
UMA

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

The lab, launched in 2020 and operated in partnership with Boston

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 pro f table, 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.

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
- UMass Amherst's
- UMass Dartmouth's

UMass Lowell integrates its climate and sustainability efforts across the sciences, engineering, policy, education, arts, and business through its , which includes the UMass Lowell and

UMass Medical School contributes to the

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 study underpinning Boston's plans to invest in shore-based methods to

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

UMass Amherst's —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 (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 (CWE) co-leads , the country's only National Science Foundation-funded industry/university collaborative research center focused on wind energy. Both WEC and CWE are members of , 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 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 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 —home

Blue economy

Gloucester was the birthplace of the US

Today it's an epicenter of the region's

the World Bank as the "sustainable use of ocean resources for economic growth,

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

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

The conversion can be done with electricity and a catalyst, but typically uses rare-earth metals acquired through

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

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

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

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

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

focuses on traffic safety, traffic control, and intelligent transportation systems—road features that integrate advanced communication

technologies, like electronic toll collection and intelligent traffc signal control, both strategies for reducing congestion and emissions. The lab has also worked with MassDOT to quantify the emissions benefts of traffc-fow 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

and UMass Amherst's massive

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 effcient infrastructure planning.

UMass Boston's

focuses on sustainable, resilient urban infrastructure planning through its

program and

, as well as research foci in urban environments and policy and planning. The school has also carried out assessments of coastal fooding vulnerability under present and future climate changes for many of the highway and rail assets of MassDOT, including the Central Artery Tunnels. The coastal food model developed by its subcontractor, Woods Hole Group, is widely used through the Commonwealth to determine present and potential fooding.

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

at UMass Amherst was one of the frst 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.

UMass Amherst is also ranked #1 in the US and #4 in the world in agriculture by *US News & World Report*. The university's

program—the fastest-growing major in UMass Amherst's

—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. Affliated faculty are repurposing food waste and developing products from underused foods.

UMass Amherst's

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

, which operates a 1,800-square-foot urban agriculture greenhouse and urban farm with soil from compost generated from the

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.

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 are conducting research at the greenhouse with a focus on increasing the water- and energy-efficiency of food production.

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 at UMass Boston, led by environmental scientist Jennifer Bender, is dedicated to securing future seafood supply

Tomorrow's frontiers

forming the foundations of a climate-ready future.

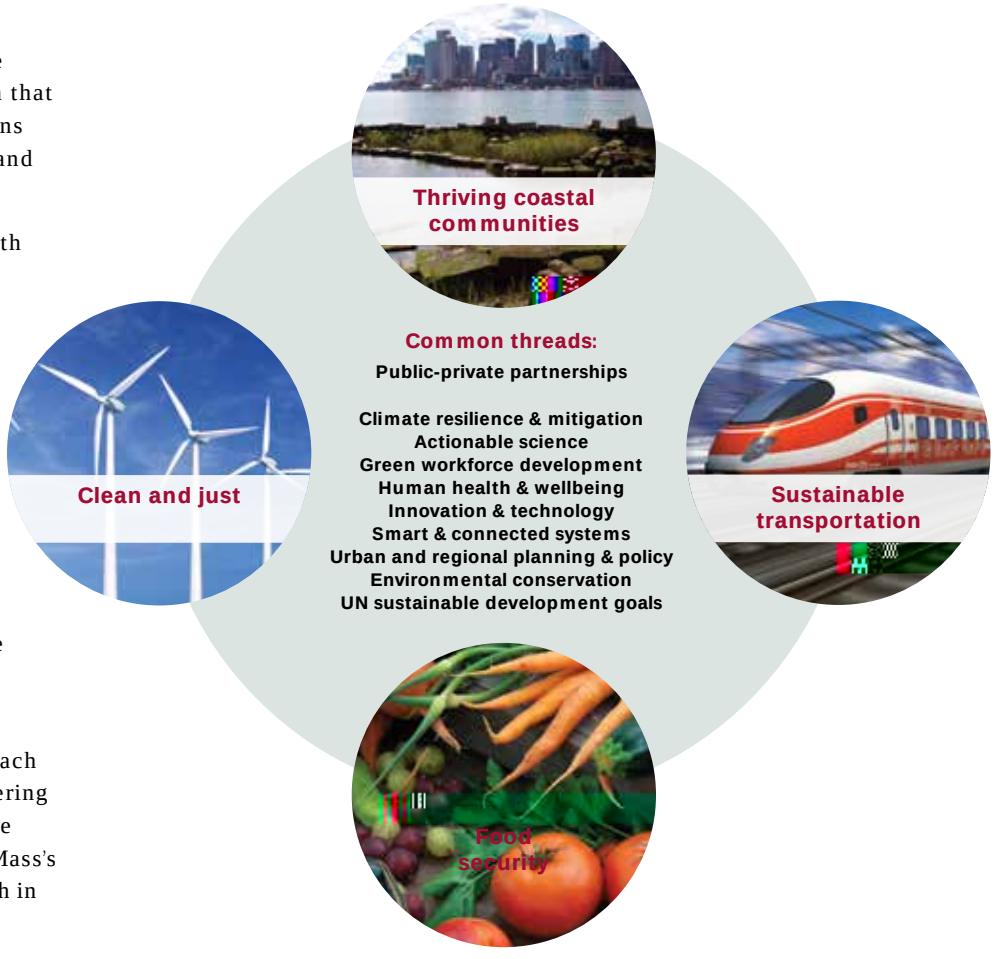
The strengths described on the previous pages boil down to this: UMass supports a flourishing ecosystem of researchers who are examining virtually every problem that the growing climate crisis threatens to throw at the Commonwealth—and finding solutions.

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.

Sustainability Grand Challenges



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 '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 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

Sustainable revitalization

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 , launched in 2019, is home to the , 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 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 , 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

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.

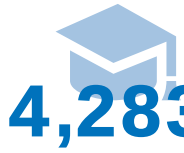
Over the next ten years, demand in the sustainability sector is projected to grow by 7.2 percent in the Commonwealth, almost twice as fast as the US Bureau of Labor Statistics' forecast for US employment as a whole. Employers will need to fill an estimated 46,900 job openings between now and 2030.

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

UMass degree completions in fields related to sustainability



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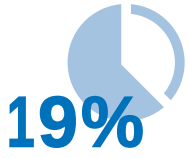

19%

related fields

Simulations for sustainability

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

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.

Dig deeper

across the University of Massachusetts. Visit the links below to ﬁnd out more about

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