HIGHLIGHTS OF CURRENT ACTIVITY AT THE UNIVERSITY OF MAINE THAT SUPPORTS THE 8 STRATEGIES OF THE STATE OF MAINE CLIMATE ACTION PLAN MAINE WON'T WAIT

The University of Maine and University of Maine at Machias represent a wide array of internationally recognized expertise that is a critical resource for the State of Maine as it moves to the implementation phase of the MAINE WON'T WAIT integrated climate action plan. Here, we provide examples of that expertise across basic and applied research, undergraduate and graduate training, and outreach that propels Maine forward to solutions and provides a framework for building a successful future for Maine people. This is not intended to be a comprehensive listing of activities or people, as hundreds of faculty as well as staff and students are engaged in climate response relevant work across our institutions. These are highlights of relevant ongoing work that underscores the University's importance to MAINE WON'T WAIT. Each section below begins with the Strategy (A through H) and their sub-strategies from the MAINE WON'T WAIT plan.

A. Embrace the Future of Transportation in Maine

1. **Accelerate Maine's Transition to Electric Vehicles**
    - By 2022, develop a statewide EV Roadmap to identify necessary policies, programs, and regulatory changes needed to meet the state's EV and transportation emissions-reduction goals.
2. **Increase Fuel Efficiency and Alternative Fuels**
    - Increase by 2024 local biofuel and biodiesel production and use in Maine transportation sectors, especially in heavy-duty vehicles (assuming Maine biofuels production becomes viable).
3. **Reduce Vehicle Miles Traveled**

Ongoing University of Maine research is poised to help the state embrace the future of transportation.

- The Maine Climate Action Plan (MAINE WON'T WAIT) has set a goal to accelerate Maine's transition to electric vehicles, including the development of a statewide EV Roadmap by 2022. UMaine has experience coordinating and collaborating the development of similar roadmaps for other sectors (forestry, marine, offshore wind) and extensive research expertise that could support the drafting and implementation of such a plan, as well as other policy initiatives around the future of transportation.

- Jonathan Rubin, Director of the Margaret Chase Smith Policy Center and Professor of Economics, specializes in the economics of energy, light-duty transportation, greenhouse gas emissions and alternative fuels and has well-developed contacts and regional knowledge from ongoing work with the Maine Department of Transportation.
    - Examples of current work with Maine DOT that directly relate to Climate Action Plan goals include analysis of state vehicle registration data and assessments of programs designed to incentivize consumers to purchase eco-friendly vehicles, as well as support for updates to DOT transit plans. UMaine researchers are examining models for rural transit from peer states similar to Maine with a goal to help the state move toward an accessible, efficient, cost-effective and well-coordinated transit system. Part of this transit planning effort is to recommend strategies that will assist Maine DOT to move toward a cleaner vehicle fleet.

- The Climate Action Plan also seeks to increase fuel efficiency and alternative fuels, including increasing local biofuel and biodiesel production. The University of Maine is recognized as a leader in biofuel development and the Forest Bioproducts Research Institute (FBRI), led by Director Hemant Pendse, brings strong momentum to realizing this goal. The Institute aims to demonstrate that forest-based products can be manufactured at a commercial scale to replace fossil-fuel derived counterparts and inspire the creation of a biorefinery in Maine.

- With pending equipment upgrades, FBRI's Technology Research Center is poised to simulate the commercial-scale production of biomass-derived jet fuel and diesel, essential for aviation and heavy equipment like trucks and forestry equipment, among other products.

Leading by example at UMaine

- The University of Maine could serve as a high-visibility model for fleet efficiency. Efforts are underway to explore electric vehicle replacement options for the university's fleet, and there are opportunities to work with the state to demonstrate EV successes and educate Maine businesses on transition costs and logistics. Already, there are more than 20 EV charging stations on the UMaine campus (most reserved for resident, faculty and staff use). A recent Efficiency Maine grant will help fund the installation of four more public, pay-to-charge level 2 charging stations on campus, bringing the total number of publicly available EV chargers to five and total on-campus chargers to 25. By expanding publicly available EV charging stations, we hope to encourage campus visitors to arrive in electric vehicles and grow community success in the unfolding transformation of transportation .

- UMaine supports alternative transportation options that reduce vehicle miles traveled, including the Black Bear Orono Express, a free shuttle service that provides transportation within UMaine and the town of Orono. To encourage the use of public transportation among members of the UMaine community, the Community Connector bus system (serving the Greater Bangor Urbanized Area) is free to anyone with a MaineCard.

B. Modernize Maine's Buildings: Energy-Efficient, Smart and Cost Effective Homes and Businesses

1. **Transition to Cleaner Heating and Cooling Systems, Efficient Appliances**
2. **Accelerate Efficiency Improvements to Existing Buildings**
3. **Advance the Design and Construction of New Buildings**
    - Enhance existing training on building codes and expand these programs to support ongoing education of contractors and code-enforcement officials.
4. **Advance the Design and Promote Climate-Friendly Building Products**
    - Develop and enhance innovation support, incentives, building codes, and marketing programs to increase the use of efficient and climate-friendly Maine forest products, including mass timber and wood-fiber insulation.
5. **"Lead by Example" in Publicly Funded Buildings**
6. **Renewable Fuels Standard**
    - Investigate options for establishing a Renewable Fuels Standard (RFS) for heating fuels
7. **Replace Hydrofluorocarbons with Climate-Friendly Alternatives**

The University of Maine is globally recognized for research into advanced materials including wood composites with potential for a wide range of applications, including construction.

- The University of Maine's Advanced Structures and Composites Center (ASCC) and Forest Bioproducts Research Institute are at the center of university research efforts to design and promote climate-friendly building products.

- The ASCC, led by Director Habib Dagher, is home to the Maine Mass Timber Commercialization Center, which brings together industrial partners, trade organizations, construction firms, architects, and other stakeholders in the region to revitalize and diversify Maine's forest-based economy by bringing innovative mass timber manufacturing to the State of Maine.

- A bio-based additive manufacturing research collaboration between the ASCC and the U.S. Department of Energy's Oak Ridge National Laboratory focuses on large-scale 3D printing (currently home of the largest 3D printer in the world) with wood products. Researchers are exploring the development of new bio-based materials that will be conducive to 3D printing of structurally demanding systems, including shelters and building components.

- UMaine researchers are pioneering green building and other products incorporating cellulose nanofibrils (CNF), including a formaldehyde-free particleboard replacement. This technology is part of UMaine's widening patent portfolio of strong, environmentally friendly products bound with CNF.

- Will Manion, Director of the School of Engineering Technology, is a member of the passivhaus Maine 50 Houses research initiative, an open-source, collaborative project to bring together cross-cutting expertise to build 50 high-performance retrofits of common Maine building typologies using passive house principles. A key goal is to develop best practices that can be reproduced economically throughout the state and other northern latitudes.

- Sharon Klein, Associate Professor of Sustainable Energy in the School of Economics, is a board member with the non-profit organization Window Dressers, and regularly engages UMaine students in her energy classes in researching and building affordable, custom-fit window insert panels that can drastically increase the thermal efficiency of single-pane and double-pane windows.

Leading by example at UMaine

- UMaine has designed and built Certified, Silver, and Gold level Leadership in Energy and Environmental Design (LEED) buildings, including the Advanced Structures and Composites Center (LEED Certified), Wells Conference Center, New Balance Recreation Center, and Foster Center for Innovation (all LEED Silver), as well as the Offshore Wind Laboratory at the ASCC (LEED Gold). LEED is an internationally recognized green building certification developed by the U.S. Green Building Council. While not formally certified, UMaine's Emera Astronomy Center was designed to LEED Silver standards. LEED certification will be sought for the Ferland Engineering Education and Design Center that is currently under construction.

C. Reduce Carbon Emissions in Maine's Energy and Industrial Sectors through Clean-Energy Innovation

1. **Ensure Adequate, Affordable Clean-Energy Supply**
    - Achieve by 2030 an electricity grid where 80% of Maine's usage comes from renewable generation.
    - Set achievable targets for cost-effective deployment of technologies such as offshore wind, distributed generation, and energy storage, and outline the policies, including opportunities for pilot initiatives, necessary to achieve the results.
2. **Initiate a Stakeholder Process to Transform Maine's Electric Power Sector**
    - Establish a comprehensive stakeholder process in 2021 to examine the transformation of Maine's electric sector and facilitate other recommendations of the Maine Climate Council.
3. **Accelerate Emissions Reductions of Industrial Uses and Processes**
    - Launch an Industrial Task Force to collaboratively partner with industry and stakeholders to consider innovations and incentives to manage industrial emissions through 2030 and reduce total emissions by 2050.
4. **Encourage Highly Efficient Combined Heat and Power Facilities**
    - Analyze policies, including the potential for long-term contracts, needed to advance new highly efficient combined heat and power production facilities that achieve significant net greenhouse gas reductions.

From floating offshore wind and hydropower to development of Combined Heat and Power (CHP) and solar, the University of Maine is a leader in clean-energy innovation to support Maine's energy and economic future and a resource to support related policy development.

- Offshore wind energy represents Maine's largest untapped natural and renewable energy resource, with more than 156 GW of potential energy waiting to be harnessed off the coast of Maine. The Gulf of Maine boasts a higher quality offshore wind resource than most parts of the United States and the University of Maine's Advanced Structures and

Composites Center is a global authority on floating offshore technologies. New England Aqua Ventus, a public-private development effort to construct a single semisubmersible concrete floating platform that will support a commercial 10–12 megawatt wind turbine off Monhegan Island, represents UMaine's most advanced effort in the area of clean energy innovation. When operational (projected 2023), this project will demonstrate patented UMaine floating offshore wind technology at commercial scale and generate clean, renewable power for the Maine grid.

- UMaine economic researchers support policy development around the cost-effective deployment of clean energy technologies. An economic impact report on the New England Aqua Ventus project by Professor of Economics Todd Gabe offers an example of this capacity, highlighting millions of dollars in positive economic impact and hundreds of jobs for Maine.

- UMaine was tapped by the U.S. Department of Energy to lead the Northeast Combined Heat and Power Center (NECHPC), one of eight regional partnerships dedicated to the promotion, technical support and deployment of cost-effective and highly efficient combined heat and power (CHP) technologies throughout the nation. The goal is to facilitate and accelerate the deployment of CHP technologies in the Northeast by providing assistance and technical support to businesses and institutions looking to invest in CHP technology. David Dvorak, UMaine Professor of Mechanical Engineering Technology, is Director of the CHP Technical Assistance Partnership.

- UMaine is home to the Solar Thermal Energy Laboratory. Directed by Assistant Professor of Mechanical Engineering Justin Lapp, the lab seeks new and innovative ways to harness clean renewable solar energy for thermal applications, and to optimize heat transfer processes to conserve energy. The university also is a partner in the National Community Solar Partnership, a coalition of people working in business, academia, non-profit and government organizations, to make community solar accessible to low- and moderate-income Americans across the nation. Sharon Klein, Associate Professor of Sustainable Energy, leads UMaine's collaboration in this partnership, which is run by the U.S. Department of Energy.

- In a unique public-private partnership, the UMaine Cooperative Extension is supporting an agricultural research plot in Rockport to study how wild blueberry cultivation performs within a solar array. The research aims to demonstrate best practices in agricultural solar construction and highlight the potential for co-development opportunities for Maine's wild blueberry growers.

- UMaine has research expertise and infrastructure to support the study and advancement of tidal power. Gayle Zydlewski, Director of Maine Sea Grant, and Teresa Johnson, Associate Professor of Marine Policy, worked in partnership to explore the promise of tidal power in Maine and seek to ensure that development of this renewable energy source promotes economic development and protects marine ecosystems. Related research aims to identify regulatory barriers to the continued development and long-term sustainability of the tidal power industry and to examine how scientific information is produced and used in the regulatory and permitting process.The University also is home to the Alfond W2 Ocean Engineering Lab at the ASCC (which has capacity to test wind, wave and tidal energy devices).

- UMaine is a key partner in the Future of Dams project, a multi-state, interdisciplinary research initiative supporting stakeholder engagement and decision-making around relicensing New England hydropower dams. An important source of low-carbon energy in the region, dams can also have adverse effects on economies and ecosystems. The Maine team - led by David Hart, Director of the Mitchell Center for Sustainability Solutions - examines competing interests over the presence and function of dams to inform decision-making about their future. A new dam decision support process and tool for communities developed by Associate Professor of Sustainable Energy Sharon Klein could be adapted to directly contribute to the goal to "Initiate a Stakeholder Process to Transform Maine's Electric Power Sector."

- UMaine's FBRI (previously mentioned for biodiesel research) also is working with partners in Maine and beyond to advance biofuel development for home heating and exploring the use of biochar as a fuel source.

Leading by example at UMaine

- UMaine has committed to use 27,000,000 kWh of renewable electricity per year, primarily hydro and solar, via the state-funded Net Energy Billing program.

- Approximately 400 heat pumps have been installed in University of Maine campus buildings, helping to increase efficiency in heating and cooling.

- For the last four years, the University of Maine Office of Sustainability has hosted a full-time AmeriCorps volunteer devoted to energy efficiency on campus and in the local community.

- UMaine is currently in the conceptual design phase to rebuild the Central Steam Plant with the goals of the university's 2040 climate commitment in mind. Daniel Dixon, Research Assistant Professor in the Climate Change Institute and Director of the Office of Sustainability, secured a $250,000 grant from the United States Forest Service to help fund the conceptual and schematic design phases of the project.

- UMaine is a key partner in the University Energy Institute Collaborative, a coalition of leaders of energy and sustainability research institutes across the United States. Associate Professor of Sustainable Energy Sharon Klein represents the Mitchell Center in this collaboration and is leading the Energy Equity Committee across this national network.

D. Grow Maine's Clean Energy Economy and Protect Our Natural Resources Industries

1. **Take Advantage of New Market Opportunities**
    - Support the ability of Maine's natural resource economies to adapt to climate change impacts
    - Grow Maine's forest-products industry through bioproduct innovation, supporting economic growth and sustainable forest management and preservation of working lands.
    - Establish the University of Maine as the coordinating hub for state-applied research on forestry, agriculture, and natural land-related climate concerns, including research and development of climate-friendly bio-based wood-market innovation; and research around climate-friendly agricultural practices.
    - Increase the amount of food consumed in Maine from state food producers from 10% to 20% by 2025 and 30% by 2030 through local food system development.
2. **Clean-Energy Jobs and Businesses in Maine**
    - Launch a workforce initiative by 2022 that establishes ongoing stakeholder coordination between industry, educational, and training organizations to support current and future workforce needs.
    - Establish programs and partnerships by 2022 for clean-tech innovation support to encourage the creation of clean-energy and climate solutions.

Given the University of Maine's land grant and sea grant mission and deep ties to the state's natural resource economies, the institution is uniquely positioned to inform and support these sectors as they adapt and innovate to address climate change impacts while simultaneously contributing to Maine's greenhouse gas goals. A goal of the climate plan is to "establish the University of Maine as the coordinating hub for state-applied research on forestry, agriculture, and natural land-related climate concerns." In fact, UMaine already serves this function, though there are opportunities to improve coordination and collaboration within the institution and with partners throughout Maine including state government.

- For more than 100 years, the University of Maine Cooperative Extension has been putting university research to work in homes, businesses, farms, and communities in every corner of Maine. Many of the recommendations to Maine's agricultural community come directly from research conducted at the University of Maine's Maine Agricultural and Forest Experiment Station farms. The Extension network, overseen by Dean Hannah Carter, is and will continue to be central to climate-related outreach essential to Maine's key agricultural and natural resource sectors, with notable ongoing research supporting Maine's small diversified mixed vegetable farms as well as Maine's dairy, blueberry and potato economies.

- UMaine is a key partner in efforts to grow Maine's forest products industry through participation in the cross sector

FOR/Maine collaborative, and among other areas integrated in the Center for Research on Sustainable Forests. Previously mentioned work at UMaine's Forest Bioproducts Research Institute is central to and coordinated with this effort, finding new uses for renewable resources harvested from Maine's sustainably managed forests and supporting new revenue streams for the regional lumber and pulp and paper industries. UMaine's Cooperative Forestry Research Unit connects Maine's forestry community with the University of Maine. CFRU scientists conduct applied research that provides Maine's forest landowners, the forestry community, and policymakers with the information needed to ensure both sustainable forestry practices and science-based forest policy. For the past 40 years, the CFRU has shaped the evolution of forest practices in the state and advanced the principles of sustainable forest management.

- UMaine Cooperative Extension's agricultural outreach is only a piece of their commitment to Maine's wider food system. Extension helps support, sustain, and grow the $3.6 billion food-based economy in Maine and is the only entity in our state that touches every aspect of the Maine food system. UMaine Extension faculty and staff provide essential background information to policymakers, legislators, and others as they decide issues related to the food system, including the regulation of pesticides, licensing of food producers and processors, and ways to stimulate the Maine economy for the future. Extension also supports the development of new and value-added food products and food processing improvements, and provides education and training on food safety. Extension advocates for food security and improved nutrition for Maine people through initiatives such as Maine Harvest for Hunger (an effort to grow fresh vegetables and fruits to donate to food pantries and soup kitchens) and horticulture education. Extension programs, such as the Expanded Food and Nutrition Education Program, help clients in every Maine county to stretch their resources and better feed their families. Given Extension's longstanding commitment to food system development and support for state food producers, the network will be essential to any strategy to increase the amount of food consumed in Maine from state food producers. Cooperative Extension's Maine Farm and Seafood Products Directory, developed in response to demand for local food products at the start of the pandemic, is an existing resource that serves this goal.

- University of Maine researchers across disciplines are exploring opportunities to reduce food waste and move Maine toward a circular food system. Several projects affiliated with the Mitchell Center for Sustainability Solutions consider food waste in different contexts, including empowering Maine businesses toward sustainability, opportunities to address hunger and reduce waste, and risks related to food waste recovery. In 2017, the Mitchell Center's Materials Management team (which coordinates the center's research related to solid waste, including food waste) assisted the Maine Legislature in evaluating a bill to reduce food waste and hunger in Maine.

- Aquaculture represents an increasingly important economic sector for Maine and the expansion of sustainable aquaculture offers an opportunity for increased food security and more efficient protein production. Aquaculture research has a long history at the University of Maine and UMaine has an outstanding array of facilities, resources, and people committed to world-class research. UMaine's Aquaculture Research Institute provides leadership for Maine's aquaculture research and development and plays a key role in coordinating aquaculture interests, assets, and facilities (including the Darling Marine Center, Center for Cooperative Aquaculture Research, and Cooperative Extension Aquatic Animal Health Lab). Maine Sea Grant's work in aquaculture, part of its Safe & Sustainable Seafood focus area, includes continued development of new culture techniques and target species, as well as marketing, industry support, and connections to consumers.

- Through work with the cross-sector Alliance for Maine's Marine Economy, Maine Sea Grant is helping to facilitate the development of a strategic 10-year roadmap for Maine's marine resource economy, with a focus on building and strengthening Maine's seafood economy's resilience to disruptions caused by severe weather and coastal flooding events that cause negative impacts across the seafood value chain.

- The Sea Grant American Lobster Initiative (ALI) funds research and convenes resource managers, fisheries representatives, and scientists to increase the lobster industry's resilience to ecosystem change. ALI-supported research addresses critical knowledge gaps about American lobster and its iconic fishery (one of the most valuable catches in the U.S., with 80% from Maine) in a dynamic and changing environment. The ALI also helps strengthen communication and collaboration channels between the lobster industry and research community and will provide fishermen the opportunity to respond to present changes and prepare for the future in a rapidly changing Gulf of Maine.

- Maine Sea Grant's Aquaculture in Shared Waters (AQSW) training and business development program, which began in 2013, is the largest in the state and convenes multiple partners and experts. AQSW and the broader Maine

Aquaculture Hub orients aquaculture opportunities within marine spatial planning and has created funding opportunities to support innovation for technologies, operations, and markets for seaweed, shellfish, and finfish. This work along with two new efforts, Maine Aquaculture Hub (MAH) and the National Seaweed Hub (NSH), expands sustainable opportunities for these industries.

- UMaine is and will continue to be an integral partner in State efforts to develop a clean-energy workforce and to encourage clean-tech innovation. The New England Aqua Ventus project is an example of existing coordination in these areas. Ongoing offshore wind R&D at the UMaine ASCC will provide experiential learning opportunities for scores of students. Already, the New England Aqua Ventus developers have pledged to work with UMaine, the Maine Community College System, and Maine Maritime Academy to attract K–12 students to science, engineering and business programs, prepare college students and help to create a skilled workforce in Maine with the technical skills necessary to support offshore wind development and operation. Research on bioproducts through UMaine's FBRI offers similar experiential opportunities for students and R&D support for industry.

- UMaine already is a key partner with the State in efforts to develop and promote the creation of clean-energy and other climate solutions. UMaine's Office of Innovation and Economic Development works closely with government officials, businesses, and other stakeholders to support this goal and these efforts could be strengthened and targeted with a focus on marketing university expertise and resources available to support clean technology companies.

- Sean Birkel, Research Assistant Professor and Maine State Climatologist has developed the data visualization website ClimateReanalyzer and the Maine Climate Office data portal. He also works with colleagues in Cooperative Extension to provide critical climate and weather data to Maine farmers on a daily basis.

Leading by example at UMaine:

- UMaine Dining is committed to local products and sustainable practices. The University of Maine has surpassed its goal of sourcing 20% of its food purchases locally by 2020, with a goal of 25% by 2025. This includes produce grown on campus by the Black Bear Food Guild and UMaine Greens, both student-led initiatives. UMaine Dining is a leader in the State of Maine for institutional local food implementation and staff are active participants in FINE (Farm to Institution New England), a six-state network of nonprofit, public and private entities working to transform the food system by increasing the amount of local foods served in schools, hospitals, colleges, and other institutions.

- UMaine has a longstanding commitment to reducing food waste through composting. The on-campus composting system helps UMaine divert more than 400,000 lbs of food waste per year, while also providing hands-on educational opportunities to students. The compost is used at Rogers Farm, at J.F. Witter Teaching and Research Center, on gardens and campus landscaping, and in the UMaine Greens greenhouses.

E. Protect Maine's Environment and Working Lands and Waters: Promote Natural Climate Solutions and Increase Carbon Sequestration

1. **Protect Natural and Working Lands and Waters**
2. **Develop New Incentives to Increase Carbon Storage**
3. **Expand Outreach to Offer Information and Technical Assistance**
    - Increase technical service provider capacity by 2024 to deliver data, expert guidance, and support for climate solutions to communities, farmers, loggers and foresters at the Department of Agriculture, Conservation and Forestry, Maine Forest Service, Department of Inland Fisheries and Wildlife, the Department of Marine Resources, and the University of Maine.
4. **Enhance Monitoring and Data Collection to Guide Decisions**
    - Establish a "coordinating hub" with state and non-state partners for key climate-change research and monitoring work to facilitate statewide collaboration by 2024.
    - Incorporate climate research and climate-change-related technologies into Maine's research and development priorities, such as those developed by the Maine Innovation Economy Advisory Board and the Maine Technology Institute.

Central to the University of Maine's land grant and sea grant mission is a commitment to improving the quality of life

for people in Maine and around the world, and promoting responsible stewardship of human, natural, and financial resources through integrated teaching, research, and outreach. Our responsibilities in these areas can guide and inform broad-based efforts to protect Maine's environment and working lands and waters. While it is impossible to concisely convey the breadth and depth of UMaine research on these topics, the following examples highlight areas of leadership.

- UMaine is home to the Maine Agricultural and Forest Experiment Station (MAFES), the College of Natural Sciences, Forestry, and is agriculture's center for applied and basic research that strives to enhance the profitability and sustainability of Maine's natural resource-based industries, protect Maine's environment, and improve the health of its citizens. MAFES is UMaine's largest research center, with approximately 70 affiliated faculty members who use cutting-edge tools to address emerging and longstanding challenges and develop opportunities in agriculture and food sciences, forestry and wood products, fisheries and aquaculture, wildlife, outdoor recreation, and rural economic development. Other research programs strive to grow the economy, protect the environment, promote public health, and assist rural communities across Maine. MAFES faculty specialize in areas including (but not limited to) integrated pest management, environmental economics, ecology, forestry, land management, natural resources, wildlife management, conservation, sustainable agriculture, food science, invasive species, environmental toxicology, and oceanography. In addition, MAFES encompasses research facilities across the state to include five research farms, laboratories and testing facilities.

- UMaine's Center for Research on Sustainable Forests is a hub for interdisciplinary forest research that seeks to advance understanding about the region's forest resources and forest-based economy, in part through the use of emerging technologies such as high-resolution digital imagery and GPS. The Center, led by Director Aaron Weiskittel, is home to the Intelligent GeoSolutions research team, which has developed sophisticated machine learning algorithms that provide near real time, highly accurate geospatial information about Maine forest attributes of high relevance to forest management, and scalable to large areas using satellite imagery and USFS FIA plot data. These geospatial tools are also critical for land use decisions in Maine. Examples include identifying locations most suitable for future development, conservation, agricultural uses, or forestry; identifying potential conflicts and compatibilities between different land uses (such as land use for solar farm development). The group's ForEST app provides decision support to private and public forest managers, natural resource agencies, conservation organizations, and other stakeholders by making it easy to visualize, explore, and interpret map data relevant to spruce budworm mitigation and land use planning. The Center also has linkages to long-term, intensive forest research sites (e.g., Penobscot Experimental Forest, Howland Forest, Holt Forest, and others).

- UMaine's Natural Climate Solutions Initiative is evaluating the potential of alternative natural climate solutions (NCS) to decrease greenhouse gas (GHG) emissions through management in forestry and agriculture. The project seeks to assess current practices to determine the degree to which foresters and farmers are using NCS; determine the most cost-effective NCS opportunities for Maine; understand key barriers to adopting NCS; and generate information about which practices can be implemented on a broader scale. An interim report was published in 2020 with research slated for completion in spring 2021. Adam Daigneault, Assistant Professor of Forest, Conservation, and Recreation Policy, leads the NCS Initiative team.

- The Darling Marine Center (DMC), led by Director Heather Leslie, is UMaine's full-service marine field station and a facility central to supporting climate-related research with implications for Maine's marine ecosystems and coastal communities and economies. An internationally recognized center for marine research, the DMC connects people to the ocean by generating and sharing knowledge of coastal and marine ecosystems and the human communities that are part of them.

- A key focus area (one of five) for Maine Sea Grant is healthy coastal ecosystems, with work dedicated to informing and improving state and community-based ecosystem management efforts through research, monitoring, and facilitation and coordination for water quality, habitat and ecosystem management initiatives. Through work with the Northeast Coastal Acidification Network (NECAN) and NOAA Ocean Acidification Program on the Shell Day project, Maine Sea Grant and partners provided training and resources on ocean acidification monitoring to 57 water quality groups. In partnership with NOAA's Northeast Fisheries Science Center, Sea Grant conducts an annual survey of the planktonic, fish, bird, and marine mammal species that inhabit the Penobscot River estuary in order to understand how the ecosystem changes in response to habitat restoration.

- UMaine researchers led the development of Maine's first preliminary comprehensive carbon budget, which analyzed available information to calculate Maine's carbon budget between 2006–16 by major emissions source and land use. Cross disciplinary UMaine researchers can provide expertise on every major component of Maine's carbon cycle, from fossil fuels and forests to farms and coastal waters. This initial estimate directly informed the Maine Climate Council process and paved the way for future research that can further define Maine's carbon cycle and support state goals of carbon neutrality by 2045.

- UMaine is a leader in coastal ocean observing systems. The University of Maine Ocean Observing System (UMOOS) — part of the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) — provides observations of circulation and ocean conditions in the Gulf of Maine for those who make a living on the water. This information informs weather forecasters and modelers, and provides data that is integral to ongoing marine ecosystem research. UMaine's Physical Oceanography Group (led by Professor of Oceanography Neal Pettigrew) is responsible for operating UMOOS and Pettigrew is internationally recognized for his research group's innovative surface data buoy designs that became the nation's first coastal ocean observing system.

- Maine's coastal ecosystems, from lakes to rivers, estuaries and in-shore waters, are impacted by numerous stressors, including warming, fisheries declines, invading species, harmful algal blooms (HABs), and severe disturbance events. The Maine-eDNA initiative is a 5-year research, education and outreach program that seeks to transform our understanding and promote the sustainability of Maine's coastal ecosystems via environmental DNA (eDNA) innovations that unlock new scales of inference and collaboration. The initiative will advance both ecological understanding of coastal macrosystems and the inference capacities of environmental DNA (eDNA) science needed to translate knowledge into action.

- Threats to land use change are critical to the Maine response to climate and UMaine's basic and applied sciences define the socioeconomic drivers of these changes, and provide cutting-edge tools such as geographic information systems (GIS) and remote sensing at the Wheatland Laboratory to inventory and track land use through Maine.

- The University of Maine has conducted research on watershed hydrology and freshwater resources that helps us monitor hydrological and biogeochemical processes over time and in response to a changing physical and chemical climate. The Bear Brook Watershed in Maine) has been one of the longest-running whole forested watershed manipulation experiments in the world. Another example is the Watershed Process and Estuary Sustainability Research Group led by Sean Smith, Associate Professor in Earth and Climate Sciences.

- Soil Health has emerged as an organizing concept for a response to climate change to both sequester carbon and build resilience in farm and forest management. Numerous faculty and programs contribute to this area of knowledge with research from MAFES and Cooperative Extension (such as the Natural Climate Solutions work with sustainable agriculture and specifically soil science research described above) informing Maine's opportunities in this area.

- Climate Change Adaptation is a broad concept that describes research and outreach to enhance the ability of society and the natural resource sectors of our economy to minimize the negative consequences of climate change today, and prepare for what is expected in the future. This work cuts across numerous research units mentioned above and others (such as the Maine Climate and Ag Network, dedicated to identifying and communicating challenges, opportunities, and potential solutions regarding climate and Maine agriculture) and is fundamental to the land grant - sea grant mission of the institution.

- The University of Maine Center for Cooperative Aquaculture Research is home to Maine's leading R&D sea vegetable nursery. Sea vegetables take up nitrogen, phosphorus, and carbon, while releasing oxygen, to improve water quality while providing additional crops. The University of Maine's Darling Marine Center and the University of Maine at Machias also have sea vegetable nursery facilities and experimental aquaculture leases, where researchers and farmers work together to develop new farming techniques and valued added products. Maine Sea Grant is an authority on sea vegetable aquaculture, processing, and role in ecosystems, providing resources for growers including Cooperative Extension staff who focus on this topic.

- The University of Maine is recognized as an authority on issues of global climate change through the work of the Climate Change Institute. There, researchers are documenting the changing climate from the Arctic to Antarctica and Greenland with recent coverage in National Geographic featuring the establishment of the highest weather station in the world on Mount Everest. The Climate Change Institute also is home to the Maine Climate Office run by the Maine State Climatologist, Dr. Sean Birkel, with an internationally recognized digital portal for climate and weather data including the Climate Reanalyzer.

Leading by example at UMaine

- The University of Maine campus is home to 7,500 acres of forested land that sequesters carbon, supports the forest economy through timber sales, and provides recreation opportunities for students and the community and habitat for wildlife.

- The University of Maine has committed to become carbon neutral by 2040 and has signed the Second Nature Carbon Commitment.

F. Build Healthy and Resilient Communities

1. **Empower Local and Regional Community Resilience Efforts**
2. **Adopt Official Sea-Level Rise Predictions**
3. **Emphasize Resilience Through Land-Use Planning and Legal Tools**
4. **Strengthen Public-Health Monitoring, Education, and Prevention**

Improving the quality of life for people in Maine is central to the University of Maine's mission, and this includes providing research-based knowledge to inform Maine's communities and help them prepare for the effects of climate change. University of Maine research supports all aspects of Maine's climate-related community resilience, public health, and emergency management planning. In particular, the University helps communities harness data to understand areas of vulnerability and develop and implement adaptation strategies, including helping communities identify and apply for funding to support these efforts. Well-established programs, such as Cooperative Extension and Sea Grant, already are deeply involved in this work, and there is an opportunity to coordinate resources to enhance support.

- UMaine Cooperative Extension and Maine Sea Grant professionals work with, facilitate, and co-coordinate the Climate Change Adaptation Providers Network (CCAP), a network of 75 practitioners, engineers, researchers, and agency representatives dedicated to helping coastal communities prepare for and adapt to climate change. A key initiative is the Collaborating Toward Climate Solutions (CTCS) project team, led by Extension Professor and Climate Change Educator Esperanza Stancioff. CTCS works with municipal officials to incorporate climate change resilience into planning and implementation. Other Extension work with partners in southern Midcoast Maine is also exploring opportunities to build social resilience to climate change.
    - Since 2010, CCAP has been convening (and will continue to convene) climate change experts and municipal leaders partnering to share best practices and to reach citizens and municipal planners directly through site visits, professional development, training and consulting in order to assist communities in adaptation planning and implementation processes. CTCS currently assists municipal officials in 18 Maine communities to identify and incorporate their community-specific climate change resilience strategies into their planning and implementation processes. CTCS also has one annual meeting jointly with the New Hampshire Coastal Adaptation Workgroup (NH CAW) to build regional collaborations and share information.
    - Cooperative Extension professionals and partners are helping coastal communities access state and federal funds (e.g. the FEMA Building Resilient Infrastructure and Communities Fund) and other resources through our CTCS project. In a related effort, Maine Sea Grant coastal access programming focuses on protecting Maine's working waterfront infrastructure (piers, wharves, docks, boat ramps, and commercial infrastructure) from climate change impact.
    - As part of their focus on Resilient Communities and Economies, Maine Sea Grant facilitates the Maine

Ocean and Coastal Acidification Partnership, and is a key partner in the Northeast Coastal Acidification Network, which is the leading group in the region for the synthesis and dissemination of ocean and coastal acidification information.

- The Senator George J. Mitchell Center for Sustainability Solutions is a hub for University of Maine efforts related to improving human well-being while protecting the environment. The Mitchell Center specializes in interdisciplinary, stakeholder-engaged solutions to the urgent sustainability challenges facing Maine. A key ongoing initiative is the Road to Solutions, which addresses environmental, social, and economic issues, including renewable energy, local agriculture, municipal planning, forest management, solid waste, and coastal water quality. Road to Solutions projects are organized under seven topic areas: Forestry, Agriculture & Food Systems, Urbanization & Infrastructure, Climate & Energy, Coastal Systems, Freshwater Resources, Environmental & Social Justice, and Cooperation Science. Faculty affiliated with the Mitchell Center represent a wide range of colleges and departments across the university, and all research teams include experts in the social, economic, and environmental dimensions of sustainability challenges and decision-making. These interdisciplinary teams work in close partnership with stakeholders to maximize the relevance and potential value of research. The Mitchell Center also recently worked with the Maine Climate Council to produce an equity assessment of the Council's draft strategies for the MAINE WON'T WAIT climate action plan.

- A four-year, $4 million interdisciplinary research initiative led by the University of Maine will build some of the first mechanistic models of shifts in species ranges in response to climate change. The goal is to develop novel approaches and software for modeling, visualizing and forecasting spatial and temporal data to better predict and help rural communities respond to the impact of climate change on biodiversity. This research is highly relevant to Maine's agricultural communities and can support farmers' efforts to adapt to climate change.

- The University of Maine has expertise in cooperation science and social-ecological systems modeling that can inform the design of climate-related policy solutions and help surmount societal challenges.

- Maine Sea Grant manages a beach profile monitoring program using volunteer-collected data, along with other coastal processes data, to identify seasonal and long-term erosion trends that inform beach management planning. Established in 1999, the program collects and shares reliable data to encourage collaboration among stakeholders and decision-makers including property owners, regulators, and scientists. As a testament to the value of the program, the majority of the participating cities and towns have committed to continuing long-term monitoring by including program funding in their annual budgets.

G. Invest in Climate-Ready Infrastructure

1. **Assess Climate Vulnerability and Provide Climate-Ready Design Guidance**
    - Complete a statewide infrastructure-vulnerability assessment by 2023, as well as develop and implement design standards for resilience in infrastructure projects.
2. **Establish the State Infrastructure Adaptation Fund**

With cross-sector research expertise that can support climate vulnerability assessments in Maine communities and world-class R&D and engineering programs and facilities, the University of Maine is well suited to advise on all aspects of resilience in infrastructure.

- Aforementioned University of Maine research into community resilience and adaptation planning (including work done by individuals affiliated with Cooperative Extension, Maine Sea Grant, the Mitchell Center, and the Climate Change Institute, among others) will continue to inform infrastructure-vulnerability assessments in Maine communities. Building on data analyzing climate-related threats to Maine infrastructure, the University of Maine's engineering centers can actively support the development and implementation of solutions.

- Work to upgrade Maine's culvert network funded through the Mitchell Center's Maine's Water Resources Research Institute offers an example of how such interdisciplinary collaboration can work. Underperforming culverts threaten both the safety of transportation infrastructure and the health of aquatic ecosystems. UMaine researchers, working with the Maine Department of Transportation, Maine Department of Environmental Protection, Maine Municipal Association, The Nature Conservancy and NOAA Fisheries, are developing decision-making tools for culvert replacement that produce the greatest benefits to infrastructure and ecosystems at the least cost. By examining connections among road safety, ecosystem health, and climate resilience, this project demonstrates how innovative collaborations among government agencies, non-governmental organizations and interdisciplinary research teams can enhance data-driven decision-making. In related research, 3D-printed culvert diffusers developed by researchers at UMaine are being tested in Maine as a cost-efficient option to improve function and extend the life of existing culverts.

- The University of Maine Advanced Structures and Composites Center is a world leader in developing new composite technologies for a range of civil infrastructure applications. The Center leads and is home to the Transportation Infrastructure Durability Center (TIDC), a consortium of six New England universities dedicated to developing innovative, sustainable, next-generation solutions to improve the durability and extend the lifespan of existing and new transportation assets in New England and beyond. TIDC research areas include monitoring and assessment of civil infrastructure and development of new materials, technologies, and systems to improve durability and extend the life of infrastructure. Ongoing work includes projects tied to rails, bridges, pavement, connected vehicles, green infrastructure, and sustainable transportation planning.

    - University of Maine research in this area has led to Brewer-based spinout company AIT Bridges, an engineering and manufacturing company commercializing patented UMaine composite technology for use in bridge construction. AIT's composite arch bridge system has been used in more than 25 bridges around the world, and the first bridge to feature its composite tub girder technology recently opened in Hampden, Maine. Both technologies were developed at the ASCC.

H. Engage with Maine People and Communities about Climate Impacts and Program Opportunities

1. **Raise Awareness about Climate Change Impacts and Opportunities**
    - Launch a multifaceted, ongoing communications effort in 2021 based on the Climate Action Plan to raise public awareness and understanding about climate change in Maine, the state's climate-response actions, and climate-related programs and opportunities.
2. **Increase Public Education Offerings Related to Climate Change and Energy**
    - Develop enhanced educational opportunities for climate science and clean-energy careers in Maine public schools to meet increasing interest from students and educators. Launch a process in 2021 to engage key stakeholders, including students, older youth, educators, and state leaders in next steps.
3. **Start the "Maine Climate Corps" for Climate-Related Workforce Development**
    - Partner with service-learning organizations and nonprofit organizations to launch a Maine Climate Corps program by 2023.
4. **Recognize Climate Leadership by Maine Businesses and Organizations**

With outreach as a cornerstone of our mission and the existing networks to support statewide engagement, the University of Maine will play a key role in State efforts to communicate about climate change impacts and opportunities. Given our already broad and deep engagement in this work, the University will continue to be a partner in statewide coordinated public engagement campaigns. As outlined in prior sections, the University of Maine is a hub of expertise in climate-related topics. University resources can and should be strategically engaged to support State of Maine climate action goals and communications activities.

- The University of Maine already is dedicated to raising awareness about climate change impacts and opportunities. Aforementioned centers, units, and individuals at UMaine all lead aspects of this effort as part of their existing work. The Cooperative Extension (including 4-H) and Maine Sea Grant networks are notable for the breadth of existing programs that address climate-related topics with stakeholder groups of all ages. In addition to University-sponsored outreach events and programs, University faculty, staff and students are regularly called upon to present information to

the public in a variety of forums, speaking throughout the state before schools, companies, interest groups and others.

- Another example of UMaine leadership in this space is the Maine Shellfish Learning Network, co-founded by Associate Professor Bridie McGreavy. The Maine Shellfish Learning Network (MSLN) focuses on building relationships and improving communication between many different participants within Maine and Wabanaki wild clam and mussel fisheries. These communities face a host of pressing issues, including a steady decline in shellfish landings, increases and changes in predation, climate change, water quality, social bias, and limited civic capacity for managing the resource. Harvesters, towns, and community groups across the coast are working together to advance solutions to these issues.

- The University is a statewide leader in K-12 outreach. In a given year, the faculty and staff at the University of Maine connect with tens of thousands of youth and educators. Through campus tours, classroom visits, professional development workshops, summer camps, and curriculum development initiatives, students from all over the state of Maine are introduced to the unique programs offered by the University of Maine. Such outreach already encompasses climate-related topics – a notable example is 4-H STEM programming – but existing programs could be expanded or tailored to support state climate action goals.

- The University is home to a wealth of public-facing resources devoted to informing Maine's people about climate change from physical facilities to websites to events and programs to targeted materials, such as learning toolkits for K-12 students and other curriculum support. Reports, such as Maine's Climate Future – 2020, demonstrate the progression of accelerating change in the climate in Maine and its effects, as well as research in the Climate Change Institute about changing biophysical and human systems throughout the planet.

- Workforce development is a key aspect of the University of Maine's educational mission. Climate research expertise coupled with programs that support related R&D engage students of all ages and transfer knowledge toward careers in climate science and clean energy. For university students, experiential opportunities abound in research areas including offshore wind, biomaterials, and aquaculture. In the K-12 age group, the ASCC's wind blade design challenge and aquaculture internship opportunities through the Center for Cooperative Aquaculture Research drive interest in related careers. As with outreach programming, workforce development efforts could be expanded or tailored to support state climate action goals.

- UMaine offers three Renewable Energy minors to undergraduate students. Faculty who teach required courses for those minors regularly engage students in projects with community members to help solve technical, economic, environmental, cultural/equity, and policy-related renewable energy issues. These University-stakeholder collaborations enrich student learning and help communities make progress on energy and climate-related solutions.

- The University of Maine could support the development of a "Maine Climate Corps" in myriad ways. UMaine could contribute both climate and program development expertise to drafting an effective framework for the corps. While program development is underway, existing internship programs for college students offered through the University of Maine could be tailored to support climate action goals (and already are placing interns in climate-related work). Examples include the Maine Government Summer Internship Program through the Margaret Chase Smith Center, the SEA Fellows program developed by UMaine and University of Maine at Machias, fisheries research internship opportunities offered through Maine Sea Grant and NOAA, and the Innovate for Maine Fellows Program. University centers and programs could both supply candidates for and host "Maine Climate Corps" interns.

- The University of Maine Office of Innovation and Economic Development encourages climate leadership among businesses by connecting them with research expertise and resources at the University that can help advance transitions to environmentally friendly processes and materials. This can take the form of connecting companies with UMaine R&D expertise around biomaterials, renewable energy, decision-support frameworks on adaptation, or licensing related products or technologies developed at UMaine.

Leading by example at UMaine

- In February 2007, the University of Maine became a charter signatory of the American College & University Presidents' Climate Commitment (ACUPCC), who's main supporting organization is Second Nature. UMaine is a signatory of the The Carbon Commitment, which is focused on reducing Greenhouse Gas emissions and achieving carbon neutrality

as soon as possible. By signing The Carbon Commitment, UMaine agreed to develop a Climate Action Plan to achieve carbon neutrality by 2040. This involves conducting a public Greenhouse Gas emissions inventory and implementing immediate steps to reduce greenhouse gas emissions.

- The Sustainability Tracking, Assessment & Rating System (STARS) is a program of AASHE, The Association for the Advancement of Sustainability in Higher Education. STARS is a comprehensive sustainability rating system for colleges and universities that addresses the environmental, social and economic dimensions of sustainability. UMaine completed its first STARS report in April 2019, earning a STARS silver rating. UMaine's report is on the STARS website.