SUSTAINABILITY REPORT 2017-18

wpi.edu/+sustainability
green@wpi.edu

WPI

Pause for a moment.

Draw in a breath.

Let it out.

Look around.

Think about it:

What is sustainability? How does one act sustainably?

TABLE OF CONTENTS

Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609
wpi.edu/+sustainability
green@wpi.edu

A MESSAGE FROM PRESIDENT LESHIN

I am proud to write to you to introduce the important sustainability work WPI has accomplished this year. As with so much of our scholarship and research at WPI, we view sustainability through a global lens. The work we undertake on campus has a direct impact on our community, our country, and our world. Over the past year, we have focused our sustainability efforts on student and faculty research projects, engagement, and infrastructure. Taken together, I am proud that WPI continues to be a leader in sustainability and remains at the forefront of environmental technologies.

Through projects and research, WPI's undergraduate and graduate students are developing technological solutions to societal problems across the globe. Interactive Qualifying Projects (IQPs), our distinctive undergraduate interdisciplinary team projects, focused on topics such as single-use waste plastics in Costa Rica, community clean water access in Paraguay, and urban farming in Copenhagen. Closer to home, students are supporting local organizations through our project centers like the Worcester Community Project Center and the Massachusetts Water Resources Outreach Center. Examples of Major Qualifying Projects (MQPs), our undergraduate capstone projects, include rainwater energy harvesting, hydrothermal liquefaction of food waste, and design of sustainable pavements.

Our faculty continue to engage in collaborative and multidisciplinary research that advances the development of new materials, methods, and technologies in labs and centers on campus. For instance, the Center for Resources Recovery and Recycling (CR3), the WPI Fuel Cell Center, and the Center for Advanced Research in Drying all made national news in the past year for their impact on industry.

Engagement and culture change are key parts of prioritizing sustainability. On campus, our students and faculty are working and learning together to bolster the impact of our institution and our graduates' current and future contributions. Over the past year, WPI student engagement in sustainability has continued to expand due to our eco-representative programs, outreach of the student sustainability leaders roundtable, and events held by numerous sustainability-themed student clubs.

In terms of infrastructure, WPI just opened its fifth LEED certified building. Our new Foisie Innovation Studio and Messenger Residence Hall, designed and built to LEED Gold specifications, combines living and learning in 78,000 square feet. As the world's most widely used green building rating system, LEED (Leadership in Energy and Environmental Design) provides a framework to create healthy, highly efficient and cost-saving green buildings.

Additionally, we have retrofitted a dozen academic and administrative buildings for energy efficiency and resource conservation, and we supported three energy efficiency and conservation projects in 2018 through our Green Revolving Fund. This fund provides financing for sustainability projects that provide energy conservation and waste reduction, resulting in cost savings that can be returned to the fund over time.

I encourage our community to celebrate our accomplishments in sustainability, and continue this active engagement as we move forward. Over the next year, we will accomplish two important initiatives: a review of and update to our current Sustainability Plan, and the launch of the Green Revolving Fund's Community Initiative, for which a portion of the GRF has been specially allocated for on-campus projects proposed by the WPI community. These endeavors serve to guide the way to a more sustainable WPI and worldwide community in the future. Please learn about them and plan to be part of these efforts.

Laurie Leshin
President, WPI

SUSTAINABILITY REPORT 2017-18
Executive Summary

wpi.edu/+sustainability
green@wpi.edu

WPI's Sustainability Plan, completed in 2014, established goals in the areas of Ecological Stewardship, Social Justice, and Economic Security. The 2017-18 Sustainability Report describes WPI's progress in FY18 towards meeting these goals. This executive summary provides a brief overview of some of the highlights in academics, research and scholarship, facilities and operations, and community engagement. More detail can be found in the following full report.

Academics

By integrating sustainability throughout its academic programs, WPI provides graduates an understanding of sustainability, and the ability to develop sustainable solutions to the world's problems. WPI's project-based curriculum provides WPI graduates the foundation for developing technological solutions to sustainability problems, and understanding the social and environmental impacts of their solutions. Sustainability enters WPI's academic programs through a wide array of activities, including:

- More than 100 sustainability-related courses
- 21 projects entered in the 10th annual Sustainability Project Competition
- 8 Great Problem Seminars addressing sustainability, including topics such as Feed the World and The World's Water
- More than 45 Global Project Centers and dozens of IQPs and MQPs focused on sustainability topics
- Over 40 Lectures and seminars related to sustainability hosted both campus-wide and by departments from Fire Protection Engineering to Computer Science
- Named a Grand Challenge Scholars School by the National Academy of Engineering

Research and Scholarship

Through WPI's research and scholarship activities, faculty and students strive to ensure a sustainable world. WPI's research addresses a variety of topics in sustainability, extending beyond the scope of this summary. A selection of recent research topics is included in this Sustainability Report, and other topics can be found throughout WPI's web pages. Some of the key features of WPI's research include:

- Approximately $2.9 million in grants for sustainability-related research projects
- More than 60 faculty research projects related to sustainability, including topics on biofuel, durable infrastructure, process design, fuel cells, and many more

What is sustainability?

Why does it matter?

What can we do about it?

Campus Operations

WPI has continued to make progress in the operation of campus facilities, including a number of initiatives to reduce energy consumption and waste generation. These initiatives include the WPI Greenhouse Gas Reduction Plan, Green Revolving Fund, and Green Purchasing Policy. Some of the measures and challenges associated with our progress are as follows:

- 4% decrease in natural gas consumption per FTE per heating degree day (HDD) from FY17 (8% decrease in natural gas consumption per FTE per HDD from FY14)
- 2% decrease in electricity consumption per FTE from FY17 (9.8% decrease
- in electricity consumption per FTE from FY14)
- 9.5% decrease in Scope 1 and 2 greenhouse gas emissions from FY14
- 27.1% recycling rate (3.7% decrease in recycling rate from FY14)
- 7% increase from Fiscal Year (FY) 17 in water consumption per full time equivalent (FTE)

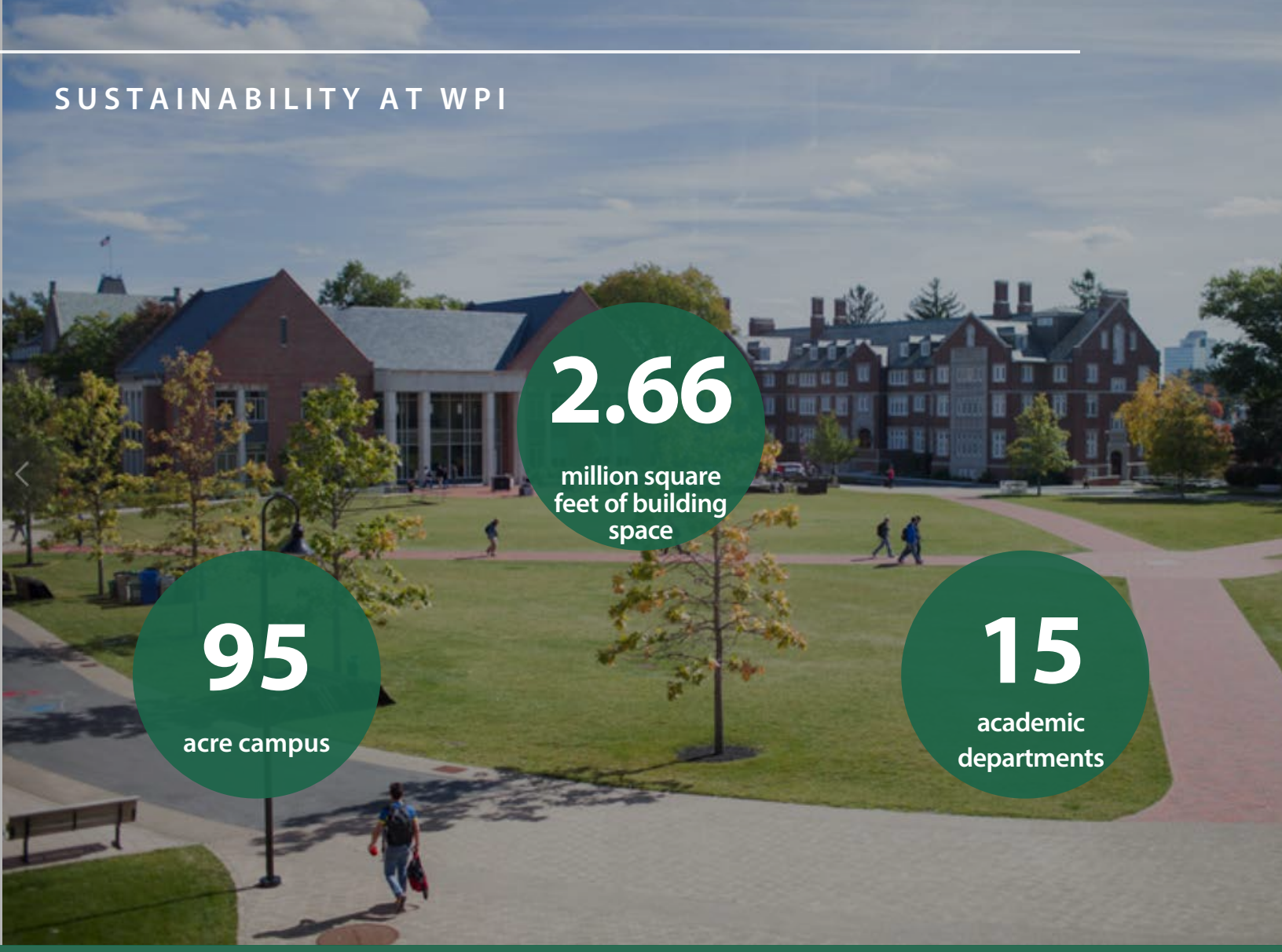
Community Engagement

WPI continues to expand its impact through community service and outreach. The university's project-based programs, along with its network of clubs and organizations, continue to promote a culture of sustainability to enhance the welfare of our communities on campus and beyond our campus. A few of the key attributes include:

- More than 29,000 community service hours
- Eight clubs/organizations highly engaged in sustainability, with many others providing benefits
- Gompei's Gears Bike Share Program, including 18 bikes allowing users to take thousands of rides
- Six free electric vehicle chargers with over 45 unique users per month
- New Sustainability Literacy Survey given to incoming freshmen at start of year and to all of the WPI community at end of year

This report is intended to provide an understanding of the nature and impact of sustainability activities throughout the WPI community, and insight into answers to questions above.

SUSTAINABILITY AT WPI



Sustainability - it's an idea that has been implicit in WPI's mission since 1865, and has been reiterated explicitly within the past decade.

In 2007, the WPI President's Task Force on Sustainability (now the Sustainability Advisory Committee) was established to coordinate efforts around the sustainability of academic, research, and facilities-related activities and to lead the campus toward a broader understanding of sustainability in support of WPI's educational mission.

The Sustainability Advisory Committee produced the WPI Sustainability Plan in 2014, which will be under a 5-year-review during the 2018-19 school year. The Plan called for the creation of a formal Office of Sustainability and a Director of Sustainability position; both were established in May 2014. This past year, the Office of Sustainability devised WPI's first formal Greenhouse Gas Reduction Plan, which was presented to the WPI community in July 2017.

The document you are reading now, the WPI Sustainability Report, was first published as a student Interactive Qualifying Project (IQP) in 2010 documenting sustainability at WPI. The Report has been published annually since then, recording new sustainability activities and continuous progress in four key areas of WPI: Academics, Research and Scholarship, Campus Operations, and Community Engagement.

Why these four sections? They provide a useful set of categories for developing and evaluating our progress towards our sustainability goals. The first two sections are the goals and main focus of the university: Research, to create and discover knowledge, and Academics, to convey that knowledge and the skills of discovery. Operations, the third section, details how the university functions on a physical level - the use, management, and amount of resources on campus. This section focuses on comparison with previous years to reveal trends in resource usage. The fourth section, Community Engagement, explores how the members of the WPI community interact, share, and communicate about sustainability with activities and events on campus, in Worcester, and around the globe.

This year's 2017-2018 Sustainability Report, the 9th report of its kind, addresses the 2018 Fiscal Year, from July 1, 2017 to June 30, 2018.

The report offers snapshots of sustainability at WPI: quantitative data in operations and the number of sustainability-related courses, and qualitative notes on academic and campus activities.

The hope of this report is to provide an understanding of the nature and impact of sustainability activities throughout the WPI community, which will assist the university in its sustainability decisions going forward.

Overall, this report is intended to provide insight into the question: what does sustainability mean at WPI, and how do we, the WPI community, apply it to our actions?

**Full time equivalent*

ACADEMICS

At WPI, learning has always been about theory and practice, and sustainable solutions must incorporate both. On the one hand, advances in theory provide new insights into how to best address current sustainability issues; on the other hand, these ideas must be put into practice in order to have any effect.

Students typically begin their discovery of technical solutions to sustainability issues in classrooms, where they increase their awareness and knowledge of sustainability issues. This knowledge is then applied in class projects like the Great Problems Seminars, Interactive Qualifying Projects, Major Qualifying Projects, Graduate Qualifying Projects, and research.

By integrating sustainability throughout its academic programs, WPI seeks to create graduates who leave campus with an understanding of, and the abilities to develop sustainable solutions to, the world's problems. These graduates will take into account the social and environmental as well as the technological impact of solutions - because how can you address a problem if you don't address the people it affects and the environment in which it occurs? From WPI, graduates will take with them knowledge and experience that they will apply to sustainability issues on a global scale for the rest of their lives.

COURSES

Renewable Energy, the *System Dynamics* of water resource models, the *Environment in Philosophy and Literature* - these courses exemplify how facets of sustainability are pervasive throughout the WPI curriculum. To the right is a sampling of courses related to sustainability offered during the 2017-2018 academic year, with course descriptions abstracted from the 2017-18 WPI Undergraduate and Graduate Catalogs.

In 2017-18, WPI offered:

103 Undergraduate courses related to sustainability

28 Graduate courses related to sustainability

And continues to add new sustainability-themed courses and research opportunities.

UNDERGRADUATE

Architectural Engineering 3026:
Building Envelope Design
Presents the basic principles of building envelope design, including double skin facades and passive solar design.

Gov. Political Science, & Law 2319:
Global Environmental Politics
Examines international institutions coordinating efforts around such global debates as deforestation, biodiversity, and climate change.

Economics 2117:
Environmental Economics
Investigates the effect of human activity upon the environment and vice versa, challenges with government intervention, pollution and scarcity, and the costs and benefits of improving environmental conditions.

Biology 1002:
Environmental Biology
A broad overview of natural ecosystems, population growth, and the interaction between human populations and our environment.

Chemical Engineering 3702:
Energy Challenges in the 21st Century
An overview of energy production challenges. Topics include fossil fuels, the hydrogen economy, biofuels, nuclear energy, fuel cells, batteries, and the electricity grid.

Philosophy 2717:
Philosophy and the Environment
Explores: what is the scope of the current environmental crisis? What does this reveal about our worldviews and social institutions? What moral and spiritual resources can help us respond?

GRADUATE

Civil Engineering 562:
Biosystems in Environmental Engineering
Topics include: application of microbial and biochemical understanding to river and lake pollution, natural purification processes, and biological aspects of wastewater treatment.

System Dynamics 561:
Energy & Environmental Dynamics
Develops proficiency in system dynamics simulation of energy and environmental problems using case studies such as the complex tradeoffs in the management of large river basins and accelerated eutrophication of fresh-water lakes.

LECTURES & SEMINARS

Which lectures and seminars?

WPI hosts campus-wide sustainability lectures throughout the year, and various WPI organizations and academic departments ranging from the Foisie Business School to the Fire Protection Engineering Department offer frequent seminars and dissertations on sustainabiity-related topics.

Why host them?

To take a step toward WPI's goals of prompting people to think; of causing them to re-evaluate their worldviews, their actions, their society, and their technology; and of encouraging them to talk with each other about it.

To introduce the community to sustainability topics in the most interesting and easiest way possible: by having an expert - someone deeply engaged in, knowledgeable, and passionate about their field - curate the most relevant information on the subject, and then share it.

Below is a selection of the lectures from this year:

Sustainability and Social Justice: Wicked Problems

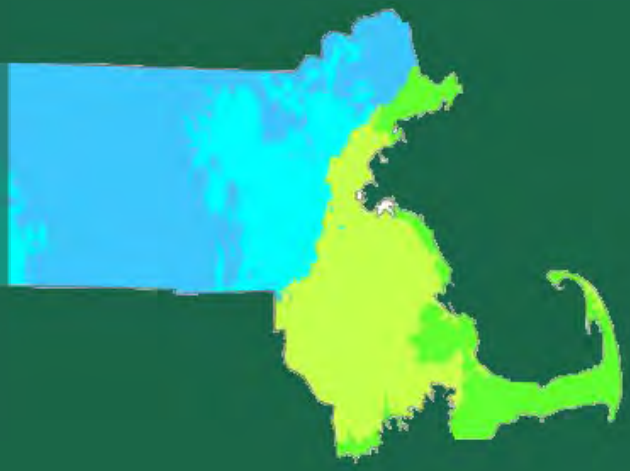
By WPI Professors Laureen Legert, Rob Krueger, Patricia Stapleton, and Elisabeth Stoddard

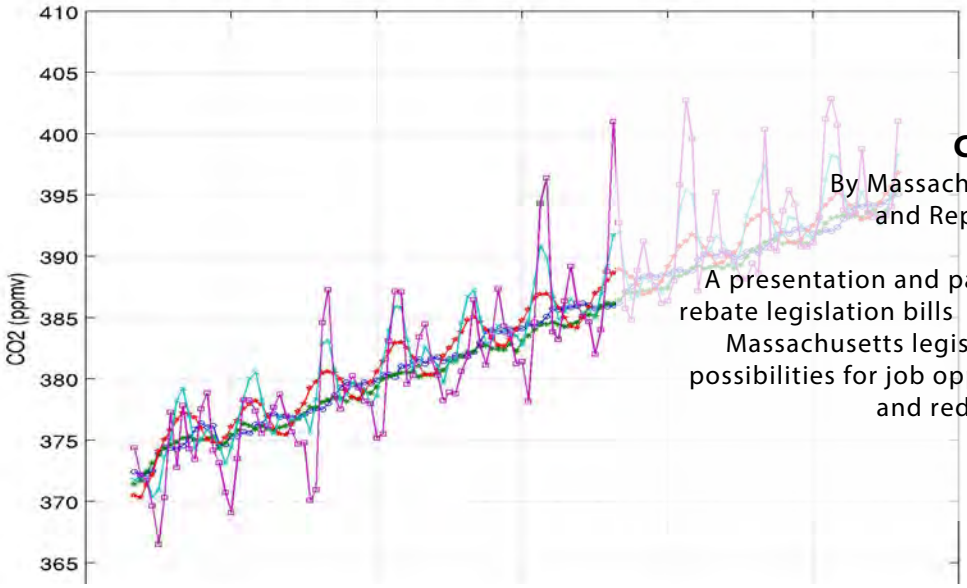
A presentation and round-table discussion on the double edge of cutting edge city sustainability indicators, political framing of "sustainability," post-sustainable development practices in the western Balkans, and making sustainability inclusive and equitable.

Implementing an Integrative Climate Change Strategy for the Commonwealth

By Kathleen Theoharides
Assistant Secretary of Climate Change for the Commonwealth of Massachusetts in the Executive Office of Environmental and Energy Affairs

An overview of Executive Order No. 569, signed in 2016 by Governor Baker to establish an integrated climate change strategy for Massachusetts working across the government, communities, and infrastructure.





Carbon Pricing

By Massachusetts Senator Mike Barrett
and Representative Jen Benson

A presentation and panel discussion on the carbon fee and rebate legislation bills sponsored by Barrett and Benson in the Massachusetts legislature (S. 1821 and H. 1726) and the possibilities for job opportunities, better health for residents, and reduced carbon emissions.

Melting of Ice and Formation of Lateral Cavity during In Situ Burning in Ice-Infested Waters

A Fire Protection Engineering PhD Dissertation by doctoral candidate Hamed Farmahini Farahani

Recycling of Passenger Vehicles

A Materials Science and Engineering PhD Dissertation by PhD candidate Sean Kelly

Scalable User Assignment in Power Grids

A Computer Science Masters Thesis presentation by masters candidate Shijian Li

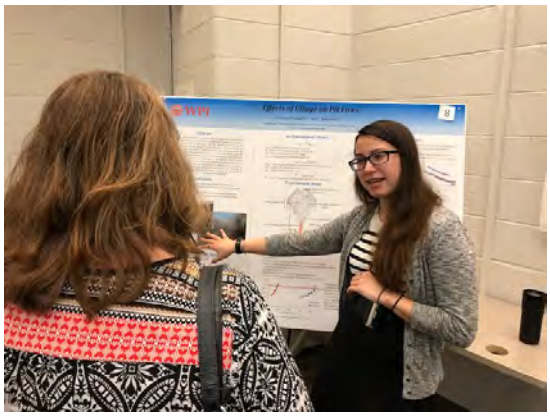
10th ANNUAL SUSTAINABILITY PROJECT COMPETITION: Envisioning Sustainable Futures

The 10th annual **Sustainability Project Competition** took place in April in Gordon Library and featured 21 projects by freshmen through graduate students, on topics ranging from Design of Sustainable Pavements to Farming Without Harming. Sustainability spans every field, from electrical engineering to civil engineering to social systems. It is important to everyone, from freshmen to graduate students to faculty and staff. Yet issues in sustainability are all too easily overlooked. The goal of the competition is to spark a cycle of recognition, interest, and action throughout the community with projects that have impact in industry and everyday life, in Worcester and beyond. The prizes went to the winner in each of three categories:

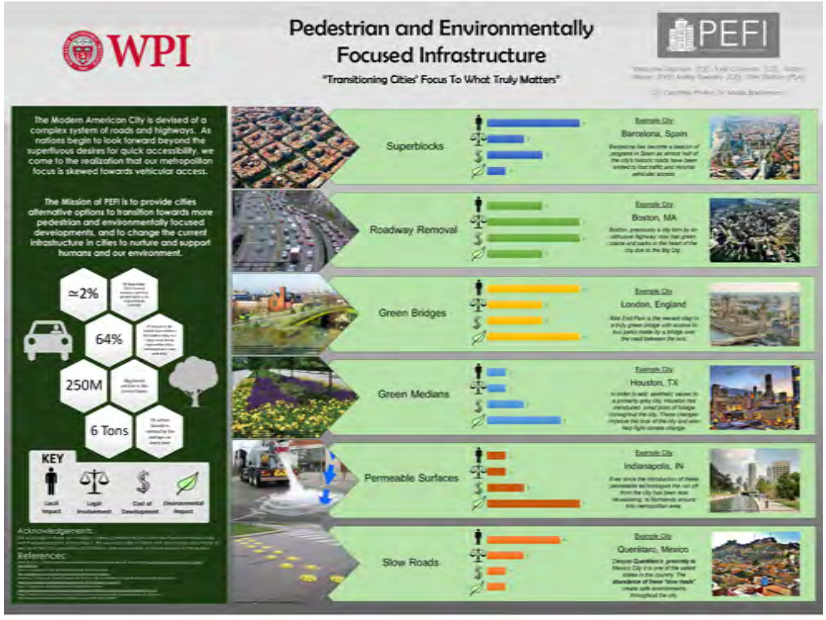
Graduate: Effects of Ullage in Pitfires (pictured right)
By Veronica Kimmerly
Advisor: Ali Rangwala

Upperclassman: Sorting of Automotive Manufacturing Wrought Aluminum Scrap (pictured above)
By Shady Zummar
Advisor: Diran Apelian

First-Year: Closing the Grocery Gap in Worcester: Redesigning the Bioshelter for Maximum Sustainability and Efficiency
By Jacqueline Kral, Jameel Gammal, and Audrey Berner,
Advisors: Kristin Wobbe, Lisa Stoddard



GREAT PROBLEMS SEMINAR (GPS) - FIRST YEAR



Now it its 11th year, WPI's **Great Problems Seminar** (GPS) is a two-term course that immerses first-year students in research on the great opportunities and quandaries facing the global population, culminating in a project which addresses an aspect of those challenges.

WPI's GPS program allows students and faculty to depart from their declared disciplines and examine a wide range of the world's most critical challenges, from food access to infrastructure design, all of which pertain to an aspect of sustainability.

2017 GPS POSTER COMPETITION WINNERS INCLUDE:

Pedestrian and Environmentally Focused Infrastructure (poster above)

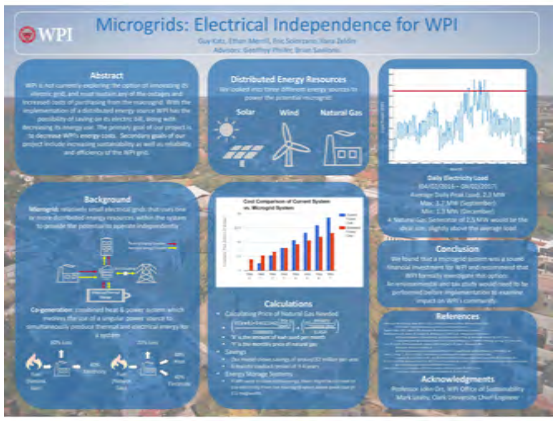
By Kyle Coleman, Aidan Mayer, Kelley Townley, Kristophe Zephyrin
Advisors: Marja Bakermans, Geoffrey Pfeifer

Microgrids: Electrical Independence for WPI (poster right)

By Guy Katz, Ethan Merrill, Eric Solorzano, Ilana Zeldin
Advisors: Geoffrey Pfeifer, Brian Savilonis

Angolan Housing Design for Congolese Refugees

By Alisha Anderson, Sophie Antoniou, Abigail O'Sullivan, Hannah Schulz
Advisors: Courtney Kurlanska, Soroush Farzin-Moghadam



GPS courses offered during academic year 2017-18:

- Designing Process: Living on the Edge
- Extinction: Who Will Survive?
- Feed the World
- Heal the World
- Humanitarian Engineering: Past and Present
- Ignorance Is Not Bliss: Can Schools and Technology Help?
- Livable Cities
- The World's Water

The I**nteractive Qualifying Project** (IQP) is a junior-year team project, generally not directly related to the student's major area of study but instead focusing on the relation between technology and society. Hence, a large percentage of these projects address an aspect of sustainability.

GLOBAL PROJECTS FOR ALL

From the moment we set foot outside our hometowns, we begin to see things from a different perspective. We begin to see that in other places, other people often understand the world differently and act in dissimilar, sometimes more sustainable ways than we do. Study abroad is about the chance to see the world in a different light - both what's different about it, and what's the same. It's about seeing how the choices we make in our own lives play out in the lives of people who live across the globe.

That's why beginning with the class of 2022, every new first-year, full-time, degree-seeking student at WPI will receive a Global Project Scholarship, a credit of $5,000, to defray the cost of an off-campus project. Why travel somewhere else when you could stay where you are? Because it helps us realize that we all deal with the same problems, but that there are many different approaches to addressing them. Because it helps us see that, despite our differences, we all live on the same Earth.

PRESIDENT'S AWARDS

The President's IQP Awards are given to student teams whose conception, performance, and presentation of their Interactive Qualifying Projects (IQPs) were judged outstanding in focusing on the relationships among science, technology, and the needs of society. Winners often include sustainability-themed projects.
This year's finalists included:

A Citizen Science Platform for Long-Term Monitoring of Microplastic Pollution in Port Phillip Bay
By Andrea Bayas, Maura Buckley, Cierra Ford, Javier Lawes
Advisors: Stephen McCauley, William Michalson

A Recommended Recycling Processing System for the Informal Waste Collectors of Oshakati, Namibia
By William Bennett, Emily Chretien, Sophia Gomarlo, Peter Hurley
Advisors: Robert Kinicki, Sarah Wodin-Schwartz

Stormwater Management Educational Materials for Central Massachusetts Municipalities
By Alex Legere, Anthony Perullo, Amy Toscano, Justin Waters
Advisors: Corey Dehner, Purvi Shah

SELECTED IQP PROJECT CENTERS

WPI has over 40 off-campus project centers as well as 4 on-campus project centers. Many IQPs focus on various aspects of sustainability, from transportation to waste disposal. Below is a selection from the sustainability-related IQPs from this year:

Australia Project Center
Promoting Sustainable Homes: Expanding Sustainability Outreach
By John G Bauer, Syed Ayaz Naeem, Jerome Peter Santos, Richard Charles Smith
Advisors: Katherine Foo, Lorraine Higgins

Morocco Project Center
A Sustainable Future in Agriculture: An Investigation into Support Systems for Natural and Organic Farmers in Morocco
By Sarah Jonell Boecker, Shahnaz Isabella Ghahremani, Maggie Kuck, Shane Michael O'Dell
Advisors: Bethel Eddy, Robert Kinicki

Paraguay Project Center
Native Community Solid Waste Management
By Jorge Luis Castillo, Alicia Costi, Cassidy Marcelle Sequin
Advisor: Robert Traver

Thailand Project Center
Reducing Single-Use Plastic in a Thai School Community: A Sociocultural Investigation in Bangkok, Thailand
By Keely Heyer, Kelly Martin, Emily Paige Molstad, Paula Sardi
Advisors: Esther Boucher, Steven Taylor

Massachusetts Water Outreach Center
Stormwater Runoff Reduction on the Worcester Polytechnic Institute Campus
By Celeste Marsan, Blayne Patrick Merchant, Ryan Kenneth Racine, Benjamin James Secino
Advisor: Corey Dehner

Sustaining WPI On-Campus Project Center
Waste Reduction Through A Reusable Container Program
By James Sean Curtin, Shea Robert Mooney, Stephen J Peccerillo
Advisors: Suzanne LePage, Derren Rosbach

Sustainable Food Systems Project Center
Sustainable Technologies [in New England Small Chicken Operations]
By Jared Grier, Karen Mushrall, Kyle Howard Tyler
Advisor: Elisabeth Stoddard

MAJOR QUALIFYING PROJECT (MQP) - SENIOR YEAR

Once you graduate, what will you be able to *do*?

To answer this question, all students at WPI complete a **Major Qualifying Project** (MQP), a team-based, professional-level design or research experience that allows them to demonstrate mastery in their field. Students also learn effective communication skills and how to weigh the scientific, social, and ethical dimensions of a problem. The tie between technology, society, and the environment is an important element of sustainability.

Below is a selection from the MQPs from the 2017-18 school year which relate to sustainability:

Provost's Award:
The Homelessness Reduction Act of 2017
By Tess Hudak
Advisors: Patricia Stapleton, Jennifer DeWinter, Dominic Golding

Provost's Award:
Collapsible Temporary Housing Design and Optimization
By Reid Billings, Michael Morlock, Jack Nigro, Ryan Rigney, Nasjela Thodhonagi
Advisor: Sarah Wooden-Schwartz

Design of a Bicycle- and Solar-Powered Lighting System for Rural Vietnamese Students
By Cassondra Dale, Emilee Gancarz, Chau Tran
Advisor: Fred Looft

Disposable Mentality:
Evaluating the Reusable Container Program By
By Emma Brimdyr
Advisor: Patricia Stapleton

Jet Blast Energy Harvester
By Constantine Christelis, William Dziuban, Jessica Norman
Advisor: Fiona Levey

Sustainable Pavement Design by Recycling
By Basliel Teferi Demessie, Guilherme Motta Baracchini, James Vorosmarti
Advisor: Rajib Mallick

Sustainable Rooftop Technologies:
A Structural Analysis of Buildings at WPI
By Sebastian Miranda, Ryan Stokes, Ian Alexander Taylor
Advisor: Leonard Albano

WPI offers degree programs in Environmental Engineering (BS and MS), Environmental and Sustainability Studies (BA and minor), and a recently approved minor in Sustainability Engineering. In addition, sustainability is integrated into the curricula for many of the degree programs at WPI. Students can complete concentrations in sustainability in a wide range of fields, including Architectural Engineering, Civil Engineering, and Mechanical Engineering. At the graduate level, WPI offers certificates in Renewable and Distributed Power Systems, Water Quality Systems, and Water Resources.

RESEARCH AND SCHOLARSHIP

Have you ever changed the amount of sugar in a recipe? Skipped differently shaped rocks to see which travels farthest? This is research on a small, everyday scale. Research at a university differs in many aspects from these everyday examples, but it shares the same purpose: investigation and experimentation aimed at the discovery and interpretation of facts, the revision of accepted theories in light of new facts, or the practical application of theories. It is the search for knowledge to improve our lives and practices.

Research in sustainability matters now not only because the world is changing (it is always changing) but because *we* are changing it. Where will we be if our knowledge does not change with us?

WPI's research addresses a variety of topics in sustainability, covering a range that extends beyond the scope of this summary. The following descriptions provide a sampling of the research completed at WPI over the past year on sustainability-related topics. including a handful of in-depth descriptions and a number of shorter summaries. Other topics can be perused on WPI's web pages.

BIOFUEL

If you have ever scraped leftover mashed potatoes into your kitchen trash can, you have encountered what many institutions - from supermarkets to universities to amusement parks - generate on a copiously larger scale: food waste.

The ideal would be to not waste the food at all. But, barring that, can we make the waste into something useful - like fuel?

Chemical Engineering Professor **Michael Timko** and his research team are pursuing this goal. Their work focuses on increasing the yield of hydrothermal liquefaction - a process that turns organic matter like food, known as biomass, into a fuel similar to crude oil. Hydrothermal liquefaction is renewable and it approaches carbon neutrality: the carbon dioxide produced during combustion is offset by the carbon dioxide absorbed during the photosynthesis of the plants that compose the biofuel.

Timko and his researchers combine waste food with water to make wet biomass. They place the biomass under pressure and heat it to around 300℃. The combination of heat and pressure breaks apart the polymers - the fats, lipids, proteins, and carbohydrates - in the food into four phases: oil (biofuel), solid char, impure water, and gas.

This process is not new - it's been developing since oil prices spiked over 50 years ago, causing people to begin exploring alternate fuel sources. The problem with it isn't new either: only about a quarter of the energy in the food waste is recovered. A large fraction of the organic compounds stay in the water phase and remain waste products that are not converted to biofuel.

Timko is testing new materials to catalyze the process. Adding catalysts to the reaction can reduce the amount of carbon compounds lost to the water phase, thereby increasing oil yields and decreasing water phase contaminants. Traditionally, scientists have employed soluble catalysts such as sodium carbonate (Na_2CO_3). Instead of soluble catalysts, however, Timko is using solid catalysts like cerium zirconium mixed oxides, red clay, and hydroxyapatite, a component of bone. Solid catalysts don't dissolve, so they can be separated after the reaction and do not need to be neutralized and disposed of afterwards.

Timko's team has achieved proof of concept: solid catalysts can greatly increase the amount of oil recovered while decreasing carbons lost in the water phase. Their continued research means more and more of what was food waste can be transformed into usable energy.

DURABLE INFRASTRUCTURE

Imagine that you're five years old. You've built the masterpiece of all masterpieces in your living room: a block tower unrivaled by any block tower built by anyone else ever. It is complete and perfect and will stand forever, but now it's snack time and you wander off to find something to eat.

An hour later you ramble back into the living room to find that your little brother has completely obliterated your tower, scattering blocks all across the floor. Now exchange your block tower for a highway, your 5-year-old self for a construction team, the hour-long snack break for a decade, your little brother for snow and water and heat waves and trucks.

What happens to both your block tower and the highway? The infrastructure you built breaks down.

"Originally I thought it was a purely technical problem, that potholes were everywhere because asphalt was bad. But there's a social aspect to it, too: it's really easy to build infrastructure, but no one plans for the maintenance, for the entire life of the system."

- Aaron Sakulich, Professor of Civil & Environmental Engineering

Infrastructure that breaks down means frequent repairs, which means more traffic and emissions around construction, and more wasted materials. That's why Professor **Aaron Sakulich**'s research, and the work of Civil and Environmental Engineering Professor **Rajib Mallick** and his Pavement Research Group, focus on new, more durable, longer-lasting materials and methods.

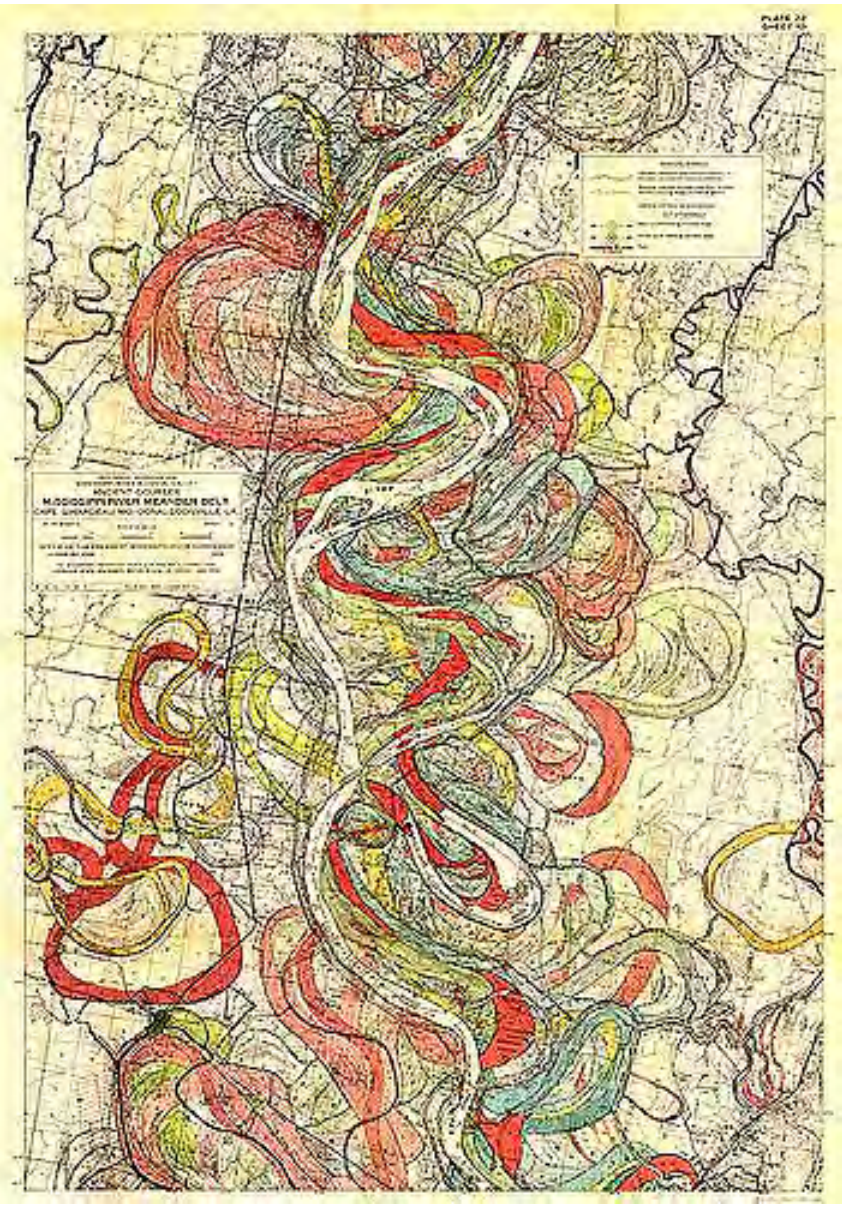
Sakulich has been working on self-healing coatings to prevent corrosion of steel rebar in concrete. Concrete is really good at withstanding squishing (compressive forces), but if you pull on it a little (tensile forces) it comes apart. That's why everything - bridges, buildings, dams - is built out of steel-reinforced concrete: steel is good at withstanding tensile forces. The two work together to keep the building standing.

But over the building's lifetime, water and salts work their way slowly through the concrete to the steel bars, causing them to rust. Rust takes up more space, due to its chemical structure, than the iron atoms in the steel did. Recall that concrete cannot long tolerate tensile forces: once a little rust builds up around the steel rebar inside the concrete, it stretches the concrete, which eventually breaks, which allows more oxygen in, which means more rust, which means more stretching.

One solution to the rusting problem is epoxy-coated rebar. The coating prevents oxygen from getting to the metal, but only if the coating is intact. Sakulich is working on a self-healing coating that will repair itself if it gets damaged during construction or transport to the construction site. Sakulich and Chemical Engineering Professor **Amy Peterson** have been researching microencapsulated tung oil. The tung oil is mixed with water and a catalyst to form tiny droplets with solid outer shells (microcapsules), then mixed into the epoxy and painted onto the rebar. When the coating is damaged, the polymer shells break and the oil spills out, forming a new coating on the metal to prevent water, salt, and air from getting through.

Meanwhile, Mallick and his Pavement Research Group are working on sustainable roadways: longer-lasting, more durable materials for roads. Moisture damage from rain and freeze-thaw cycles in winter and spring are the principal causes of rapid pavement deterioration all over New England. Funded by the New England Transportation Consortium (NETC) as well as the Maine Department of Transportation (DOT), Mallick has been studying the moisture susceptibility of pavements and developing analysis techniques to identify poor quality materials and mixes accurately in a short period of time. This work will help transportation departments make highly accurate predictions regarding performance of materials during mix design, which means significantly reduced risk of failure of pavements due to moisture damage, and hence longer-lasting pavements that are resilient to extreme events.

MISSISSIPPI RIVER MAPS



In the 1940s, U.S. Army engineers undertook a massive research project to map the courses of the Mississippi River over the past 10,000 years. Why? Because the river was ready to change course - to "jump."

Over time, rivers erode their banks, deposit sediment in other areas, and gradually alter their courses. As shown in the map on this page, over the last few thousand years, the Mississippi has charted courses hundreds of miles apart because of this process.

What does this have to do with sustainability? Well, the earth is a big system, and everything has repercussions, many of which relate to sustainability.

Just after World War II, a third of the Mississippi's water was flowing down another course. Based on the pattern of deposition and water flow, the waterway showed every sign of jumping entirely onto that path. It if had done so, New Orleans would have perished as a port city, and every other city along the Mississippi's current path would have faced similar repercussions.

For that reason, the U.S. Army mapped the river's past courses to understand its flow. Then they built a control station to stop the water from changing course again. It took, and continues to take, massive amounts of energy, construction, and reconstruction, but the Mississippi still flows through New Orleans today.

Professor **David Spanagel** is studying the maps of the Mississippi's courses and their usage. Spanagel's field is the history of science: how we arrived at our current state of knowledge, how knowledge changes, and what constraints limit and guide that change. His research prompts questions about the maps' usage and the methods behind them, especially in relation to sustainability.

"All that work in the 1940's shows that the river is going to move," says Spanagel, "and then all of our underlying ingenuity goes to stopping it."

The project raises many questions. For example, which solutions are more sustainable over time: the ones that pit humanity against the environment in a fight for control, or the ones that allow us to work with our environment in adaptable and renewable ways?

MICROWAVE POWER TRANSMISSION

Mathematics Professor **Vadim Yakovlev i**s studying microwave power transmission. Microwave power transmission could be used in any situation where you can't get energy through wires: a house on a mountain, a temporary camp, or distant construction zone. Important factors such as health risks from high density microwave power transmission must be considered, but the technology could be used in situations such as the transmission of solar energy from satellites and reduce the cost, resources, and energy of power line construction.

NET-ZERO NEIGHBORHOODS

Architectural Engineering Professor **Soroush Farzin-Moghadam** and his team study net-zero neighborhoods: neighborhoods which produce a balance of zero total emissions for all systems: all of your food is grown and eaten or repurposed there, the same amounts of water and energy are produced as used, everything that is waste for you is used by someone else and vice versa.

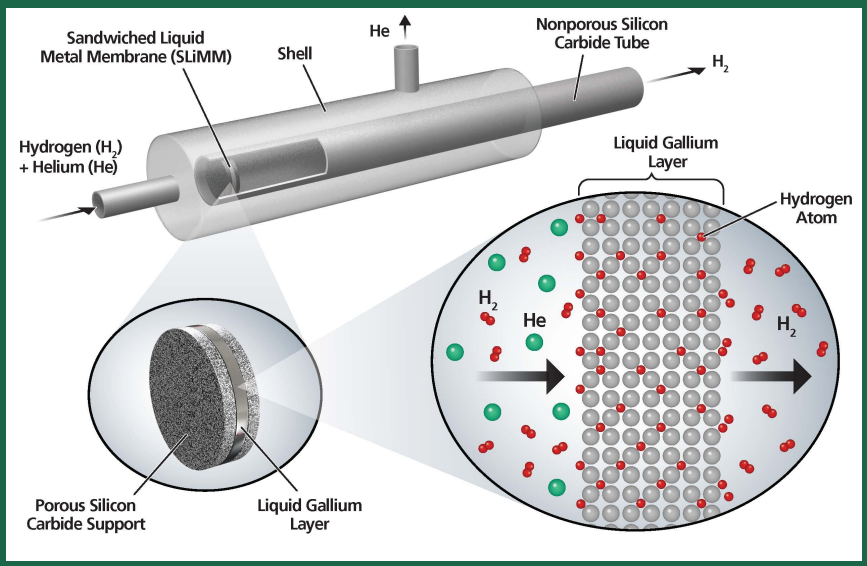
PROCESS DESIGN

Let's talk about economics. When you're designing a chemical process - like extracting rare earth metals or making solar panels - it has to be 1) technically feasible, and 2) economically viable - in other words, it has to make profit. Often, the initial conceptual design of a process or product is conceived in these terms alone, and only later in the process does the original design undergo changes to deal with safety and sustainability concerns. This can lead to suboptimal final products in comparison to considering these aspects simultaneously during conceptual design.

Chemical Engineering Professor **Nikolaos Kazantzis** and his collaborators propose incorporating safety and sustainability into the conceptual design process by using a return on investment matrix. A typical return on investment analysis takes into account only economic return on investment and related criteria. Kazantzis and his collaborators' work, which received the 2018 Sustainability Engineering Forum Award from the American Institute of Chemical Engineers, adds metrics for sustainability and safety considerations at the initial conceptual stage of process design.

Managers didn't see the economic benefit, says Kazantzis, of incorporating sustainability and safety concerns into the initial design: "We want to challenge the idea that there is an irreconcilable tension between economic objectives and care for the environment." What his Safety and Sustainability Weighted Return on Investment Metric (SASWROIM) offers is an intellectually rigorous analysis of the trade-offs and synergistic performance enhancement opportunities between economic and environmental fronts. The proposed metric puts a quantifiable value on safety and sustainability measures, in terms that process engineers are familiar with, and allows them to understand the full range of their options and ultimately choose optimal designs.

"We live in an uncertain world where things can go wrong," says Kazantzis. "We deal with unintended consequences, costs that you may not see, so it makes sense to take a precautionary approach and pre-invest in safety and sustainability measures." Kazantzis's metric allows us to consider sustainability and safety right alongside science and profit - and often create better products and processes by doing so.



Sandwiched Liquid Metal Membrane

Illustration by Curtis Sayers for WPI

CATALYSTS AND FUEL CELLS

Chemical Engineering Professor **Aaron Deskins** optimizes catalysts to convert carbon dioxide (CO2), a greenhouse gas, into useful materials like fuels. Mechanical Engineering Professor **Yu Zhong** and his team are working on solid oxide fuel cells, which produce near-zero emissions.

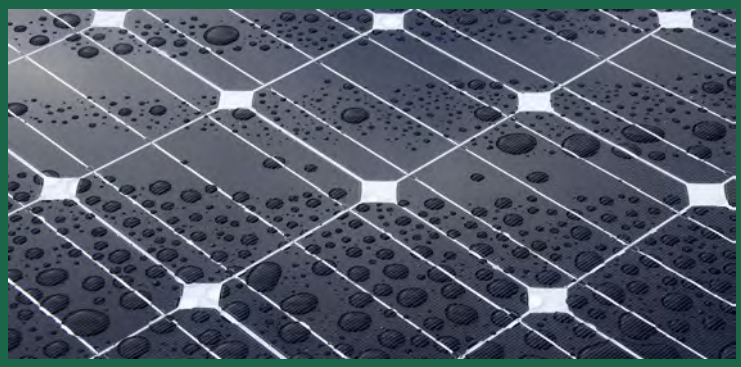
LIQUID METAL MEMBRANES

Chemical Engineering Professor **Ravindra Datta** and his team were the first to research liquid metal membranes (see graphic to left) for use in separating hydrogen after the steam reforming process. More efficient - cheaper and faster - hydrogen separation means cheaper and more available hydrogen as a possible cleaner fuel source.

RESEARCH - VARIOUS

THIN FILM SOLAR PANELS

Electrical and Computer Engineering Professor **Maqsood Mughal** is working on replacing toxic cadmium (Cd) in first generation panels with indium sulfide (In2S3). He also researches electrochemical deposition as a more energy-, resource-, and time-efficient method of layering materials onto substrates for the panels.



GREEN MARKETING

Doctoral candidate **Qingyun Zhu** is working with Business Professor **Joseph Sarkis** on green product marketing - collecting and organizing theories on how consumers behave and how to encourage environmentally friendly product purchasing. Doctoral candidate **Mahtab Kouhizadeh** is working on applying blockchain technology to green supply chains. This would allow users to be certain that every step in the supply chain was accounted for: in theory, you could track a single fish along every step of the the way from its capture to the table and know how sustainable the process was.

AIR MOTION

Architectural Engineering Professor **Shichao Liu** is investigating personalized thermal comfort and air motion. Increasing air motion by the appropriate amount achieves the same effect as turning your air conditioner down one degree. But the advantage of air motion is that it is aimed directly at occupied space and takes hundreds of times less energy than air conditioners, which waste energy cooling the entire room.

GEOTHERMAL HEAT PUMPS

Mathematics Professor **Burt Tilley i**s modeling the physics of temperature change over the length of the pipes in geothermal heat pumps, which take less energy and create less emissions than conventional heating sources like fuel oil.

URBAN GREENING

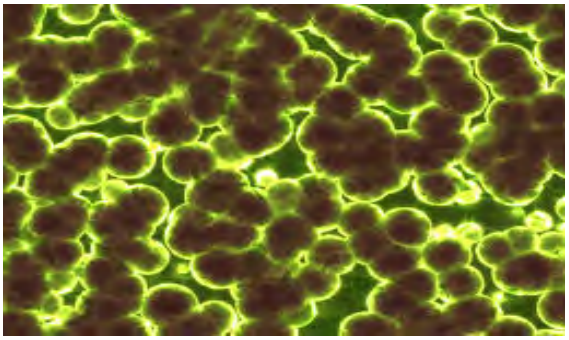
Interdisciplinary & Global Studies Professor **Katherine Foo** is studying the interaction between landscape design and societal values, political networks, and economic forces. In particular, her work focuses on the opportunities and challenges of the network structure of urban tree initiatives.

SUSTAINABILITY-RELATED RESEARCH CENTERS

- Fuel Cell Center
- Energy Research Group
- Integrative Materials Design Center
- Metal Processing Institute
- Center for Resource Recovery and Recycling
- Center for Advanced Research in Drying

BIODIVERSITY
Interdisciplinary & Global Studies Professor **Nicholas Williams** has published collaborative papers in the past year analyzing biodiversity on smallholder farms and gardens in Nicaragua and Sri Lanka. Agricultural biodiversity is key to adapting crops to changing climates, for example having varieties of more drought-tolerant wheat.

PACLITAXEL
Doctoral researcher **Michelle McKee** and Chemical Engineering Professor **Susan Roberts** are working on optimizing paclitaxel (used in Taxol, a chemotherapy drug) production from plant cell cultures. Optimizing plant cell culture production means higher and more reliable yields without decimating the Pacific yew tree populations from which the cells are taken.



MICROORGANISMS
Chemical Engineering Professor **Eric Young** and his lab are researching the use of microorganisms - bacterias, yeasts, and fungi - to biologically produce chemicals. These microorganisms naturally produce useful materials, such as fatty acids that can be converted easily into biodiesel. Young's work delves into understanding these organisms and figuring out how they can be modified to optimize their production.

MORALITY

"Let's say you're driving home late from the library with a cup of coffee. Why don't you throw the empty cup out the window?"

This issue of personal responsibility is one factor of the environmental crisis explored by Philosophy Professor **Roger Gottlieb** in his new book, *Morality and the Environmental Crisis*. Gottlieb addresses the political and collective dimensions of the subject, and also offers multiple ways to understand our personal actions in relation to the environmental crisis, which is one facet of sustainability in today's world.

One reason not to toss our coffee cup is that we cannot truly be certain of the effect of any action. We cannot guarantee that our coffee cup isn't going to have any impact.

A second way of thinking about the scenario is this: our action of throwing the coffee cup out the window becomes a permanent moral fact about us as a person. We have now become the kind of person who throws coffee cups out the window instead of putting them in a trash can (or instead of using a reusable mug). We are all responsible for our personal actions, regardless of the actions of those around us and regardless of their consequences.

In comparison to one coffee cup, however, the scale of the environmental crisis is enormous: droughts and hurricanes and rising waters are not just affecting millions of people but millions of species. Considering the future, it's easy to despair that it will only get worse. It's easy to deny what's happening, or to argue that because the issue is so big and complicated our individual actions will have a negligible effect.

Yet, "Life is a miracle," says Gottlieb. "And what's inside came from and is sustained by what's outside." We, as humans, cannot live without an Earth and environment to support us. Each individual action makes a difference, because the world is made of individuals.

With respect to the environment, with respect to sustainability, "We have to be honest with ourselves," says Gottlieb. When you think to yourself, 'I'm doing the best I can' - are you?

FOISIE INNOVATION STUDIO

A 78,000 square foot building begun in August 2016 and completed in August 2018, Foisie Innovation Studio will serve as a center for WPI's project-based curriculum. It houses innovation spaces including classrooms and a global impact lab, as well as 140 students in the Messenger Residence Hall on its three upper stories. The building is expected to be certified LEED Gold (since 2007, the Board of Trustees' policy has called for all new buildings on campus to be LEED certifiable).

- At least 80% of demolition and construction waste was diverted from landfill
- A majority of the wood used is Forest Stewardship Council (FSC) certified
- Occupancy sensors and daylight dimmer sensors are used to reduce lighting energy consumption
- Low-flow and efficient indoor water systems reduce water usage
- Efficient heating, ventilation, and cooling systems are designed to reduce energy usage

ENERGY MANAGEMENT RETROFITS

Each year, WPI completes retrofits of various older buildings to make them more energy and cost efficient. The buildings retrofitted this year include:

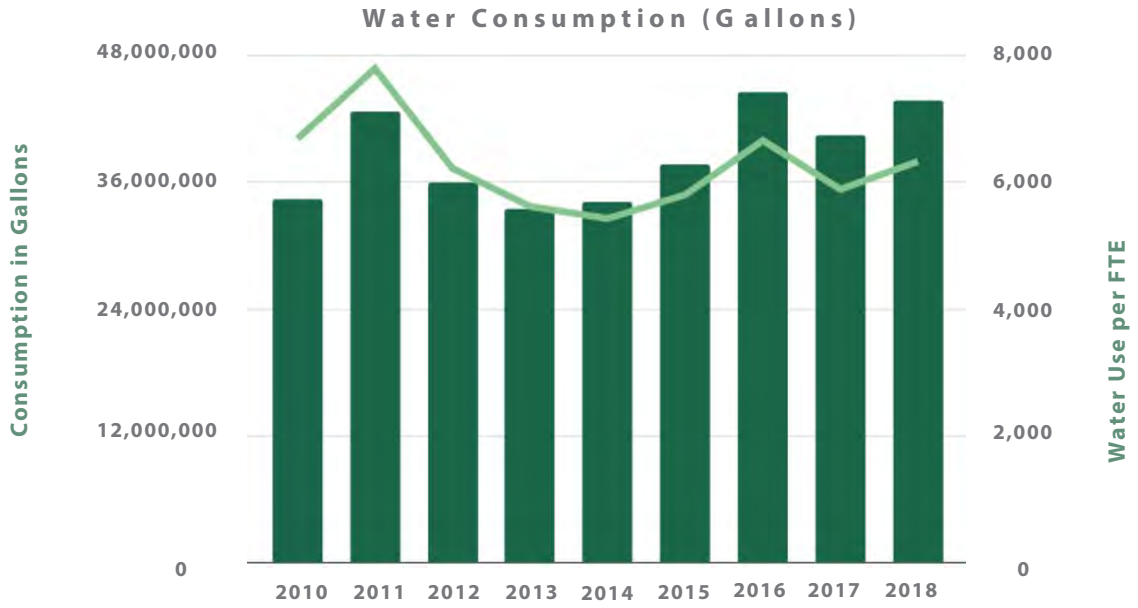
- The Sports and Recreation Center - upgrading of HVAC system and reprogramming of automated controls
- Salisbury Labs - lighting, HVAC, and weather protection upgrades
- Exterior lighting - upgrades for pole-mounted fixtures in parking lots and building-mounted wall packs

GREEN REVOLVING FUND

The retrofits above were funded by the WPI Green Revolving Fund. Established in 2017, the WPI Green Revolving Fund finances projects that enhance WPI's sustainability through increased efficiency or reduced consumption. Each project is designed to produce savings which are reinvested in the Fund each year.

Without water, human beings cannot survive. Period.

A portion of the water we use on campus, however, is not directly dedicated to bodily needs; in fact most of it is not. Water is what we use to shower and wash our dishes; it runs through our radiators to heat our rooms. But water is a limited resource, and it takes energy and materials to retrieve, purify, deliver, and purify it again - so it matters how much we use. Just as important as the total amount we use is how we understand water as a resource and what we decide to use it (or waste it) for - because this is what dictates the final total.



Note: FTE stands for full-time equivalent. For students, this is taking a full course load; for faculty and staff this is working full-time.

WPI used 44,381,832 total gallons of water this year, and 6413 gallons per FTE. This is a 7% increase from last year per FTE and an 15.5% increase from 2014 per FTE.

Our goal in the Sustainability Plan was to decrease consumption of utilities per FTE by 25%. We did not reach that goal for water. But we learned that in order to set realistic goals, we need to understand how we use our water. We learned that to progress toward those goals, we need concrete methods that include both technological changes, like low-flow faucets, and behavioral changes, like altering our water-use habits. And we learned that we need to better communicate our goal to the community which is using the water.

ENERGY CONSUMPTION

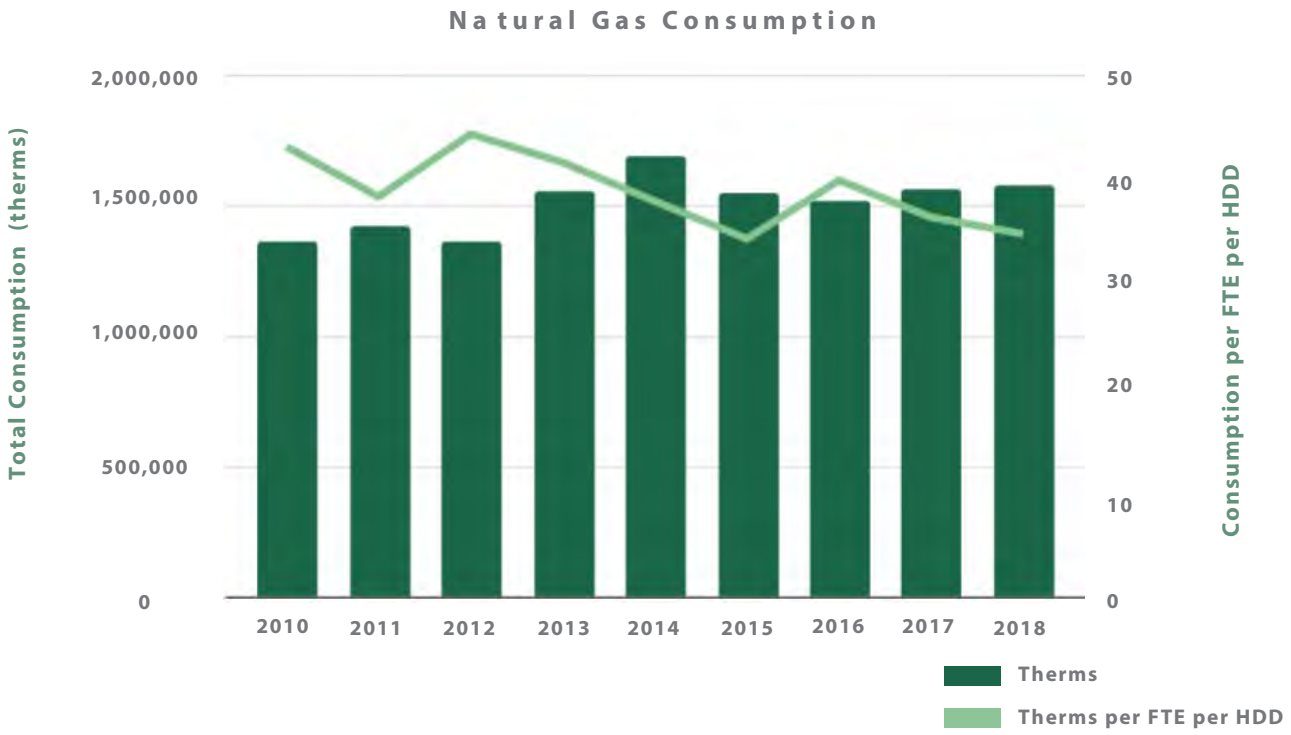
We use energy for everything - lights, heating, cooling, hot water, computers. How we choose to consume energy is one half of the matter. The other half is where our energy comes from.

The WPI campus uses energy in two main energy forms: natural gas and electricity.

Natural gas is used for thermal energy (heating), and is reported in therms.

Electrical energy is used for everything else, including lighting and air conditioning systems. Electricity is reported in kilowatt-hours (kWh).

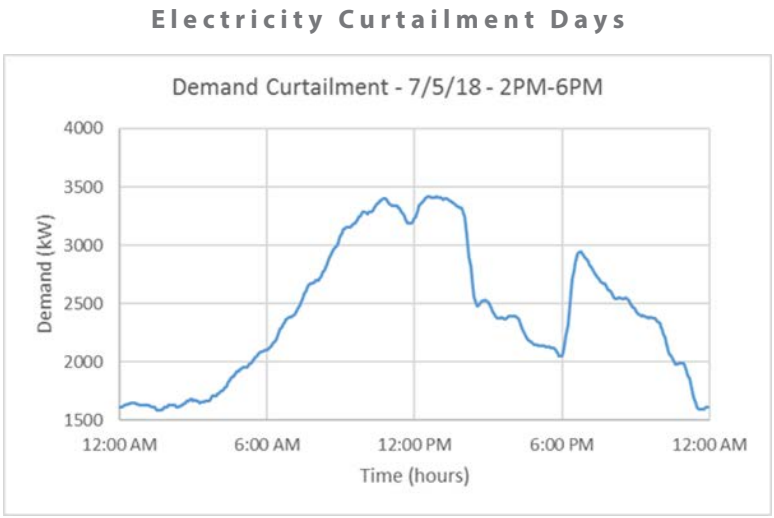
NATURAL GAS



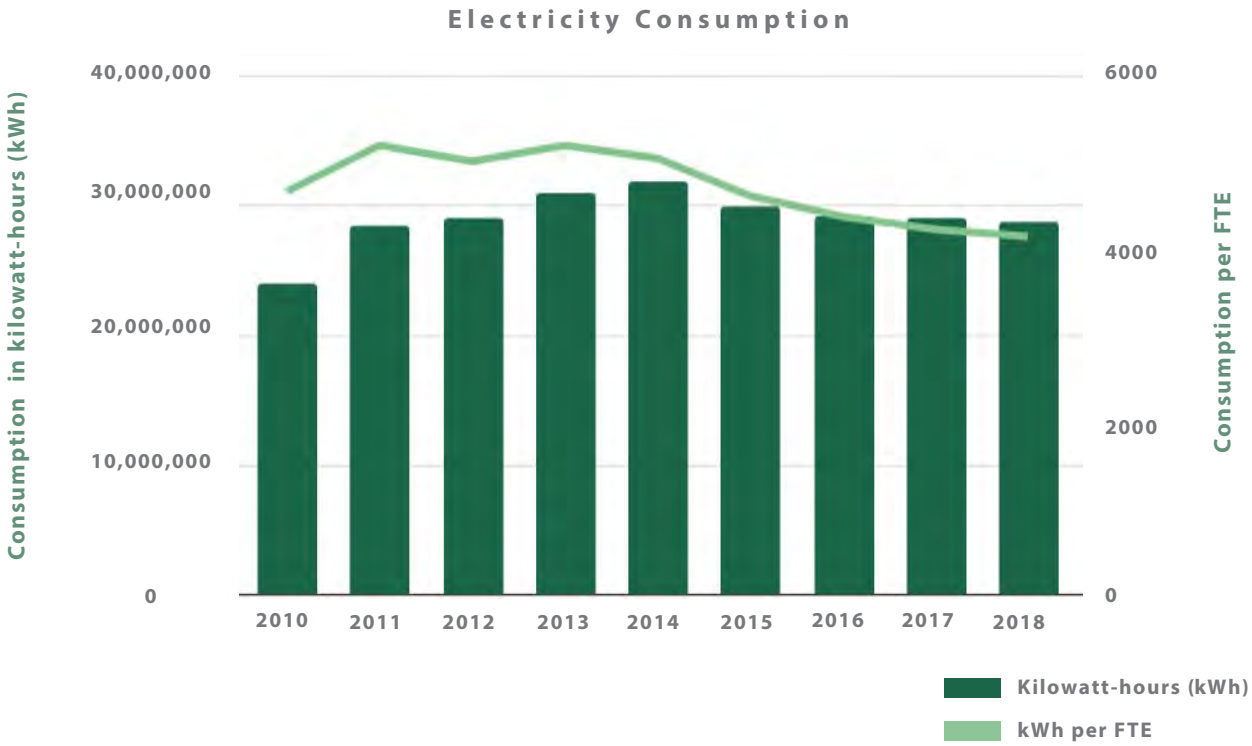
Understanding Natural Gas Units:

- Each British Thermal Unit (BTU) is the amount of energy needed to increase the temperature of 1 pound of water by 1° Fahrenheit at sea level. British Thermal Units are used to measure heat (thermal) energy.
- 100,000 British Thermal Units (BTU) is one therm.
- A Heating Degree Day (HDD) is the number of degrees below 65°F that each day's average temperature is. For example, if the average temperature for the day were 62°F, that is 3 below 65°F, so the HDD number would be 3. Whether a building is heated depends on many factors, so 65°F was selected as a reasonable reference point in order to create a standard. Heating Degree Days are totaled for the entire year to quantify how much heat was needed during that year. The total number of therms is divided by the number of Heating Degree Days in a year to allow for comparison across years.
- Note: Total gas consumption includes gas consumption by the WPI residents of Salisbury Estates.

ELECTRICITY



On high temperature days when demand for electric energy peaks, utility providers are sometimes forced to use less efficient and more polluting electricity-generating facilities to maintain supply capacity and avoid power outages. On those days, WPI reduces its power use by shutting off some non-essential equipment and cycling air conditioning on and off across campus during peak usage hours (generally 2-5 pm). Through these actions, WPI is able to significantly decrease its electricity consumption on peak power days in an effort to support the integrity of the New England electrical grid, limit the use of less clean electric production, and reduce peak demand charges.



Total natural gas consumption for FY18 was 1,579,790.60 therms, while gas consumption per FTE per HDD was 34.9. This is a decrease by 4% in gas consumption per FTE per HDD from last year, and a decrease by 8% in gas consumption per FTE per HDD from FY14.

Total electricity use was 28,719,736 kilowatt-hours (kWh), while electricity use per FTE was 4150 kWh. This is a decrease by 2% in electricity use per FTE from last year, and a decrease by 9.8% per FTE from FY14.

We have done much better in the energy arena than in the water arena, decreasing both natural gas consumption per FTE and electricity consumption per FTE by a significant amount. Similar observations may be made as with our water goals, however: knowing what we know now, we recognize that we need to better understand resource consumption especially in light of increasing population demands, provide concrete plans for achieving them, and articulate to the rest of the community what the goals are and how we - the ones who are using the energy - can help reach those goals.

GREENHOUSE GASES

What is a greenhouse gas?

Greenhouse gases are a group of gases - including carbon dioxide, nitrous oxide, water vapor, and fluorinated gases - which trap heat (longwave radiation) in the atmosphere. They allow light from the sun (shortwave radiation) to enter the atmosphere, but when that light hits the earth and bounces up as heat, the heat is reflected back down to earth and cannot escape. This is called the greenhouse effect, and it is exactly the way a greenhouse works, only with gases instead of a glass roof. Greenhouse gases are essential to life on earth - without them, the average temperature on Earth would be around 0°F.

What, then, is the problem with greenhouse gases?

The problem is that human activities - burning coal and gas, large-scale cattle ranching, driving gasoline cars - have greatly increased (and continue to increase) the amount of greenhouse gases in the atmosphere. This means that the average global temperature has started to increase - commonly known as global warming, or climate change. This warming varies across the earth, with some regions, such as the poles, facing much greater temperature changes than others. But the problem is not just the changing temperatures, it's about how temperature affects everything else - from decreased rainfall to expanding deserts, from acidified oceans to more frequent hurricanes, from disappearing ice caps to rising seas. If the warming continues as it has been - and if our emissions of greenhouse gases stay the same or rise as the rest of the world industrializes - large portions of land currently occupied by humans will be rendered uninhabitable, corresponding with loss of human life and the extinction of other species. Therefore, continuing to emit greenhouse gases at our current level is unsustainable.

What is WPI doing to reduce emissions of greenhouse gases?

We developed a WPI Greenhouse Gas Reduction Plan, shared with the WPI community in July 2017, to decrease greenhouse gas emissions from the WPI campus and WPI activities.

Greenhouse Gas Emissions Terms

Greenhouse gas emissions are separated into three categories, or scopes:

- Scope 1: direct greenhouse gas emissions from sources that are owned or controlled by WPI. These include emissions from fossil fuels burned on site such as in boilers, WPI-owned and leased vehicles, and refrigeration.
- Scope 2: indirect emissions from the electricity purchased from the grid. That is, the corresponding amount of emissions from natural gas, nuclear, and coal power plants and other power sources that provide electricity to WPI.
- Scope 3: Other emissions. These include emissions from faculty commutes, study abroad travel, construction, and purchased equipment and supplies, and are more varied and difficult to quantify.

GREENHOUSE GAS REDUCTION PLAN

The goal of the Greenhouse Gas Reduction plan is for WPI, even as it grows in population and building square footage, to reduce its Scope 1 and Scope 2 greenhouse gas emissions by **20% by 2025**, relative to the benchmark of its 2014 emissions.

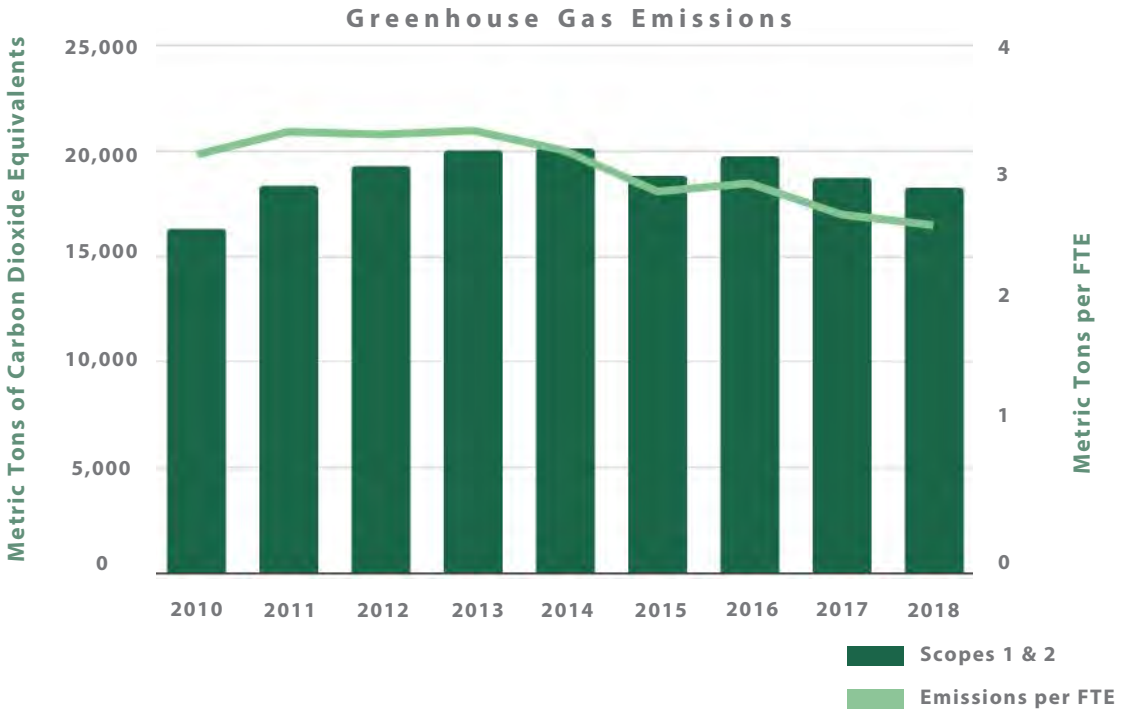
In FY14, WPI's Scope 1 and Scope 2 emissions totaled 20,178 metric tons, or 3.2 metric tons per FTE. This year (FY18), WPI's Scopes 1 and 2 emissions totaled 18,024 metric tons, or 2.60 metric tons per FTE (not including refrigerants). This represents a decrease of 10.7% in total emissions since FY14, despite a growing WPI population.

Scope 3 emissions are not included in WPI's initial Greenhouse Gas Reduction Plan, but as part of the plan WPI commits to measure and report Scope 3 where possible in order to develop programs to reduce or compensate for those emissions going forward.

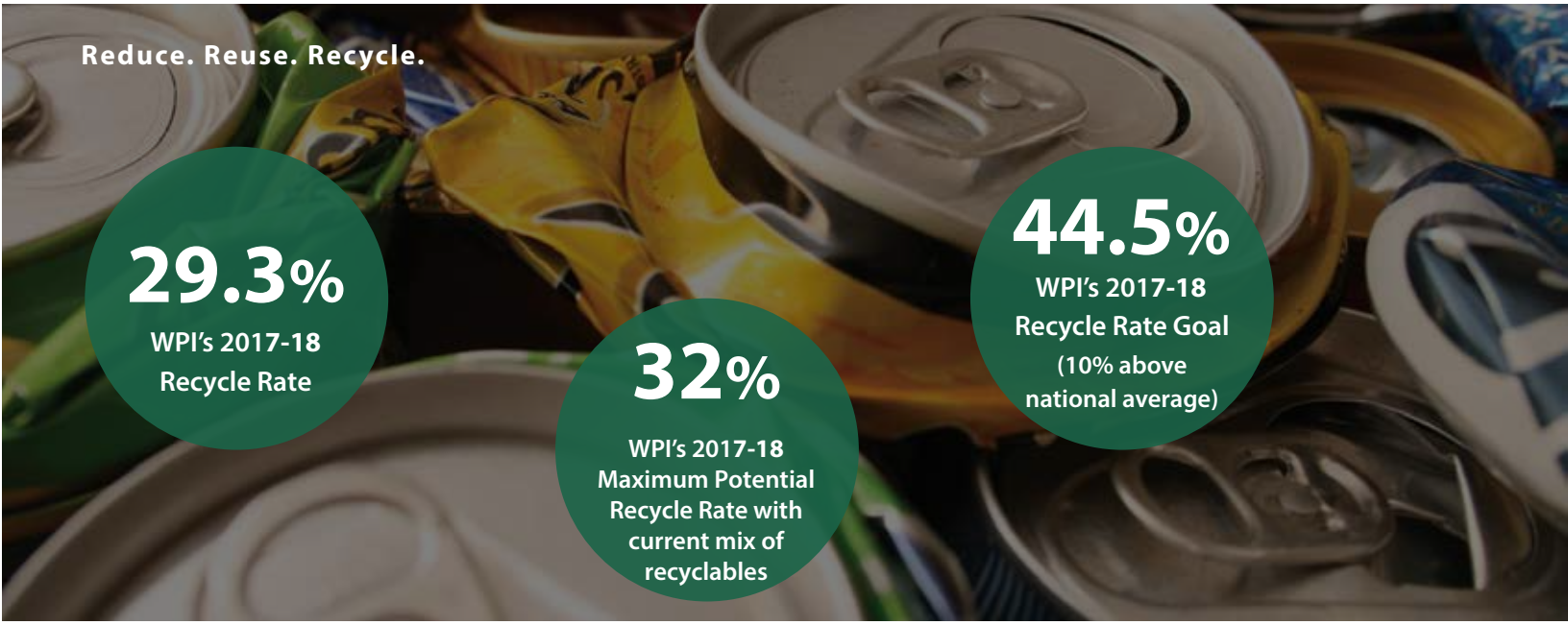
In the past, WPI worked on reducing its environmental impact and greenhouse gas emissions by focusing on areas such as energy efficiency, increased recycling efforts, and retrofits of buildings. These efforts reduce energy use, emissions, and cost.

Now, the Greenhouse Gas Reduction Plan proposes a series of retrofits and operations projects, such as energy efficiency upgrades in order to meet the goal of 20% reduction. All of the operations and infrastructure projects in the Greenhouse Gas Reduction Plan decrease greenhouse gas emissions and save money on energy costs, with almost all of them paying back their implementation cost within 7.5 years.

"Recognizing that the increase of carbon dioxide and other greenhouse gases in the atmosphere is a major contributor to climate change, and further recognizing that the emission of these gases due to human activities is a primary cause of this increase, WPI commits to taking responsible action to track our emissions and to minimize the quantity emitted." - WPI Greenhouse Gas Reduction Plan



Note: Greenhouse gas emissions are measured in terms of carbon dioxide equivalents. This is because different gases differ in their lifespans and in the magnitude of their effects on the atmosphere. In order to allow for comparison, all greenhouse gas emissions are converted to the same unit, which is the equivalent (effect) of a metric ton of carbon dioxide.



What is Waste?

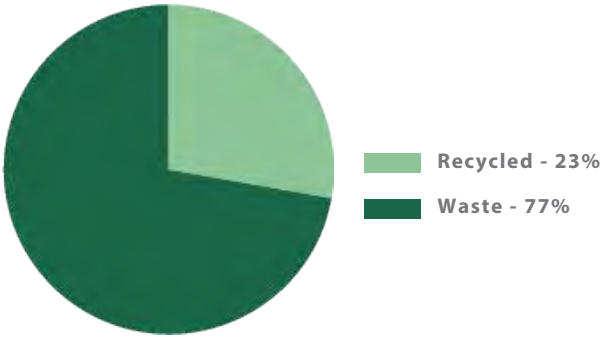
Well, it's an interesting question. Half of it has to do with what materials we use to make things and what things we make and use. The other half has to do with how we dispose of things after using them. Waste can be broken into three questions: what is it, where is it from, and where is it going? This section mainly addresses where it's going: WPI's trash goes to incinerators to be burned for energy (not landfill, but still not a clean process). A portion of food waste is sent to a local pig farmer to be used as feed. Recyclables are sent to be recycled for other purposes and goods.

Annual Waste Audit

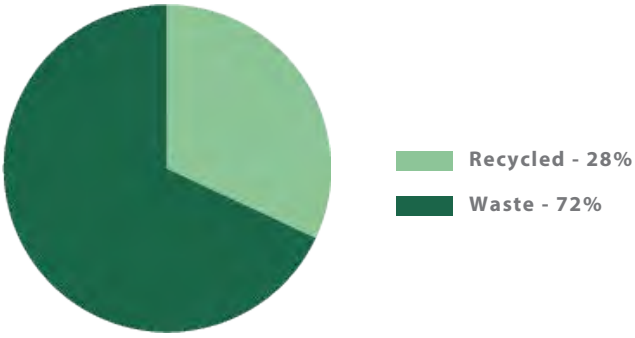
WPI completes an annual waste audit of all the waste generated in a single day in the Campus Center and the Gordon Library to raise awareness of waste generated on campus and what materials can be recycled, as well as to measure WPI's recycling rate (the amount of waste that is actually recycled). This year our audit revealed that 23% of the total waste was recycled, but there was a potential of 28%, if all materials had been disposed of properly. This small difference tells us something about sourcing: if our goal is a 44.5% recycling rate, then we need to change what materials we are purchasing or using in the first place. In order to achieve a large change in recycling rate, we need to examine the first half of the equation: what materials and products can we choose to allow for a higher recycling rate and decreased total waste?

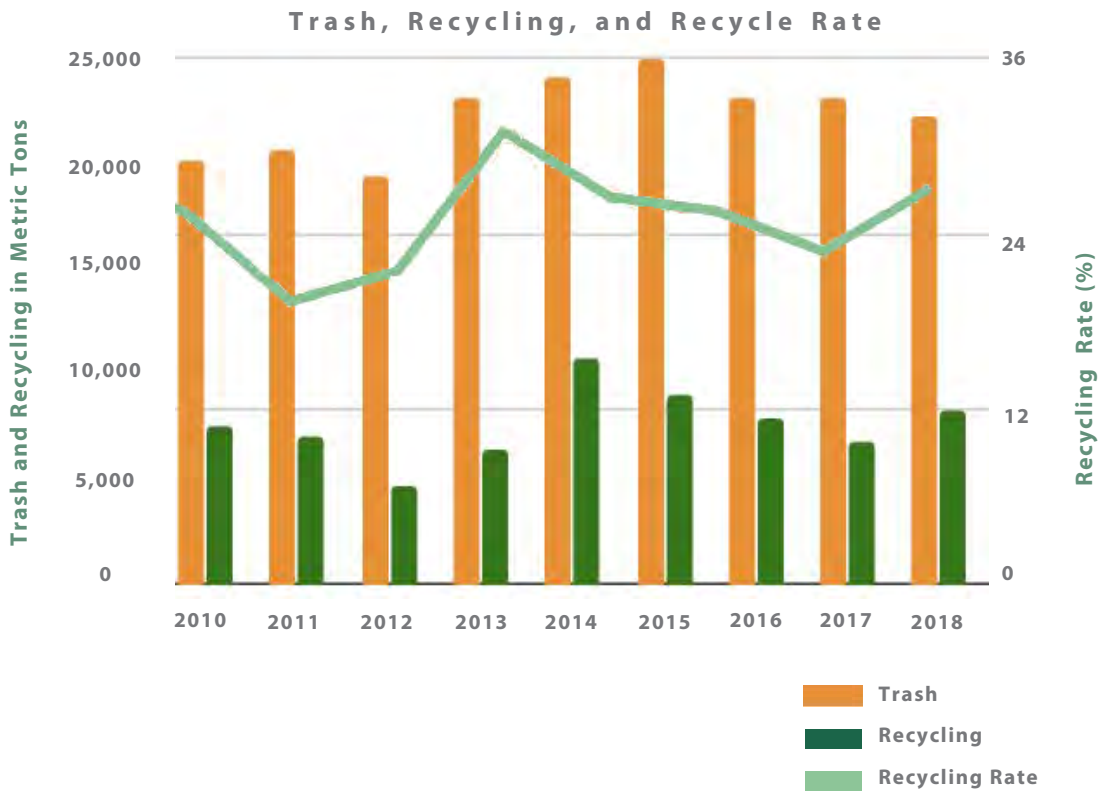
Below are the results of this year's audit, where Actual Recycling is the recycling rate (by weight) measured by the audit, and Potential Recycling is the rate that would have been achieved had everything been sorted properly.

Actual Recycling



Potential Recycling





In February 2014, WPI set the goal to achieve a recycling rate of 44.5%, 10% above the national average of 34.5% reported by the EPA. This year, total waste including recycling was 735 metric tons, an increase of 2% from last year. The recycling rate was 29.3%, an increase of 7% from last year, but a decrease of 1% from the benchmark year of FY14. This rate does not include surplus furniture and equipment re-purposed on campus or by the local community.

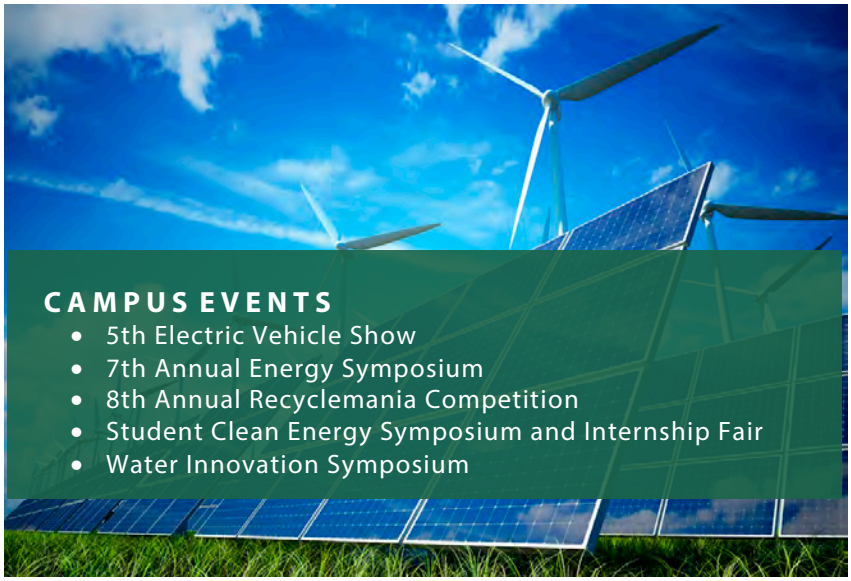
As with other operations areas, reduction in waste and improvement in recycling rates going forward requires realistic goals, concrete action plans, and communication with the community. Careful decisions need to be made regarding not only disposal of used materials but also material sourcing and daily materials consumption.

DINING SERVICES

A large fraction of the waste we generate, and perhaps the easiest to visualize and control, is food waste. Important factors of waste related to food include food sourcing, food type, and food disposal. This is where dining services comes in. At WPI, dining services provider Chartwells focuses on sustainability by:

- Purchasing only cage-free shell eggs and sustainable seafood
- Reducing kitchen food waste through the Trim Trax program
- Sending approximately 60 tons of food waste per year to a pig farm to be used as animal feed
- Donating food to local shelters through the Food Recovery Network and other organizations
- Offering presentations on mindful and healthy eating
- Expanding vegan and vegetarian options with an extra vegetarian main dish for Meatless Mondays

Since the first Sustainability Report in 2010, the Community Engagement section has highlighted events and activities related to sustainability designed to impact the WPI community, both on campus and beyond. Below are some of the highlights from this year.



CAMPUS EVENTS

- 5th Electric Vehicle Show
- 7th Annual Energy Symposium
- 8th Annual Recyclemania Competition
- Student Clean Energy Symposium and Internship Fair
- Water Innovation Symposium

Farmers' Markets

Twice a month from August through November, these markets featured fresh, local vegetables and fruits such as corn, apples, carrots, and pumpkins from Dick's Market Garden, Inc., Lunenburg, MA.

E-waste Drive

Lead. Cadmium. Arsenic. Mercury. All metals. All toxic. All embedded in various parts of the phone in your back pocket. That's why WPI hosts an annual E-waste Drive: so community members can bring their electronics to be disposed of properly or reused by someone else.

LEED Training

Leadership in Energy and Environmental Design (LEED) was launched in 2000 by the U.S. Green Building Council, a private non-profit organization that promotes sustainability in building design, construction, and operation. LEED is one of a number of programs that evaluate buildings on their sustainability. The program rates buildings on a point scale in areas including energy performance, water efficiency, material sourcing and disposal, and air quality. LEED, as with any point system, is not perfect, but it is the most widely used and recognized green building standard in the world.

Each year, the Green Team partners to offer a discounted LEED Green Associate Certification course to the WPI community. The course teaches general knowledge of green building practices for both commercial and residential spaces.

29,039 **Total Volunteer Hours reported to the Student Activities Office**

Grand Challenge School

Access to clean water. Energy from fusion. Managing the nitrogen cycle. Carbon sequestration methods. These are some of the opportunities facing society in the 21st century, selected by the National Academy of Engineering (NAE) as 4 of its 14 Grand Challenges. These challenges fall under 4 themes: sustainability, health, security, and joy of living.

In August 2017, the NAE named WPI a Grand Challenge Scholars School in recognition of the university's unique, project-based education. WPI has offered the Grand Challenges Scholars Program since 2009. The program is a combined curricular, co-curricular, and extracurricular program with five competencies that are designed to prepare students to address these grand challenges.

George C. Gordon Library

If the goal of a university is the advancement of knowledge, then its iconic central temple is its library. From stone tablets to scrolls to books to computer servers, libraries have been repositories of knowledge for generation after generation. Students flock to them in droves to study, to pore over texts, and occasionally to nap. Therefore, what better place to hold and share knowledge of sustainability then WPI's George C. Gordon Library? The Gordon Library:

- Features an online Sustainability Guide to sustainability-related resources
- Sends old hardcover books to be shredded for pet bedding instead of being thrown away
- Donates 750+ food items per year to organizations around Worcester as part of the Library's Food for Fines program

GREENHOUSE

At the heart of WPI's main campus atop the roof of Salisbury Labs sits the **Biology and Biotechnology greenhouse.** The greenhouse houses a wide variety of plants, including over 30 different kinds of succulents. Since its foundation in 1996, it has served as a research space and as an experimental classroom for courses incorporating hands-on activities related to plants, such as the annual Plant Diversity course taught by Professor **Pamela Weathers**. Research conducted in the greenhouse has ranged from investigations on aphids to studies on bee behavior and conservation.

Plant Parenthood

Begun in 2014, Plant Parenthood was revitalized this year by **Barbara Milanese** to teach students how to propagate and care for plants. The program was scheduled twice a week in all four terms, with two sessions each day to allow students to visit between classes. Each participant started a new plant from the leaf of an old one - succulents like gollum jade and various types of kalanchoes, or the baby sprout of a spider plant. These plants are easy to care for and easy to propagate: lay a cutting on the dirt, give it a little water, and within a month or two - each species is different - it will begin to sprout into a new plant, with roots growing down into the soil and new leaves budding from where it was cut from the main plant. A group of future students will later pot these new plants and take them home, while the current group will pot and take home plants started by a previous group.

Besides bringing home a new plant for their dorm or apartment, students participate in a cycle of sowing new plants for future groups and bringing home the work of past groups. They gain a familiarity with plants, marveling at the circle of life that allows the leaf of one plant to become a new plant of its own. They pay it forward to others and simultaneously benefit from others' effort, working together with people separated from them in time and space whom they may never meet, but whose actions affect them and who they can affect in turn - exactly the way sustainable practices work in every other aspect of life.

YouthGROW

YouthGROW is a program run by the Regional Environmental Council, an environmental and food justice organization founded in Worcester in 1971. YouthGROW began in 2003, and the 2017-18 school year was its third year of involvement with the WPI greenhouse. The youth development program hires 35-40 low income high school students and employs them on its two urban organic farms, teaching them urban agriculture and leadership skills. In a partnership with the WPI greenhouse staff, the greenhouse provides space for seedlings - from peppers to eggplants - that will be sent to the REC's plant sales and community gardens. Students and staff on campus help with planting and watering the seedlings, creating a collaboration between the on-campus and greater Worcester communities.

Additionally, WPI students are encouraged to volunteer on the REC's organic farms, one of which is less than two miles from the WPI campus. By helping with harvesting they are exposed to agricultural experiences that are uncommon in urban areas and learn about the possibilities of growing their own food.

The greenhouse is also home to the new **Greenhouse and Horticulture Club**, which meets in the Greenhouse twice a week for general maintenance and care for the plant specimens in the greenhouse. This includes teaching members watering, transplanting, pest control, and propagation skills.

Green Team

The Green Team is dedicated to promoting and increasing sustainability on campus. Every year they host several events to raise awareness of environmental and sustainability initiatives within WPI, Worcester, and beyond, including the annual waste audit, annual e-waste drive, annual Energy Efficient Lighting Fair, and Project Clean Plate. The Green Team also runs Gompei's Gears and strives to be a leader in sustainability on the WPI campus.

Students for a Just and Stable Future

Students for a Just and Sustainable Future (SJSF) is a branch of a larger student volunteer network of campuses throughout New England which envisions a world where all living beings are able to meet their needs, resolve conflicts peacefully, and take ecological responsibility for the Earth. SJSF seeks to move WPI toward this goal with a main focus on addressing the climate crisis. This year they are launching a campaign to make WPI disposable-water-bottle-free.

Engineers Without Borders

Engineers Without Borders (EWB) is a chapter of EWB-USA whose mission is to build a better world through engineering projects that empower communities to sustainably meet their basic human needs. The WPI EWB chapter received the **2017 EWB-USA Premier Chapter Award** for their work in Guachtuq, Guatemala. The chapter has focused on increasing water security through the design and construction of 36 rainwater harvesting systems, the last two of which were designed and constructed entirely by the community. Forty-one community members became certified to repair and maintain their new water systems after attending a weekend of instructional workshops. As the saying goes, this is teaching people how to fish for a lifetime.

Global Humanitarian Alliance

Sustainability isn't just local - it's global. Global Humanitarian Alliance (GHA) is an organization devoted to helping the underprivileged people in Worcester and in developing countries by providing clean water, sanitation, and education. At WPI, GHA seeks to raise students' awareness on issues regarding global poverty and related topics through "BeAware" talks, as well as by connecting people to project opportunities in Worcester. BeAware talks this year included: "Worcester: Creating a Livable and Resilient City," a panel on cities and how they create and affect human life, focusing on the greatest challenges in Worcester, from walkability and bicycle urbanism to economic development.

Habitat for Humanity

Sustainable housing for all is one part of sustainability. Habitat for Humanity is a non-profit organization whose WPI chapter advocates, fundraises, and builds housing for those without it. The group completes an annual week-long Build Trip, and supports the local community by volunteering at Worcester Restore and participating in Worcester Build projects. On campus, members spread awareness about poverty and homelessness.

Food Recovery Network

WPI's chapter of the Food Recovery Network fights food waste and hunger by recovering perishable food from on-campus dining locations and events that would otherwise go to waste and donating it to local homeless shelters in the Worcester area. WPI's chapter was started in 2015 by a group of students in the Global Problem Seminar: Livable Cities. Student volunteers for the Food Recovery Network pick up food from dining halls and transport it to shelters in Worcester.

Veg Club

Food sourcing and agricultural practices and emissions are large yet often unseen factors in the sustainability of everyday life. Veg Club provides support and resources to those living or trying a vegetarian or vegan lifestyle in the WPI community. They focus on food education and promoting vegetarian and vegan options on the WPI campus.

Worcester Poverty Stoplight Initiative

Economic equality and quality of life considerations are one part of sustainability. The Worcester Poverty Stoplight Initiative is a new group which intends to address the problem of poverty in the local Worcester area. The club will initially focus on creating a localized definition of poverty in Worcester, going beyond income-based metrics to assess areas such as health and infrastructure. They plan to address these problems by connecting those in need with existing resources, or through new, creative solutions.

Student Sustainability Leaders Roundtable

Once each term, leaders from the clubs and the Office of Sustainability meet to discuss their efforts around campus, share insight, and coordinate activities. They identify ways that the Office of Sustainability can assist clubs, and how the clubs can assist the Office of Sustainability in their shared goal of increasing sustainability on campus.

Sustainability in Greek Life

Fraternities and sororities are founded on the principles of scholarship, leadership, and community service, and many of WPI's chapters reside in houses around campus. Below are some of the sustainable practices WPI Greek Life implements in their houses (self-reported by each chapter).

18 All 18 chapters recycle aluminum, cardboard, glass, paper, and plastic

13 chapters have motion sensing lights in areas of frequent usage

10 chapters use only energy-saving light bulbs (14W CFLs and T8 fluorescents).

1 2018 Sustainability in Greek Life at WPI Award presented to Phi Sigma Sigma

ECO-REPS

Eco-Reps are volunteers who work with the Office of Sustainability to learn about ways to live and work more sustainably on campus, and then spread that knowledge. This year, the Reps focused on promoting Trash2Treasure and Green2Go, a reusable container program offered at food locations around campus including the Campus Center Food Court, Goat's Head Restaurant, and Library Café.

What makes Eco-Reps necessary?
First: WPI is a university with a large undergraduate population. Every year, a new group of eager 18-year-olds joins the campus, and a group of new graduates leaves. All those graduates who learned how to save energy, water, and food, to build sustainable skyscrapers, to wire solar panels, and to throw soiled paper in the trash but clean and empty pizza boxes in the recycling bin - they're all gone. And a group of students who don't know all of that have arrived to start the journey. So the first reason for having Eco-Reps is to teach freshmen, new grad students, and transfers what sustainability means at WPI.

Second: it's easy to forget. For a lot of people, turning off the lights when you leave the room is a habit. If it isn't, or if you come back from summer or IQP out of practice, the Eco-Reps are there to remind you and answer your questions.

Third: you can call it peer-to-peer learning or "D4 best floor!" People are likely to listen to those they share a bond with - their fellow students, floormates, teammates. By leveraging those connections, Eco-reps aim to enable sustainability leaders to share their knowledge and best practices with those around them.

It's the Office of Sustainability's job to enhance sustainability on campus, and one way it does that is through the work of student interns - because who else is more involved in the community than its students? Throughout the year, four interns in the Office of Sustainability worked on projects to increase sustainability and awareness around campus, including:

- Sustainable transportation planning for campus
- Sustainable procurement of campus office supplies
- Ditch the disposables, and:

Food Waste Diversion at the Campus Center

What makes a good trash can - or a good waste disposal station?

Experts have studied where to place trash and recycling bins so that people will recycle, instead of throw away, as much as possible and as well as possible. As well as possible? How can you recycle badly? Well, maybe you can't recycle badly, but you can recycle wrong - that is, you can throw things in the trash that can be recycled and you can throw things in the recycling that can't be recycled. A lot of people are what we call "hopeful recyclers" - when in doubt, they recycle things without knowing whether they're recyclable. This practice - "recycling" unrecyclable objects - is known as contamination. Contamination is bad. One contaminated object in a bag or dumpster can make the whole load unrecyclable, either because it gets on everything else (spilled food and drinks) or because it would be too difficult to sort through the whole mess to retrieve that handful of items.

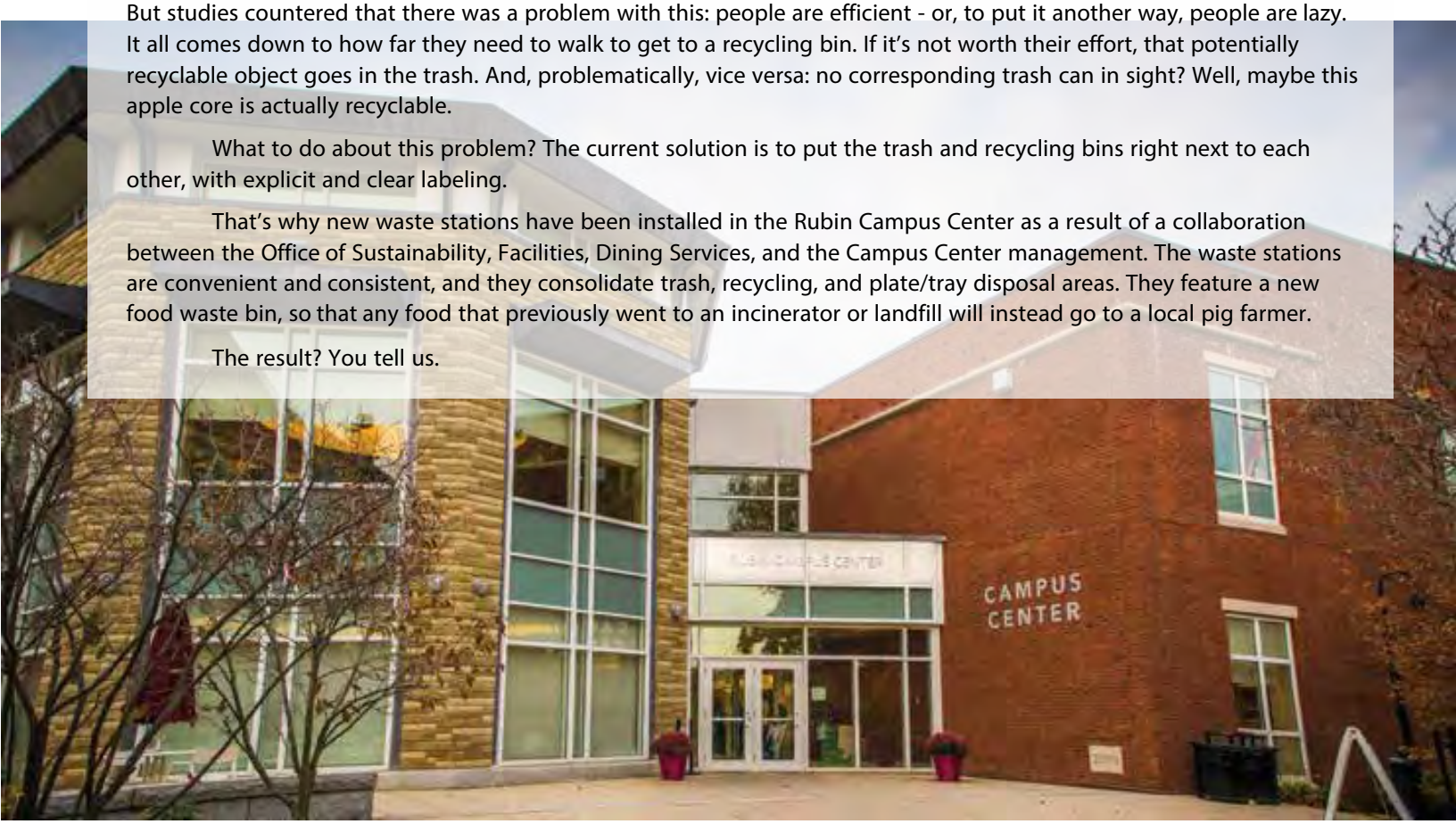
But what's wrong with contamination? What makes something like a half-full soda bottle or a cheese-covered pizza box so hard to recycle? To make a long story short, contamination such as food gums up and breaks the machines that are used to recycle things. Broken machines mean nothing can be recycled. It makes more sense for waste centers to toss anything that even looks suspicious rather than risk their entire operation due to contamination.

To eliminate contamination, conventional wisdom said to put trash and recycling bins far away from each other. But studies countered that there was a problem with this: people are efficient - or, to put it another way, people are lazy. It all comes down to how far they need to walk to get to a recycling bin. If it's not worth their effort, that potentially recyclable object goes in the trash. And, problematically, vice versa: no corresponding trash can in sight? Well, maybe this apple core is actually recyclable.

What to do about this problem? The current solution is to put the trash and recycling bins right next to each other, with explicit and clear labeling.

That's why new waste stations have been installed in the Rubin Campus Center as a result of a collaboration between the Office of Sustainability, Facilities, Dining Services, and the Campus Center management. The waste stations are convenient and consistent, and they consolidate trash, recycling, and plate/tray disposal areas. They feature a new food waste bin, so that any food that previously went to an incinerator or landfill will instead go to a local pig farmer.

The result? You tell us.



TRANSPORTATION

Private transportation is one of the biggest culprits behind air pollution, greenhouse gas emissions, and traffic jams. To reduce these issues, WPI offers its community various shared transportation and low-emissions vehicle options.

Gompei's Gears

A bicycle is the most efficient human-powered vehicle on earth. You can walk and you can run, but a bike will outstrip you in seconds, and take less energy to do so. Bikers can average 25 miles per hour (mph) on the 2,200 mile-long Tour de France, over 80 mph on pavement in special speed bikes, and over 160 mph drafting behind special pace vehicles. It doesn't matter, though, how fast you go: they don't emit a thing.

Since 2016, WPI students, staff, and faculty have taken advantage of Gompei's Gears, a free bike share program originally conceived as an IQP and now run by the Green Team. Gompei's Gears gives students, faculty, and staff access to bicycles from convenient locations on campus, and is an easy, healthy, and sustainable way to travel to or from the WPI campus.

4 locations around campus

18 Gompei's Gears bikes

1000s of rides and counting

EV Chargers

Electric vehicles (EVs) don't have exhaust pipes. That's because they produce no direct emissions, unlike traditional gasoline-powered cars and trucks, whose exhaust streams include particulate matter, carbon monoxide, and greenhouse gases like carbon dioxide. EVs still leave a footprint in production, and it matters where their energy comes from: there's a difference between driving on electricity that was produced by solar panels and electricity that was produced by burning coal. But in terms of sustainability they are a large step forward from traditional combustion engines, especially as renewable and lower emissions power sources become increasingly prevalent.

WPI provides free electric vehicle charging on campus at six charging ports, located in the Park Avenue Garage.

200 sessions per month, average

45 unique drivers per month, average

155,000+ total mileage

MassRides

A free program by the Massachusetts Department of Transportation whose mission is to reduce traffic congestion and improve air quality by providing resources to help commuters make smart transportation choices. Services include:

- Meet Your Match - An event to pair carpoolers
- Try It Day - An event encouraging alternative methods of commuting to campus
- Staff Emergency Ride Home - Reimbursement for staff who carpool or use efficient vehicles to commute to campus, but due to an emergency cannot return home via the same vehicle

Students also have access to:

- Carpoolworld - a WPI-only ride-sharing venue
- CityRide Shuttle - from 5pm to midnight during the academic year to WPI, Union Station, Assumption, and Blackstone Valley Shopping Center/Cinema
- Evening shuttle - seven days a week from 5:30 p.m. to midnight to nine campus stops including Gateway Park, Price Chopper, and Salisbury Estates
- Gateway Shuttle - Monday through Friday during working hours to six locations, including Faraday Hall, Gateway Park, and the Bartlett Center
- SNAP - from 6pm to 4am during academic terms to and from residential locations within a mile radius of campus
- Worcester Regional Transit Authority buses - college semester UPASS available for $125 per semester
- Zipcars - 9 Zipcars on campus for faculty, staff, and students as an environmentally friendly alternative to keeping a car on campus

Wind Turbine Storage at Holy Name

Have you ever watched a quaking aspen quake? The shifting patterns of its leaves are mesmerizing. Now picture a wind turbine: sleek, white, taller than 40 of you stacked on top of yourself, its blades sweeping through the same arc over and over again. Also mesmerizing, in a different way. And both are driven by the same force: wind.

Wind turbines, like the one at Holy Name High School, harness the wind and turn it into electricity for human use. The wind turbine at Holy Name, for which WPI students performed a Wind Feasibility Study back in 2006, is the first wind turbine in the city of Worcester. Since its construction in 2008, it has provided between 50% and 95% of the energy used by Holy Name High School each year, varying depending on the weather conditions and amount of energy consumed that year.

This is the promise and the pitfall of natural energies like wind: they are renewable, in that they cannot be exhausted, they produce zero emissions while harnessing natural forces - and they are often variable. Solar power can only gather energy during the day. Wind turbines only gather energy when the wind blows. They can offset each other - for example, wind in many places is greatest at night when solar panels lie dormant - and other sources, such as tidal and geothermal energy, are more constant. But the ideal, or what prior WPI Director of Sustainability **John Orr** calls "the holy grail of clean energy generation," is energy storage: being able to store natural energy so that when it varies the stored energy can be called upon to meet demand.

In October 2017, Holy Name High School, in a partnership with WPI and National Grid funded in part by the U.S. Department of Energy, unveiled a new energy storage system. The 500-kilowatt vanadium redox flow battery system, the size of 8 tractor-trailers stacked in two rows of four, will store energy generated by the wind turbine for later use. WPI sees its role in the partnership as a boost for sustainability in the surrounding community through the clean energy and storage offered by the wind turbine and storage system.

Trash 2 Treasure

It's the end of the school year, and you're leaving your dorm room for the last time. What happens to all the stuff you don't want - the used microwave, that clothing iron you bought and never used? Where does it go?

To reduce the waste from items residents no longer want, WPI student **Maria Daigle** started Trash 2 Treasure (modeled on the program begun at UNH by Alex Fried) this past year. For a week at the end of the year, boxes were placed in each dorm - Morgan, East, and Faraday, among others - where students moving out could place their unwanted items such as appliances, clothing, fans, and calculators. Hundreds of items, including 744 pounds of clothing, were collected and donated to the Hartsprings Foundation, where they will go to help local children in the Big Brother Big Sisters mentoring program.

The program will continue next year, with the eventual goal of storing the unwanted items and selling them during move-in at a reduced costs to new students. Programs like this and similar partnerships in previous years are a success in turning waste into reuse. But what is driving us to buy things if we're just going to throw them out at the end of the year? And what consequences do we have the privilege of ignoring because we can dump unwanted items in the nearest trash can and pay someone to dispose of it for us?

Supporting Solar

Can you name all the planets in the solar system? Maybe you can or maybe you can't, but there's one thing everyone can name and point to: the sun. The sphere of radiating energy and heat that makes life here on Earth possible and that is the most abundant, clean source of energy we have.

This past year, WPI entered a 20-year contract with solar energy developer Nexamp to support new solar panel arrays in Rutland and two other locations. Nexamp manages the financing and construction of the solar grids, while WPI receives credit for the solar energy they harvest through a system known as virtual net metering.

This system allows WPI to support the expansion of clean energy in Massachusetts even without solar generation on campus. It saves the university money through the electricity credits, and it helps provide clean energy to residents and nonprofits around the solar facilities. As WPI sees it, this is sustainability at a broader scale: the expansion of clean energy throughout Massachusetts.

SUSTAINABILITY LITERACY SURVEY

WPI is a university, its goal is education, and one part of that education is sustainability. In order to measure how well sustainability is being communicated to students, the Office of Sustainability has implemented a new Sustainability Literacy Survey. The survey is given twice a year: once in August to incoming freshman and once in April to the entire community. Participation is currently voluntary. The 2017-18 school year was the first year the survey was taken, so the results cannot yet be compared over time, but the Office hopes to use them to understand what sustainability means to the WPI community and how it can better achieve its goals based on that understanding.

CONCLUSION

We asked you at the beginning of this report to pause for a moment, to let a breath in and out, to ask yourself: what is sustainability? How can we act sustainably?

If you can answer those questions (and ideally this report has provided a couple examples of how some of us do), then you have the foundation for the most important question of all: why does it matter? Why does sustainability *matter*?

That question is something we'll leave you to think about for yourself. In the end, sustainability is about people, it's about how we live and what we choose to value - and that is an individual decision.

We want to let you know, however, that during this upcoming 2018-19 school year, WPI will be updating its Sustainability Plan. We will be completing a five-year review of the Sustainability Plan since it was created in 2014. We will be developing new goals and methods in light of our sustainability efforts, both successful and incomplete, over the past five years.

Who are we? We are the Office of Sustainability, the Sustainability Advisory Committee - and you, the members of the WPI community, if you decide that sustainability is important to you. Please reach out to us with your ideas, critiques, and suggestions for sustainability at WPI, particularly as we develop our 5-year update to the WPI Sustainability Plan. We invite feedback at any time by reaching out to green@wpi.edu, or to the Sustainability Advisory Commitee:

Wayne Bates, Alumnus, Principal Engineer, Tighe & Bond
Corey Dehner, Assoc. Teaching Professor, IGSD
Mary Beth Harrity, Asst. CIO, Academic Technology
Scott Jiusto, Assoc. Professor, IGSD
Kathy Loftus, Alumnus, Global Head of Energy Efficiency, WholeFoods
Linda Looft, Asst. VP, Government & Community Relations
Julie Loveless, Assoc. Director of International Admissions
Martin Luttrell, Digital Communications Manager
Paul Mathisen, Professor, Civil & Environmental Engineering, Director of Sustainability
John Orr, Professor, Electrical & Computer Engineering, Emeritus
Derren Rosbach, Assoc. Teaching Professor, Civil & Environmental Engineering
Joe Sarkis, Professor, School of Business
Greg Snoddy, Dean of Students
Winston Soboyejo, Provost
Jeff Solomon, CFO
Bill Spratt, Director, Facilities Operations
Liz Tomaszewski, Assoc. Dir. of Sustainability, Facilities Systems Manager
Kristin Wobbe, Assoc. Dean, Undergraduate Studies

It's your campus.

It's your community.

It's your planet.

It's your choice.

ACKNOWLEDGEMENTS

Sustainability is a community-wide effort, as was the creation of this report. Thank you, therefore, to everyone who took the time to answer my emails, meet with me in person, and share with me what sustainability means to them. Even though their work may not be directly mentioned, the ideas they explained and took the time to discuss with me are the foundation upon which this report stands.

Specifically, thank you to the following:

For taking the time to meet in person and explain their work and why it matters:

Barbara Milanese, Bettny Mazur, Diane Begreen, Joe Kraskouskas, Michelle McKee, Mike Bocka, Shavaun Cloran, and Professors Aaron Deskins, Aaron Sakulich, Burt Tilley, David Spanagel, Eric Young, Joseph Fehribach, Joseph Sarkis, Katherine Foo, Lisa Stoddard, Maqsood Mughal, Michael Timko, Nicholas Williams, Nikolaos Kazantzis, Patricia Stapleton, Ravindra Datta, Roger Gottlieb, Shichao Liu, Soroush Farzin-Moghadam, Suzanne LePage, and Vadim Yakovlev.
Thanks especially to Professor Robert Traver for all of the questions he asked and answered.

For providing information by email:

Alison Donta-Venmen, Bill Grudzinski, Caitin Donlan, Christine Kobza, Ed Reynolds, James Monaco, John Orr, Maria Daigle, Michelle O'Connell, Mike Dorsey, Monelle Verdolino, Nicole Luiz, and Professors Pamela Weathers, Rajib Mallick, and Yu Zhong.

For the beautiful photos they provided:

Jacleen Becker and Matthew Burgos.

For editing and suggestions:

Director of Sustainability Professor Paul Mathisen.

For making the writing of this report so much more fun than sitting at a computer by myself:

All of the Facilities workers, including (but far from limited to) Amy Rojotte, Hannah Poirier, and Yvette Rutledge.

And for, among other things, answering innumerable questions, providing invaluable suggestions and resources, and caring about her work:

Associate Director of Sustainability Liz Tomaszewski

Sincerely, and with the hope that this report has provided some food for thought,

Maya Sun
Chemical Engineering, Class of 2021

Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609
wpi.edu/+sustainability
green@wpi.edu