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Science and Technology Issues in the 116th Congress

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SUMMARY

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Frank Gottron, Coordinator
Specialist in Science and Technology Policy

Science and Technology Issues in the 116th Congress

Science and technology (S&T) have a pervasive influence over a wide range of issues confronting the nation. Public and private research and development spur scientific and technological advancement. Such advances can drive economic growth, help address national priorities, and improve health and quality of life. The ubiquity and constantly changing nature of science and technology frequently create public policy issues of congressional interest.

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 116th Congress. This set is not exhaustive, however. Given the rapid pace of S&T advancement and its importance in many diverse public policy contexts, other S&T-related issues not discussed in this report may come before the 116th Congress. The selected issues are grouped into 10 categories

- Overarching S&T Policy Issues,
- Agriculture,
- Biomedical Research and Development,
- Climate Change Science 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.

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Contacts

Introduction

Science and technology (S&T) play an important role in our society. Advances in science and technology can help drive economic growth and meet national priorities in public health, environmental protection, agricultural productivity, defense, and many other areas.

Federal policies affect scientific and technological advancement on several levels. The federal government directly funds research and development (R&D) activities to achieve national goals or support national priorities, such as funding basic life science research through the National Institutes of Health (NIH) or developing new weapons systems in the Department of Defense (DOD). The federal government also establishes and maintains the legal and regulatory framework that affects S&T activities in the private sector. In addition, federal tax, trade, and education policies can have effects on private sector S&T activity.

This report serves as a brief introduction to many of the science and technology policy issues that may come before the 116th Congress. Each issue section provides background information and outlines selected policy issues that may be considered. Each issue includes a heading entitled "For Further Information" that provides the author's name and the titles of relevant CRS reports containing more detailed policy analysis and information. Cited reports are current as of their individual publication dates, but may not reflect developments that have occurred since their publication.

Overarching S&T Policy Issues

Several issues of potential congressional interest apply to federal science and technology policy in general. This section begins with a brief introduction to the roles each branch of the federal government plays in S&T policymaking, then discusses overall federal funding of research and development. Additional sections address issues related to the emergence of disruptive technologies; the America COMPETES Act; oversight of federally supported academic research; technology transfer; the adequacy of the science and engineering workforce; science, technology, engineering, and mathematics (STEM) education; and innovation-related tax policy.

Federal Science and Technology Policymaking Enterprise

The federal S&T policymaking enterprise is composed of an extensive and diverse array of stakeholders in the executive, legislative, and judicial branches. The enterprise fosters, among other things, the advancement of scientific and technical knowledge; 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. In addition to appropriating funding for S&T programs, Congress enacts laws to establish, refine, and eliminate programs, policies, regulations, regulatory agencies, and regulatory processes that rely on S&T data and analysis. However, congressional authorities related to S&T policymaking are diffuse. Many House and Senate committees have jurisdiction over important elements of S&T policy. In addition, there are dozens of informal congressional caucuses in areas of S&T policy such as research and development, 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, in the Executive Office of the President, advises the President and other Administration officials on S&T issues.

Executive agency responsibilities for S&T policymaking 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. 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. The federal government has played an important role in supporting R&D efforts which have led to scientific breakthroughs and new technologies, from jet aircraft and the internet to communications satellites and defenses against disease.

Between FY2008 and FY2013, federal R&D funding fell from $140.1 billion to $130.9 billion, a reduction of $9.3 billion (6.6% in current dollars, 13.4% in constant dollars). 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, the most recent annual aggregate number available. However, in constant dollars, the FY2017 level was $9.6 billion (5.6%) below its high of $169.7 billion in 2010. Concerns by some about reductions in 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). At the same time, some Members of Congress express concerns about the level of federal funding in light of the current federal fiscal condition. 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 116th Congress undertakes the appropriations process it faces two overarching issues: (1) the direction in which the federal R&D investment will move in the context of increased pressure to limit discretionary spending 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 R45150, *Federal Research and Development (R&D) Funding: FY2019*, coordinated by John F. Sargent Jr.

CRS Report R44888, *Federal Research and Development Funding: FY2018*, coordinated by John F. Sargent Jr.

Disruptive and Convergent Technology

The rapid pace of technology innovation and application is substantially affecting both the global economy and human behavior. A disruptive technology can be thought of as a rapidly evolving set of innovations in any technology space that has potentially broad economic and social impacts. Two or more different technologies may be integrated to create a new, convergent technology that may also be disruptive. Consider the smartphone, perhaps the best-known example of a technology that is both disruptive and convergent. It combines a telephone, a computer, a camera, and a geolocation application into a single device. It has become so popular over the last decade that, according to some estimates, more than half of the world's population uses one. Those users average more than four hours daily on the device, predominantly for activities other than voice phone calls.

The emergence of such technologies has the potential to create large-scale economic and social disruptions. Smartphones and other forms of mobile computing, for example, have had large economic effects on the telecommunications sector, as well as large social impacts.

Among other technologies associated with major disruptions are social media, cloud computing, and data analytics ("big data"). Additional examples include artificial intelligence (AI), autonomous vehicles, blockchain, energy storage, gene editing, and the internet of things. The economic and social impacts of such technologies are difficult to predict and present complex facets to Congress as it responds to the opportunities and challenges those technologies pose. Not only are the paths of their development and implementation uncertain, but systematic data collection on them is sparse.

The complexity and pace of advancement of such technologies create policy issues and challenges of potential interest to the 116th Congress. Questions disruptive technologies may raise include the following:

- If Congress seeks to facilitate the growth of such technologies, what options might it consider? For example, how might Congress decide which technologies to prioritize for investment? How would congressional support for research and development affect growth? What kinds of incentives might Congress consider providing?
- What issues do such technologies raise for international economic competition, and what are the options for congressional response? For example, if other countries are investing heavily in some potentially disruptive technologies, how might Congress balance the benefits and disadvantages to the nation of investing in the same technologies or different ones?
- What are the potential negative impacts of such technologies on societal goals and values, and what steps might Congress consider for prevention and

mitigation? For example, how might Congress respond to public concerns about privacy and security? How might such technologies affect the U.S. workforce and economic opportunity, and what are the potential responses?

For Further Information

Eric A. Fischer, Senior Specialist in Science and Technology

America COMPETES Act Reauthorization

The America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act (P.L. 110-69) was enacted in 2007. The act, a response to concerns about U.S. competitiveness, authorized certain federal research, education, and innovation-related activities. In 2010, Congress passed the America COMPETES Reauthorization Act of 2010 (P.L. 111-358), extending and modifying certain provisions of the 2007 law, as well as establishing new provisions. Congressional appropriations have generally been below authorized levels, and the specific authorizations of appropriations in the 2010 act have expired. Following previous reauthorization efforts that inspired debate about such topics as the scientific peer review process, certain provisions of these acts were reauthorized and modified as part of the American Innovation and Competitiveness Act (AICA, P.L. 114-329), enacted at the end of the 114th Congress. The 116th Congress may consider additional provisions from the COMPETES acts that were not addressed through the AICA, such as expired authorizations of appropriations for the National Science Foundation (NSF) and the National Institute of Standards and Technology (NIST).

The COMPETES acts were originally enacted to address concerns that the United States could lose its advantage in scientific and technological innovation. Economists have asserted that economic, security, and social benefits accrue preferentially to nations that lead in scientific and technological advancement and commercialization. Some analysts have suggested that historical U.S. leadership in these areas is slipping. In particular, some stakeholders have questioned the adequacy of federal funding for physical sciences and engineering research and the domestic production of scientists and engineers.

The COMPETES acts were designed to respond, in part, to these challenges by authorizing increased funding for the NIST, NSF, and Department of Energy's Office of Science. Together, the acts also authorized certain federal STEM education activities, the Advanced Research Projects Agency-Energy (ARPA-E), and prize competitions at federal agencies, among other provisions.

Those who have expressed opposition to aspects of the COMPETES acts have done so from several perspectives. Some critics question the existence of a STEM labor shortage and thus the need for programs aimed at increasing the number of STEM workers. Other critics agree with the assertion of a shortage, but question whether the federal government should address it, believing that the market will make the necessary corrections to meet the demand. With respect to U.S. competitiveness, some analysts prefer alternative approaches to those proposed in the COMPETES acts, such as research tax credits or reducing regulatory costs. Other analysts object to the financial cost associated with the COMPETES acts, given concern about the federal budget deficit and debt.

For Further Information

Laurie A. Harris, Analyst in Science and Technology Policy

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

CRS Insight IN11001, *Revisiting the Doubling Effort: Trends in Federal Funding for Basic Research in the Physical Sciences and Engineering*, by John F. Sargent Jr.

CRS Report R44345, *Efforts to Reauthorize the America COMPETES Act: In Brief*, by John F. Sargent Jr.

Technology Transfer from Federal Laboratories

Every year, approximately one-third of the federal government's research and development spending is 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 may have applications 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 generated from federal laboratories to the private sector where it can be further developed and commercialized.

Congressional interest in promoting the transfer of technology from federal laboratories is largely based on meeting social needs and promoting economic growth to enhance the nation's 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 or CRADAs. In other cases, it can occur when the legal rights to government-owned patents are licensed to a private firm.

Despite previous efforts to increase the effectiveness of technology transfer from federal laboratories to the private sector, the transfer of federal technologies remains restrained. Critics of current mechanisms argue that working with federal laboratories continues to be difficult and time-consuming. Proponents assert that federal laboratories are open and receptive to partnering with private firms, but it remains up to them to take advantage of federal laboratory technologies and capabilities. At issue is whether additional legislative initiatives and federal incentives are needed to encourage increased technology transfer from federal laboratories, or if the available resources are sufficient.

In December 2018, the National Institute of Standards and Technology released "Return on Investment Initiative for Unleashing American Innovation," a draft paper proposing various strategies and actions to accelerate and improve the transfer of technology to the private sector, including building a more entrepreneurial R&D workforce and increasing engagement with private sector technology development experts and investors. Several of the proposed actions may require congressional approval and additional legislative authority to implement.

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

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 60 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, academicians, 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.

Science, Technology, Engineering, and Mathematics Education

The term "STEM education" refers to teaching and learning in the fields of science, technology, engineering, and mathematics. Policymakers have had an enduring interest in STEM education. Popular opinion generally holds that U.S. students perform poorly in STEM subjects—especially when compared to students in certain foreign education systems—but the data paint a complicated picture. Over time, U.S. students appear to have made gains in some areas but may be perceived as falling behind in others.

Various attempts to assess the federal STEM education effort have produced different estimates of its scope and scale. These efforts have identified between 105 and 254 STEM education programs and activities across 13 to 15 federal agencies. Annual federal appropriations for STEM education are typically estimated to be in the range of $2.8 billion to $3.4 billion.

The national conversation about STEM education frequently develops from concerns about the U.S. science and engineering workforce. As discussed in the previous section, some observers assert that the United States faces a shortage of STEM workers; others dispute this claim. Many proponents argue that a general increase in STEM abilities among the U.S. workforce could benefit the nation in any case. On the other hand, some scholars oppose the use of education policy to increase the supply of STEM workers, either because they perceive such policies as overemphasizing the economic outcomes of education at the expense of other values (e.g., personal development or citizenship) or because they perceive the labor market as the more efficient mechanism for dealing with these issues.

Opinions differ as well on the appropriate scope, scale, and emphasis of federal STEM education policy. Some observers prefer policies aimed at lifting the STEM achievement of all students—such as teacher or faculty professional development; or changes in curriculum, standards, or pedagogy. Others emphasize policies designed to meet specific needs—such as scholarships for the "best and brightest," federal workforce training in areas of high demand (e.g., information technology and cybersecurity), efforts to close academic achievement gaps between various demographic groups, or programs to increase the participation of traditionally underrepresented groups in STEM fields.

For Further Information

Boris Granovskiy, Analyst in Education Policy

CRS Report R45223, *Science, Technology, Engineering, and Mathematics (STEM) Education: An Overview*, by Boris Granovskiy

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

Tax Incentives for Technological Innovation

The 116th Congress may consider new federal policies to promote technological innovation, which involves the creation, development, and use of new technologies. Among the concerns fueling such an interest is what many view as inadequate growth in domestic high-paying jobs in a range of industries in recent years. Among the pathways to accelerating growth in these jobs are (1) faster rates of entrepreneurial business formation, (2) increased business investment in domestic research and development (R&D), (3) greater domestic production of products and services derived from that research, and (4) increased employer spending on training workers to acquire the skills needed to earn higher-paying jobs. The technical skills required to perform such jobs can be thought of as a critical component of the domestic climate for investment in innovation.

Congress can directly influence the rate of high-wage job creation through adopting tax incentives for investment in R&D, worker training, and higher education. Under current federal tax law, three provisions directly affect entrepreneurial business formation and business investment in R&D: (1) an expensing allowance for research expenditures under Section 174 of the tax code (which is scheduled to switch to a five-year amortization period for that spending starting in 2022), (2) a nonrefundable tax credit for increases in research expenditures above a base amount under Section 41, and (3) a full exclusion for capital gains from the sale or exchange of qualified small business stock held by the original investor for five or more years under Section 1202. There is no federal tax incentive under current law for employer investment in worker training.

The 2017 tax revision (P.L. 115-97) substantially cut income tax rates for corporate and noncorporate business income, beginning in 2018. The new law also modified or repealed a number of tax provisions affecting business after-tax profits. Some argue that the tax cuts alone should be sufficient to increase the number of high-paying domestic jobs in a range of industries. Others are skeptical that many large U.S. employers will invest the windfall gains from the tax cuts in expanding domestic production and boosting worker wages, training, and education. In their view, many such companies (including U.S. multinational corporations) are more likely to use much of their tax savings to buy back stock, raise dividends, or acquire competing firms.

One previously proposed option for increasing the number of high-paying domestic jobs that the 116th Congress may examine is the creation of a tax incentive known as a patent or innovation box. Such an incentive lowers the tax burden on income earned from the commercial use of qualified intellectual property, such as trademarks or patents. Depending on its design, a patent box could give U.S. and foreign companies investing in innovation a stronger incentive to expand their investment in U.S. R&D and production activities. Potential drawbacks to such a subsidy include its budgetary cost and the lack of a sound economic justification for a tax subsidy that benefits only companies that develop or purchase successful patented innovations, not companies that develop profitable new technologies that never are patented.

A second option for spurring faster growth in domestic high-paying jobs is a tax incentive for employers to invest in worker training and education. Several bills were introduced in the 115th Congress to promote employer investment in training programs such as apprenticeships and collaboration with community colleges to design courses of study targeted at the skill needs of employers. The U.S. economy benefits from an expansion in high-paying jobs only if there are enough workers to fill them. Potential drawbacks to such a tax subsidy include the likelihood it would reward employers for doing what they would do without a tax subsidy and a lack of evidence that employers systematically underinvest in worker training and education.

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

Agriculture

The federal government supports billions of dollars of agricultural research annually. The 116th Congress is likely to face issues related to funding this research, a proposed relocation of the Department of Agriculture's science and economic analysis agencies, and issues arising from advances in agricultural biotechnology, including the development of cell-cultured meat.

Agricultural Research

The U.S. Department of Agriculture's (USDA's) Research, Education, and Economics (REE) mission area has the primary federal responsibility of advancing scientific knowledge for agriculture. USDA-funded research spans the biological, physical, and social sciences related broadly to agriculture, food, and natural resources.

USDA conducts its own research and administers federal funding to states and local partners primarily through formula funds and competitive grants. The outcomes are delivered through academic and applied research findings, statistical publications, cooperative extension, and higher education. USDA's research program is funded with nearly $2.9 billion per year of discretionary funding and about $120 million of mandatory funding.

The most recent farm bill (P.L. 115-661, Agriculture Improvement Act of 2018), enacted in December 2018, governs agricultural research programs through FY2023. In keeping with past farm bills, this farm bill reauthorizes a wide range of existing research and education provisions (e.g., funding of land grant university research) and also authorizes several new research provisions. One provision that is likely to be closely watched is the Agriculture Advanced

Research and Development Authority (AGARDA) pilot program. Modeled on the Defense Advanced Research Projects Agency, AGARDA will operate under the Office of Chief Scientist to address long-term and high-risk research challenges in the agriculture and food sectors.

For Further Information

Tadlock Cowan, Analyst in Natural Resources and Rural Development

CRS Report R40819, *Agricultural Research: Background and Issues*, by Jim Monke

CRS Report R45197, *The House Agriculture Committee's 2018 Farm Bill (H.R. 2): A Side-by-Side Comparison with Current Law*, coordinated by Mark A. McMinimy

CRS In Focus IF10187, *Farm Bill Primer: What Is the Farm Bill?*, by Renée Johnson and Jim Monke

The National Institute of Food and Agriculture and Economic Research Service Relocation Proposal

In August 2018, the Secretary of Agriculture announced a reorganization of the department that included relocating the National Institute of Food and Agriculture (NIFA) and Economic Research Service (ERS) outside the National Capital Region. The Secretary has stated that he would like to complete the relocation in 2019. As two of the department's science and agricultural economic analysis agencies, such a move has prompted significant commentary within Congress and by other Washington-based scientific organizations. While nearly 135 cities have announced their interest in hosting the relocated agencies, an ongoing USDA Inspector General (IG) study is examining the department's legal and budgetary authority to execute the moves. As this IG study is completed, Congress may choose to exercise its authority to ensure that the proposed move is in accordance with federal laws and regulations.

For Further Information

Tadlock Cowan, Analyst in Natural Resources and Rural Development

Agricultural Biotechnology

The 116th Congress may provide oversight of issues regarding bioengineered foods labeling, or foods containing bioengineered ingredients, proposed regulatory changes governing the introduction of genetically engineered (GE) plants and animals into the environment, and recent technical innovations in gene editing that could raise new regulatory issues for agricultural biotechnology.

The 114th Congress passed a bill signed into law in July 2016 (P.L. 114-216) to establish a "national bioengineered food disclosure standard." The final rule was published in late December 2018. Food manufacturers can adopt either text, a symbol, or an electronic/digital link for identifying bioengineered foods. The disclosure act is to cover foods made through conventional genetic engineering technology, and as well as newer techniques in the definition of bioengineered foods.

P.L. 114-216 also required USDA to conduct a study that identifies potential technological factors that could affect consumer access to bioengineered food disclosure through electronic or digital methods such as codes on food products read by smart phones. Observers are concerned that such digital methods of disclosure could have differential impacts on those without cell phones (e.g., the elderly, low-income families) and those without access to high-speed broadband. The congressionally required study, completed in July 2017, specifically addresses the availability of wireless or cellular networks, availability of landline telephones in stores, and particular factors that might affect small retailers and rural retailers as well as consumers. With the final rule now published, the disclosure law is to be implemented by USDA's Agricultural Marketing Service. The 116th Congress may begin to address various public issues that arise from implementing the new disclosure rule.

The development over the past several years of new technologies to genetically engineer plants, in particular through novel gene-editing technologies such as CRISPR-Cas9, has raised new regulatory issues. USDA currently regulates GE plants under the Plant Protection Act (PPA; 7 U.S.C. §770). However, USDA has stated that newer technologies may fall outside the purview of the PPA, and thus the department might have no regulatory jurisdiction over plants genetically engineered using these new technologies. For example, USDA's Animal and Plant Health Inspection Service (APHIS) asserted in April 2016 that the agency had no regulatory authority under the PPA and, by default, approved a mushroom variety and a waxy corn variety created through the CRISPR-Cas9 gene editing technology. The Department of Agriculture then announced in March 2018 that they had no plans to regulate plants that could otherwise have been developed through traditional breeding techniques, which characterizes some gene editing techniques. This decision raises important questions about how such genetically engineered plants are to be regulated as they are introduced. As genetically engineered plant varieties created by these newer techniques become more common, and as the public becomes more aware that these varieties are not regulated under the PPA, Congress could revisit the 1986 framework that governs U.S. biotechnology regulation.

For Further Information

Tadlock Cowan, Analyst in Natural Resources and Rural Development

CRS In Focus IF10376, *Labeling Genetically Engineered Foods: Current Legislation*, by Tadlock Cowan

CRS Report R43518, *Genetically Engineered Salmon*, by Harold F. Upton and Tadlock Cowan

CRS Report RL32809, *Agricultural Biotechnology: Background, Regulation, and Policy Issues*, by Tadlock Cowan

CRS Report RL33334, *Biotechnology in Animal Agriculture: Status and Current Issues*, by Tadlock Cowan

CRS Report R43100, *Unapproved Genetically Modified Wheat Discovered in Oregon and Montana: Status and Implications*, by Tadlock Cowan

Cell-Cultured Meat

Cell-cultured meat (also referred to as cell-based meat, lab-grown meat, and clean 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, including cell-cultures from cattle, hogs, poultry, and fish, to scale up and, in some instances, move closer to commercial viability. Some cell-cultured meat innovators believe their products could be sold within a few years in certain markets and become widely available in 10 years.

A debate 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)—has regulatory jurisdiction over cell-cultured meat surfaced in early 2018. 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" (MOU) to facilitate communication and division of responsibilities between the two agencies.

In February 2018, the U.S. Cattlemen's Association petitioned USDA to have FSIS establish meat labeling requirements that exclude cell-cultured products. The petition requested that only meat derived directly from animals raised and slaughtered be labeled "beef" and "meat."

Congress took up cell-cultured meat in April 2018 when USDA Secretary Perdue testified before the House Committee on Appropriations, stating that meat grown in laboratories would be under the sole purview of USDA, and any product labeled as meat would be under USDA jurisdiction. In May 2018, the House-reported agricultural appropriations bill (H.R. 5961) included a general provision that would have required USDA "for fiscal year 2018 and hereafter" to regulate cell-cultured products made from cells of amenable species of livestock and poultry, as defined in the Federal Meat Inspection Act and Poultry Products Inspection Act.

In June 2018, FDA stated that under the Federal Food, Drug, and Cosmetic Act, FDA has jurisdiction over "food," which includes "articles used for food" and "articles used for components of any such article." Thus, according to FDA, both of the substances used in the manufacture of cell-cultured products, and the final products that will be used for food, are subject to the FDA's jurisdiction. Any substance that is intentionally added to food is considered a food additive and is subject to premarket review and approval by FDA. An exception to this requirement is when there is a consensus, among qualified experts that the substance is "generally recognized as safe" (GRAS) for its intended use.

In November 2018, a joint statement from USDA and FDA announced that both agencies "should jointly oversee the production of cell-cultured food products derived from livestock and poultry." The statement further clarified that FDA would oversee cell collection, cell banks, cell growth, and the process of differentiation. USDA is to oversee the production and labeling of food products derived from the cells. This statement initiates the process of developing the regulatory framework for cell-culture meat and poultry; however, other key aspects of the regulations have yet to be announced. For example, fish, for which cell-cultured technology is being developed, is regulated by FDA, but was not mentioned in the statement. In addition, there are still questions on how to obtain premarket approval and how inspection of cell-cultured meat facilities will be conducted. Finally, the statement did not resolve the contentious issue of cell-cultured meat labeling terminology. Cell-cultured meat regulation decisions may be further clarified in the near future—perhaps through a MOU between FDA and USDA.

For Further Information

Sahar Angadjivand, Analyst in Agricultural Policy

Joel L. Greene, Analyst in Agricultural Policy

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

Biomedical Research and Development

Advances in science and technology related to biomedical research and development underpin improvements in medications and treatments. Some of the biomedical R&D issues that the 116th Congress may face include those related to the budget and oversight of the National Institutes of

Health, the role the Food and Drug Administration in approving new medicines and laboratory tests, and issues related to stem cell-based medicine and genomic editing.

National Institutes of Health and the 21st Century Cures Act

The National Institutes of Health is the lead federal agency conducting and supporting biomedical research. Congress provided the agency with $39 billion in funding for FY2019 for basic, clinical, and translational research in NIH's laboratories as well as in research institutions nationwide. The extramural research program (more than 80% of the NIH budget) provides grants, contracts, and training awards to support over 30,000 individuals at more than 2,500 universities, academic health centers, and research facilities across the nation. NIH represents about one fifth of total federal research and development spending, and half of non-Department of Defense research and development funding.

NIH is a large and complex organization made up of 27 institutes and centers (ICs). Each IC sets its own research priorities and manages its research programs in coordination with the Office of the Director (OD). The individual ICs may focus on particular diseases (e.g., The National Cancer Institute), areas of human health and development (e.g., The National Institute on Aging), scientific fields (e.g., National Institute for Environmental Health Sciences), or biomedical professions and technology (e.g., National Institute of Biomedical Imaging and Bioengineering). Congress provides separate appropriations to 24 of the 27 ICs, to OD, and to a buildings and facilities account.

The 21st Century Cures Act (P.L. 114-255) authorized four major Innovation Projects at NIH, some conducted in partnership with other federal agencies such as the Food and Drug Administration (FDA) or Department of Defense (DOD)

- the Precision Medicine Initiative (PMI; $1.5 billion for FY2017 through FY2026),
- the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative ($1.5 billion for FY2017 through FY2026),
- cancer research ($1.8 billion for FY2017 through FY2023), and
- regenerative medicine ($30 million for FY2017 through FY2020).

The 116th Congress may continue previous congressional interest and oversight of the implementation and progress of the Innovation Projects authorized by the 21st Century Cures Act.

For Further Information

Kavya Sekar, Analyst in Health Policy

Judith A. Johnson, Specialist in Biomedical Policy

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The Food and Drug Administration: Medical Product Innovation

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

The 21st Century Cures Act (P.L. 114-255), for example, modified FDA drug and device regulatory pathways to support innovation. Administratively, FDA has issued a series of gene therapy draft guidance documents, concomitant with NIH stepping down oversight of gene therapy human clinical trials. Innovation in this area includes gene editing-based products (e.g., CRISPR) as well as cell-based gene therapies (e.g., CAR-T therapies).

Pursuant to the Substance Use-Disorder Prevention that Promotes Opioid Recovery and Treatment (SUPPORT) for Patients and Communities Act (P.L. 115-271), FDA must meet with stakeholders and issue guidance to address the challenges of developing nonaddictive medical products for treatment of pain or addiction through regulatory mechanisms established in the 21st Century Cures Act (e.g., application of novel clinical trial designs). Additionally, the agency launched an *Innovation Challenge* to incentivize the development of medical devices to detect, treat and prevent addiction and pain.

Medical devices are increasingly connected to the internet, hospital networks, and other medical devices, which can increase the risk of cybersecurity threats. Currently, FDA does not have explicit statutory authority pertaining to medical device cybersecurity. However, manufacturers are required to comply with Quality Systems Regulations (QSRs), which are good manufacturing practices for medical devices. QSRs may address, among other things, risk analysis, including cybersecurity risk. In October 2018, FDA entered into a Memorandum of Agreement with the Department of Homeland Security, to implement a framework for greater coordination and information sharing between the two agencies about medical device cybersecurity threats and vulnerabilities.

For Further Information

Agata Dabrowska, Analyst in Health Policy

Victoria Green, Analyst in Health Policy

Amanda Sarata, Specialist in Health Policy

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Oversight of Laboratory-Developed Tests (LDTs)

In vitro diagnostics (IVD) are devices that provide information used by clinicians and patients to make health care decisions. IVDs are used in laboratory analysis of human samples and include commercial test products and instruments used in testing, among other things. Laboratory-developed tests (LDTs) are a class of IVD that is manufactured and offered within a single laboratory. Genetic tests are a type of diagnostic test that analyzes various aspects of an individual's genetic material (DNA, RNA, chromosomes, and genes). Most genetic tests are LDTs.

The regulation of LDTs has been the subject of debate over the past 15 years. The FDA has exercised enforcement discretion over LDT regulation, meaning that most LDTs and genetic tests have not undergone FDA premarket review nor received FDA clearance or approval for marketing. Given the growing use and complexity of LDTs and genetic tests, the FDA has revisited how LDTs should be regulated.

In October 2014, FDA published draft guidance on the regulation of LDTs in the *Federal Register.* The agency summarized the public comments it received on the guidance documents in its January 2017 discussion paper on LDTs. This discussion draft included an outline of a possible approach to LDT oversight. The agency also noted in this discussion paper that it would not issue final guidance to allow for further discussion and to "give our congressional authorizing committees the opportunity to develop a legislative solution."

Recently, various legislative approaches have been under discussion. A discussion draft bill circulated in early 2017, the "Diagnostic Accuracy and Innovation Act (DAIA)," was crafted with industry and other stakeholder input. It outlined a regulatory approach for IVD tests that was risk-based and flexible. FDA responded to this draft in August 2018 with a novel regulatory approach for these tests, including a mechanism for pre-certifying certain related tests to streamline premarket requirements, among other things. In December 2018, a new draft bill based on DAIA and incorporating FDA's feedback was released entitled the "Verifying Accurate, Leading-edge, IVCT Development (VALID) Act."

For Further Information

Amanda Sarata, Specialist in Health Policy

Judith Johnson, Specialist in Biomedical Policy

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CRS Report RL33832, *Genetic Testing: Background and Policy Issues*, by Amanda K. Sarata

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.

Recently, 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 116th 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

Kavya Sekar, Analyst in Health Policy

Agata Dabrowska, Analyst in Health Policy

Judith A. Johnson, Specialist in Biomedical Policy

Amanda Sarata, Specialist in Health Policy

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CRISPR: Advanced Genome Editing

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

Over the next 5 to 10 years, the National Academy of Sciences (NAS) projects a rapid increase in the number and type of biotechnology products, many enabled by CRISPR. CRISPR has increased both the pace of development and the variety of crops being genetically modified. Scientists are also beginning to use CRISPR in human clinical trials for a variety of cancers, among other conditions.

While CRISPR offers a number of potential benefits it may also pose new risks and raise ethical concerns. For example, in 2018 a Chinese scientist claimed that he used CRISPR to modify human embryos creating twin girls who may be more resistant to HIV. These claims have not been published in the scientific literature and therefore have not been verified. The announcement, however, has renewed debate regarding the ethics of genetic engineering. It has also prompted discussion about how existing law and regulation in the United States apply to the conduct of this type of research, its clinical testing in humans, and specifically its potential applications in human embryos. Currently, federal funds cannot be used for research involving human embryos. Additionally, the FDA is prohibited from using federal funds to review clinical research involving the gene editing of human embryos.

CRISPR-related approaches are also being considered by some researchers to reduce or eliminate mosquito populations that serve as the primary vector for the transmission of malaria—potentially saving lives and substantially reducing medical costs. A 2016 report from NAS indicates that existing mechanisms may be inadequate to assess the potential immediate and long-term environmental and public health consequences associated with this use of the technology.

In the 116th Congress, policymakers might 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 might 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 ways to harmonize 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

Tadlock Cowan, Analyst in Natural Resources and Rural Development

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

Climate Change Science and Water

The 116th Congress may consider whether and how the federal government might address climate change and issues related to water resources. Science and technology considerations permeate these deliberations and may be grouped into six interrelated topics: federal expenditures; 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 technology. Additionally, Congress may face several issues related to ensuring reliable water quality and quantity.

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

Federal funding and tax incentives for climate-related S&T reached almost $17 billion in FY2016, the last year reported to Congress by the Office of Management and Budget in response to annual appropriations directives. The funding was spread across 16 reporting agencies, though some related expenditures may not be 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. Congress has not thus far reduced appropriations for most climate change-related S&T programs as proposed by the President’s budgets for FY2018 and FY2019. The 116th Congress will again consider appropriations for climate change-related programs and incentives.

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Climate Change-Related Science

Congress may scrutinize several recent scientific assessments—domestic and international—that strengthened previous assessments: Human-related emissions of greenhouse gases (GHG) are accumulating in the atmosphere, intensifying the natural greenhouse gas effect, and increasing acidity of the oceans. The latest major U.S. assessment, the Climate Science Special Report (CSSR), released in October 2017 by the U.S. Global Change Research Program (USGCRP), 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 USGCRP's November 2018 Fourth National Climate Assessment (NCA4) concluded, *inter alia*, 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 NCA4 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 assessments above, and much of the observations and research on which they are founded, have resulted from decades of federal (and nonfederal) investment, amounting to tens of billions of dollars, in global change science. The 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.

The 116th Congress may seek to understand the scientific foundations for recent U.S. and international assessments, including the data and methods that increasingly support attribution of many observed changes and extreme weather events to human-related GHG emissions. Congress may also express priorities for further scientific research. In light of the state of climate science, Congress may consider the level of appropriations for its priorities and the 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 accessibility to federally supported information.

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Jane A. Leggett, Specialist in Energy and Environmental Policy

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

A large majority of federal climate change-related expenditures is aimed at advancing "clean energy." 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). 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. Still others advocate for developing CO_2 removal 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, 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 116th 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;
- 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. Research has been intended to advance fossil fuel combustion, renewable energy (including biofuels), efficiency, storage, vehicles and their fuels, nuclear energy, and the electricity grid. Some incentives focus on "supply-push" of technologies (e.g., R&D funding), while others emphasize "demand-pull" (e.g., tax incentives for purchasers), with numerous examples suggesting that coordinated use of both could be most effective. Cleaner energy technologies 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.

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Jane A. Leggett, Specialist in Energy and Environmental Policy

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Climate Change and Infrastructure

Leaders in both chambers of Congress, as well as President Trump, are interested in federal investment in the nation's infrastructure. In evaluating options for infrastructure, two types of linkages with climate change may be important to consider 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 and offer resilience to climate changes, including 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 technical specifications or incentives to harden or increase the resiliency of long-lived infrastructure funded 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.

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Jane A. Leggett, Specialist in Energy and Environmental Policy

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Science and Technology for Adaptation and Resilience

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, Congress may review federal programs for S&T to support adaptation or resilience to projected 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. Improved understanding 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 may include easing access to scientific research, climate and seasonal projections, impact assessments, and adaptation decision tools. One question would be the degree to which federal financial support encourages or discourages consideration of vulnerabilities and adaptation in private, state, and local decisionmaking, as 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, infrastructure, and operations. Effective agency decisions would all 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

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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. (As noted earlier, 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) is also an emerging technology. DAC would remove atmospheric CO_2 directly from the atmosphere.

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*).

Emerging technologies for carbon utilization and DAC have energized 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 $5 billion total in annual appropriations for CCS activities at DOE, primarily for research and development within DOE's Office of Fossil Energy (FE). Congress provided nearly $727 million to FE R&D in FY2018 and $740 million for

FY2019. The Trump Administration's FY2019 budget request would have shifted away from CCS R&D to fund other priorities.

Globally, two fossil-fueled power plants currently generate electricity and capture CO_2 in large quantities: the Boundary Dam plant in Canada and the Petra Nova plant in Texas. Both plants offset some of the capture costs by selling the captured CO_2 for purposes of enhanced oil recovery. The 115th Congress enacted a tax provision (Title II, Section 41119 of P.L. 115-123, which amended Internal Revenue Code, Section 45Q). The amendment increases the tax credit for CCS. Some stakeholders suggest that the changes to Section 45Q could be a "game changer" for CCS development in the United States. The 116th Congress may explore how the 45Q tax credit is being implemented, and whether further legislative changes to the provision might be needed to accelerate deployment of CCS.

For Further Information

Peter Folger, Specialist in Energy and Natural Resources Policy

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CRS Report R41325, *Carbon Capture: A Technology Assessment*, by Peter Folger

Water

Reliable water quantity and quality supports the U.S. population and economy, including public and ecosystem health, agriculture, and industry (e.g., energy production, fisheries, navigation, and manufacturing). Research related to developing, using, and protecting water supplies and aquatic ecosystems is diverse. Because of this diversity, 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 various prize competitions for water data, science, and technologies and developed cooperative arrangement 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 116th 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 116th Congress include the following:

- water monitoring infrastructure and science programs, including, water quality monitoring, stream gauges, buoys, and groundwater assessments;
- water-related weather, climate, and earth system science including storm surge, hurricane, rainfall, and drought forecasts and associated remote sensing investments (see "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., the Open Water Data Initiative); and
- coordination of the federal water science and research portfolio, including partnerships with academic and private entities.

Water infrastructure research encompasses 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
- 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 and perfluoroalkyl substances [PFASs]);
- 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, including methods for increasing resilience of drinking water systems against natural disasters, protecting drinking water sources for public water system from contamination (e.g., nature-based stormwater management, watershed management approaches, and nonpoint source pollution management).

For Further Information

Nicole T. Carter, Specialist in Natural Resources Policy

Peter Folger, Specialist in Energy and Natural Resources Policy

Elena H. Humphreys, Analyst in Environmental Policy

Eva Lipiec, Analyst in Natural Resources Policy

Anna E. Normand, Analyst in Natural Resources Policy

Pervaze A. Sheikh, Specialist in Natural Resources Policy

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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 116th 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 and Development

The Department of Defense spends more than $90 billion per year on research, development, testing, and evaluation (RDT&E). 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 federal defense-related R&D funding's share of global R&D funding has fallen from about 36% in 1960 to about 4% in 2016, 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

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Energy

Energy-related science and technology issues that may come before the 116th Congress include those related to reprocessing spent nuclear fuel, advances in nuclear energy technology, the development of biofuels and ocean energy technology, and international fusion research.

Reprocessing of Spent Nuclear Fuel

Spent fuel from commercial nuclear reactors contains most of the original uranium that was used to make the fuel, along with plutonium and highly radioactive lighter isotopes produced during reactor operations. 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. However, reprocessed plutonium can also be used in nuclear weapons, so critics of reprocessing contend that federal support for the technology could undermine U.S. nuclear weapons nonproliferation policies. The potential commercial viability of reprocessing or recycling is also an issue.

In the 1950s and 1960s, the federal government expected that all commercial spent fuel would be reprocessed to make fuel for "breeder reactors" that would convert uranium into enough plutonium to fuel additional commercial breeder reactors.

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, along with a federal demonstration breeder project. During the Reagan Administration, Congress provided funding to restart the breeder demonstration project, but then halted project funding in 1983 while continuing to fund breeder-related research and development by the Department of Energy (DOE). During the Clinton Administration, research on producing nuclear energy through reprocessing was largely halted, although some work on the technology continued for waste management purposes.

During the George W. Bush Administration, there was renewed federal support for reprocessing, with a proposal to complete a pilot plant by the early 2020s. During the Obama Administration, plans for the pilot plant were halted and DOE's Fuel Cycle Research and Development Program was redirected toward development of technology options for a wide range of nuclear fuel cycle approaches, including direct disposal of spent fuel (the "once through" cycle), deep borehole disposal, and partial and full recycling. The Trump Administration proposed deep reductions in Fuel Cycle R&D in FY2018 and FY2019. However, the Consolidated Appropriations Act for 2018 (P.L. 115-141) increased the program's funding from $208 million in FY2017 to $260 million in FY2018—a 26% boost. Funding was increased slightly further, to $264 million, by the Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019 (P.L. 115-244). The level of funding for nuclear fuel cycle and waste disposal R&D may be a continuing issue in the 116th Congress.

Another DOE project related to reprocessing policy is the uncompleted Mixed Oxide Fuel Fabrication Facility (MFFF) at the Department's Savannah River Site in South Carolina. MFFF would produce 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 contend that MFFF would subvert U.S. nonproliferation efforts by encouraging the use of plutonium fuel. Because of rising costs, the Obama Administration proposed to halt the MFFF project in FY2017 and pursue alternative plutonium disposition options. The Trump Administration's FY2018 budget request also called for terminating MFFF. The FY2018 National Defense Authorization Act (P.L. 115-91) authorized DOE to pursue an alternative disposal option if its total costs were found to be less than half of those for completing and operating MFFF. The Consolidated Appropriations Act for 2018 conformed to the NDAA authorizing language. Energy Secretary Rick Perry certified in May 2018 that the cost saving requirement for terminating MFFF would be met. For FY2019, P.L. 115-244 appropriated $220 million, the same as the request, to begin shutting down the project. Termination of MFFF could shift the debate on plutonium disposition policy toward other options, such as dilution and disposal in a deep repository. R&D funding for such alternatives could be an issue for the 116th Congress.

For Further Information

Mark Holt, Specialist in Energy Policy

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

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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. A growing number of private-sector firms are pursuing commercialization of advanced nuclear technologies as well.

Advanced nuclear energy technologies include high-temperature gas-cooled reactors, liquid metal-cooled reactors, and molten salt reactors (in which the nuclear fuel is dissolved in the coolant), among a wide range of other concepts. Many of these concepts would involve nuclear chain reactions using fast neutrons, which are not slowed by a moderator. Research on advanced reactor coolants, materials, controls, and safety is carried out by DOE's Advanced Reactor Technologies program. The program received $111.5 million for FY2019 (P.L. 115-244), 51% above the Administration request. The appropriation includes $20 million for research and development on microreactors—reactors with electric generating capacity of only a few megawatts, a tiny fraction of the capacity of existing commercial reactors.

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. They have urged NRC to develop a licensing and regulatory framework that could apply to all nuclear concepts. They also have recommended a "staged review process" to provide conditional NRC approval for advanced reactor designs at key milestones toward the issuance of an operating license. NRC and DOE are currently implementing the Joint Advanced Non-Light Water Reactors Licensing Initiative to adapt existing general design criteria for LWRs for use by advanced reactor license applications. Under that initiative, NRC issued "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors" on April 9, 2018. NRC is also supporting industry efforts to develop guidance for technology-neutral reactor licensing.

Legislation to promote advanced nuclear power technologies, the Nuclear Energy Innovation Capabilities Act of 2017 (P.L. 115-248), was signed by President Trump on September 28, 2018. A major provision of the bill would authorize DOE national laboratories or other DOE-owned sites to host reactor demonstration projects sponsored fully or partly by the private sector. It would also require DOE to determine the need for a fast-neutron "versatile" test reactor and authorize grants to help pay for NRC licensing of advanced reactor designs. Related legislation, the Nuclear Energy Innovation and Modernization Act (P.L. 115-439), was signed into law January 14, 2019. Among other provisions, it would require NRC to develop a regulatory framework that would encourage commercialization of advanced nuclear technology. Some public-private R&D on advanced nuclear technology is already being conducted at national labs under DOE's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative. Congress appropriated $65 million (P.L. 115-244) for early-stage development of a versatile advanced test reactor in FY2019. The 116th Congress may consider additional legislation on advanced reactors, including funding for R&D, licensing, and demonstration.

For Further Information

Mark Holt, Specialist in Energy Policy

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

Biofuels

Biofuels—liquid transportation fuels produced from biomass feedstock—are often described as an alternative to conventional fuels. Some see promise in producing liquid fuels from a domestic feedstock that may reduce dependence on foreign sources of oil, contribute to improving rural economies, and lower greenhouse gas emissions. Others regard biofuels as potentially causing more harm to the environment (e.g., air and water quality concerns), encouraging landowners to put more land into production, and being prohibitively expensive to produce. The debate about the feasibility of biofuels is complex, as policymakers consider a multitude of factors (e.g., feedstock costs, timeframe to reach substantial commercial-scale advanced biofuel production, environmental impact of biofuels). The debate can be even more complicated when considering that biofuels may be produced using numerous biomass feedstocks and conversion technologies.

Congress has expressed interest in biofuels for decades, with most of its attention on the production of "first-generation" biofuels (e.g., cornstarch ethanol). Farm bills have had a significant effect on biofuel research and development. Starting in 2002, the farm bills have contained an energy title with several programs focused on assisting biofuel production. In addition, the DOE Office of Energy Efficiency and Renewable Energy (EERE) supports research and development for domestic biofuel production. Congress and the Administration have debated the amount of funding both USDA and DOE should receive 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 one policy that has supported an increase in advanced biofuel production—the Renewable Fuel Standard (RFS). The RFS requires U.S. transportation fuel to contain a minimum volume of biofuel, a growing percentage of which is to come from advanced biofuels. The RFS is under scrutiny for various reasons, including the Environmental Protection Agency (EPA) exercising its regulatory authority to issue a waiver and reduce the total renewable fuel volume below what was required by statute and concerns about RFS compliance. This creates significant uncertainty for certain stakeholders, with the result that some of the advanced biofuel targets are not being met. An overarching issue is that the statute may require more biofuel to be produced than can be used given the existing motor fuel distribution infrastructure and the limited fleet of passenger vehicles that are built to run on higher percentage blends of biofuels. The 116th Congress may consider whether to modify various biofuel promotional efforts, or to maintain the status quo.

For Further Information

Kelsi Bracmort, Specialist in Natural Resources and Energy Policy

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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 in a low-oil-price environment, address safety and environmental concerns, and enable advances in emerging sectors such as U.S. offshore wind. Private industry, universities, and government are all involved in ocean energy R&D. At the federal level, the Department of Energy and the Department of the Interior (DOI) both support ocean energy research.

One area of policymaker interest involves deepwater oil and gas operations. Industry interest in expanding deepwater activities, improving efficiency, and reducing costs has prompted improvements in drilling technologies and steps toward automated monitoring and maintenance. The oil and gas industry and federal regulators also have focused on safety improvements to reduce the likelihood of catastrophic oil spills in deep water. In 2016, DOI promulgated safety regulations that tighten requirements for offshore blowout preventer systems and other well control equipment. In April 2018, DOI published proposed revisions to the rule, including several changes that could reduce the cost to industry and time involved in meeting certain technological requirements. For both the original rule and the proposed revisions, stakeholders have debated the potential costs of compliance and whether the technological requirements are unnecessarily prescriptive or, conversely, not prescriptive enough to achieve safety aims.

Congress may also consider technology issues related to offshore drilling in the Arctic, where sea ice and infrastructure gaps pose challenges for the economic viability and safety of mineral exploration. A focus of industry R&D is on technology to extend the Arctic drilling season beyond the periods where sea ice is absent—for example, by developing ice-capable mobile offshore drilling units (MODUs). DOI finalized safety regulations for Arctic exploratory drilling in 2016. President Trump's Executive Order 13795 ordered DOI to review these regulations and DOI's Fall 2018 *Regulatory Agenda* includes an anticipated rule revision. Some have argued that the regulations are too costly for industry and give inadequate weight to available technologies (such as those for well capping) that could reduce safety costs. Others question whether any rules or technologies can adequately ensure drilling safety in the Arctic given the environmental risks.

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. A focus of R&D is technology to increase offshore turbine efficiency and reduce costs, including floating turbines for deep waters, where resources may be more abundant and user conflicts fewer. Other research explores improvements to electrical infrastructure, such as integrating transmission networks for multiple projects. A potential issue for Congress is whether and how to support or incentivize offshore wind development and other ocean renewables.

For Further Information

Laura Comay, Specialist in Natural Resources Policy

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ITER

ITER (formerly known as the International Thermonuclear Experimental Reactor) is an international fusion energy research facility currently under construction in Cadarache, France. When completed, ITER is to be the world's largest fusion reactor and the first capable of producing more energy than it consumes. Although the energy output from ITER will not be harnessed to produce electricity, fusion researchers see ITER as the next step toward implementation of fusion energy as a power source.

ITER is an international collaboration. Along with the United States, the partners are the European Union, China, India, Japan, Russia, and South Korea. The United States withdrew from the initial design phase of ITER in 1998 at congressional direction, largely because of concerns about cost and scope. The project was restructured, and the United States rejoined in 2003. The formal international agreement to build the facility was approved in 2006.

The European Union, as host, is responsible for 45% of the construction cost, while the United States and the other participating countries are responsible for 9% each. Most of the U.S. share (which is $132 million in FY2019) is being contributed in kind, in the form of components and equipment sourced mostly from U.S. companies, universities, and national laboratories.

The construction phase of ITER is planned for completion in 2027. Once operational, the facility is expected to have a lifespan of 15-25 years. During the operation phase, and during subsequent deactivation and decommissioning, the agreed U.S. cost share is 13%.

In recent years, ITER management issues, schedule delays, and cost growth have sometimes led to proposals in Congress to terminate U.S. participation. A central issue is that U.S. funding for ITER may be crowding out funding for domestic fusion energy research. DOE budget documents show the cost of U.S. participation in ITER in FY2020 and beyond as "to be determined" once the Administration decides whether to continue participating in the project.

In 2018, at DOE's request, the National Academies of Science, Engineering, and Medicine issued a strategic plan for fusion energy research. It recommended, first, that "the United States should remain an ITER partner as the most cost-effective way to gain experience with a burning plasma at the scale of a power plant." Second, looking beyond ITER, it recommended that "the United States should start a national program of accompanying research and technology leading to the construction of a compact pilot plant that produces electricity from fusion at the lowest possible capital cost." The DOE Fusion Energy Sciences Advisory Committee has also embarked on a strategic planning effort, encompassing both ITER and domestic research, with a final report anticipated in late 2020. The 116th Congress may continue oversight of ITER's scientific progress, cost, and schedule, and may revisit the debate about whether to continue U.S. participation.

For More Information

Daniel Morgan, Specialist in Science and Technology Policy

Homeland Security

The federal government spends billions of dollars supporting research and development to protect the homeland. Some of the issues that the 116th Congress may consider include how the Department of Homeland Security performs research and development; federal efforts to develop and procure new medical countermeasures against chemical, biological, radiological, and nuclear agents; and federal efforts to ensure the safety and security of laboratories working with dangerous pathogens.

R&D in the Department of Homeland Security

The Department of Homeland Security (DHS) has identified five core missions: to prevent terrorism and enhance security, to secure and manage the borders, to enforce and administer immigration laws, to safeguard and secure cyberspace, and to ensure resilience to disasters. New technology resulting from research and development can contribute to all these goals. The Directorate of Science and Technology has primary responsibility for establishing, administering, and coordinating DHS R&D activities. The Domestic Nuclear Detection Office (DNDO) is responsible for R&D relating to nuclear and radiological threats. Several other DHS components, including the Coast Guard, also fund R&D and R&D-related activities related to their missions.

Coordination of DHS R&D is a long-standing congressional interest. In 2012, the Government Accountability Office (GAO) concluded that because so many components of the department are involved, it is difficult for DHS to oversee R&D department-wide. In January 2014, the joint explanatory statement for the Consolidated Appropriations Act, 2014 (P.L. 113-76) directed DHS to implement and report on new policies for R&D prioritization. It also directed DHS to review and implement policies and guidance for defining and overseeing R&D department-wide. In July 2014, GAO reported that DHS had updated its guidance to include a definition of R&D and was conducting R&D portfolio reviews across the department, but that it had not yet developed policy guidance for DHS-wide R&D oversight, coordination, and tracking. In December 2015, the explanatory statement for the Consolidated Appropriations Act, 2016 (P.L. 114-113) stated that DHS "lacks a mechanism for capturing and understanding research and development (R&D) activities conducted across DHS, as well as coordinating R&D to reflect departmental priorities." The Common Appropriations Structure that DHS introduced in February 2016 in its FY2017 budget request includes an account titled Research and Development for each DHS component. It remains to be seen whether this change will help to address congressional concerns about DHS-wide R&D coordination.

DHS has reorganized its R&D-related activities several times. In December 2017, it established a new Countering Weapons of Mass Destruction Office (CWMDO), consisting of DNDO, most functions of the Office of Health Affairs (OHA), and some other elements. DNDO and OHA were themselves both created, more than a decade ago, largely by reorganizing elements of the S&T Directorate. The Countering Weapons of Mass Destruction Act of 2018 (P.L. 115-387) expressly authorized the establishment and activities of CWMDO. The 116th Congress may examine the implementation of that act.

For Further Information

Daniel Morgan, Specialist in Science and Technology Policy

Chemical, Biological, Radiological, and Nuclear Medical Countermeasures

The anthrax attacks of 2001 highlighted the nation's vulnerability to biological terrorism. The federal government responded to these attacks by increasing efforts to protect civilians against chemical, biological, radiological, and nuclear (CBRN) terrorism. Effective medical countermeasures, such as drugs or vaccines, could reduce the impact of a CBRN attack. Policymakers identified a lack of such countermeasures as a challenge to responding to the CBRN threat. To address this gap, the federal government created several programs to encourage private sector development of new CBRN medical countermeasures. Despite these efforts, the federal government still lacks medical countermeasures for many CBRN threats, including Ebola.

The Biomedical Advanced Research and Development Authority (BARDA) and Project BioShield are two key pieces of the federal efforts supporting the development and procurement of new CBRN medical countermeasures. BARDA directly funds the advanced development of countermeasures through contracts with private sector developers. Project BioShield provides a procurement mechanism to remove market uncertainty for countermeasure developers. It allows the federal government to agree to buy a countermeasure up to 10 years before the product is likely to finish development. Congress has modified these and related programs to improve their performance, efficiency, and transparency to oversight. However, some key issues remain unresolved, including those related to appropriations, interagency coordination, countermeasure prioritization and implementation of the 2018 *National Biodefense Strategy*. In addition to questions regarding the amount of funding, Congress may consider whether the appropriations are efficiently balanced throughout the research and development pipeline. Policymakers may consider whether the congressionally-mandated planning and transparency requirements have sufficiently enhanced coordination of the multiagency countermeasure development enterprise. Additionally, Congress may consider whether the countermeasure prioritization process appropriately balances the need to address traditional threats such as anthrax and smallpox with the threat posed by emerging infectious diseases such as Ebola. Finally, Congress may consider the administration's progress implementing the new National Biodefense Strategy and how it affects the medical countermeasure research and development enterprise.

For Further Information

Frank Gottron, Specialist in Science and Technology Policy

Microbial Pathogens in the Laboratory: Safety and Security

In addition to its general oversight of workplace safety, the federal government addresses the safety of laboratory personnel who work with infectious microorganisms through guidance such as Biosafety in Microbiological and Biomedical Laboratories (BMBL), published by the Department of Health and Human Services (HHS) Centers for Disease Control and Prevention (CDC) and National Institutes of Health (NIH). BMBL sets "Biosafety Levels" for work with the highest-risk pathogens. BMBL guidance is often adopted as a requirement; for example, compliance is required of federal grant recipients.

Biosecurity requirements, to protect the public from intentional and unintentional releases of pathogens, were first mandated by Congress in 1996, and expanded through subsequent reauthorizations. The Federal Select Agent Program (FSAP), administered jointly by CDC and the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), oversees the possession of "select agents," certain biological pathogens and toxins with the potential to cause serious harm to public, animal, or plant health. All U.S. laboratory facilities—including those at government agencies, universities, research institutions, and commercial entities—that possess, use, or transfer select agents must register with the program and adhere to specified best practices. All persons given access to select agents must undergo background investigations conducted by the Federal Bureau of Investigation (FBI).

Several incidents involving the mishandling of select agents in federal laboratories have occurred in recent years. For example, samples of decades-old but viable smallpox virus were found in an FDA laboratory on an NIH campus. Laboratories at CDC, one of the select agent regulatory agencies, had incidents involving the anthrax agent, a virulent avian influenza virus, and Ebola virus. Each incident was attributed, at least in part, to lapses in protocol or some other form of human error. Several incident reports have recommended improvements in the "culture of safety" in laboratories, standardized microbial handling practices, and better incident reporting, among other measures. Additional entities, including the House Committee on Energy and Commerce, the Comptroller General, and the HHS Inspector General have also investigated these lapses and made similar recommendations.

The FSAP is designed to ensure the secure handling of designated pathogens while allowing important research on these pathogens to proceed. The 2018 Farm Bill amended the authority to regulate animal and plant pathogens, requiring the Secretary of Agriculture, when determining which agents to list, to consider the potential effects of such listing on animal and plant disease research. The HHS Secretary is not required to make a similar consideration when determining the list of agents that may pose a threat to public health. The 116th Congress may choose to continue FSAP program oversight, including through committee investigations, since program reports show that occupational exposures persist in regulated facilities. Congress may also review and revise the authorities for the public health and agriculture arms of the program. The authorizations of appropriations for each expired in 2007.

For Further Information

Sarah A. Lister, Specialist in Public Health and Epidemiology

Information Technology

The rapid pace of advancements in information technology presents several issues for congressional policymakers, including those related to cybersecurity, artificial intelligence, broadband deployment, access to broadband networks and net neutrality, public safety networks, emergency alerting, 5G networks, the Internet of Things, federal networking R&D, and quantum information science.

Cybersecurity

The federal policy framework for cybersecurity is complex, including more than 50 statutes as well as presidential directives and related authorities.

The 116th Congress may face a number of significant issues related to cybersecurity, in addition to the oversight of enacted laws. Among those issues are the following:

- *Cybersecurity for critical infrastructure,* given that most of the nation's critical infrastructure is not owned by the federal government and regulatory cybersecurity requirements vary substantially among the sectors;
- *Prevention of and response to cybercrime*, especially given its substantially international character;
- *The relationship between cyberspace and national security*, including information operations aimed at election infrastructure and political campaigns; and
- *Federal R&D and other investments* to protect information systems and networks.

In addition to such short- and medium-term issues, Congress may consider responses to a number of long-term challenges, including the following:

- *Design*—the degree to which information systems can be designed with security built in, in the face of economic obstacles and the other challenges;
- *Incentives*—ways to correct an economic incentive structure for cybersecurity that has often been called distorted or even perverse, with cybercrime widely regarded as cheap, profitable, and comparatively safe for the criminals, while cybersecurity is often considered expensive and imperfect, with uncertain economic returns;
- *Consensus*—finding consensus on a consistent and effective model for approaching cybersecurity, given stakeholders from different sectors and different work subcultures with varying needs, goals, and perspectives; and
- *Environment*—a rapidly evolving cyberspace environment that both complicates the threat environment and may pose opportunities for shaping the direction of that evolution toward greater security, including, for example, the growth and influence of disruptive technologies (see "Disruptive and Convergent Technology").

For Further Information

Eric A. Fischer, Senior Specialist in Science and Technology

Chris Jaikaran, Analyst in Cybersecurity Policy

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CRS Report R45127, *Cybersecurity: Selected Issues for the 115th Congress*, coordinated by Chris Jaikaran

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Artificial Intelligence

The rapid development and growing use of artificial intelligence (AI) technologies has been of increasing interest to policymakers. Congressional activities on AI in the 115th Congress included multiple committee hearings in both the House of Representatives and the Senate, the introduction of numerous AI-focused bills, the passage of AI provisions in legislation, and a variety of congressional briefings. Activity related to AI may continue in the 116th Congress.

Generally, AI is considered to be computerized systems that work and react in ways commonly thought to require intelligence, encompassing many methodologies and applications. Common examples include machine learning, computer vision, natural language processing, and applications in such areas as robotics and autonomous vehicles. In addition to transportation, AI is already being employed across a variety of sectors, including health care, agriculture, manufacturing, and finance. Current AI technologies fall into a category called "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.

Potential policy considerations for AI span cross-sector and sector-specific topics, in both the defense and nondefense spaces. For example, broad concerns have focused on workforce impacts from the implementation of AI and AI-driven automation, including potential job losses and the need for worker retraining; the balance of federal and private sector funding for AI; international competition in AI research and development (R&D) and deployment, particularly with China and Russia; the development of standards and testing for AI systems; the need for and effectiveness of federal coordination efforts in AI; and incorporation of privacy, security, transparency, and accountability considerations in AI systems. Particular considerations for AI in the defense space have included the balance of human and automated decisionmaking in military operations; how the Department of Defense engages with the private sector for defense adaptation of commercially developed AI systems and access to AI expertise; and private sector concerns about the use of AI R&D in combat situations.

For Further Information

Laurie A. Harris, Analyst in Science and Technology Policy

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CRS In Focus IF10937, *Artificial Intelligence (AI) and Education*, by Joyce J. Lu and Laurie A. Harris

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Broadband Deployment

Broadband—whether delivered via fiber, cable modem, copper wire, satellite, or wirelessly—is increasingly the technology underlying telecommunications services such as voice, video, and data. Since the initial deployment of broadband in the late 1990s, Congress has viewed broadband infrastructure deployment as a means towards improving regional economic development, and in the long term, to create jobs. According to the Federal Communications Commission's (FCC's) National Broadband Plan, the lack of adequate broadband availability is most pressing in rural America, where the costs of serving large geographical areas, coupled with low population densities, often reduce economic incentives for telecommunications providers to invest in and maintain broadband infrastructure and service. Broadband adoption also continues to be a problem, with a significant number of Americans having broadband available, but not subscribing. Populations lagging behind in broadband adoption include people with low incomes, seniors, minorities, the less-educated, nonfamily households, and the nonemployed.

The 116th Congress may face a range of broadband-related issues. These may include the continued transition of the telephone-era Universal Service Fund from a voice to a broadband-based focus, funding for broadband programs in the Rural Utilities Service, infrastructure legislation that may include funding and incentives for broadband buildout, the adequacy of broadband deployment data and mapping, the development of new wireless spectrum policies, and to what extent, if any, regulation is necessary to ensure an open internet. Additionally, the 116th Congress may choose to examine the existing regulatory structure and consider possible revision of the 1996 Telecommunications Act and its underlying statute, the Communications Act of 1934. Both the convergence of telecommunications providers and markets and the transition to an Internet Protocol (IP) based network have, according to a growing number of policymakers, made it necessary to consider revising the current regulatory framework. How a possible revision might create additional incentives for investment in, deployment of, and subscribership to, our broadband infrastructure is likely to be just one of many issues under consideration.

To the extent that Congress may consider various options for further enhancing broadband deployment, a key issue is how to develop and implement federal policies intended to increase the nation's broadband availability and adoption, while at the same time minimizing any deleterious effects that government intervention in the marketplace may have on competition and private sector investment.

For Further Information

Lennard G. Kruger, Specialist in Science and Technology Policy

Angele A. Gilroy, Specialist in Telecommunications Policy

CRS Report RL30719, *Broadband Internet Access and the Digital Divide: Federal Assistance Programs*, by Lennard G. Kruger and Angele A. Gilroy

CRS Report RL33816, *Broadband Loan and Grant Programs in the USDA's Rural Utilities Service*, by Lennard G. Kruger

Access to Broadband Networks and the Net Neutrality Debate

Determining the appropriate framework to ensure an open internet is central to the debate over broadband access. A focal point in the policy debate centers on what, if any, steps are necessary to ensure unfettered internet access to content, services, and applications providers, as well as consumers.

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 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 more 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 Federal Communications Commission's (FCC's) authority to implement such regulations is an issue of growing importance in the wide ranging policy debate over broadband access. What, if any, action should be taken to ensure net neutrality is part of the overall discussion. The FCC, in 2015, adopted rules (2015 Order) that established a comprehensive regulatory framework to address the regulation of broadband internet access providers. The 2015 Order contained among its provisions those that reclassified such services as a telecommunications service and established conduct rules for providers. However, the FCC, in December 2017, adopted new rules (2017 Order) that largely reverse the 2015 regulatory framework and shift much of the oversight from the FCC to the Federal Trade Commission and the Department of Justice. The FCC's move to adopt the 2017 Order has reopened the debate over what the appropriate framework is to ensure an open internet and whether Congress should enact legislation to establish this framework.

A consensus on what that framework should entail remains elusive. Some Members of Congress support the less regulatory approach contained in the 2017 Order, which, they argue, will stimulate broadband investment, deployment, and innovation. Others support the regulatory framework adopted in the 2015 Order, which provides for a more stringent regulatory framework, and is needed, they state, to protect content, services, and applications providers, as well as consumers, from potential discriminatory behaviors which conflict with net neutrality principles. Still others, while supporting a framework containing specific behavioral rules to address potential anticompetitive practices, do not support the telecommunications services classification. Whether Congress will take action to amend existing law to provide guidance and more stability to FCC authority remains to be seen.

For Further Information

Angele A. Gilroy, Specialist in Telecommunications Policy

CRS In Focus IF10955, *Access to Broadband Networks: Net Neutrality*, by Angele A. Gilroy

CRS Report R40616, *The Net Neutrality Debate: Access to Broadband Networks*, by Angele A. Gilroy

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), authorized FirstNet to establish a new, nationwide broadband network for public safety, and provided $7 billion in funding for the project. The network is intended to address the communication problems first responders experienced during September 11, 2001, whereby public safety systems were not interoperable, and responders could not communicate or coordinate an effective response.

Congress authorized FirstNet to enter into a public-private partnership to deploy the network. In March 2017, FirstNet selected AT&T, through a competitive bidding process, as its partner. AT&T has been deploying the network as specified in its agreement with FirstNet and state-specific plans, and public safety agencies are subscribing to FirstNet.

A concern for policymakers is that the FirstNet/AT&T contract and state plans contain detailed information on deployment; however both are deemed proprietary and not available for public review. Without details on how the network is being deployed in each state, and how federal resources are being used, it may be difficult for Congress to ensure the requirements of the law are being met. Given the federal investment in the project ($6.5 billion and 20 MHz of valuable broadband spectrum), and the importance of the FirstNet network to the life of safety of first responders and citizens, the 116th Congress may consider continuing its oversight of this project.

For Further Information

Jill Gallagher, Analyst in Telecommunications Policy

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

Emergency Alerting

Local officials are responsible for issuing emergency alerts. Some localities use commercial alerting systems to send electronic alerts (e.g., cell phone alerts, email alerts). Others rely on the federal alerting system—the Integrated Public Alert and Warning System (IPAWS), which allows local officials to send alerts across many media outlets (e.g., cell phone, television, radio). Many localities use both systems to ensure alerts are received.

The false alert of an incoming ballistic missile to Hawaii on January 13, 2018, raised questions about alerting roles and responsibilities. While the national alerting system—IPAWS—worked as intended, the roles and responsibilities for issuing alerts of incoming missiles was debated in Congress.

The 2017 and 2018 wildfires in California raised additional alerting issues. Several counties in California used a commercial alerting system that reached only those residents who signed up for the service (whereas IPAWS would have sent an alert to all devices in the affected area). Local officials were concerned that cell phone alerts issued through IPAWS could not be narrowly targeted, and would result in over-alerting, mass evacuation, and overcrowding on evacuation routes, which could put people and first responders in danger.

In January 2018, the Federal Communications Commission adopted rules requiring carriers to improve geo-targeting of wireless emergency alerts (WEA)—alerts to cell phones issued through IPAWS. Carriers must comply with these rules by November 30, 2019.

The 116th Congress may examine roles and responsibilities for issuing different alerts, and consider policies that clarify alerting procedures. Congress may also consider investments in activities (e.g., best practices) to improve local alerting capabilities, and programs that educate individuals on the appropriate response to alerts. Lastly, Congress may examine state and local back-up alerting capabilities in the event communication systems fail, and wireless alerts cannot be delivered.

For Further Information

Jill Gallagher, Analyst in Telecommunications Policy

CRS In Focus IF10816, *Emergency Alerting—False Alarm in Hawaii*, by Jill C. Gallagher

5G Technologies

As more people are using more data on more devices, demand for mobile data is rising. Current telecommunication networks cannot always meet consumer demands for data. Telecommunication companies are continually deploying new technologies to offer better coverage, faster speeds, more data, and new services to customers.

The newest technologies are called fifth-generation (5G) technologies, as they succeed 2G, 3G, and 4G systems. 5G technologies offer vastly improved speeds and greater bandwidth to meet demands for mobile data. 5G technologies enable providers to expand services to consumers (e.g., video streaming, virtual reality applications) and support new systems for industrial users (e.g., medical monitoring, industrial control systems). When fully deployed, 5G is expected to power the Internet of Things—systems of interconnected devices (e.g., smart homes), and emerging technologies (e.g., autonomous vehicles).

5G is expected to drive the development of new technologies, support new uses by consumers and industry, and create new markets, new revenues, and new jobs. Since companies that are first to market with new technologies often capture the bulk of the new revenues, companies around the world are racing to develop and deploy 5G technologies. Recognizing the potential for economic gain, countries (i.e., central governments) are supporting the development and deployment of 5G technologies. In the United States, the federal government has allocated spectrum for 5G and streamlined cell siting regulations to speed deployment.

The 116th Congress may continue to monitor U.S. competitiveness in the global 5G market, and consider policies (e.g., spectrum allocation policies) and programs that could expedite 5G deployment. In developing 5G policies, Congress may consider concerns of some local governments and individuals related to 5G deployment, including local authority over 5G cell sites, deployment of 5G to rural areas, and privacy and security of data transmitted over 5G devices and systems.

For Further Information

Jill Gallagher, Analyst in Telecommunications Policy

The Internet of Things

The Internet of Things (IoT) may continue to be a focal point of far-reaching debates during the 116th Congress. The term refers to networks of objects with two features—a unique identifier and internet connectivity. Such "smart" objects can form systems that communicate among themselves, usually in concert with computers, allowing automated and remote control of many independent processes and potentially transforming them into integrated systems. Such objects may include vehicles, appliances, medical devices, electric grids, transportation infrastructure, manufacturing equipment, building systems, and so forth. The IoT is increasingly impacting homes and communities, factories and cities, and nearly every sector of the economy, both domestically and globally, among them agriculture (precision farming), health (medical devices), and transportation (self-driving automobiles and unmanned aerial vehicles).

An increasing number of these systems require access to radio frequency spectrum in order to connect to the internet or other networks. The development of 5G wireless technologies is likely to develop in tandem with the IoT, potentially expanding substantially the opportunities for growth in use of IoT devices.

Although the full extent and nature of impacts of the IoT remain uncertain, some economic analyses predict that it will contribute trillions of dollars to economic growth over the next decade. The IoT, for example, may be able to facilitate more integrated and functional infrastructure, especially in "smart cities," through improvements in transportation, utilities, and other municipal services. Sectors that may be particularly affected are agriculture, energy, government, health care, manufacturing, and transportation.

The federal government may play an important role in enabling the development and deployment of the IoT, including R&D, standards, regulation, and support for testbeds and demonstration projects. No single federal agency has overall responsibility for the IoT. Various agencies have relevant regulatory, sector-specific, and other mission-related responsibilities, such as the Departments of Commerce, Health, Energy, Transportation, and Defense, the National Science Foundation, the Federal Communications Commission, and the Federal Trade Commission.

The range of issues that might be the subject of congressional activity includes the following:

- security of objects and the systems and networks to which they are connected, given especially that many IoT devices are operational technology, the compromise of which can have physical impacts (see also "Cybersecurity");
- privacy of the information gathered and transmitted by objects;
- standards for the IoT, especially with respect to connectivity;
- transition to a new Internet Protocol (IPv6) that can handle the anticipated exponential increase in the number of IP addresses required by the IoT, along with the growth of 5G wireless;
- methods for updating the software used by IoT objects in response to security and other needs;
- energy management for IoT objects, especially those not connected to the electric grid; and
- the role of the federal government in development and deployment, standards, regulation, and communications, including the impact of federal rules regarding "net neutrality."

The Internet of Things represents more than devices connected through networks, and more than internet or radio frequency spectrum policy. Its growth will likely require significant changes in—and coordination among—many government departments and agencies.

For Further Information

Eric A. Fischer, Senior Specialist in Science and Technology

CRS Report R44227, *The Internet of Things: Frequently Asked Questions*, by Eric A. Fischer

Digital Services Tax

The rise of e-commerce, social media, and big data analytics have allowed new business models to emerge as part of the "digital economy." In the realm of international tax policy, though, certain types of activities and markets in the digital economy have been singled out for "digital services taxes" (DSTs) by some jurisdictions—primarily in Europe. For example, Spain is set to implement a DST of 3% on the gross revenue derived from certain digital services (e.g., online advertising, online marketplaces, and user data tracking services) derived from users within Spain beginning in 2019. Similarly, the United Kingdom (UK) intends to implement a 2% DST on revenues from social media platforms, online marketplaces, and search engines derived from UK user activity in 2020. Both DSTs have minimum thresholds based on global total revenue and revenue from covered business activities to local users that effectively target the largest global digital economy companies. The EU is also actively considering a digital tax across all member states.

This issue may be of interest to Congress because the taxes appear to primarily target U.S. corporations, such as Facebook, Google, and Amazon. As such, there is opposition to unilateral efforts by foreign countries to tax the digital economy. DSTs also raise potential issues for U.S. foreign tax credit treatment under bilateral tax treaties, which are considered and ratified by the Senate. Additionally, some Members of Congress may support one of the purported justifications for DSTs (a perceived "unfairness" arising from the relatively low rate of tax paid by some firms in the digital economy), but would prefer alternative remedies to raise taxes or reduce tax preferences on these corporations. For example, the 2017 tax revision (P.L. 115-97) enacted a new tax on global intangible low-taxed income ("GILTI"), which is designed to be a minimum tax on foreign-source income earned from intangible assets (e.g., patents, trade secrets). In the 115th Congress, the "No Tax Break for Outsourcing Act" (H.R. 5108; S. 2459) would have increased the GILTI tax rate to 21% (the same as the top statutory corporate income tax rate), among other changes.

For Further Information

Sean Lowry, Analyst in Public Finance

CRS Report R45186, *Issues in International Corporate Taxation: The 2017 Revision (P.L. 115-97)*, by Jane G. Gravelle and Donald J. Marples

Evolving Technology and Law Enforcement Investigations

Changing technology presents opportunities and challenges for U.S. law enforcement. Some technological advances (e.g., social media) have arguably provided a wealth of information for investigators and analysts. Others have presented unique hurdles. While some feel that law enforcement now has more information available to them than ever before, others contend that law enforcement is "going dark" as some of their 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 and information are constantly passing. As such, law enforcement may have trouble accessing certain information they otherwise may be 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 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 "going dark" debate originally focused on data in motion, or law enforcement's ability to intercept real-time communications. However, more recent technology changes have impacted law enforcement's capacity to access not only communications but stored content, or data at rest. Some officials have urged the technology community to develop a means to assist law enforcement in accessing certain data. At the same time, law enforcement entities have taken steps to bolster their technology capabilities. In addition, policymakers have been evaluating whether legislation may be an appropriate response to current law enforcement concerns involving access to communications and data.

For Further Information

Kristin Finklea, Specialist in Domestic Security

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

The 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 21 NITRD member agencies invest approximately $5 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 will 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 116th 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 is 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. Today, QIS is a component of the National Strategic Computing Initiative (Executive Order 13702), which was established in 2015. More recently, in September 2018, the National Science and Technology Council (NSTC) issued the National Strategic Overview for Quantum Information Science. The policy opportunities identified in this strategic overview 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 a July 2016 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 2019 and may provide context for developing legislation in the 116th Congress.

For Further Information

Patricia Moloney Figliola, Specialist in Internet and Telecommunications Policy

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

Physical and Material Sciences

Some of the policy issues in the physical and material sciences that the 116th Congress may address include funding and oversight of the National Science Foundation and the multiagency initiative supporting research and development in the emerging field of nanotechnology.

National Science Foundation

The National Science Foundation 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 primary share of the federal STEM education effort, both by number of programs and total investment. Enacted funding for NSF in FY2018 was $7.77 billion.

Congress has a long-standing interest in NSF's funding levels and the prioritization and direction of such funding. At various points in NSF's history, some policymakers have pursued a policy of authorizing large increases in the NSF budget over a defined period of time (e.g., a 100% increase over seven years, sometimes referred to as a "doubling path policy"). Actual appropriations have rarely reached authorized levels, however, and growth in NSF's budget has slowed in recent years. Advocates of large funding increases assert that steep and fast increases in NSF funding are necessary to ensure U.S. competitiveness. Other analysts argue that steady, reliable funding increases over longer periods of time would be 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. Additionally, some policymakers prefer to direct federal funding to research with a more applied or mission-oriented focus than that which is typically funded at NSF.

In terms of congressional direction of funding, analysts and legislators have periodically debated questions about prioritizing NSF funding for the physical sciences and engineering over funding for the social, behavioral, and economic sciences, as well as expanding support for multidisciplinary funding.

Policy issues that the 116th Congress may continue to address include

- the selection, funding, and management of large-scale construction projects, scientific instruments, and facilities, including the use of management fees;
- increased support for mid-scale research infrastructure;
- research reproducibility and replicability; and
- the effectiveness and costs of NSF's use of nonfederal personnel—through the Intergovernmental Personnel Act program—often called "rotators."

Other lasting federal policy issues for the NSF focus on the balance between scientific independence and accountability to taxpayers; the geographic distribution of grants; NSF's role in broadening participation in STEM fields; support for various STEM education programs; and the production of data about the U.S. scientific and technological enterprise.

For Further Information

Laurie A. Harris, Analyst in Science and Technology Policy

CRS Report R45009, *The National Science Foundation: FY2018 Appropriations and Funding History*, 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 FY2018, Congress appropriated approximately $24.0 billion for nanotechnology R&D; for FY2019, President Trump requested $1.4 billion in funding. 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 has been enacted into law. The 116th 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.

CRS Report RL34401, *The National Nanotechnology Initiative: Overview, Reauthorization, and Appropriations Issues*, by John F. Sargent Jr.

CRS Report RL34614, *Nanotechnology and Environmental, Health, and Safety: Issues for Consideration*, by John F. Sargent Jr.

Space

Congress has historically had a strong interest in space policy issues. Space topics that may come before the 116th 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 include the goals and strategy of NASA's human spaceflight program, the impact of constrained budgets on NASA's other missions, and the future of NASA's Earth Science program. The 116th Congress may address these and other issues through NASA reauthorization legislation.

With the end of the space shuttle program in July 2011, the United States lost the capability to launch astronauts into space. Since that time, NASA has relied on Russian spacecraft for crew transport to the International Space Station (ISS). For ISS cargo transport, NASA-contracted U.S. commercial flights have been delivering payloads of supplies and equipment since October 2012.

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 transport to low Earth orbit, including the ISS, NASA is supporting commercial development of a crew transport capability like the commercial cargo capability achieved in 2012. Commercial crew transportation services are expected to become operational in late 2019 or 2020.

Second, for human exploration beyond Earth orbit, NASA is developing a new crew capsule called Orion and a new heavy-lift rocket called the Space Launch System (SLS). The first crewed test flight of Orion and the SLS is scheduled for 2023. Most details of the subsequent exploration missions of Orion and the SLS remain to be determined. In February 2018, NASA announced plans for a Lunar Orbital Platform–Gateway (LOP-G) in lunar orbit, to be accessed via Orion and the SLS, that would serve as a platform for deep-space human exploration.

Rapid developments in the commercial space sector may change the relationship between NASA and industry. For example, SpaceX has announced plans for commercial flights carrying passengers around the Moon and back as well as, in the longer term, to Mars. Some observers see this sort of development as potentially competing with NASA's human spaceflight plans. More broadly, the emergence of new commercial capabilities in space may present NASA with new opportunities for public-private partnerships or may shift its R&D priorities. For example, NASA has announced plans to end direct funding for the International Space Station by 2025, instead relying on a combination of public-private partnerships and commercial service contracts.

The 2010 authorization act authorized funding increases for NASA that were not subsequently appropriated. In considering reauthorization, the 116th Congress may examine whether reduced budget expectations require corresponding changes to planned programs. One common concern is that the cost of planned human spaceflight activities may mean less funding for other NASA missions, such as unmanned science satellites, aeronautics research, and space technology development.

NASA's Earth Science program, in which climate research is a major focus, is of particular congressional interest. Some in Congress have argued that other NASA activities should have higher priority or that some or all of NASA's Earth Science responsibilities should be transferred to other agencies. Supporters counter that space-based Earth observations are an integral part of NASA's science mission.

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 IF10828, *The International Space Station (ISS) and the Administration's Proposal to End Direct NASA Funding by 2025*, by Daniel Morgan

CRS In Focus IF10940, *The James Webb Space Telescope*, 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, 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. The 115th Congress considered, but did not enact, legislation to simplify and reform this regulatory framework. In addition, in May 2018, the Administration called for changes to the regulation of commercial space in Space Policy Directive–2, *Streamlining Regulations on Commercial Use of Space*. The 116th Congress may continue this focus on regulatory reforms.

How the federal government makes use of commercial space capabilities is also evolving. 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 their own spacecraft. DOD has its own satellite communications capabilities, but 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. The 116th Congress may address these developments primarily through oversight of agency programs and decisions on agency budgets.

For More Information

Daniel Morgan, Specialist in Science and Technology Policy

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

CRS Report R44708, *Commercial Space Industry Launches a New Phase*, by Bill Canis

Earth-Observing Satellites

The constellation of 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 in building and operating U.S. Earth-observing satellites. Congress is particularly interested in the agencies meeting budgets and time schedules so that critical space-based observations are not missed due to delays and cost overruns. Concerns have been raised in the past by some in Congress about the possibility of a "data gap" in the polar-orbiting weather satellite coverage. The successful launch of the first Joint Polar Satellite System satellite JPSS-1 (now NOAA-20) on November 18, 2017, has alleviated those concerns for the near-term. Congress provided full funding, $776 million for the second polar-orbiting satellite, JPSS-2, in the FY2018 enacted appropriations.

On November 19, 2016, the Geostationary Operational Environmental Satellite-R (GOES-R) weather satellite launched and was placed into orbit. Renamed GOES-16, it is an advanced weather satellite with sensors that should help improve hurricane tracking and intensity forecasts, prediction and warning of severe weather events, and rainfall estimates that will lead to better flood warnings. GOES-16 also carries the first operational lightning mapper in geostationary orbit, and will better monitor space weather—perturbations to the Earth's magnetic field caused by intense bursts of energy from the sun. On March 1, 2017, GOES-S successfully launched carrying the same suite of instruments as its predecessor. The satellite is in its final stage of calibration before transitioning to operation status in January 2019. Renamed GOES-17, the satellite experienced a problem with one of its key imaging instruments after launch, the Advanced Baseline Imager (ABI), which impairs its functionality. NASA has stated that despite the ABI problem, GOES-17 will provide more and better data than currently available. Both satellites represent the first two in a series of four Earth-orbiting weather satellites planned by NOAA through 2036. The 116th Congress may continue to scrutinize budget and time schedules for polar-orbiting and geostationary satellites, as well as consider how the private sector could provide Earth-observing satellite data to supplement the current NASA NOAA, and USGS-operated satellite systems.

For Further Information

Peter Folger, Specialist in Energy and Natural Resources Policy

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

Author Information

Frank Gottron, Coordinator
Specialist in Science and Technology Policy

Sahar Angadjivand
Analyst in Agricultural Policy

Kelsi Bracmort
Specialist in Natural Resources and Energy Policy

Nicole T. Carter
Specialist in Natural Resources Policy

Laura B. Comay
Acting Section Research Manager

Tadlock Cowan
Analyst in Natural Resources and Rural Development

Agata Dabrowska
Analyst in Health Policy

Patricia Moloney Figliola
Specialist in Internet and Telecommunications Policy

Kristin Finklea
Specialist in Domestic Security

Eric A. Fischer
Senior Specialist in Science and Technology

Peter Folger
Specialist in Energy and Natural Resources Policy

Jill C. Gallagher
Analyst in Telecommunications Policy

Marcy E. Gallo
Analyst in Science and Technology Policy

Gary Guenther
Analyst in Public Finance

Laurie A. Harris
Analyst in Science and Technology Policy

Mark Holt
Specialist in Energy Policy

Elena H. Humphreys
Analyst in Environmental Policy

Chris Jaikaran
Analyst in Cybersecurity Policy

Judith A. Johnson
Specialist in Biomedical Policy

Lennard G. Kruger
Specialist in Science and Technology Policy

Jane A. Leggett
Specialist in Energy and Environmental Policy

Eva Lipiec
Analyst in Natural Resources Policy

Sarah A. Lister
Specialist in Public Health and Epidemiology

Sean Lowry
Analyst in Public Finance

Daniel Morgan
Specialist in Science and Technology Policy

Anna E. Normand
Analyst in Natural Resources Policy

Angele A. Gilroy
Specialist in Telecommunications Policy

Boris Granovskiy
Analyst in Education Policy

Victoria R. Green
Analyst in Health Policy

Joel L. Greene
Analyst in Agricultural Policy

Amanda K. Sarata
Specialist in Health Policy

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

Kavya Sekar
Analyst in Health Policy

Pervaze A. Sheikh
Specialist in Natural Resources Policy

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