in the development and deployment of polar-orbiting and geostationary satellites.

Since FY2015, Congress has supported the development and upcoming 2021 launch of Landsat 9, the latest remote sensing satellite in a series beginning in 1972 to provide images of the Earth's surface. Landsat 9 is essentially a rebuild of Landsat 8, and aims to replace Landsat 7, which may run out of fuel in 2021. Once Landsat 9 is operational, it and Landsat 8 are to acquire around 1,500 high-quality images of the Earth per day, with a repeat visit every 8 days, on average. Congress may consider the future of the Sustainable Land Imaging Program under which NASA and the USGS develop, launch, and operate Landsat satellites. NASA and the USGS anticipate releasing information about the plans for Landsat Next, the mission following Landsat 9, during 2021. When considering the agencies' proposal, the 117th Congress may consider whether to pursue the development of another satellite similar to Landsat 9 or to explore alternatives such as

various technological improvements, cost savings opportunities, public-private partnerships, and international cooperation and data sharing.

For Further Information

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CRS Report R44335, *Minding the Data Gap: NOAA's Polar-Orbiting Weather Satellites and Strategies for Data Continuity*, by Peter Folger

CRS Report R46560, *Landsat 9 and the Future of the Sustainable Land Imaging Program*, by Anna E. Normand

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