Public Meeting of the

President's Council of Advisors on Science and Technology (PCAST)

January 18, 2024

Meeting Minutes

MEETING PARTICIPANTS

PCAST MEMBERS

1. Frances Arnold, Co-Chair
2. Maria T. Zuber, Co-Chair
3. Dan E. Arvizu
4. Dennis Assanis
5. John Banovetz
6. Frances Colón
7. Lisa A. Cooper
8. John O. Dabiri
9. William Dally
10. Sue Desmond-Hellmann
11. Inez Fung
12. Andrea Goldsmith
13. Laura H. Greene
14. Paula Hammond
15. Eric Horvitz
16. Joe Kiani
17. Jon Levin
18. Steve Pacala
19. Saul Perlmutter
20. William Press
21. Jennifer Richeson
22. Vicki Sato
23. Lisa Su
24. Kathryn Sullivan
25. Terence Tao
26. Phil Venables
27. Catherine Woteki

PCAST STAFF

1. Lara Campbell, Executive Director
2. Reba Bandyopadhyay, Deputy Executive Director
3. Bich-Thuy (Twee) Sim, Assistant Director for Transformative Medicine and Health Innovation
4. Melissa A. Edwards, Assistant Deputy Executive Director
5. Kimberly Lawrence, Administrative Specialist

START DATE AND TIME: Thursday, January 18, 2024, 1:45 PM Eastern Time

LOCATION: Eisenhower Executive Office Building and livestreamed via Zoom.gov

WELCOME

PCAST Co-chairs: Frances Arnold, Maria Zuber

The PCAST co-chairs—Frances Arnold, California Institute of Technology; and Maria Zuber, Massachusetts Institute of Technology—called the meeting to order. Zuber said PCAST was excited to discuss and potentially vote on two reports to the President. Zuber then introduced the co-leads of the Cyber-Physical Resilience working group, Phil Venables and Eric Horvitz, who summarized the report's findings and recommendations and answered questions from PCAST members.

SESSION: DISCUSSION AND CONSIDERATION FOR APPROVAL OF PCAST REPORT TO THE PRESIDENT ON STRATEGY FOR CYBER-PHYSICAL RESILIENCE

Zuber introduced the session by noting that in the increasingly digital world, cyber-physical resilience is essential for ensuring the robustness and adaptability of interconnected systems in the face of cyber threats and disruptions. It involves the ability of systems to withstand, recover from, and adapt to adverse events, whether they originate from cyberattacks, natural disasters, or other challenges. The key is maintaining continuous operation, minimizing downtime, and safeguarding against cascading effects that could affect both the digital and physical parts of critical systems.

PHIL VENABLES

Venables said U.S. society is becoming increasingly dependent on an interwoven set of physical and digital technologies on which the nation's critical infrastructure depends. Cyberattacks, natural threats, and accidents place those services at risk, and attacks will always have an effect no matter how good the cyber-physical defense system is. However, it is possible to focus on resilience in the face of those consequences to ensure the nation can maintain minimum viable services in the face of an attack. While the Biden-Harris Administration has made significant progress at increasing resilience, the nation needs to amplify and accelerate the activities that are underway.

For decades, Venables said, the nation's focus has been on enhancing cybersecurity and keeping information technology (IT) systems secure, yet despite many successes, cyberattacks continue to succeed. After an attack, the traditional response has been to identify the compromised IT component and make it more secure and reliable. Eventually, however, another attack gets through, and the response has been to build more fortifications and turn the "security screws" tighter, which actually makes these systems more brittle. Therefore, while the nation needs to continue investing in cyber defense, there is the increasing realization that it is just as important to ensure IT systems are resilient despite being compromised. If components are attacked, compromised, or fail, systems must continue to run, even if not at peak performance. Cyber-physical resilience aims to provide that capability.

Venables explained that cyber-physical systems rely on both physical and computational components to perform key services, with core physical aspects of systems intertwined with and relying upon digital technologies and communications dependent on local and internet connectivity. Nation-states and criminal gangs have attacked critical infrastructure and disrupted their operations, and evidence suggests

that nation-states are prepositioning attacks to use in the event of conflict. Natural events such as extreme weather and maintenance errors have also shut down critical infrastructure.

ERIC HORVITZ

Horvitz listed the set of overarching principles for fortifying the cyber-physical resilience of the nation's critical infrastructure that frame the working group's recommendations:

- The complexity of cyber-physical systems underpinning U.S. critical infrastructure requires coping with vulnerabilities that cannot be identified completely, much less eradicated.
- Cyber-physical risk is high, while protections are disproportionately low.
- Cyber-physical systems are often networked and depend on other cyber-physical systems that are themselves networked.
- New technologies, especially artificial intelligence systems, will transform the landscape of cyber-physical security, amplifying both attack and defense capacities.
- Future systems must be designed and made resilient from the start using cyber-informed engineering.

The goal of the recommendations, said Horvitz, is not to stop attending to cybersecurity. Rather, it is to allocate significant attention to putting resilience at the heart of the design and operations of the nation's cyber-physical systems.

Horvitz said the first recommendation is to establish performance goals centering on resiliency for the nation's critical infrastructure. Meeting these goals would establish minimum delivery objectives for critical services, even in the face of adversity, and establish more ambitious performance goals to measure all organizations' ability to achieve and sustain those objectives. Setting performance goals will bring the capabilities and brittleness of the nation's systems into focus, provide transparency on where different sectors in the economy are regarding resilience, and enable tracking progress and sharing information. As part of this recommendation, the working group recommends that the Cybersecurity and Infrastructure Security Agency (CISA) work with Sector Risk Management Agencies (SRMAs) and their Sector Coordinating Councils (SCCs) to define sector minimum viable operating capabilities and minimum viable delivery objectives, establish and measure leading indicators that characterize the multiple dimensions of resilience of the nation's systems, and commit to stress testing using these measures and transparency regarding the results.

Examples of minimum viable delivery objectives, said Horvitz, are "bounded impact" and "bounded failure." A bounded impact measure sets an allowed upper limit on the effect of a failure on a population, such as no more than 50,000 people will be without electricity for more than one week. Bounded failure measures a system's resiliency in terms of the maximal effect of any single point failure via containing spread by creating independence and resilience of subsystems and components should other system components fail. Bounded failure can guide efforts to pursue and certify independencies or well-defined influences among system components to enable isolating and managing failures instead of having them cascade through a larger system in complex and poorly understood ways.

Horvitz said the working group developed 10 broadly defined leading indicators an organization can use to identify its most critical systems. Some of these metrics are straightforward, such as communication

failure and hard restart recovery time. Others, such as common mode failures and dependencies, will have to be defined more precisely in the context of each sector and organization.

The working group's second recommendation, said Horvitz, is to bolster and coordinate what is now fragmented and unfocused research and development (R&D) on cyber-physical resilience by marshaling the nation's academic and private sector R&D capabilities. To achieve this recommendation, the working group requests that CISA, in partnership with the National Security Agency, create a national critical infrastructure observatory to build and extend prior efforts to pull together knowledge and tools capable of providing a broader operational understanding of the nation's infrastructure across sectors. Horvitz said experts told the working group the nation's adversaries likely have a better picture of U.S. infrastructure and its weaknesses than we do, a gap that must be closed. This resource would enable secret and open studies, including ongoing red-team testing.

Horvitz said this recommendation also calls for formulating a comprehensive national plan for cyber-physical resilience R&D; for the leadership of the Office of Science and Technology Policy, National Science and Technology Council, and Networking and Information Technology Research and Development program to coordinate activities across agencies and the federal Advanced Research Project Agencies (ARPAs), and to standup a vibrant ARPA for infrastructure with research; increasing engagement on international standards; and embedding cyber-physical resilience skills into engineering professional and education programs.

PHIL VENABLES

Venables said the third recommendation is to break down silos and strengthen government cyber-physical resilience capacity. This recommendation calls for establishing consistent prioritization of critical national infrastructure, bolstering staffing and capabilities of the SRMAs, clarifying and strengthening SRMA authorities to set minimum standards for organizations in their responsible sectors and enforce performance goals, and enhancing the Department of Homeland Security (DHS) Cyber Safety Review Board to undertake more reviews and focus on both security and resiliency.

The final recommendation, said Venables, is to develop greater accountability for industry, boards, chief executive officers, and other executives, given that private sector owners and operators run much of the nation's critical infrastructure. Though many private sector organizations are investing in and improving the security and resilience of their systems, there is more to do. This recommendation calls for enhancing the SCCs and promoting supply chain focus and resilience by design. The goal, said Venables, is to identify the 20 percent of the organizations that can drive 80 percent of the outcomes for a sector.

Venables said the nation must move beyond defending against attacks on the cyber-physical systems upon which its critical infrastructure depends and address resilience to provide minimal viable services in the face of attacks and disruptions. The recommendations aim to set more ambitious performance goals that move beyond security to include resilience, create a more aligned R&D agenda to support those goals, including building a national critical infrastructure observatory, equip government agencies with more capabilities and authorities to deliver resilience, and stimulate private sector owner/operators of critical infrastructure to amplify executive-level "tone at the top" and increase "resources in the ranks".

After the working group's co-leads' presentation, discussion among PCAST members followed.

ZUBER MODERATED THE Q&A AND DISCUSSION BETWEEN PCAST MEMBERS AND VENABLES AND HORVITZ

Zuber asked where a small organization with limited resources and old equipment can get guidance about the path forward given its current situation. Venables said many utility companies are small businesses operating on a shoestring, but what they share is an underpinning set of technologies and service providers that support them. Mining the supply chain can identify those technologies and providers and increase their level of resilience and security to benefit the entire sector. CISA and other agencies will have to ensure that local municipalities and profit-making organizations invest appropriately in security and resilience of critical infrastructure they own or operate.

Andrea Goldsmith asked if the U.S. cyber-physical security threat is unique and if there are opportunities to partner with other countries to address these challenges. Venables said there are many commonalities, and all nations have been progressively equipping their critical infrastructure with cyber-physical systems. Some infrastructure sectors, such as finance, are global. He said many federal agencies partner with their counterparts, particularly in allied nations, to share risks and vulnerabilities and search for common solutions. Where the United States differs is the proportion of national critical infrastructure in private sector hands, making it harder to impose standards. This is why the working group recommended SRMAs should pursue more authorities to drive an appropriate level of minimum standards for those industries.

Saul Perlmutter asked how PCAST can help achieve the goals aimed at the private sector in the fourth recommendation. Venables said the private sector will have to participate voluntarily, though an increasing number of sectors are subject to some minimum regulation. There are elements in the report that addresses aligning and explaining the incentives private sector organizations have for maintaining security and resilience. The report calls for more senior-level involvement in the SCCs to help them realize these goals align with their own objectives. Horvitz added that the report suggests allowing more people inside companies, aside from the specific individuals with clearance to access confidential information about an attack, to understand what happened and respond.

Paula Hammond asked about how the recommendations will affect local municipalities given the limited resources they may have. Venables said CISA is engaged with state, local, tribal, and territorial governments and their municipal utilities to provide assistance, and DHS grants can help municipalities address cyber-physical threats. He noted the report stresses the importance of involving representatives from small utilities, not just large companies, in the SCCs.

Terence Tao asked about the feasibility of making contingency plans to have a surge capacity of experts to advise or even assume operational control in case the scale of a disaster overwhelms an organization's senior leadership. Some industries, said Venables, have contingency plans such as agreements between companies to provide surge capacity. One consequence of focusing on minimum viable delivery objectives may be that organizations will realize they have to figure out how to provide assurance they can hit them, which may prompt them to develop shared surge capacity within their industries.

Lisa Cooper asked if the report addresses how systems in predominantly underserved communities can implement the recommendations. Venables said the report recognizes that some consequences of cyber-physical failures disproportionately affect certain communities, and it focuses on the local

utilities and municipalities that will need incentives to enable the necessary level of investment. DHS CISA tries to address this through grant programs and other incentives.

Cooper then asked what this would cost. Venables said it is hard to say at this point because the private sector will bear much of the cost since it controls the dominant portion of the nation's critical infrastructure. Many of the recommendations will channel private sector investments into the areas needing the most attention, but federal agencies may have to provide additional investments, such increasing staff in the SRMAs. In general, though, this is more about focusing resources than adding significantly more resources.

Jon Levin asked how the metrics will be determined and tracked over time given this is an adversarial system and the possible risk of publicizing where gaps exist. Horvitz said the assumption is that adversaries already know these gaps and that resilience is a strong deterrent itself. Tracking leading indicators, rather than lagging indicators, provides a picture of what good outcomes would be as opposed to what bad outcomes already occurred.

Dennis Assanis asked at what point does the nation invest in either designing a better system versus having parallel systems with some redundancy. Horvitz said the purpose of drilling down into systems is to find points of surprising dependency and then introducing redundancy there rather than recreating the entire system.

Assanis then asked what academic disciplines would play a major role in preparing scientists and engineers to design systems for resilience. Venables said civil, chemical, and electrical engineers should have a grounding in cyber-physical resilience and that it becomes part of their professional engineering qualifications. While there are efforts to increase the cybersecurity workforce, many computer science degrees do not have a formal education component on cybersecurity or resilience, and that needs to change. Horvitz added that fail-safe design is already a core principle for engineers and that concept needs to be extended to cyber-physical resilience. Zuber noted the working group spoke with companies developing more resilient models to deal with the threats of the Internet of Things who said customers were unwilling to pay for those features. The needed culture change, she said, is to build resilience into base models and not have an option to purchase a non-resilient system.

Arvizu said there was a time when a global engineering services company had contracts to service over 150 small U.S. water utilities, and he wondered if this was a positive or negative for cyber-physical resilience. Venables said the recommendations call for each sector to dig into its digital and physical supply chains to identify services companies that are the common provider across a range of other companies to ensure they are considered part of the collective infrastructure. This can be a great leverage point because if that provider is resilient, there will be a positive effect on everyone. For example, many small community banks outsource their IT systems to a handful of service providers, and the Treasure Department has focused on boosting the resilience of those providers. Other critical infrastructure sectors need to do the same thing, said Venables. Regarding communications, he said it will be interesting to see what organizations discover about what stops functioning and what does not when internet communications fail.

Steve Pacala asked how much of the work ahead would be easy and cheap to accomplish and how much would be expensive because it will require replacing equipment. Horvitz said that would depend on what the nation or a community would find tolerable as a minimum delivery of service. Venables said the report made the point that many of the steps, if done well, would deliver huge, adjacent commercial benefits such as increased reliability and efficiency that would make up for any additional costs.

Vicki Sato wondered if business leaders' experiences during the COVID-19 pandemic regarding the importance of business continuity will make the task of getting senior executives involved easier. However, given the complexity of this issue, she asked if individual companies should build their own fail-safe models and testing procedures or if a cadre of external experts would be better suited to tackle this problem. Venables said the national critical infrastructure observatory can take a systematized view of cross-sector dependencies and some SCCs have run joint drills across sectors. One reason the report calls for more executive-level engagement in the SCCs is to conduct more cross-sector drills to see what the effects might be.

Frances Colón asked if a legislative path to enforce transparency is necessary as opposed to voluntary disclosure. Venables cited the example of the Emergency Planning and Community Right-to-Know Act that requires companies in specific manufacturing industries to report on their management of toxic chemicals to the Toxic Release Inventory. By making this information public, this requirement created a strong incentive to improve their environmental performance. This program does not set standards, but it enforces transparency that led companies to take corrective actions. Something similar could work for cyber-physical resilience with guardrails to protect sensitive information. CISA is driving work on cyber performance goals that are disclosed and managed within closed communities. The report recommends setting a path for how results are shared first within a community in a trusted manner and then ultimately released to the public.

Laura Greene asked if the report mentions developing secure methods that academics can use to collaborate safely on cyber-physical security with people around the world. Horvitz said he can see academics publishing papers about flexibility, response, and resiliency looking at specific systems and configurations and how they relate to fail-safe design that would not put the nation at risk.

With the discussion concluded, PCAST voted unanimously to accept the report.

SESSION: DISCUSSION AND CONSIDERATION FOR APPROVAL OF PCAST REPORT TO THE PRESIDENT ON ACCELERATING EFFECTIVE REDUCTION OF GREENHOUSE GAS EMISSIONS

Zuber introduced the session by noting the imperative to reduce greenhouse gas (GHG) emissions to mitigate the adverse effects on ecosystems, biodiversity, weather patterns, sea level, overall environmental stability, and human health. She then introduced the co-leads of the Accelerating Effective Reduction of Greenhouse Gas Emissions working group, Inez Fung, Saul Perlmutter, and William Press, who summarized the report's findings and recommendations and answered questions from PCAST members.

INEZ FUNG

Fung said President Biden's ambitious goals of achieving zero carbon emissions for the power sector by 2035 and the entire U.S. economy by 2050 are targeted to save many thousands of people from air pollution deaths, increase employment in high-quality energy-related jobs, revitalizing the nation's industrial sector, and demonstrating a commitment to meeting global climate targets. Achieving this vision requires a dramatic decrease in GHG emissions, which includes carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. Methane, responsible for 30 percent of net warming since the industrial revolution, is 80 times more potent on a 20-year time scale than carbon dioxide but has a short atmospheric lifetime of 10 years compared to hundreds of years for carbon dioxide. The administration recognizes that reducing methane emissions quickly will slow warming in the near term while reducing health hazards, which is why the United States and the European Union made the Global Methane Pledge in 2021 to reduce global methane emissions at least 30 percent from 2020 levels by 2030. The transformative investments of the Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law, along with other actions, have put the nation on track to meet that goal. Federal agencies, state and local governments, industry, academia, and nongovernmental organizations have stepped up to meet the challenge of reducing GHG emissions to keep the goal of limiting warming to 1.5℃ within reach while yielding additional benefits, including improving public health and agricultural productivity.

Fung said the White House Interagency Working Group released the National Strategy to Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System (National Strategy) in November 2023. The PCAST Accelerating Effective Reduction of Greenhouse Gas Emissions working group endorses the strategy this document articulates and believes it will be extensible to international efforts on sustained, coordinated global GHG monitoring. Fung said each GHG has its own emission sources and removal mechanisms and requires complementary approaches for estimating emissions. Activity-based estimations are ground-based, people-intensive, and require extrapolation to arrive at a sector or industry's emissions. Whereas activity-based approaches provide granular, targeted measurements, atmospheric-based measurements cover emissions over a coarse area and require estimates from activity-based measurements and modeling to produce emissions estimates and trends. Merging the two approaches has been limited to research and is not operational.

Looking ahead to 2050, Fung said there are many questions that research has not yet answered. These include:

- How can we accelerate emissions reduction by identifying the largest sources in real time so we can act promptly?
- How can we provide emission information that can inform and incentivize both voluntary and enforcement-based emissions reduction efforts?
- How do we know which practices are most impactful and cost effective for reducing emission and boosting jobs and American competitiveness?
- How do we verify that our investments have produced the maximum national emissions reduction?
- How do we confirm that the reductions are sustained over time?
- How do we determine how best to adjust our course if we veer off path?

- What can we learn in the next 10 years to guide our national strategy for the next 30 years?

Fung said the working group's report lays out two requirements for accelerating the path toward net zero GHG emissions. First, the United States needs a unified and integrated measurement, monitoring, reporting, and verification (MMRV) program. This program should provide comprehensive, reliable measurements of GHG emissions sustained to 2050 and beyond. It should produce standardized reporting, with rigorous and independent verification, that integrates emissions from agriculture, oil and gas operations, and other sources, and includes ongoing engagement with stakeholders to ensure the data support their evolving needs to reduce emissions. Second, successfully reducing emissions requires having accurate, granular, timely, and sustained information on GHG emissions accessible to those driving mitigation activities.

The working group's recommendations, said Fung, build on the National Strategy and ongoing efforts by federal agencies, the private sector, academia, and others. The first recommendation is to establish a unified, common operating picture for the nation of emissions MMRV to enable accurate, validated, and timely GHG information at multiple geographic and temporal scales. This would build on the National Strategy to create a durable entity with the administrative authorities and budget to provide the data and resources to understand the nation's GHG successes and challenges through 2050 and beyond. This recommendation calls for the President to immediately establish a national GHG monitoring and information office to guide and provide oversight for developing the National Strategy to 2050 and beyond. This office would host all U.S. data on GHG concentrations and emissions, ensuring a common operating picture and enabling actionable information to facilitate reducing emissions. The core of this office would be the U.S. GHG Center discussed in the National Strategy, but it would include all relevant agencies from its inception to keep them all on the same path.

Fung said the second recommendation is to increase the nation's capacity to track and accelerate progress toward net zero GHG emissions in 2050 and beyond by strengthening research and infrastructure to innovate around the MMRV of GHG emissions. Achieving this recommendation requires developing a multi-decadal strategy for MMRV of GHG emissions using satellite observations and coordinating interagency research programs to accelerate the innovation of affordable sensors and their calibration, to develop systems that could automate GHG data collection and reporting, and to expand the GHG monitoring efforts across the country. Fung noted the private sector has developed small satellites capable of measuring methane plumes at high resolution.

Recommendation three, said Fung, calls for expanding comprehensive and up-to-date monitoring and reporting of methane emissions from all sectors and incorporating verification using atmospheric approaches. Three specific actions in the recommendation are to:

- Accelerate and expand monitoring and timely reporting of data on methane emissions from the entire supply chain of oil and gas industries and the entire life cycle of fossil methane. This effort should build on collaborations to identify large emitters and combine activity-based and atmospheric-based measurements. Current ground-based measurements can underestimate methane emissions by factors of 5-10 based on airplane-based measurements.

- Expand atmospheric methane monitoring coverage to include neighborhoods near large methane sources, such as oil and gas production facilities and livestock feedlots, and in urban areas across the country.
- Accelerate the transition from research to operations for integrating atmospheric-based and activity-based emission estimations to produce consistent regional, national, and global scale methane emissions estimates.

The working group's final recommendation is to accelerate, expand, modernize, and sustain the MMRV of GHG emissions from the agricultural and forestry sectors, focusing first on methane, to assess and enhance the effectiveness and implementation of climate-smart agriculture and forestry practices. Current estimates from agriculture, for example, come from decadal surveys and take five years post-survey to be released, so they are likely out of date. This recommendation calls for establishing protocols and metrics for direct measurement of GHG emissions from systems that are significant but poorly quantified sources, especially methane emissions from rice cultivation, enteric fermentation, waste management systems, and managed and working wetlands. It also calls for accelerating collection, reporting, and dissemination of data on agricultural practices and associated emission factors relevant for assessing the nation's annual GHG emissions from agriculture. Data latency should be no more than two years.

Fung said the working group's recommendations aim to support and accelerate the National Strategy and agency efforts to reach net zero GHG emissions by providing timely, granular, and validated information to all parties engaged in reducing emissions. Merging ground-based and atmospheric-based emissions data will maintain U.S. leadership in GHG quantification and serve as a guide to other nations as they develop their own emissions monitoring systems.

After the working group's co-leads' presentation, discussion among PCAST members followed.

ZUBER MODERATED THE Q&A AND DISCUSSION BETWEEN PCAST MEMBERS AND FUNG, PERLMUTTER, AND PRESS

Zuber asked if data measurements have to be accurate or precise, given that the detailed calibrations needed to produce accurate data adds complexity. Fung replied the goal is not just to monitor emissions, but to determine whether climate-smart agricultural investments are reducing emissions. Precision, she said, relates to determining the emissions source, while accuracy is needed for aggregating data.

Sue Desmond-Hellmann asked if the working group discussed the need to communicate the details of the plan to the public to gain public acceptance of the plan. Fung said the working group did not address that in its report because the National Strategy covers it, but the report does call for engaging disadvantaged communities living next to large methane sources because that was not included in the national plan. Catherine Woteki added that engagement with the agricultural sector is important because collecting activity-based data relies on farmers' willingness to complete the surveys that generate those data. She added that it is essential to shorten the time between surveys given the number of innovations being developed that will reduce methane emissions from cattle, for example.

William Dally asked if the working group discussed how to turn monitored and reported data into action to reduce emissions. Fung replied that the idea is to use the data to emphasize how reducing emissions will boost the economy, competitiveness, and health and have that be an incentive for people, companies, and industries to participate in reducing GHG emissions.

Dally also asked which emissions are the most important to address first. Fung replied that the Biden-Harris Administration has targeted methane emissions from the oil and natural gas sector first and then agriculture, which is the biggest unknown.

Press asked Fung and Woteki how optimistic they are that the Biden-Harris Administration can catalyze a culture change at the U.S. Department of Agriculture (USDA) that would convince the department these global problems should be part of its mission. Woteki said when the working group spoke with USDA officials, the officials realized USDA needs better, more reliable, and more frequent measurements of methane emissions to advance USDA's climate-smart programs. The IRA provided USDA with a large funding boost for its climate-smart agriculture and forestry programs, and USDA has put over $100 million in grants to demonstrate how adopting climate-smart agricultural practices can increase farmers' income. The approach in agriculture, she added, is to promote action with voluntary incentives. Fung said researchers conducting USDA-funded pilot projects want the standardized data in standardized formats advocated by the U.S. Greenhouse Gas Center as part of the National Strategy.

Horvitz asked whether the incentive programs and regulations for mandatory reporting are sufficient to ensure the measurements are credible or if there is great uncertainty from the reported numbers about whether the regulations are being followed. He also asked whether there are recommendations to change regulations to provide better incentives. Fung said academic research has shown that before 2021 and the Global Methane Challenge, measurement of methane emissions from hydrocarbon processing, which were self-reported and self-certified, were underestimating emissions and not comprehensive. Post-2021, the Environmental Protection Agency (EPA) has proposed rules to expand measurements that are shifting the situation in a positive direction in a manner that was encouraging to the working group and argued making a recommendation.

Dennis Assanis asked if tropospheric monitoring of GHG emissions has a role to play. Fung said it already is, starting with the 2014 launch of the Orbiting Carbon Observatory. The limitation of these data is they are not granular enough to pinpoint a specific source of emissions.

Tao asked if the recommendations propose specific targets, benchmarks, or milestones for specific levels of resolution or data coverage. Fung replied the field is currently data limited, which is why measurement and monitoring are so important for maximizing the return on investment. The recommendations do not include specific targets because technological capabilities are evolving so quickly. Pacala added that the challenge today is not that individual measurements are wrong but that coverage is incomplete. The working group decided that when merged, atmospheric- and ground-based measurements are good enough to produce a more accurate picture of where emissions are occurring. Pacala added that one reason USDA and EPA have been interested in this report is they know the nation is embarking on new practices that will reduce emissions at a reasonable cost and they will need methods to measure the results.

Arvizu asked if the report addresses future scenarios informed by the types of reductions in carbon emissions beyond methane that occur. Fung said the first recommendation calls for establishing an enduring entity that would guide the National Strategy and provide oversight for the entire enterprise. The second recommendation calls for advancing technology to measure as-yet unidentified sources, such as permafrost, to provide long-term oversight. Arvizu said the report focuses on providing a feedback mechanism to assess whether policies are working rather than on proposing new policies.

Venables, noting this is a global problem, asked if the working group envisioned there should be data sharing or technology transfer with other nations to enable them to implement similar capabilities. Fung said this is happening, with 13 of the 17 carbon dioxide- or methane-observing satellites belonging to other nations. Data are being shared among the operators of the satellites.

Dally asked if there is a need for an intermediate atmospheric measurement system that would provide additional resolution beyond the kilometer-scale pixels for the current satellites. Fung said there will be two small drone-like devices launched in 2024 to serve as "plume mappers" capable of flying over the regions identified by the course-resolution satellite observations.

With the discussion concluded, PCAST voted unanimously to accept the report.

PUBLIC COMMENT

Two minutes of public comments were provided.

CLOSING COMMENTS

Arnold thanked the two working groups for their hard work using science to move forward for the nation. Zuber noted that the third PCAST co-chair, Arati Prabhakar, was returning from the World Economic Forum and passed along her gratitude for PCAST work on these topics. She then adjourned the public meeting.

PUBLIC MEETING ADJOURNED: 4:19 PM Eastern Time

I hereby certify that, to the best of my knowledge, the foregoing minutes are accurate and complete.

Frances Arnold, Ph.D.
Co-Chair
President's Council of Advisors on Science and Technology

Arati Prabhakar, Ph.D.
Co-Chair
President's Council of Advisors on Science and Technology

Maria Zuber, Ph.D.
Co-Chair
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