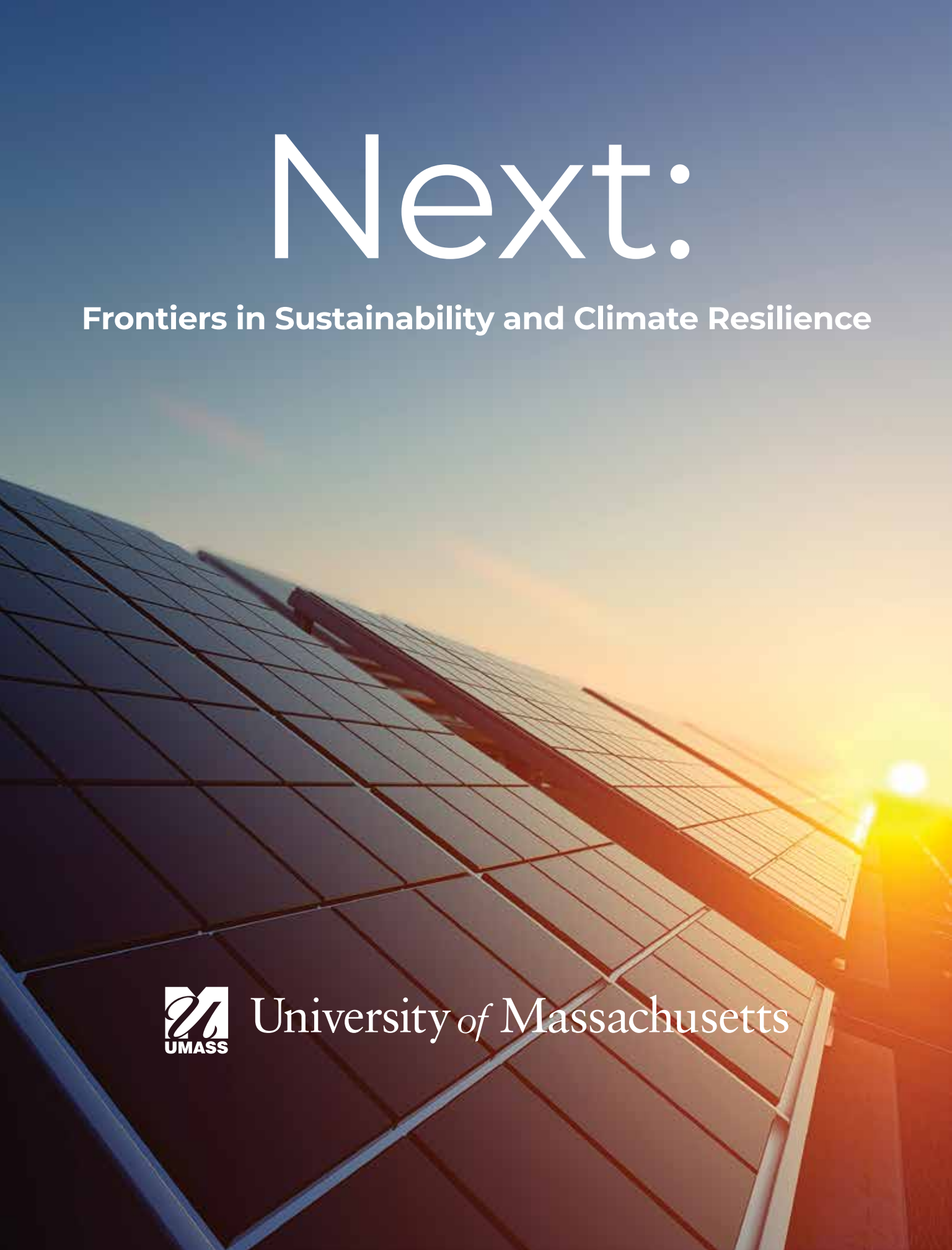
Next:

Frontiers in Sustainability and Climate Resilience



UMASS

University of Massachusetts

The Stone Living Laboratory

Sea-level rise and intensifying storms increasingly threaten to inundate densely populated coastal cities like Boston. Located on Boston Harbor's Rainsford Island and ringed by a network of onshore, offshore, and drone-based sensors measuring weather, waves, water quality, and current, UMass Boston's Stone Living Laboratory will develop and test approaches for protecting developed coastlines that mimic natural systems, such as boulder fields and urban salt marshes.

The lab, launched in 2020 and operated in partnership with Boston Harbor Now, the National Park Service, and the City of Boston, is the first research facility in the world where full-scale, in-situ experiments of this kind can be carried out, and will inform climate-resilience strategies for coastal cities worldwide.

Extreme weather. Sea-level rise. Food and water shortages. Climate change is challenging our region, nation, and world on an unprecedented scale. Science is exposing the sobering extent of these problems, but also revealing solutions—opportunities to create a future that is not just low-carbon, but also equitable and even profitable, built around a robust sustainable economy and quality of life.

As a national hub for innovation, Massachusetts is well positioned to be a leader in the transition to sustainability, and has already taken the step of committing to net-zero carbon emissions by 2050. Hitting this target and moving toward sustainability and climate resiliency will require wide-ranging, science-informed innovation in support of two goals:

1. Mitigating greenhouse gas emissions to reduce climate impacts. Reducing the amount of carbon dioxide we produce will require innovation in transportation and energy production, the top carbon-emitting sectors, in particular.
2. Developing adaptation strategies for navigating climate impacts that we are already experiencing and will unavoidably have to manage for centuries to come.

The good news: These are challenges UMass has prepared to face—for decades, in some areas. We have unparalleled expertise in offshore wind power, an energy source with huge generative potential. We have world-renowned, system-wide strength in coastal and climate science and adaptation. We are already leading the way in transforming transportation across the state. And we have active research and social justice efforts addressing all 17 of the UN's Sustainable Development Goals—many in partnership with national and state government and industry.

In short, the research that will undergird a sustainable society is underway at UMass. The green and blue workforce of the future is training in our laboratories even now. UMass is ready to help the Commonwealth become the model of a thriving state in a changing climate.

BIG IDEAS

As the US's first National Climate Advisor, UMass Boston alumna Gina McCarthy is setting the Biden administration's ambitious domestic climate agenda, focused on reducing greenhouse gases that drive climate change. McCarthy led the Environmental Protection Agency under President Obama, capping power plant carbon emissions for the first time and creating stricter emissions standards for vehicles.

Wind and wildlife

The impact of offshore wind turbine installations on commercially important fish and shellfish is an open question of great interest to the fishing industry. Scientists from the UMass Dartmouth School for Marine Science & Technology are collaborating with commercial fishermen and lobstermen to monitor the sea life communities at the future site of Vineyard Wind, the US's first utility-scale offshore wind project. The team has conducted a full year of baseline studies and will continue to survey the area and a similar control area four times each year throughout the construction and operation of the wind farm to assess its impact on wildlife, data that could inform the development of future offshore wind projects.

Today's strengths

Global warming has created urgent imperatives to focus UMass's research talent on understanding and overcoming the potential impacts of climate change. In the following four areas, UMass researchers are at the forefront of climate and sustainability science.

Climate change, coastal resilience, and marine science research

UMass is well known for its excellence in climate- and marine-related science. The system operates three schools largely dedicated to these topics:

- UMass Boston's **School for the Environment**
- UMass Amherst's **School of Earth and Sustainability**
- UMass Dartmouth's **School for Marine Science & Technology**

UMass Lowell integrates its climate and sustainability efforts across the sciences, engineering, policy, education, arts, and business through its **Rist Institute**, which includes the UMass Lowell **Climate Change Initiative** and **Environmental, Earth & Atmospheric Sciences Department.** UMass Medical School contributes to the **Intercampus Marine Science Graduate Program**'s Oceans and Human Health concentration.

Expertise across the five campuses is broad, but also deep.

UMass Boston is a world leader in environmental monitoring via satellite-based remote sensing. Methods developed in environmental geographer Crystal Schaaf's lab for using global light reflectance to map land-cover changes, for example, are the standard in the field.

The model of ice-sheet melting and sea-level rise developed by UMass Amherst **Climate System Research Center** geologist Rob DeConto is one of the most significant findings in climate science, which is why it was featured on the covers of *Nature* and *The New York Times* in 2016. The UMass Dartmouth **Marine and Undersea Technology Research Program** has received $8.8 million from the Office of Naval Research in 2020 alone for its work on improving the predictive power of ocean models and underwater sensing and communication technologies for unmanned underwater vehicles.

These efforts provide information vital to environmental protection and coastal resilience. UMass Boston's **Center for Coastal Environmental Sensing Networks** is developing predictive environmental sensor networks for the management of coastal resources, including a Department of Energy-funded sensor network testbed in Boston Harbor.

UMass Amherst's **Coastal Systems Program** tracks nutrient loading in coastal waters and evaluates innovative systems for the treatment of wastewater—the primary source of nutrient pollution worldwide. The university's **Center for Collaborative Adaptive Sensing of the Atmosphere**, a National Science Foundation

A new climate modeling study authored by UMass Amherst geosciences PhD candidate Shaina Sadai finds that meltwater from the Antarctic Ice Sheet will have significant effects on global climate in the future, underscoring the importance of meltwater measurements for accurate climate predictions.

UMass Dartmouth autonomous underwater vehicle "Blue" can continuously collect and transmit ocean data for several weeks at sea.

Engineering Center with $40 million in funding, creates atmospheric sensing networks that enhance our ability to understand and predict dangerous weather events.

Many government agencies, from local to federal, draw upon the UMass faculty's solutions-focused expertise to shape climate policy. UMass Boston climate adaptation expert Paul Kirshen and hydrologist Ellen Douglas, for example, have been key contributors to the City of Boston's Climate Ready Boston coastal resiliency initiative. Kirshen led the **Sustainable Solutions Lab** study underpinning Boston's plans to invest in shore-based methods to manage coastal flooding rather than a barrier across Boston Harbor.

The system also houses the US Department of the Interior's **Northeast Climate Adaptation Science Center** at UMass Amherst, one of eight such centers across the nation investigating ways to help wildlife and ecosystems adapt to climate change. The center covers an enormous geographic area that is home to more than 130 million people, and has provided extensive climate impact studies that are relevant to many industries, including transportation, insurance, real estate, tourism, agriculture, and more.

The **Massachusetts Marine Fisheries Institute** at UMass Dartmouth, a cooperative venture with the Massachusetts Division of Marine Fisheries, also typifies the solution-focused, data-driven, community-engaged nature of UMass's climate and marine research as a whole. Affiliated scientist Kevin Stokesbury's video surveys mapping scallop abundance in Atlantic fishing grounds, for example, enabled limited harvesting in previously closed areas, boosting the struggling fishery and demonstrating the possibilities of sustainable rotational management.

Stokesbury, whose lab now provides fisheries assessments for the US and Canada, has been recognized by the industry for helping reverse the decline of New Bedford's scallop industry.

Network of coastal research stations and observational assets

UMass operates a system-wide network of coastal research stations that spans the Commonwealth, in diverse ecosystems from Cape Ann to Nantucket.

On the South Coast, UMass Dartmouth's **School for Marine Science & Technology** (SMAST) operates a wide array of observational technologies, including coastal radar and seafloor video equipment monitoring offshore fishing grounds. SMAST is part of the **Mid-Atlantic Regional Association Coastal Ocean Observing System**, a federal program that collects and shares coastal data from Massachusetts to North Carolina.

UMass Boston's 107-acre **Nantucket Field Station** comprises several undeveloped coastal habitats,

including 40 acres of pristine salt marsh invaluable as a baseline for studies of wetland contamination. The university's new **Stone Living Laboratory**, by contrast, is a unique testbed for coastline protection strategies, equipped with instruments measuring coastal processes and testing the performance of nature-based coastal flood protection systems in Boston Harbor's high-density urban environment.

UMass Amherst's **Gloucester Marine Station**—located on the rapidly warming Gulf of Maine, near Gloucester's commercial fishing fleet—is ideally positioned for research, policy, and outreach related to marine ecology, coastal resilience, sustainable seafood, and ocean-based economic development.

Together, this network gives the system a uniquely powerful, holistic view of the Massachusetts marine environment and the communities where lives and livelihoods are intertwined with it.

Renewable energy

UMass is a global leader in renewable energy.

The system is renowned as the pioneer of scalable offshore wind power, which has the potential to more than meet the entire US electricity demand.

UMass Amherst's **Wind Energy Center** (WEC) was the first academic wind energy engineering program in the country. Now, with more than 40 years of research behind it, the center is leading transformational efforts to develop multi-line anchor floating wind turbines that would dramatically reduce the cost and increase the feasibility of offshore wind. Center faculty literally wrote the book on the subject: *Wind Energy Explained*, written by UMass Amherst engineers James Manwell and Jon MacGowan with former center engineer Anthony Rogers, is the primary textbook for wind energy graduate programs worldwide.

UMass Lowell's **Center for Wind Energy** (CWE) co-leads **WindSTAR**, the country's only National Science Foundation–funded industry/university collaborative research center focused on wind energy. Both WEC and CWE are members of **POWER US**, a Massachusetts Clean Energy Center–sponsored academic research consortium that is setting national priorities for innovation in offshore wind, in consultation with planning experts from the **McCormick School of Public Policy** at UMass Boston and ocean science experts from UMass Dartmouth. In June 2020, UMass Dartmouth scientists were also tapped by the Baker-Polito Administration to conduct fisheries studies as part of the US Bureau of Ocean Science Energy Management's **Regional Fisheries Studies to Guide Offshore Wind Development** initiative.

But wind power is just one sustainable energy source in development at UMass. UMass Boston is a global leader in the "green chemistry" movement, and the university's **Center for Green Chemistry**—home

Blue economy

Gloucester was the birthplace of the US commercial fishing in the late 1600s. Today it's an epicenter of the region's burgeoning "blue economy"—defined by the World Bank as the "sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health." In 2019, UMass Amherst's Gloucester Marine Station partnered with the UMass Dartmouth Public Policy Center, with support from local government and industry, to launch the 10-year North Shore Blue Economy Initiative.

Its goal? To design a resilient, sustainable economic development strategy for the local seafood, marine construction, ship building, tourism, and marine transportation industries—not from an ivory tower but down on the docks. This effort has brought together more than 200 leading state officials, top organizations, businesses, educational institutes, government agencies, and other coastal-resiliency experts throughout the region.

Recycling CO2 into fuel

Burning fossil fuels pumps carbon dioxide into the atmosphere. Recycling that CO2 back into raw materials for more fuel could be a way to have our cake and eat it, too—achieving carbon-neutrality without a full-blown transition to zero-carbon power.

The conversion can be done with electricity and a catalyst, but typically uses rare-earth metals acquired through an energy guzzling and often toxic extraction process. With funding from the NSF, UMass Boston green chemist Jonathan Rochford is developing catalysts made from manganese—one of the most abundant metals on earth—that would reduce the environmental impact of the recycling process. Studies are also underway to further optimize this process by driving catalysis directly with solar energy.

to the world's first green chemistry PhD program—is developing carbon-neutral fuel cycles with recycled atmospheric carbon dioxide, as well as high-efficiency, low-cost energy storage methods for electric vehicles, rechargeable batteries, and efficient capacitors for storing and releasing renewable energy to the electrical grid.

Engineers at UMass Dartmouth, meanwhile, are advancing wave energy conversion. Mechanical engineer Mehdi Raessi has created a 3D computational tool for designing and testing conversion devices, significantly accelerating their development. Environmental engineer Daniel MacDonald has patented a low-cost, low-maintenance wave-energy convertor that can provide continual power to electronics at sea, including buoys, autonomous underwater vehicles, and ocean monitoring sensors. A student team updating his device won second place in the Department of Energy's inaugural, international Marine Energy Collegiate Competition in August 2020.

The system is also working to enhance solar power, which outpaces wind energy in terms of electricity production in the Commonwealth. Perovskite-based solar cells—at least as efficient as common silicon cells and far cheaper to make—have the potential to boost solar productivity considerably, but break down too quickly to be practical. Researchers in UMass Amherst's **Advanced Laboratory for Iontronic, Electronic and Nanomaterials** are working on the problem, to date achieving efficiencies of more than 21 percent with more than 4,500 hours of stability—one of the most stable perovskite cells ever produced.

Transportation and infrastructure

With a network of more than 100 affiliated researchers from all five campuses, the **UMass Transportation Center** at UMass Amherst is the system's hub for transportation research, much of it with direct relevance to sustainability and climate resilience. Since 2018, affiliated faculty have been awarded 46 grants totaling $21 million, including $11.4 million from the Massachusetts Department of Transportation for three years of on-demand research and service for the state.

Together, UMass and MassDOT have, for example, investigated the impact of commuter buses on greenhouse gas emissions, developed a strategic plan for the rollout of efficient self-driving vehicles in the state, and predicted infrastructure-threatening increases in 100-year floods in key waterways. The center is also creating and testing road designs that encourage sustainable micro-mobility options and developed and delivered training for MassDOT's pedestrian, bike, and transit-friendly Complete Streets initiative to 82 percent of the state's cities and towns in just two months.

The federal government is also a partner. The US Department of Transportation relies on UMass Amherst's **Arbella Human Performance Lab** to simulate how road users react to automated vehicles; suss out risk factors for car crashes involving pedestrians and bicycles; investigate how safely drivers, bicyclists, and pedestrians navigate certain roadway features; and assess traffic conflicts among drivers, bicyclists, and pedestrians in real time through connected simulators.

UMass Lowell's **Simulation, Modeling, and Analysis of Real-Time Transportation (SMART) Systems Lab** focuses on traffic safety, traffic control, and intelligent transportation systems—road features that integrate advanced communication

technologies, like electronic toll collection and intelligent traffic signal control, both strategies for reducing congestion and emissions. The lab has also worked with MassDOT to quantify the emissions benefits of traffic-flow improvement strategies and incentivizing the switch to greener travel modes.

UMass researchers are also investigating infrastructure wear-and-tear in a changing climate. Highways and bridges, built to last for decades, are already facing extremes of heat, wind, and rain that they weren't designed to withstand. UMass Dartmouth's nationally recognized **Highway Sustainability Research Center** and UMass Amherst's massive **Robert B. Brack Structural Testing Facility** are both focused on increasing the resilience and sustainability of transportation infrastructure.

The UMass Dartmouth center has created asphalt mixtures that are composed of nearly 50 percent recycled materials; high-durability pavements developed there are in use now on US highways. UMass Amherst's facility tests the strength of full-size pieces of infrastructure weighing up to 55 tons, to study, for example, the endurance of new materials and methods for constructing sustainable buildings and bridges, and to evaluate the usable life left in decommissioned structures—which is key to efficient infrastructure planning.

UMass Boston's **School for the Environment** focuses on sustainable, resilient urban infrastructure planning through its **Urban Planning and Community Development** program and **Center for Rebuilding Sustainable Communities after Disasters**, as well as research foci in urban environments and policy and planning. The school has also carried out assessments of coastal flooding vulnerability under present and future climate changes for many of the highway and rail assets of MassDOT, including the Central Artery Tunnels. The coastal flood model developed by its subcontractor, Woods Hole Group, is widely used through the Commonwealth to determine present and potential flooding.

Food security

Moderate to severe food insecurity impacts more than a quarter of the world's people today. Scientists predict that climate change will reduce crop yields, especially in areas that are already experiencing scarcity. Ensuring adequate food for the global population in a changing climate is a critical priority, and UMass is addressing it across the system.

UMass brings tremendous expertise to the table. The **Department of Food Science** at UMass Amherst was one of the first of its kind in the country and today boasts the National Research Council's top-ranked PhD-level food science research program. In addition to studies aimed at extending food shelf-life and safety, the department is developing plant "milks," nutritionally complete plant-based "meats," and lab-grown meat—"future foods" that can reduce our dependence on animal agriculture, a major source of greenhouse gas emissions and water and crop consumption.

Extending the life of existing transportation infrastructure and developing more resilient bridges, pavements, and roadways are focuses for research groups at UMass Amherst and UMass Lowell.

UMass Amherst is also ranked #1 in the US and #4 in the world in agriculture by *US News & World Report*. The university's **Sustainable Food and Farming** program—the fastest-growing major in UMass Amherst's **Stockbridge School of Agriculture**—is working to revolutionize the food system from production to distribution with regenerative approaches that use carbon-capturing techniques, climate-resilient crops, biofuels, precision agriculture, no-till systems, integrated cover-cropping, biodiversity, nanotechnology, and biomass recycling. Affiliated faculty are repurposing food waste and developing products from underused foods.

UMass Amherst's **Carbon Farming Initiative** is one of a handful of sites around the country training people in regenerative farming. Stockbridge School scientists are collaborating with other universities to study interactions between microbes and plant roots that store carbon in soils, with the goal of improving carbon sequestration in agricultural systems. Micro- and nanoplastics—increasingly studied in marine environments, but little investigated in agricultural soils—are another focus area. Baoshan Xing's lab has shown that nanoplastic pollutants in soils can accumulate in plants, with both ecological effects and implications for agricultural sustainability and food security.

Food-waste diversion is a key feature of UMass Lowell's **Urban Agriculture Program**, which operates a 1,800-square-foot urban agriculture greenhouse and urban farm with soil from compost generated from the

university's award-winning dining facility food-waste diversion program. In addition to being a full-scale agricultural production facility—20 percent of the produce grown there is donated to the community, including the university's student food pantry—the greenhouse and farm are testing grounds for sustainable food production. Faculty and students from UMass Lowell's **Energy Engineering program** are conducting research at the greenhouse with a focus on increasing the water- and energy-efficiency of food production.

UMass Amherst's 20-acre Student Farming Enterprise marked its 14th season of sustainable agriculture research and training in 2020.

UMass is also deeply involved with developing a sustainable seafood industry in Massachusetts, from supporting sustainable fisheries practices to sustainable seafood farming—both important food security strategies and major components of an ocean-based "blue" economy. The online **Sustainable Marine Aquaculture program** at UMass Boston, led by environmental scientist Jennifer Bender, is dedicated to securing future seafood supply and training skilled workers for a sustainable aquaculture industry.

Optimal fishery yield is important for sustainable food supply and defined using ecological, economic, and social factors. SMAST at UMass Dartmouth has an international reputation for providing scientific support for managing sustainable fisheries. Important work being carried out at UMass Dartmouth includes the effects of climate change on fishery catch rates and the impact of wind farms on the American lobster, Atlantic Cod, and the marine ecosystem.

Water is a necessary asset for food security, and there are many water experts on the UMass faculty. Environmental engineer Casey Brown of the UMass Amherst **Hydrosystems Group** is a global expert on the impact of climate change on water management. His team wrote the guidebook the World Bank uses to evaluate water project investments under climate change and recently worked with the California Department of Water Resources to evaluate climate vulnerabilities in California's 700-mile State Water Project, which irrigates 750,000 acres of farmland. UMass Amherst is also home to the **Water Resources Research Center**, one of 54 national institutes (one for each US state and several territories) federally mandated to address regional water issues by the Water Resources Research Act of 1964. UMass Boston's Paul Kirshen and Ellen Douglas have both co-authored IPCC and US National Climate Assessment reports on the impacts of climate change on water resources and management strategies.

Microplastics and coral die-off

Five to twelve million metric tons of plastic enters the ocean each year. Once there, it remains indefinitely, so understanding its impact on marine life, fisheries, ecosystems, and green infrastructure is a critical need. UMass Boston zooplankton ecologist Juanita Urban-Rich studies microplastics in aquatic systems, and in 2019 was part of the first team of scientists to discover that corals are eating the particles of plastic debris, which can harbor dangerous bacteria—often preferring them to real food. The findings suggest that wild coral might be dying off in part due to plastic-borne infections.

Tomorrow's frontiers

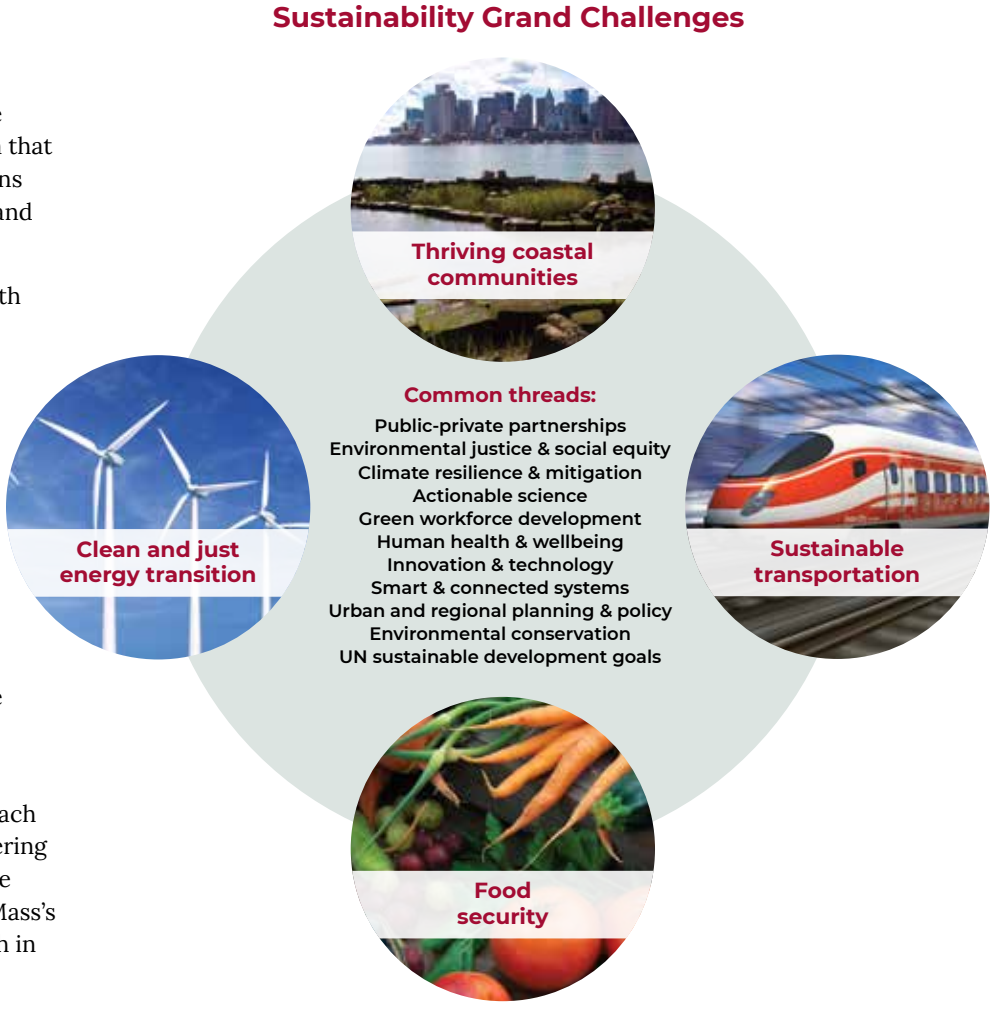
The next ten years represent an inflection point in sustainability and climate resilience: the phase in which plans and pilot projects scale up and carbon emissions shift down, forming the foundations of a climate-ready future.

The strengths described on the previous pages boil down to this: UMass supports a flourishing ecosystem of researchers who are examining virtually every problem that the growing climate crisis threatens to throw at the Commonwealth—and finding solutions.

A climate-prepared Commonwealth will be built on four mutually reinforcing imperatives:

- Zero-carbon and carbon-neutral energy sources
- Transportation without greenhouse gas emissions
- Resilient coastal communities
- Food security and sustainable fisheries

Complex scientific questions and engineering challenges underlie each of these essential frontiers. Answering those questions and meeting those challenges will be the focus of UMass's climate and sustainability research in the coming decade.



Next frontier 1:
Thriving coastal communities and the blue economy

What will define the thriving coastal communities of the future? Climate adaptation and sustainable marine economies.

Coastal communities worldwide will need to master resilience to storms, heat, and sea-level rise; actively work toward food, water, and energy security; and create green infrastructure. While daunting, these changes are essential—and lay the groundwork for booming blue economies.

Over the next decade, UMass will continue to conduct research that informs these efforts. Two examples of many: Findings from the UMass Amherst **Sediment and Coastal Dynamics Lab**'s investigations of the impact of coastal development and climate change on Atlantic tidal marshes—which serve as coastal barriers and as nurseries for many fish species—will have implications for resilient infrastructure planning and food security. Data from the **Stone Living Lab** will guide strategies protecting coastal cities from storm surges and tidal inundation.

It is an unprecedented, dynamic time for the marine economy. Wild capture fisheries, aquaculture, and offshore energy are important components of blue prosperity, and for sustainable and resilient coastal communities. This is certainly true in Massachusetts, which has a robust presence in all three sectors.

Today, New Bedford leads the nation for fisheries value—$431 million in 2018, making it the top port in the country for the 19th straight year. That value is driven by the scallop fishery, but the groundfish

fishery also has huge potential if rebuilt and sustainably managed, a topic of current research at UMass Dartmouth's **Massachusetts Marine Fisheries Institute**. The $1.5 billion US aquaculture industry is poised to make great strides in productivity. Aquacultured oysters are the third highest-valued seafood produced in Massachusetts today, but the potential is much higher.

The US market for offshore wind is expected to exceed $60 billion by 2024, and coastal Massachusetts is the hub of the newly developing wind farm industry, thanks in large part to wind power research and development out of UMass Amherst and UMass Lowell. UMass Dartmouth's **School for Marine Science & Technology** will also continue to play an integral role in the region's development with research in marine ecosystems, climate, physics, ocean observation, ocean modeling, and fisheries science.

UMass Amherst is piloting a new initiative that sits at the nexus of all of these topics: the **Northeast Center for Coastal Resilience** (NCCR). Building on the system's four coastal research sites, NCCR will bring together faculty, coastal resilience experts, and coastal communities to advance actionable coastal science, inform policy and local decision making, and support blue economy and workforce development, including blue technology, sustainable fisheries and aquaculture, defense, and offshore wind operations, and infrastructure.

Next frontier 2:
Food security

In Massachusetts, the blue economy is tightly interwoven with the issue of food security, and many of the food-system questions we will seek to answer over the coming decade pertain to fisheries and coastal waters.

Emergent challenges in fisheries science are navigating the effects of climate change and evaluating the benefits, impacts, and tradeoffs between offshore renewable energy development and wild capture fisheries. Key UMass research efforts address these issues:

- Managing the coexistence of offshore wind energy development and sustainable fisheries
- Assessing additional aquatic food production opportunities through shellfish, seaweed, and fish
- Developing low-cost distributed meshed sensor networks to monitor water quality throughout coastal waters
- Incorporating shellfish production into water remediation with conservation benefits

The system's faculty are also active in food security research more broadly. **Food Systems and Security** investigators at UMass Amherst, for example, are actively investigating food processing capacity with an eye toward ensuring less food waste. UMass Amherst has also established a new **Center of Excellence for Nano-Enabled Agriculture and Environment Research**, which will address the major challenges of global food security and food safety.

Next frontier 3:
Clean and just energy transition

The Commonwealth's commitment to carbon-neutrality by 2050 requires a robust slate of zero-carbon energy sources. Over the next decade, UMass's research efforts in offshore wind energy, wave energy conversion, and high-efficiency, cost-effective solar will continue to advance the state of the art and increasingly contribute to the state's energy portfolio. Sustainable fuels and

Sustainable revitalization

UMass Dartmouth art historian Pamela Karimi's teaching grounds intellectual inquiry firmly within the community. At the center of this unique approach is her class, "Architecture and Sustainability in the American Post-Industrial City," which considers pressing issues of revitalization and sustainability in the context of New Bedford. Her students work with local activists, politicians, and artists to generate proposals for repurposing vacant lots and abandoned mills, building cost-effective community greenhouses, and supporting urban farming.

energy storage technologies—fields that promise to reduce the carbon emissions of our transportation system and increase the reliability of a sustainable electrical grid—represent a major commitment across the UMass system.

To be sustainable, this transition to clean energy must be accessible to all residents of the Commonwealth. UMass Amherst's **Energy Transition Institute**, launched in 2019, is home to the **ELEVATE program**, which—with $6.3 million from the National Science Foundation—draws on UMass's longstanding strengths in technology and social justice to investigate market mechanisms, grid algorithms, and policies to minimize system costs and promote equity. Through action research, the UMass Boston **Sustainable Solutions Lab** is actively supporting environmental justice and climate-change adaptation.

Next frontier 4:
Sustainable transportation

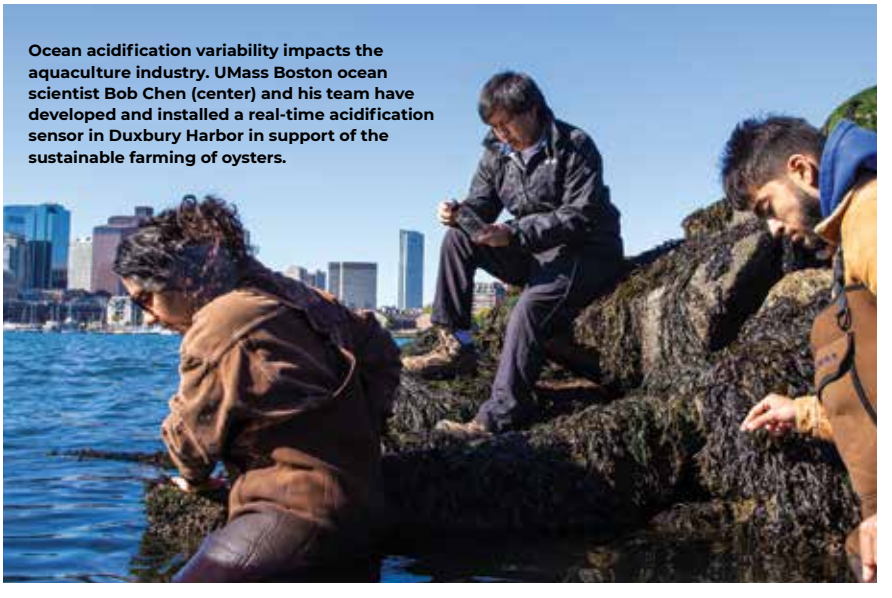
The transportation sector is in a moment of rapid evolution, due to the imperatives of climate change. UMass transportation scientists will advance the transition to sustainable transport over the next five to ten years by building on current research into micromobility and flexible transit, zero-emission vehicles and alternative fuels, disruptive technologies like self-driving cars, and infrastructure management.

Promising new technologies are already emerging from our labs. One area of exciting potential comes out of UMass Lowell's **Chemistry Department**, which has pioneered a more efficient way to power electric vehicles, enabling EVs of all sizes to run longer without emitting greenhouse gases. The new technology uses water, carbon dioxide, and the metal cobalt to produce hydrogen gas, a carbon-neutral fuel which reacts with oxygen in a fuel cell to generate electricity and emit only water.

Floating giants

Floating wind turbines—which can be built in deeper water than fixed platform wind farms—have the potential to open a huge area of the world's coastal waters to wind development. But turbines, with blades as long as a football field and towers as tall as the Empire State building, are the largest rotating machines on earth; the mechanical challenges of buoying them on shifting seas are not trivial. Mechanical engineer Matt Lackner, associate director of the UMass Amherst Wind Energy Center, focuses his research on reducing damaging vibrations in floating turbines buffeted by wind, current, and waves.

These vibrations are far from the only challenge facing floating offshore wind, however; issues range from regulatory complications to rain erosion to the disturbance of wildlife habitats and commercial fishing. So Lackner and his colleagues at the Wind Energy Center have brought together a team of doctoral students from engineering, wildlife biology, and political science to tackle the project from all angles.



Ocean acidification variability impacts the aquaculture industry. UMass Boston ocean scientist Bob Chen (center) and his team have developed and installed a real-time acidification sensor in Duxbury Harbor in support of the sustainable farming of oysters.

Building the sustainability workforce

Climate resilience efforts are spawning new industries and new opportunities for workers.

Global renewable energy consumption has grown by more than 13 percent per year on average since 2010. Electric car sales topped 2 million worldwide for the first time in 2019 and are projected to exceed 30 million by 2030. Today, more than 470,000 Massachusetts citizens work in fields related to sustainability and coastal resilience, from agriculture to city planning to wind energy.

Over the next ten years, demand in the sustainability sector is projected to grow by 7.2 percent in the Commonwealth, almost twice as fast as the US Bureau of Labor Statistics' forecast for US employment as a whole. Employers will need to fill an estimated 46,900 job openings between now and 2030.

Where will workers with training to fill those positions come from?

The majority will be graduates of UMass. The UMass system is the top producer of trained professionals in sustainability fields in the state. In 2019, UMass awarded more than 4,000 bachelor's, master's, and doctoral degrees in programs related to sustainability and climate resilience—19 percent of the state's total degree completions.

Massachusetts employment data in occupations related to sustainability

474.1k
Current MA employment in 130 related fields in 2020

46.9k
Projected estimated MA annual job openings (2020–2030)

7.2%
Projected growth in MA employment over next ten years (2020–2030)

UMass degree completions in fields related to sustainability

4,283
UMass degree completions in 75 related fields in 2018–2019

#1
UMass rank in degree completions among MA institutions

19%
UMass percent of all degree completions in related fields (2018–2019)

Simulations for sustainability

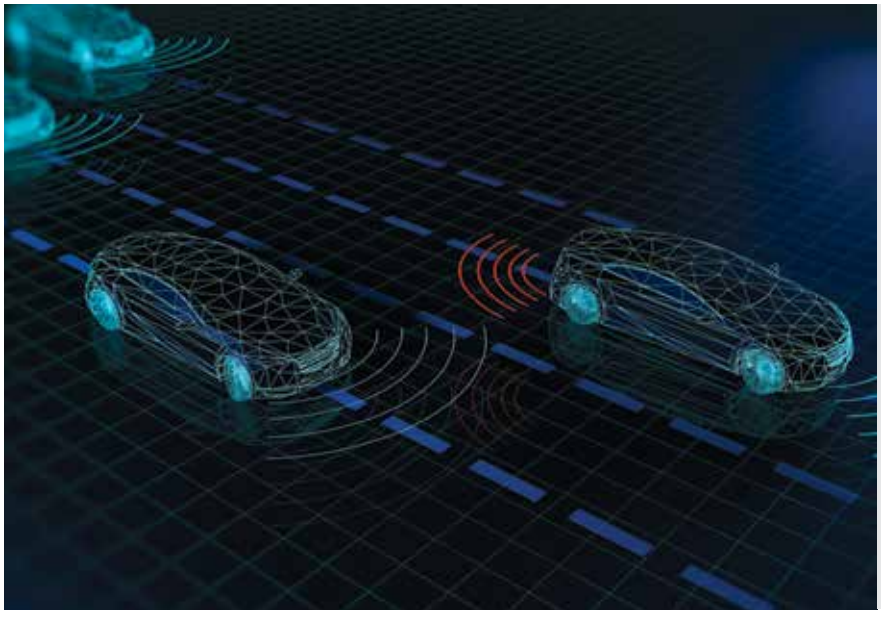
Emissions and traffic congestion can both be improved by getting people out of their cars and onto their feet. But that works only to the extent that cyclists and walkers feel safe alongside vehicles. UMass Amherst transportation engineers Michael Knodler and Eleni Christofa investigate how drivers behave around road features like bike lanes and bike boxes that are intended to improve safety and access for non-car travelers. Their observations, drawn from statistical analysis of crash data, field studies, surveys, and driving and biking simulators at the UMass Arbella Human Performance Laboratory, inform the design of safer, more sustainable streets.

Climate change is the environmental, social, and economic challenge of our time. It is also an opportunity to create sustainable systems in which economy, environment, and equity can all flourish.

The burgeoning blue economy is a case in point. In Massachusetts, the population, major urban centers, and economic activity are concentrated on the coast, as is the case globally. While this means that the Commonwealth is vulnerable to—and increasingly impacted by—sea-level rise, intensifying storms and floods, marine and coastal habitat loss, and saltwater intrusion on fresh water, it also means that opportunities exist for the state to build on its historic strengths to lead the transition to a sustainable future.

Innovation in marine science and technology can inform best practices for the emerging offshore wind industry. Sustainable fisheries and aquaculture can ensure food security and revitalize the fishing industry and its workforce. In these and many other facets of sustainable society—from transportation to green building—the actions of the Commonwealth can broadly inform coastal-resilience policy and practice worldwide, demonstrating the power of science-based solutions.

Facing and overcoming the climate crisis will require academia, government, and industry to forge new paradigms for the future together. That work has already begun, and UMass is proud to be a part of it.



Tomorrow's traffic

UMass Lowell engineer Danjue Chen received a five-year, $500,000 career-development award from the National Science Foundation in 2020, for her research into the complex interplay between self-driving and human-driven cars on the road. Chen will use the highly competitive CAREER award to continue modeling traffic around connected vehicles (which communicate wirelessly with other vehicles and road infrastructure) and automated vehicles, which both have the potential to increase fuel economy and reduce emissions.

Dig deeper

Sustainability and climate-resilience research is happening in labs and centers across the University of Massachusetts. Visit the links below to find out more about some of the work going on across the state and the researchers conducting it.

Climate and marine science research
Northeast Climate Adaptation Science Center (Amherst)
necsc.umass.edu

Massachusetts Marine Fisheries Institute (Dartmouth)
www.umassd.edu/mfi

MUST (Dartmouth)
must.umassd.edu

School for Marine Science & Technology (Dartmouth)
www.umassd.edu/smast

Coastal Systems Program (Dartmouth)
www.smast.umassd.edu/Coastal

Intercampus Marine Science Graduate Program
marine.massachusetts.edu

Climate System Research Center (Amherst)
blogs.umass.edu/csrc

Collaborative Adaptive Sensing of the Atmosphere (Amherst)
www.casa.umass.edu

Center for Coastal Environmental Sensing Networks (Boston)
www.cesn.org

Sustainable Solutions Lab (Boston)
www.umb.edu/ssl

Climate Change Initiative (Lowell)
www.uml.edu/research/climate-change

School of Earth & Sustainability (Amherst)
www.umass.edu/ses

Rist Institute for Sustainability and Energy (Lowell)
www.uml.edu/sustainability/Engagement/RISE

Coastal research stations
Gloucester Marine Station (Amherst)
www.umass.edu/ses/gloucester-marine-station

School for Marine Science & Technology (Dartmouth)
www.umassd.edu/smast

Stone Living Lab (Boston)
stonelivinglab.org

Nantucket Field Station (Boston)
www.umb.edu/nantucket

Renewable energy
POWER US Partnership (Amherst, Boston, Dartmouth, Lowell)
power-us.org

Wind Energy Center (Amherst)
www.umass.edu/windenergy

Center for Wind Energy (Lowell)
www.uml.edu/research/wind-energy

WindSTAR (Lowell)
www.uml.edu/Research/Windstar

Renewable energy (continued)
Wave energy conversion (Dartmouth)

The Energy Transition Initiative (Amherst)
www.energytransitionumass.org

McCormick School of Public Policy and Global Studies (Boston)
mccormack.umb.edu

Rist Institute for Sustainability and Energy (Lowell)
www.uml.edu/sustainability/Engagement/RISE

Center for Green Chemistry (Boston)
www.umb.edu/greenchemistry

Transportation and infrastructure
UMass Transportation Center (Amherst)
www.umasstransportationcenter.org

Arbella Human Performance Lab (Amherst)
www.ecs.umass.edu/hpl

Brack Structural Testing Facility (Amherst)
cee.umass.edu/news/structural-testing-facility-focuses-sustainable-infrastructure

Highway Sustainability Research Center (Dartmouth)
www.umassd.edu/pavement

Simulation, Modeling and Analysis of Reseal Time Transportation (SMART) Systems Lab (Lowell)

Urban Planning and Community Development (Boston)
environment.umb.edu/graduate-programs/urban-planning-and-community-development-ms

Food and water security
Department of Food Science (Amherst)
www.umass.edu/foodsci

Sustainable Food and Farming program (Amherst)
www.umass.edu/ses/program/sustainable-food-farming-bs

Urban Agriculture Program (Lowell)
www.uml.edu/sustainability/engagement/urban-agriculture

Energy Engineering Program (Lowell)
www.uml.edu/engineering/mechanical/programs-of-study/energy

Hydrosystems Group (Amherst)
blogs.umass.edu/hydrosystems

Water Resources Research Center (Amherst)
wrrc.umass.edu

Sustainable Marine Aquaculture (Boston)
online.umb.edu/programs/aquaculture_certificate

Department of Biomedical and Nutritional Sciences (Lowell)
www.uml.edu/Health-Sciences/biomedical-nutritional

Department of Fisheries Oceanography (Dartmouth)
www.umassd.edu/smast/departments/fisheries-oceanography

Massachusetts Marine Fisheries Institute (Dartmouth)
www.umassd.edu/mfi

University of Massachusetts

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