Per- and Polyfluoroalkyl Substances (PFAS) Federal Research and Development Strategic Plan

A Report by the

JOINT SUBCOMMITTEE ON ENVIRONMENT, INNOVATION, AND PUBLIC HEALTH

PFAS Strategy Team

of the

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

AUGUST 2024

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About the PFAS Strategy Team

Congress directed an Interagency Working Group (IWG) to coordinate federal research on Per- and Polyfluoroalkyl Substances (PFAS) through the National Defense Authorization Act (NDAA) for Fiscal Year (FY) 2021.[1] In response, OSTP developed the PFAS Strategy Team (PFAS ST) under the Joint Subcommittee on Environment, Innovation, and Public Health (JEEP) in late 2021. The PFAS ST coordinates interagency PFAS research and development activities and supports the development and implementation of the PFAS strategic research plan. The PFAS ST is co-chaired by OSTP, Department of Energy (DOE), and Department of Defense (DOD).

About this Document

The NDAA for FY 2021 directs the PFAS ST to identify all currently federally funded PFAS research and development; to identify scientific and technological challenges that must be addressed to understand and to significantly reduce the environmental and human health impacts of PFAS; to identify cost-effective (1) alternatives to PFAS that are designed to be safer and more environmentally friendly, (2) methods for removal of PFAS from the environment, and (3) methods to safely destroy or degrade PFAS; and to establish goals and priorities for federally funded PFAS research and development that take into

[1] William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, (P.L. 116-283) (hereafter "NDAA for FY 2021") Section 332.

account the current state of research and development. The PFAS ST solicited input from member agencies about ongoing and prospective research and development efforts for PFAS, based on the scientific and technological challenges.

The PFAS Federal Research and Development Strategic Plan provides a federal strategy and implementation plan for addressing the strategic areas identified in the 2023 PFAS Report.[2] This strategic plan is intended to be a companion document to the 2023 PFAS Report; the first report provided the background on PFAS and context for the development of this strategic plan. The activities described in this document are reviewed through the Office of Management and Budget (OMB) annual budget process and subject to available resources.

Copyright Information

[2] NSTC PFAS Strategy Team, "Per- and Polyfluoroalkyl Substances (PFAS) Report." March 2023, https://www.whitehouse.gov/ostp/news-updates/2023/03/14/nstc_pfas_report

[3] See 17 U.S.C. §105

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Abbreviations and Acronyms

ADME	Absorption, distribution, metabolism, and excretion
AEE	FAA Office of Environment and Energy
AFFF	Aqueous Film-Forming Foams
AI	Artificial Intelligence
ARP	Office of the Associate Administrator for Airports
ARS	Agricultural Research Service
ATSDR	Agency for Toxic Substances and Disease Registry
BHSO	DOE Brookhaven Site Office
CEQ	Council on Environmental Quality
CDC	Centers for Disease Control and Prevention
CDOC	Chief Data Officer Council
CPSC	Consumer Product Safety Commission
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EHSS	DOE Office of Environment, Health, Safety and Security
EM	DOE Office of Environmental Management
EOP	Executive Office of the President
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FSIS	Food Safety and Inspection Service
GAC	Granulated Activated Carbon
HHS	Department of Health and Human Services
IWG	Interagency Working Group
JEEP	Joint Subcommittee on Environment, Innovation, and Public Health
ML	Machine Learning
NAM	New Approach Methodologies
NASA	National Aeronautics and Space Administration
NCEH	National Center for Environmental Health
NDAA	National Defense Authorization Act
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards & Technology
NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTA	Non-Targeted Analysis
OCE	USDA Office of the Chief Economist
OMB	Office of Management and Budget
OSEC	USDA Office of the Executive Secretary
OSTP	Office of Science and Technology Policy
PFAS	Per- and polyfluoroalkyl substances
QSAR	Quantitative Structure-Activity Relationship Model
R&D	Research and Development
SBA	Small Business Administration
SC	DOE Office of Science
ST	Strategy Team
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Department of Veterans Affairs

Executive Summary

President Biden has been clear that every community has the right to clean and safe water and products—free of harmful pollutants. The federal government is committed to delivering clean drinking water, clean air, safe consumer products, and safe food to everyone in America, and particularly to people in communities with environmental justice concerns. This includes reducing the harmful effects of exposure to per- and polyfluoroalkyl substances (PFAS) including certain types of cancer, decreased immune response, decreased birthweight, and increased cholesterol levels. Over the past several years, the Biden-Harris Administration has taken substantial action to accelerate efforts to prevent releases and expand cleanup of PFAS.[4] In March 2023, the PFAS Strategy Team (PFAS ST) produced a state-of-the-science report that includes gaps and opportunities used for the development of this strategic plan.[5] In addition, the 2023 PFAS report identified strategic areas of opportunity for future research including sources and pathways of exposure to PFAS; toxicity of PFAS; removal, destruction, and degradation of PFAS; and safer and environmentally friendlier alternatives to PFAS.[6]

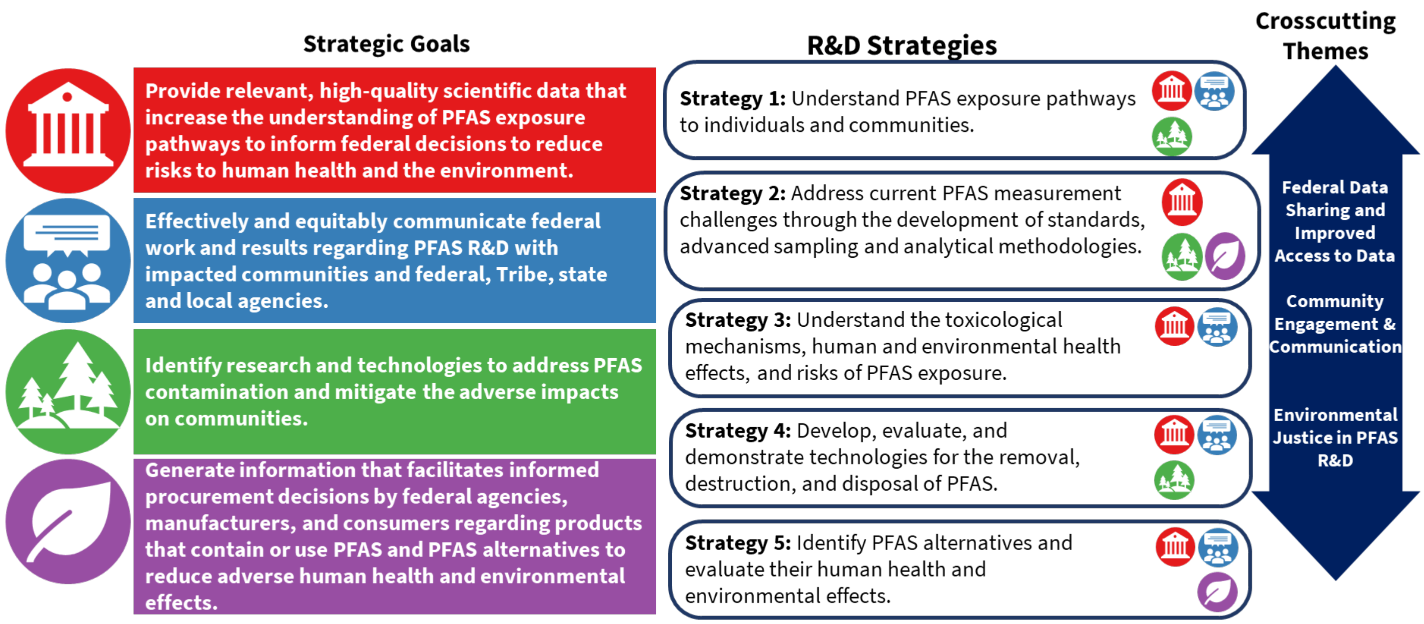

Figure 1. Visual diagram of the strategic goals, R&D strategies and crosscutting themes of the strategic plan.

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[4] White House Council on Environmental Quality, "Biden-Harris Administration Progress on Per- and Polyfluoroalkyl Substances: Steps Taken and Ongoing Actions." March 2023, https://www.whitehouse.gov/wp-content/uploads/2023/03/CEQ-PFAS-Report-March-2023.pdf

[5] NSTC PFAS Strategy Team, "Per- and Polyfluoroalkyl Substances (PFAS) Report." March 2023, https://www.whitehouse.gov/ostp/news-updates/2023/03/14/nstc_pfas_report (hereafter referred to as the "2023 PFAS Report")

[6] In this strategic plan, the PFAS ST identified five R&D strategies that address the four strategic priority areas found in the 2023 PFAS report.

Based on the four strategic areas presented in the 2023 PFAS Report, the PFAS ST identified four strategic goals that will drive federal research and development (R&D) efforts regarding PFAS:

1. Provide relevant, high-quality scientific data that increase the understanding of PFAS exposure pathways to inform federal decisions that reduce risks to human health and the environment;
2. Effectively and equitably communicate federal work and results regarding PFAS R&D through engagement with impacted communities and federal, Tribal, state and local agencies;
3. Identify research and technologies to address PFAS contamination and mitigate the adverse impacts on communities; and
4. Generate information that facilitates informed procurement decisions by federal agencies, manufacturers, and consumers regarding products that contain or use PFAS and PFAS alternatives to reduce adverse human health and environmental effects.

Within the strategic research areas, the PFAS ST has identified five R&D strategies that address the identified knowledge gaps. The five R&D strategies are:

1. Understand PFAS exposure pathways to individuals and communities;
2. Address current PFAS measurement challenges through the development of standards, advanced sampling and analytical methodologies;
3. Understand the toxicological mechanisms, human and environmental health effects, and risks of PFAS exposure;
4. Develop, evaluate, and demonstrate technologies for the removal, destruction, and disposal of PFAS; and
5. Identify PFAS alternatives and evaluate their human health and environmental effects.

   In addition to the four strategic goals, there are specific themes that cut across most or all of the R&D strategies, including federal data sharing and improved access to data, community engagement and communication, and environmental justice in PFAS R&D. These crosscutting themes should be considered in all R&D activities.

This report presents the goals, objectives, and tasks for PFAS R&D for the next five years that, through interagency coordination, would further the federal government's actions to protect Americans from the harmful effects of PFAS.

I. Introduction

Background

PFAS are a group of chemicals that have unique characteristics due to their chemical structure that contributes to their persistent, bioaccumulative, and/or toxic properties. Certain PFAS may pose significant risks to human and environmental health. Through the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (Public Law 116-283), Congress instructed the Office of

Science and Technology Policy (OSTP) Director to coordinate interagency research and development regarding PFAS.

In March 2023, the PFAS ST, formed under the National Science and Technology Council (NSTC), released a report on the federal landscape regarding PFAS R&D.[7] The 2023 PFAS Report provided a review of the state of the science related to PFAS research and development. The report identified four strategic areas for PFAS research: sources and pathways of exposure to PFAS; toxicity of PFAS; removal, destruction, and degradation of PFAS; and safer and environmentally friendlier alternatives to PFAS.

Driven by these areas of opportunity, the PFAS ST has developed this strategic plan, which identifies priority goals that align with the R&D objectives for the federal government to address PFAS knowledge gaps.

Scope of the PFAS R&D Strategic Plan

The focus of this strategic plan is on R&D objectives and implementation tasks that fulfill the strategic areas identified by the 2023 PFAS Report. The aim of these activities is to provide the best-available science for evidence-based policymaking. The strategic plan incorporates both near-term and long-term objectives, which can be achieved through intramural and extramural research. As the NDAA for FY 2021 instructs the PFAS ST to revisit this strategic plan every three years, the R&D strategies are intended to be broad and flexible to incorporate future innovation in PFAS research and emerging knowledge on PFAS.

The objectives and their respective tasks aim to inform federal and non-federal researchers about opportunities for future research. Tasks are written to provide flexibility for agencies and their programs to use their unique expertise and capabilities to address identified R&D needs. Some of the identified objectives and tasks align with ongoing R&D programs within federal agencies, but others will require new R&D program development.

There is a wide range of chemical structures that could exist under the definition of PFAS, including precursor compounds that transform into different PFAS. In addition, there are opportunities for federal agencies to prioritize PFAS individually or by defined categories according to chemical structure, physical-chemical properties, toxic effects, occurrence, use, or other characteristics. In addition, some PFAS have relatively more data available than others with regards to their physical, chemical, and toxicological properties, and therefore understudied PFAS may be more relevant for specific objectives and tasks. As individual federal agencies have different scopes and priorities, they will need to identify their own priority PFAS of concern or categories of PFAS relevant to specific agency activities. The scope of this strategic plan is to provide research that supports the development of individual agency PFAS priorities and enable interagency alignment of these priorities.

Crosscutting Themes for Interagency PFAS R&D

In addition to the four strategic goals, there are specific themes that cut across most or all of the R&D strategies. These crosscutting themes should be considered in all relevant R&D activities.

[7] 2023 PFAS Report

Federal Data Sharing and Improved Access to Data

A key component of interagency coordination on PFAS R&D activities is the sustained sharing of data among federal agencies and with the research community; the general public; and state, local, Tribal, and territorial governments. Types of shared data for PFAS could include, but are not limited to, physical and chemical properties; computational models for PFAS mixtures (exposure and toxicity); analytical method parameters and performance; environmental and human health monitoring results; toxicological testing results; epidemiological investigation data; risk assessment data; removal, treatment, and destruction technology parameters and performance; and exposure mitigation technology parameters and performance. In addition, artificial intelligence (AI) and machine learning (ML) models that develop *in silico* approaches to PFAS characterization and risk assessment can be used to improve efforts in PFAS R&D.

Interagency data sharing increases efficiency and reduces duplication of efforts by individual federal agencies. Through interagency data and information sharing, federal agencies can prevent inadvertent repetition of research studies and data, and provide pathways for new research that builds from previous studies and result in the most efficient utilization of federally sponsored PFAS research funding. To encourage the efficient exchange of data among federal agencies, the barriers to meaningful communication need to be lowered. Recommendations to lower these barriers for interagency data sharing have been presented by the Chief Data Officer Council (CDOC) Data Sharing Working Group, and include developing expedited agreement processes for interagency data sharing; improving awareness of available federal data; and improving federal data trustworthiness.[8] Incorporation of the recommendations by individual federal agencies and cooperation with guidance bodies, such as the CDOC, will enhance efforts to exchange relevant PFAS data among federal agencies.

In addition, high-quality data produced by federal agencies are valuable for the broader research community. Creating open-source databases and other data sources that provide PFAS data in accordance with Findable, Accessible, Interoperable and Reusable (FAIR) Principles,[9] while ensuring privacy and confidentiality requirements related to data use are in accordance with federal law, will allow non-federal researchers to access and utilize the unique data, creating the opportunity to elevate ongoing and future research programs. A more automated, curated, transparent, and accountable federal data-sharing framework ensure scientific data can made available to inform decisions to reduce and/or prevent PFAS contamination and minimize risks to human health and the environment.

Community Engagement and Communication

Often PFAS studies, such as environmental monitoring and human biomonitoring studies, have results that are relevant to communities. Federal agencies should create timely opportunities to meaningfully engage impacted communities in the identification of research needs and study designs, addressing any possible barriers to such participation. In addition, agencies can provide context (including scientific uncertainties) and continued support after the results are shared, and collaboratively identify corrective actions (if needed). It is vital that information be shared in accessible language.

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[8] Chief Data Officer Council, Data Sharing Working Group. "Data Sharing Working Group Findings & Recommendations." https://resources.data.gov/assets/documents/2021_DSWG_Recommendations_and_Findings_508.pdf

[9] GO FAIR Initiative, "FAIR Principles." https://www.go-fair.org/fair-principles/

Agencies should collaboratively develop communication approaches and tools for engaging impacted communities for input on their concerns in the identification of research needs and for the dissemination of R&D results and findings concerning PFAS exposure and the associated risks and health effects. This includes dissemination of high-quality information on potential sources of PFAS exposure; clinical guidance concerning PFAS exposure, risk-based recommended limits for exposures to different media, health effects, and the health care needs of those exposed; development, maintenance, and use of PFAS methodologies and databases for the purpose of determining shared ontologies and data integration; and the risks and benefits of the use of PFAS alternatives. Finally, communication strategies should incorporate multiple modes of communication (e.g., email updates, public meetings, fact sheets, science briefs, and social media) and address the communication needs of the impacted communities.

Environmental Justice in PFAS R&D

PFAS exposure through environmental contamination can disproportionately affect sensitive, or highly exposed, populations and lifestages. Addressing PFAS exposure to vulnerable populations and communities with environmental justice concerns is essential for advancing environmental justice. Within the scope of the PFAS R&D strategy, it is important that federal agencies understand the impact of their research on communities, so federal agencies can use this information to accelerate ways to prevent, mitigate, and address the impacts of PFAS in these communities and advance environmental justice. These efforts should include specific funding opportunities focused on environmental justice considerations regarding PFAS. In addition, these efforts should provide meaningful engagement for communities with environmental justice concerns and Tribal nations to align data collection and research strategies that support the needs of these communities. Finally, federal efforts should advance the priorities articulated in the Environmental Justice Science, Data, and Research Plan.[10]

For PFAS monitoring and biomonitoring studies, mindful use of environmental justice tools, such as EJScreen,[11] the Climate and Economic Justice Screening Tool,[12] and the Agency for Toxic Substances and Disease Registry (ATSDR) Environmental Justice Index,[13] can be used to provide socioeconomic and environmental information to understand the affected community, and how the study results may or may not represent other populations or communities.

II. Research and Development Strategy

Strategy 1: Understand PFAS exposure pathways to individuals and communities

PFAS are ubiquitous in outdoor and indoor environments due to their extensive uses, persistence in the environment, and limited prior control of PFAS releases due to a lack of data and technology. To

[10] NSTC Environmental Justice Subcommittee, "Environmental Justice Science, Data, and Research Plan." July 2024, https://www.whitehouse.gov/wp-content/uploads/2024/07/NSTC-EJ-Research-Plan-July-2024.pdf

[11] Environmental Protection Agency, "EJScreen: Environmental Justice Screening and Mapping Tool." https://www.epa.gov/ejscreen

[12] Council on Environmental Quality, "Climate and Economic Justice Screening Tool." https://screeningtool.geoplatform.gov/

[13] Agency for Toxic Substances and Disease Registry, "Environmental Justice Index." https://www.atsdr.cdc.gov/placeandhealth/eji/index.html

understand the prevalence of PFAS in our environment and how humans and biota can be exposed to PFAS, researchers need a more complete characterization of the presence, identity, and concentration of individual PFAS in the environment, including background (e.g., atmospheric deposition) levels. Studies are necessary for supporting a data-driven understanding of risks posed by PFAS exposure. In addition, the fate and behavior of PFAS in the environment is critical to fully characterizing a PFAS release. Developing models that accurately predict the fate and behavior of PFAS where there are limited model training data is important. Finally, studies will inform the occurrence and concentrations of PFAS in humans, biota, and the environment. With this more complete picture of pathways of exposure, there will be a better understanding of the extent of PFAS exposures and the locations of potentially highly exposed populations; this understanding can inform clean-up activities and identify specific technology needs for PFAS removal, destruction, and disposal.

Objective 1.1: Further evaluate occurrence, identity, and concentrations of PFAS in various environmental media to understand the extent of potential exposure routes and inform quantitative exposure assessments for risk assessment.

Previous studies have contributed to the understanding of the extent of PFAS contamination in the environment.[14] However, expansion of studies to conventionally understudied exposure sources and pathways, as well as the analysis of ongoing national drinking water studies, are necessary to understand where PFAS exposure occurs. Additionally, many individual studies of PFAS occurrence and distribution associated with local or regional sources have been conducted. However studies providing a better understanding of the distribution of PFAS in environmental media (atmospheric media, drinking water, surface and groundwater, sediment, soil, and marine media) for the United States in its entirety are needed and are now beginning to be determined. To understand the extent of PFAS contamination and human exposure, it is important that researchers develop and improve analytical methods to detect additional PFAS of concern, which is the scope of Strategy 2. Mixtures of PFAS in the environment occur from single-event releases (e.g., aqueous film-forming foam (AFFF) release during firefighting events), continued point-source discharges, and additional sources of PFAS, which have the potential for human and environmental exposure. Finally, occurrence and exposure efforts should consider potential disproportionate impact on specific populations and special exposure scenarios for potentially susceptible lifestages, such as fetal or early childhood development.

Task 1.1.1: Enhance environmental ambient sampling and analysis efforts for PFAS, including atmospheric emissions and deposition and transport, drinking water, groundwater, and both freshwater and marine surface waters and their associated sediments. This should include a long-term, national-scale environmental ambient PFAS monitoring study to include PFAS levels in soil, air, atmospheric wet/dry deposition, surface waters, and groundwater.

Task 1.1.2: Further characterize potential PFAS exposures in the built environment, including schools, workplaces, and other indoor/household environments. This would include the co-occurrence and use of consumer products and understanding the lifecycle of products with regard to PFAS exposure.

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[14] Evich MG, Davis MJB, McCord JP, Acrey B, Awkerman JA, Knappe DRU, Lindstrom AB, Speth TF, Tebes-Stevens C, Strynar MJ, Wang Z, Weber EJ, Henderson WM, Washington JW. Per- and polyfluoroalkyl substances in the environment. Science. 2022 Feb 4;375(6580). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8902460/

Task 1.1.3: Develop and support additional food product sampling and analysis for PFAS, including foods grown or raised in areas with water contamination; animal/livestock feed ingredients; general population dietary items; fish, wildlife, and plants related to subsistence and cultural practices of Tribal populations and other communities, developing fetuses, infants, or children; and food packaging and processing. Develop reference materials in food to support agricultural research.

Task 1.1.4: Support and expand food and animal/livestock feed production sampling and analysis for PFAS to include rural and urban soils, aquaculture systems, areas using reclaimed/reuse water, areas using contaminated groundwater, domestic sludge, and biosolids- and compost-impacted soils.

Task 1.1.5: Initiate studies regarding PFAS co-exposure and potential interactions with other contaminants (including other PFAS) in environmental samples, such as nano- and microplastics, petroleum constituents, metals, pesticides, and pharmaceuticals.

Task 1.1.6: Characterize exposures from previously unstudied or understudied sources of PFAS and their contribution to overall PFAS exposures for a comprehensive understanding of the breadth of PFAS exposures across the United States. This could include studies to understand the behavioral drivers of PFAS exposure.

Task 1.1.7: Develop and strengthen federal partnerships with state, local, and Tribal communities, territories, and private industries, for long-term understanding of PFAS exposures, including PFAS-impacted environments in communities with environmental justice concerns.

Task 1.1.8: Advance analytical and computational techniques for source attribution of PFAS contamination, including forensic methods and source contamination databases and modeling tools.

Objective 1.2: Characterize the bioaccumulation, biotic and abiotic transformation, and food web behavior of individual and mixtures of PFAS.

Given their unique physical and chemical properties,[15] certain PFAS are known to bioaccumulate and persist in humans and the environment. Some PFAS can be mobile in the environment and have been detected around the world, including in remote regions. The fate and behavior of PFAS, individually and as mixtures, in the environment can influence the assessment of health risks posed by acute and chronic exposures. The potential hazards of PFAS biomagnification in the food web remain a subject of great interest given the widespread detection of PFAS in environmental systems. Laboratory- and field-based research in the bioaccumulation and persistence of PFAS is needed to understand the potential fate, transportation, and distribution of PFAS in the environment and contribute to the cumulative assessment of health risks, including the uptake of PFAS by agricultural commodities. Research to better characterize the fate, transportation, and distribution of PFAS in the environment and in humans is necessary. Data regarding the empirical and *in silico* determination of the properties of PFAS can be

[15] : E. Kissa, Fluorinated Surfactants and Repellents, Marcel Dekker AG, 2001.

helpful for identifying potential chemically similar substitutes for read-across of toxicological data when there are gaps for targeted PFAS.

Task 1.2.1: Initiate and continue studies of the physical-chemical properties of PFAS and mixtures of PFAS. Such studies are needed to support the identification of fate and transport parameters, degradation rates, media absorption and adsorption, abiotic and biotic transformation and degradation, agricultural uptake, and other parameters useful for predicting movement of PFAS through the environment.

Task 1.2.2: Expand ongoing research to understand bioavailability, bioaccumulation, and biomagnification of PFAS and mixtures of PFAS in aquatic (estuarine, fresh, and marine), terrestrial, and avian species, and their movement within agricultural lands and the food and feed webs.

Task 1.2.3: Develop and support AI/ML techniques, and other computational modeling efforts to identify or address knowledge gaps with regards to PFAS degradation rates, media absorption and adsorption, abiotic and biotic transformation and degradation, and other parameters, including the properties and behaviors of mixtures of PFAS.

Objective 1.3: Develop and implement studies to understand PFAS exposure in humans and wildlife.

Exposure and biomonitoring studies are critical to increasing our understanding of PFAS exposure in humans and wildlife and identifying interventions to reduce exposures. Studies that identify PFAS in the environment can inform the need for, and design of, biomonitoring studies. Biomonitoring studies are important for understanding what PFAS people are exposed to and how these PFAS behave in human systems. This includes enhancing our understanding of the absorption, distribution, metabolism, and elimination (ADME) of PFAS in humans and wildlife. Less-characterized exposure scenarios, such as lactational transfer and consumer product exposure, should be explored through these studies. Studies that include both the collection of environmental exposure information and biomonitoring can best characterize the effects of the exposure on PFAS levels in the body, expanding on existing knowledge.

Task 1.3.1: Investigate additional pathways and routes of exposure, such as direct contact, dermal absorption, oral ingestion, and inhalation from indoor and outdoor environments (residential, consumer, and occupational exposures).

Task 1.3.2: Investigate pathways and routes of exposure for domestic and wild animals, including uptake, bioaccumulation, and biomagnification within domestic and wild animals and potential transfer to human exposure routes.

Task 1.3.3: Develop and support biomonitoring programs related to PFAS exposure of the general population, including studies that examine routes of PFAS exposure or transfer, such as lactational transfer.

Task 1.3.4: Develop and support biomonitoring programs that aim to identify occupational sources and types of exposures among disproportionately exposed populations, including firefighters and other workers with potentially high exposure to PFAS.

Task 1.3.5: Develop and support biomonitoring programs to study communities that may have environmental justice concerns near significant sources of PFAS contamination with a focus on susceptible populations and lifestages. These studies can enhance awareness of potential disproportional impacts and provide data relevant to advancing environmental justice.

Task 1.3.6: Develop and support studies of PFAS exposures in indoor environments through collection of dust, air, consumer products, and other media where biomonitoring may also be conducted.

Strategy 2: Address current PFAS measurement challenges through the development of standards, advanced sampling and analytical methodologies

The analysis of PFAS in the environment,[16] biological samples,[17] and consumer products[18] has driven the understanding of the fate and transport of PFAS contamination and sources of human exposure. There have been increasing numbers of PFAS that have been identified, often due to novel detection in samples or because of emerging toxicological information. This creates a moving target for PFAS analytical methods. In addition, advanced analytical techniques, like non-targeted analysis (NTA),[19] require a different approach to the identification and quantification of PFAS in environmental and biological samples. Occurrence and prevalence of novel PFAS identified through NTA coupled with expanded toxicological data can focus resources on the expansion of targeted analytical methods and availability of analytical-grade standards and certified reference materials. This approach would address the most critical needs for evaluating human and ecological exposures, modeling fate and transport, and contaminated site assessment and cleanup. To achieve this end, reference methods and materials are needed to standardize the use of NTA for PFAS identification.

In addition, there is a significant need for analytical methodologies that are capable of precise and accurate measurement of PFAS at very low levels. Novel analytical methods must be developed, or existing methods may require modifications, to accommodate additional analytes as the list of targeted PFAS expands, technology advances, and insight into toxicological effects of PFAS emerges. Current sampling and analytical techniques should be routinely re-evaluated to ensure they continue to support their intended use.

[16] Evich MG, Davis MJB, McCord JP, Acrey B, Awkerman JA, Knappe DRU, Lindstrom AB, Speth TF, Tebes-Stevens C, Strynar MJ, Wang Z, Weber EJ, Henderson WM, Washington JW. Per- and polyfluoroalkyl substances in the environment. Science. 2022 Feb 4;375(6580). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8902460/

[17] U.S. Centers for Disease Control and Prevention, "Biomonitoring Data Tables for Environmental Chemicals." https://www.cdc.gov/exposurereport/data_tables.html

[18] DeLuca NM, Angrish M, Wilkins A, Thayer K, Cohen Hubal EA. Human exposure pathways to poly- and perfluoroalkyl substances (PFAS) from indoor media: A systematic review protocol. Environ Int. 2021 Jan;146:106308. https://pubmed.ncbi.nlm.nih.gov/33395950/

[19] NTA is an analytical chemistry technique with the objective to identify unknown chemicals in samples without existing analytical standards.

Objective 2.1: Further improve targeted and non-targeted analytical methods for identifying, detecting, and quantifying PFAS in a variety of sample types.

Existing targeted analytical methods can identify and quantitate a limited number of PFAS in environmental media and other media. Targeted methods are currently limited by the number of available analytical reference standards for PFAS. With thousands of possible PFAS in the environment, analytical reference standards need to be quickly developed and measurement methods adjusted, or new methods created, to effectively prioritize further characterization of PFAS in the environment and in humans. Continued improvement of routine, targeted methodologies are needed to reduce detection levels, and to refine parameters of complex PFAS samples. Reference methods and standards are needed for NTA of PFAS.

Task 2.1.1: Develop and validate targeted methods for PFAS analysis, and refine methods to expand targeted PFAS analyte lists and reduce detection limits to better evaluate and manage risk through monitoring of PFAS in environmental and other media.

Task 2.1.2: Streamline workflows and build capacity (training, instrumentation, software) to support method development and implementation of NTA for PFAS in environmental and other media.

Task 2.1.3: Develop analytical methods to fill knowledge gaps on the occurrence, distribution, fate, and transport of PFAS, including zwitterionic, cationic, neutral, ultra-short-chain PFAS, and fluoropolymers (including side-chain fluoropolymers and fully fluorinated polymers) in various environmental media. This work will include identifying sources of analytical standards for these PFAS.

Task 2.1.4: Develop and improve analytical methods for measuring PFAS in biological samples, including human tissue, plants, and domestic and wild animals.

Task 2.1.5: Support the coordination, completion, and sharing of PFAS sampling, sample handling, and processing protocols for various matrices based on real-world studies and data to promote consistent, representative, and accurate sample collection and analysis. This work can include the development of high-throughput methods that utilize automated technologies, such as online solid-phase extraction.

Task 2.1.6: Develop and support ongoing targeted and non-targeted analytical methodologies for the analysis of blood/serum samples, dried blood spots, and human milk. Continue to support the use of archived specimens and passive sampling devices to monitor historical and current human exposure.

Task 2.1.7: Develop and refine analytical methods and data collection methods to evaluate PFAS content, migration, and emissions from consumer, commercial, and industrial products, and their impact on workplace and indoor environments.

Task 2.1.8: Develop testing programs and methods related to quantifying PFAS content, migration, and emissions in animal/livestock feed, food and food packaging, indoor exposure (dust, home/office materials), workplace settings, and consumer products.

Task 2.1.9: Expand reference materials, analytical standards, and data for the measurement of PFAS in different environmental and biological materials to enhance accurate identification and quantification of PFAS by targeted and non-targeted analytical methods.

Task 2.1.10: Develop and validate targeted and non-targeted analytical methods for the measurement of transformation products of PFAS to assess degradation and destruction technologies.

Objective 2.2: Advance the science of total fluorine and PFAS summations with method-defined analyses and protocols.

Currently, approaches to quantifying all PFAS in a material are limited. In addition, a variety of PFAS have been identified or are suspected to be present in environmental samples that cannot be quantified with today's standardized PFAS analytical methods. The inability to make quantitative measurements of total PFAS content is a potentially large source of uncertainty in managing exposure risk. To bridge this gap, there is a significant need for aggregate measurements (e.g., total fluorine and total organic fluorine content) and precursor mass balance approaches (e.g., total oxidizable precursors assay), which account for known and unknown PFAS that may be present in a material. Examination of the benefits and limitations of various method-defined total fluorine and mass balance approaches is necessary to implement such measures in regulatory and environmental health decision-making. To guide science-based decision-making, it will be important to understand the benefits and limitations of various method-defined total fluorine and mass balance approaches.

Task 2.2.1: Develop and validate methods for total fluorine and PFAS mass balance approaches, including those for total oxidizable precursors, adsorbable organic fluorine, extractable organic fluorine, total organic fluorine, and total fluorine that are applicable to a variety of matrices and types of PFAS precursors.

Task 2.2.2: Expand reference materials and data for the measurement of aggregate PFAS or total organic fluorine content in different environmental and biological materials.

Objective 2.3: Foster the development of new technologies for efficiently measuring and identifying, quantifying, and modeling PFAS occurrence in the environment.

While targeted methods using existing and well-developed instrumentation exist, the ability to collect, extract, and analyze samples can be time-consuming and costly. There is a significant need for new technologies to measure total PFAS, as well as individual PFAS and their classes, efficiently and in a cost-effective manner. Reference materials and data underpin the accuracy and precision of analytical results, which are required of any new technologies developed and provide a benchmark for understanding measurement performance. Further, while predictive models can be used to understand PFAS occurrence, fate, transport, and distribution in the environment, the models must be trained by high-quality data to produce the best results.

Task 2.3.1: Develop and validate real-time, rapid, and remote PFAS screening methods using analytical sensors, PFAS proxies, passive sampling devices, and other novel technologies for the detection of PFAS in media.

Task 2.3.2: Develop and validate methods for evaluating PFAS leaching potential from various media into the environment or humans.

Task 2.3.3: Develop and validate AI/ML tools to predict occurrence and estimated movement of PFAS in media. Tools and data sets can include breakdown or degradation products of PFAS materials that generate other PFAS.

Strategy 3: Understand the toxicological mechanisms, human and environmental health effects, and risks of PFAS exposure.

The 2023 PFAS Report noted that it is impractical to assess the human and environmental hazards posed by each of the numerous PFAS that may exist in the environment using an individual, chemical-by-chemical approach. There are additional challenges to traditional experimental approaches, such as limited availability of appropriate analytical tests and standards, background levels, intrinsic physicochemical properties, and the lack of access to confidential business information. A holistic systems approach to understanding the risk of PFAS was proposed in the 2023 PFAS Report, leveraging new approach methodologies (NAMs), high-throughput technologies, and different data streams (i.e., human health studies, ecotoxicology, *in silico* models, and epidemiology studies).

Objective 3.1: Further characterize the toxicological mechanisms of action regarding PFAS exposure in humans, wildlife, and domestic animals.

While PFOA and PFOS are arguably the most thoroughly studied PFAS in the scientific literature, numerous efforts to better understand the overall toxicity of these and many other PFAS are currently underway worldwide.[20][21][22] Ongoing efforts are largely focused on the potential for PFAS to cause a variety of adverse changes in human health, but adverse effects at the ecosystem level, including health effects on animals, are also of great concern. Understanding PFAS' toxicity to humans and the environment is a challenge due to PFAS' varying structures and properties and the lack of available toxicity data. There are several efforts underway to explore class-based or grouping strategies, as they relate to understanding and categorizing PFAS toxicological mechanisms and human health effects. Real-world exposure to PFAS in humans and the environment most often occurs as a complex mixture, as opposed to one PFAS in isolation.[23] These approaches may help to address issues including the lack of data, limited resources, and the cumulative risk posed by exposure to PFAS mixtures.

Task 3.1.1: Advance the development of NAMs, including high-throughput technologies that produce quantitative data, to provide faster assessment of PFAS hazard in multiple taxa, under multiple exposure conditions, and with individual and mixtures of PFAS. This should complement traditional toxicity testing methods to characterize long-term impacts on growth,

[20] U.S. Environmental Protection Agency, "Integrated Risk Information System." https://www.epa.gov/iris

[21] Codex Alimentarius Commission, Codex Committee on Contaminants in Food, 16th Session, April 2023.https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FMeetings%252FCX-735-16%252FCRDs%252Fcf16_CRD05x.pdf

[22] European Food Safety Authority, "Risk to human health related to the presence of perfluoroalkyl substances in food." https://efsa.onlinelibrary.wiley.com/doi/abs/10.2903/j.efsa.2020.6223

[23] U.S. Centers for Disease Control and Prevention, "Biomonitoring Data Tables for Environmental Chemicals." https://www.cdc.gov/exposurereport/data_tables.html

reproduction, carcinogenicity, neurodevelopment, chronic adverse health effects, and multi-generational effects.

Task 3.1.2: Develop scientifically supported classification schemes for PFAS with respect to adverse impacts on human health and the environment.

Task 3.1.3: Develop and support research regarding the human toxicity and ecotoxicity testing of PFAS as mixtures with PFAS and other co-occurring chemicals.

Task 3.1.4: Develop and support empirical and modeling approaches to quantify human and wildlife toxicokinetics of PFAS in support of human and wildlife exposure assessment. This can include the use of PFAS monitoring data to develop physiologically-based toxicokinetic models and biologically-based dose-response models.

Task 3.1.5: Develop and apply AI/ML tools for the characterization of common toxicological mechanisms and health effects resulting from PFAS exposure, including the potential classification of PFAS by toxicological mechanism and/or health effects.

Task 3.1.6: Support research to further understand mechanism of action of PFAS toxicity, advance development of adverse outcome pathways, and understand the impact of PFAS mixture toxicities when evaluating cumulative health effects.

Objective 3.2: Understand the occurrence of adverse human health outcomes from PFAS exposure.

PFAS exposure is ubiquitous, and most people have measurable levels in their blood.[24] People with occupational exposure and communities with contaminated drinking water typically have higher blood levels of PFAS. Characterizing risks associated with such exposures can be challenging due to the wide range of potential health effects, the co-occurrence of PFAS and other chemicals, and differing exposures, and population and lifestage susceptibility (either due to higher sensitivity among individuals or lifestages to the adverse effects of PFAS exposure or from disproportionately higher levels of PFAS contamination). Nevertheless, epidemiological studies can contribute to better understanding of the effects of PFAS mixtures, understudied adverse health outcomes, exposure routes, biomarkers of exposure and/or effect, modulating factors, and health and medical interventions.

Task 3.2.1: Develop and support epidemiological studies on the effect of PFAS exposure on adverse health outcomes, including longitudinal cohort studies, nested case-control, and case-cohort studies. Rigorous study design would minimize bias and consider the role of relevant factors, such as social determinants of health, susceptible populations, vulnerable windows of exposure, and the effect of mitigation measures.

Task 3.2.2: Develop and support epidemiological studies designed to identify communities near significant sources of PFAS contamination that may have environmental justice concerns, including occupationally exposed populations and populations, communities, and/or lifestages that are more susceptible to PFAS exposure or adverse health outcomes.

[24] U.S. Centers for Disease Control and Prevention, "Biomonitoring Data Tables for Environmental Chemicals." https://www.cdc.gov/exposurereport/data_tables.html

Task 3.2.3: Explore the development of a federal data-sharing strategy to use interagency toxicological and epidemiological data to determine human health endpoints of concern from PFAS exposure.

Task 3.2.4: Develop and support studies that evaluate the efficacy and effectiveness of clinical and non-clinical interventions to reduce the risk of adverse health consequences in persons exposed to PFAS. This may include treatment of humans with high PFAS blood concentrations and interventions to reduce the severity of adverse health outcomes related to PFAS exposure.

Objective 3.3: Support hazard identification and risk assessment for PFAS exposure to humans and ecosystems.

Federal agencies should align efforts to identify health hazards and develop risk assessment approaches for PFAS for their use in human and environmental health risk assessment. These might include models of PFAS mixture use, systematic reviews, or weight of evidence evaluations. Currently, federal toxicity and risk assessments exist for select PFAS; further supporting these efforts through alignment of federal research and increased interagency data sharing could address research needs and data gaps. This can include work regarding populations and taxa that have disproportionate exposure and/or adverse health effects. Interagency communication of these models and their results will support agency risk characterization and risk management processes, which include development of risk mitigation strategies.

Task 3.3.1: Develop aligned interagency data infrastructure and data requirements for interagency sharing of data regarding toxicological models (such as NAMs), hazard identification, exposure assessment, and dose-response studies in support of risk assessments.

Task 3.3.2: Develop aligned interagency approaches to inform, and obtain feedback from, affected communities, scientists, and other stakeholders on the human and environmental risks of PFAS exposure that includes PFAS mixture assessments and systematic reviews.

Task 3.3.3: Develop classification strategies that enable grouping of PFAS by hazard identification, exposure assessment, and dose-response studies in support of risk assessments.

Strategy 4: Develop, evaluate, and demonstrate technologies for the removal, destruction, and disposal of PFAS

The safe and environmentally friendly removal, destruction, and disposal of PFAS can be challenging because of the large number of PFAS, the stability of the carbon-fluorine bond, and the goal of reducing the PFAS contamination levels to those that are protective of human and environmental health. Collaborative research and engagement among industry, governments, and the public will help reach this objective. The 2023 PFAS Report identified many technologies for the removal, destruction, and disposal of PFAS, ranging from novel to field-ready technologies. Individual agencies have provided guidance on recommended techniques for destruction and disposal.[25,26]

New research is needed to advance these technologies to field-ready technologies. In addition, removal, destruction, and disposal technology developers should consider tailored treatments for specific exposure pathways (e.g., air, water, soil, or biosolids) to find solutions for specific exposure pathways identified in the previous goals and objectives. Media-specific technologies should consider effectiveness (e.g., soil cleanup thresholds to allow for agricultural production) and be implementable (e.g., cost effective) for the targeted media. This research can include *in situ* immobilization strategies that reduce the impact of PFAS contamination. This goal aims to support the 1) continued development of novel, more efficient and effective technologies, and 2) implementation of technologies for field-scale removal, destruction, and/or disposal of PFAS-contaminated materials.

Objective 4.1: Develop and evaluate technologies for PFAS removal, destruction, and disposal.

To address the need to develop new, environmentally friendly technologies to mitigate, sequester, or remove PFAS contamination from environmental matrices, federal agencies should continue to support research in the development, characterization, and economic costs of these new technologies. Beyond the current use of granular activated carbon (GAC) and ion exchange resin adsorption to remove PFAS from water, new technologies may prove efficient for PFAS removal from water and other contaminated materials. In addition to continued research into an effective and efficient means of PFAS incineration, several other PFAS destruction technologies are being researched, including novel technologies for removal and destruction of PFAS in environmental and biological matrices. Also, the technologies for addressing PFAS-contaminated agricultural lands and commodities should be considered, as agricultural systems present a unique challenge due to the potential for widespread, low-level contamination at farms and migration of PFAS from commodities and livestock to the food system. Current PFAS treatment technologies under development include feed and water additives, composting, molecular biology-based tools, and novel chemistries for destruction in biological matrices.

Interagency coordination of novel removal, destruction, and disposal technologies, including development, scientific, and socio-economic evaluation, and other relevant data and models, would enable efficient development and alignment of agency policies.

> **Task 4.1.1:** Characterize and assess materials and membranes for novel adsorption, separation, concentration, and stabilization technologies, including biotechnology-based removal and destruction techniques.
>
> **Task 4.1.2:** Continue to support the foundational research that advances technologies for the destruction of PFAS by both thermal and non-thermal approaches.

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[25] DOD, "Interim Guidance on Destruction or Disposal of Materials Containing Per- and Polyfluoroalkyl Substances in the United States" July 11, 2023. https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/news/Memorandum_for_Interim_Guidance_on_Destruction_or_Disposal_of_Materials_Containing_PFAS_in_the_U.S.pdf

[26] USEPA, "Interim Guidance on Destroying and Disposing of Certain PFAS and PFAS-Containing Materials That Are Not Consumer Products." April 16, 2024. https://www.epa.gov/pfas/interim-guidance-destroying-and-disposing-certain-pfas-and-pfas-containing-materials-are-not

Task 4.1.3: Support research regarding the treatment of PFAS-contaminated agricultural lands and commodities that are protective of human health and the environment, cost-effective, and implementable.

Task 4.1.4: Generate high-quality data regarding PFAS properties to enable AI/ML tools to assist in the development of novel removal, destruction, and disposal technologies.

Task 4.1.5: Continue research efforts focused on demonstrating performance and destruction efficiency of thermal treatment, by characterizing emissions (including products of incomplete combustion), residual waste streams, and optimal operating conditions (e.g., temperatures and residence times) needed for full mineralization of PFAS.

Task 4.1.6: Develop and assess removal technologies using renewable or waste materials, such as biological and agricultural waste materials.

Objective 4.2: Support the implementation of technologies for PFAS removal, destruction, and disposal.

To support technology implementation, decision-makers need data on performance, cost, and optimization parameters, especially when multiple technologies are combined in a treatment train. Ideally, the data would be generated through field-scale demonstration projects or during full-scale implementation under a range of operating conditions, including (but not limited to) a wide range of PFAS, a range of water qualities and flow rates, and a range of PFAS-containing materials (e.g., AFFF, PFAS-contaminated biosolids). Performance data should include data on all process output, including solids, air emissions, and water discharges. Further, technologies that show significant promise would benefit from validation at full-scale implementation and an analysis of the economic cost of implementation.

Task 4.2.1: Coordinate individual agency efforts and partnerships with non-federal facilities (e.g., drinking water treatment facilities, waste management facilities) to determine optimal combination of field-scale technologies for PFAS removal, destruction, and disposal.

Task 4.2.2: Engage with potential users to understand and lower the barrier to field-scale implementation of PFAS removal, destruction, and disposal technologies.

Task 4.2.3: Support the implementation of removal and destruction technologies that apply to discharge and releases at the point of manufacturing.

Task 4.2.4: Develop and implement models to evaluate technology performance, short-term and long-term costs, energy demands, scalability, and the composition of treated materials that are released to the environment.

Task 4.2.5: Further develop and optimize sorbent reactivation technologies to increase sorbent capacity to remove PFAS and prevent PFAS emissions from the reactivation process.

Task 4.2.6: Develop, model, and test the effectiveness and economic cost of removal, destruction, and disposal technologies at differing scales, such as low volumes of high concentrations (e.g., landfill leachate) and high volumes of low concentration (e.g., widespread irrigation water or soil contamination in agricultural systems).

Strategy 5: Identify PFAS alternatives and evaluate their human health and environmental effects.

PFAS alternatives largely fall into two categories: functional alternatives, which involve technical or engineering solutions to reduce the need for PFAS-containing materials, and chemical alternatives, which involve the replacement of PFAS with alternatives with lower toxicity and lesser persistence that impart a similar function in the manufacturing process or finished product. To identify potential alternatives, the federal government should better understand the uses of PFAS in products and in the supply chain, the criticality of the uses, and physical and chemical properties required for those uses. Generally, prioritization for replacement of PFAS-containing materials and products can be determined by individual federal agencies and/or through interagency coordination, based on their own assessment of the critical and essential uses of these materials.

The development and/or identification of cost-effective and more sustainable alternatives that are functionally or chemically equivalent to those made with PFAS depends on the type of product, its application, and associated human and ecological hazard in comparison to the PFAS being replaced.[27] R&D efforts to identify and reduce the use of PFAS have been conducted by a variety of government, industry, and academic institutions using literature, database, and quantitative structure-activity relationship models (QSARs); toxicological evaluations of PFAS alternatives; and transition to new products that have reduced adverse effects on human health and the environment. As new functional and chemical alternatives are developed, it will be essential that the below objectives be revisited and revised regularly to incorporate advances in technology. In addition, there are research opportunities to understand and innovate in the area of recycling and the circular economy of PFAS-containing materials, which is discussed by the NSTC Sustainable Chemistry Strategy Team's landscape report.[28]

Objective 5.1: Review current resources and products for PFAS alternatives.

As part of the effort to identify and evaluate sustainable PFAS alternatives, it will be important to apply sustainable chemistry principles and incorporate an essential use concept as a rapid pathway toward effective management and/or phase out of hazardous PFAS-containing products; this can include the continued use of PFAS-containing products that must continue to be used, particularly when the costs and risks of product replacement to national security are substantial.[29] Thorough reviews of publicly available literature and databases and toxicity/hazard databases can be used to inform federal program activities directed at the development of PFAS alternatives, as well as an understanding of the performance and human health and environmental risk trade-offs of PFAS alternatives. However, not all uses of PFAS are known or reported in publicly accessible formats. Therefore, additional research is needed to identify which products contain or are made using PFAS. Federal agencies should work with academic and industrial researchers to identify and scale-up novel alternative processes and chemicals. There have been regulatory and policy actions where federal agencies are encouraged to

[27] For the definition of sustainable, see the NSTC report on sustainable chemistry: Office of Science and Technology Policy National Science and Technology Council Sustainable Chemistry Strategy Team, "Sustainable Chemistry Report: Framing the Federal Landscape." August 2023, https://www.whitehouse.gov/ostp/news-updates/2023/08/02/nstc-sustainable-chemistry-report/ (hereafter the "NSTC SC Report")

[28] NSTC SC Report

[29] NSTC SC Report

transition to products that do not contain PFAS and suppliers that do not use PFAS.[30-31] The identification and transition to suppliers of PFAS alternatives should be expedited to mitigate potential supply chain riskswithout impact to critical infrastructure, national security, and public health.

Task 5.1.1: Engage with academic and private sector industrial researchers to support the development of novel, less toxic alternative chemistries and processes for sustainable PFAS alternatives.

Task 5.1.2: Identify and evaluate critical and essential uses of PFAS within individual agencies and sectors.

Task 5.1.3: Develop an interagency-aligned evaluation framework for prioritizing research on specific PFAS alternatives that includes considerations regarding sustainability, performance; viability and timeframe to transition; dependency on foreign sources of materials; criticality of the current product to national security, critical infrastructure, climate change mitigation and public health; and criticality of the need for a replacement product or process.

Task 5.1.4: Perform reviews of the research on current PFAS alternatives in all commercial and governmental (e.g., defense) sectors, including the performance differences between products.

Task 5.1.5: Support research that lowers the barrier for federal agencies to transition to sustainable PFAS alternatives.

Task 5.1.6: Support research to advance sustainable manufacturing and circularity of PFAS-based processes and products to preserve current critical and essential uses, which will enable an orderly transition to PFAS alternatives in critical manufacturing sectors that are dependent on PFAS.

Objective 5.2: Perform chemical characterization, product evaluation, and risk assessment of alternatives to current PFAS-containing products and processes.

An ideal PFAS alternative product or process would have less human health or environmental risks than current PFAS-containing products and processes. In order to prevent the possibility of a regrettable substitution of PFAS, there should be a thorough assessment of alternatives utilizing all available data regarding physical-chemical properties, material performance characteristics, predicted biological activity, and use and production estimates to provide insight on the viability and safety of PFAS alternatives.[32] A holistic approach should be implemented in understanding the properties and risk of PFAS alternatives, as a PFAS alternative may have lower environmentally hazardous properties (e.g., less persistent), but be more hazardous to human health (e.g., greater acute toxicity and more flammable). In addition, PFAS alternatives characterization should include a focus on the most likely exposure routes of both PFAS and the evaluated alternatives, as their properties may result in different

[30] United States Department of Defense, "Department of Defense Announces Prohibition in DFARS on Certain PFOS and PFOA Procurement." September 28, 2022, https://www.defense.gov/News/Releases/Release/Article/3172591/department-of-defense-announces-prohibition-in-dfars-on-certain-pfos-and-pfoa-p/

[31] Office of Management and Budget, "Memorandum for the heads of Executive Departments and Agencies: Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability." December 8, 2021, https://www.whitehouse.gov/wp-content/uploads/2021/12/M-22-06.pdf

[32] The substitution of a chemical or material with another chemical or material that is more harmful to human and/or environmental health.

exposure routes, for example: a more volatile PFAS alternative may be an inhalation hazard while the less volatile PFAS product is an ingestion hazard.

Task 5.2.1: Develop a database of the current commercial inventory of alternative materials and products with relevant chemical and toxicological information, manufacturer production capacity, and performance comparison of the alternatives to PFAS-containing materials and products.

Task 5.2.2: Continue to assess human health and environmental effects posed by alternative materials and products for use in comparison to other product formulations, including PFAS-containing product formulations.

III. Conclusions

Successful implementation of this strategic plan will help strengthen and advance the state of the science to successfully address regulatory, scientific, and mitigation gaps and disproportionate exposure, contamination, and toxicity regarding PFAS. While outside of the scope of this report, the PFAS ST recognizes there are additional research needs that should be further explored through intramural and extramural research, including the socio-economic effect of PFAS contamination and remediation on specific populations, such as communities with environmental justice concerns firefighters, and farmers, and medical interventions to prevent or reduce the severity of adverse health outcomes related to PFAS exposure. The NDAA requires this strategic plan to be updated every three years; therefore, these areas could be considered in future updates of this plan.

The PFAS ST will support interagency coordination during the implementation of this strategic plan, continue to engage with external stakeholders—including state, local, Tribal, and territorial communities, academia, and industry—to identify PFAS R&D needs and solutions, and will assess and revise this strategic plan as technology and information changes.