PROGRAM INFORMATION
Sustainability Ph.D.
Sustainable Systems M.S.
2014–2015
Introduction

Golisano Institute for Sustainability (GIS) is a multidisciplinary academic unit of Rochester Institute of Technology whose mission is to undertake world-class education and research in sustainability.

GIS academic and research programs focus on sustainable production, sustainable energy, sustainable mobility, and ecologically friendly information technology systems. These programs are led by a multidisciplinary team of faculty and researchers who collaborate with organizations locally, nationally, and internationally to create implementable solutions to complex sustainability programs.

The Institute was founded in 2007 with a $10M grant from B. Thomas Golisano. The GIS Sustainability Ph.D. program began in 2008 — offering the world’s first doctorate focusing on sustainable production systems. The Sustainable Systems M.S. program began in 2010.
Overview of Degree Programs

GIS’ multidisciplinary Ph.D. and M.S. programs are designed for students who are driven to become sustainability change agents within industry (executive management, product development, manufacturing & remanufacturing, supply chain management, and service), executive and legislative branches of government, nongovernmental agencies, academic institutions, professional associations, financial and investment communities, the indemnification industry, and the legal profession.

These programs focus on systems that create goods and services using processes that conserve energy and natural resources and are non-polluting, economically viable, and safe and healthful for workers, communities, and consumers. Students will develop expertise in such areas as industrial ecology, economics of sustainability, risk analysis of sustainable systems, and multicriteria decision making. They will study methodologies such as life-cycle assessment, environmental risk and impact assessment, design for the environment, pollution prevention, closed loop supply chain management, and product life assessment, and apply their expertise to their research. As a result, graduates will be prepared to undertake careers in their chosen fields with an understanding of sustainability. Students develop a program of study in their chosen area of interest in consultation with their advisor.

Sustainable Systems M.S. Tracks
Students have the option of choosing a track and corresponding elective courses in sustainable manufacturing, sustainable mobility, or sustainable energy systems, as well as others. Students must complete a minimum of 30 semester hours of combined coursework and capstone. This includes a minimum of 30 semester hours of coursework and an 6 semester hours capstone experience.

Examples of electives and independent studies are:

**Sustainable Manufacturing Track:**
- Material Cycling
- Applied Life Cycle Assessment
- Remanufacturing Processes

**Sustainable Mobility Track:**
- Sustainable Mobility Systems
- Alternative Fuels and Energy Efficiency

**Sustainable Energy Systems Track:**
- Thermodynamics for Sustainability
- Sustainable Energy Systems
- Fuel Cell Technology

Admission

An earned baccalaureate degree including at least one year of college science, one year of college mathematics (including calculus and statistics) is required. Admission decisions are based on the Graduate Record Examination (GRE), official transcripts, grade point average (3.0 or greater is required), recommendation letters (minimum two), personal statement, research interests, and TOEFL score for applicants whose native language is not English, and interviews with members of the faculty.

For registration and enrollment information, or to apply online visit [http://www.rit.edu/emcs/ptgrad/grad/](http://www.rit.edu/emcs/ptgrad/grad/). For preferred consideration, PhD applicants should apply by January 15. MS applications will be accepted until July.
Degree Requirements

Sustainable Systems M.S.
The core course requirements are:

- ISUS-702 Fundamentals of Sustainability Science
- ISUS-704 Industrial Ecology
- ISUS-708 Sustainability Practice
- ECON-711 Microeconomics for Graduate Students
- ISUS-705 Technology Policy and Sustainability
- ISUS-806 Risk Analysis

Elective courses are selected in consultation with the student’s advisor from a wide variety of courses offered by GIS or one of RIT’s eight colleges.

Sustainability Ph.D.
The core course requirements are:

- ISUS-600 Graduate Seminar
- ISUS-702 Fundamentals of Sustainability Science
- ISUS-704 Industrial Ecology
- ISUS-705 Technology Policy and Sustainability
- ISUS-806 Risk Analysis
- ISUS-808 Multicriteria Sustainable Systems Analysis
- ECON-810 Economics of Sustainability

Elective courses are selected in consultation with the student’s advisor from a wide variety of courses offered by GIS or one of RIT’s eight colleges.

Program Structure

Sustainable Systems M.S.
Typical schedule for completion in one year.

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<th>FALL</th>
<th>SPRING</th>
<th>SUMMER</th>
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<tr>
<td>ISUS–702 Fundamentals of</td>
<td>Policy Requirement**</td>
<td>Capstone</td>
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<tr>
<td>Sustainability Science</td>
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<td>ECON–711 Microeconomics</td>
<td>ISUS–704 Industrial Ecology</td>
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<td>for Graduate Students*</td>
<td>ISUS–708 Sustainability Practice</td>
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<td>ISUS–806 Risk Analysis</td>
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*Or approved substitute.
**Policy Requirements met by ISUS-705 Technology Policy and Sustainability, or appropriate substitute.

Sustainability Ph.D.
Typical schedules in the first two years for full time students are shown below. Most students will take the Qualifying Exam between their first and second year. After the second year, students will concentrate on their research and complete supporting elective courses.

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<td>ECON–711 Microeconomics</td>
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<td>ISUS–808 Multicriteria Sustainable</td>
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<td>ISUS–806 Risk Analysis</td>
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<td>Year 1</td>
<td>Qualifying Exam</td>
<td>Year 2</td>
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*May be waived for students with previous microeconomic courses.  **Policy Requirements met by ISUS-705 Technology Policy and Sustainability, or appropriate substitute.
**ISUS-600 Graduate Seminar**

This is a required course for students admitted to the Sustainability Ph.D. program. Students will learn about current research in sustainable production systems from faculty and guest speakers. Topics pertaining to the development of plans of study and research proposals, as well as teaching skills, will be covered. (Enrollment in the Sustainability Ph.D.) Class 1, Credit 1 (ES)

**ISUS-619 Tools for Graduate Research**

This class will introduce graduate students to tools and software that will be of use in conducting, analyzing, and presenting their research. An introduction, highlights of key features, and the basics of operation will be taught for software aimed at: bibliographic referencing (e.g., Endnote, Latex), statistical analysis (e.g., Excel, SPSS, SAS), analytical work (e.g., Matlab, Mathematic, Maple), advanced plotting (e.g., Deltagraph, Illustrator, Origin), equation editing (e.g., Mathtype), and search engines (e.g., setting up RSS feeds, material property databases). Assignments will be direct applications to thesis / dissertation research. (Enrollment in the Sustainability Ph.D or M.S. program or the permission of Instructor.) Class 3, Credit 3 (offered occasionally)

**ISUS-700 Special Topics**

A critical examination of issues in some area of sustainability not covered in other Golisano Institute for Sustainability courses. Topic depends on specific offering. (Enrollment in Sustainability Ph.D. or M.S. in Sustainable Systems program or permission of Instructor) Class 3, Credit 3 (offered occasionally)

**ISUS-701 Independent Study**

An independent project in sustainability not covered in the available courses. This project can be experimental research, literature review, or other appropriate work. This course requires a formal proposal and a faculty sponsor. (Enrollment restricted to students in the Sustainability Ph.D. or Sustainable Systems M.S. program) Class 1, Credit 1–3 (FS,Su)

**ISUS-702 Fundamentals of Sustainability Science**

This course prepares students to conduct original research related to sustainable production and consumption systems and apply the scientific method in an integrative, team-based approach to graduate research. This course introduces the fundamental concepts of industrial ecology, ecological economics, ecosystem health and social ecology that are essential to understanding the interaction of industrial and ecological systems. Successful students will understand multiple perspectives on sustainability such as strong and weak formulations, the importance of sustainability as an ethical concept and a life-cycle approach to organizing research related to sustainability. It is a core course within the Sustainability Ph.D. program. (Research experience and graduate standing recommended; enrollment in Sustainability Ph.D. program or Sustainable Systems M.S.; exceptions are by permission of Instructor.) Class 3, Credit 3 (F)

**ISUS-704 Industrial Ecology**

Industrial ecology is the study of the interaction between industrial and ecological systems. Students in this course learn to assess the impact and interrelations of production systems on the natural environment by mastering fundamental concepts of ecology as a metaphor for industrial systems and the resultant tools from industrial ecology, including life-cycle assessment, material flow analysis, and energy and greenhouse gas accounting. This is a core course within the Sustainability Ph.D. program. (Research experience and graduate standing recommended; enrollment in Sustainability Ph.D. or Sustainable Systems program; exceptions are by permission of Instructor.) Class 3, Credit 3 (S)

**ISUS-705 Technology Policy and Sustainability**

Public policy is a multidisciplinary field aimed at understanding how policy and regulation can be used to achieve certain social goals. These goals may include the notion of sustainability, whereby society's present needs are met without compromising the ability to meet society's future needs. This course introduces students to public policy and its role in building a sustainable society. The course places particular emphasis on: the policy process; the relationship among technology, policy, and the environment; and policy mechanisms for addressing market and government failures that threaten sustainability. (Enrollment in the Sustainability Ph.D. or Sustainable Systems M.S. program or permission of Instructor.) Class 3, Credit 3 (F)

**ISUS-708 Sustainability Practice**

This course covers theoretical and practical issues associated with analysis and progress towards sustainability. Methods and concepts covered include optimization, stochastic analysis, multicriteria decision-making and resource economics. Societal perception and response to sustainability is covered sector by sector (industry, government, academia and civil society) and through integrative case studies of particular sustainability issues (e.g. natural gas fracking). Emerging sustainability governance mechanisms are explored, in particular environmental certifications and standards (e.g. LEED, EnergyStar) and multilateral agreements. (Enrollment in the Sustainability PhD or MS program or the permission of the instructor). Class 3, Credit 3 (F)

**ISUS-710 Sustainable Product Design**

The application of sustainability and product design methods. Lectures and projects will incorporate strategies such as: effective sustainability methods and life-cycle assessment; enhancement of product value and prolonged use; and balance between recycling,
reusing and repurposing. Sustainable Product Design enables an interdisciplinary collaboration between Sustainability and Industrial Design. Both areas will offer their unique approach while learning and integrating knowledge from each other. (GIS graduate student or by approval of Instructor.) Class 3, Credit 3 (S)

**ISUS-718 Sustainable Energy Systems**

Energy will play an increasingly vital role in economic, environmental and political developments around the world. This course first investigates the current trends in energy production, distribution, and consumption associated with the primary incumbent energy system technologies: fossil fuel combustion and nuclear power. An understanding of the economic, environmental and social limitations of these technologies will lead to analysis of the potential benefits of three key renewable technologies: solar (including wind), biomass and hydrogen/fuel cells. Potential paths to market penetration for these technologies will be introduced, including geographical variations expected to occur globally and within the United States. (Graduate standing or permission of Instructor.) Class 3, Credit 3 (offered occasionally)

**ISUS-780 Capstone**

An independent project in sustainability serving as a capstone experience for students completing the non-thesis option. This course requires a formal proposal and a faculty sponsor. (Enrollment restricted to students enrolled in the Sustainable Systems M.S. program and approval of the Academic Director.) Class 1, Credit 1 (F,S,Su)

**ISUS-790 Thesis**

Independent research in sustainability leading to the completion of the MS thesis. This course requires a formal proposal and a faculty sponsor. (Enrollment restricted to students enrolled in the Sustainable Systems M.S. program). Class 3, Credit 1 (F,S,Su)

**ISUS-791 Continuation of Thesis**

MS or PhD students requiring additional time to complete their thesis. (Enrollment restricted to students enrolled in the Sustainable Systems M.S. or Sustainability PhD program). Class 0, Credit 0 to 1 (F,S,Su)

**ISUS-806 Risk Analysis**

This course examines risk identification, quantification, and management from the standpoint of the three key components of sustainability science (economics, environment, and society). Economic subjects include cost-benefit analysis, value of information, time value of money, basic decision analysis, value functions, monetizing challenges for ecosystem services, and sustainability risk management. Environmental subjects include toxicological perspectives such as fate and transport and dose-response relationships including an overview of EPA’s current practice. Policy and societal subjects include utility theory and lotteries, risk perception, ethical issues in risk quantification, and impact statements. It is a core course within the Sustainability Ph.D. and M.S. programs. (Enrollment in the Sustainability PhD or MS program or the permission of Instructor.) Class 3, Credit 3 (F)

**ISUS-807 Research**

Research in fulfillment of Sustainability Ph.D. dissertation or M.S. capstone requirements. (Enrollment restricted to students in the Sustainability Ph.D. or Sustainable Systems M.S. program.) Credit variable (F,S,Su)

**ISUS-808 Multicriteria Sustainable Systems Analysis**

This class will explore how decisions are made when confronted with multiple, often conflicting, criteria or constraints. The focus will be on the following analytical methods: linear and stochastic programming, optimization, and Monte Carlo simulation. Case studies will focus on sustainability multi-criteria problems such as energy planning, sustainable development, resource management, and recycling. Students will apply methods learned to a project involving their dissertation research. It is a core course within the Sustainability PhD and MS programs. (ISUS-806 Risk Analysis or the permission of the Instructor.) Class 3, Credit 3 (S)

**ISUS-810 Thermodynamics for Sustainability**

As energy plays a fundamental role in the system sustainability framework, it is essential that students and practitioners have an understanding of the laws of thermodynamics which govern the processes of energy usage and conversion. This course investigates the differences between energy and exergy analysis, where the latter includes not only the quantities of energy exchanged, but also the “quality” of the energy relative to some reference state. After establishing the fundamentals of exergy analysis, this concept is applied to practical sustainability problems associated with sustainable development, industrial systems and energy policy. Specific examples are also explored, including thermal storage and fuel cell systems, and life-cycle assessment. (Undergraduate thermodynamics course.) Class 3, Credit 3 (S)

**ISUS-821 Applied Life Cycle Assessment**

Life-cycle assessment (LCA) is a tool used in the field of industrial ecology to evaluate the environmental impacts of products or processes over their entire life cycle — from raw material extraction, manufacturing, use, and end-of-life management. This course will build on fundamental principles of LCA by allowing students to conduct project-based studies on the application of LCA to real-world sustainability issues. Students will apply process, economic input-output, and hybrid methodologies to evaluate technological systems for opportunities of environmental improvement. (Permission of Instructor). Class 3, Credit 3 (offered occasionally)

**ISUS-822 Material Cycling**

This class will explore the economic and environmental incentives for recycling and resource recovery. The focus will be on end-of-life fate of materials (including plastics, metals, glass, and e-waste) while
setting these within the context of overall ecosystem flows (carbon, sulfur, and nitrogen cycles, waste water, etc.). Technologies for the upgrading of secondary material streams will be studied including: physical and physico-chemical (beneficiation, electrostatic and magnetic separation), hydrometallurgical (selective precipitation, leaching, ion exchange), biotechnological (biosorption, sulfate reduction), and pyrometallurgical (filtration and fluxing). Production issues (product quality, remelt thermodynamics, exergy accounting, etc.) within the secondary industry will be explored with an emphasis on removing barriers to increased usage of scrap. Efforts for enhanced collection efforts and motivation of consumer and firm participation will also be covered (municipal collection fees, corporate take-back initiatives, legislation such as the WEEE directive, state deposits, etc.) (Enrollment in the Sustainability Ph.D. or M.S. program or the permission of Instructor.) Class 3, Credit 3 (offered occasionally)

**Student Research**

Ph.D. students, and M.S. students completing a thesis, conduct their research under faculty supervision. Examples of current topics include:

- Hydrometallurgical recycling of waste lithium-ion batteries using environmentally benign acid alternatives.
- Urban form and energy use and distributed energy systems.
- Waste to energy; forecasting technological progress; and electrical vehicles implementation and the smart grid.
- Environmental impacts of material flows, policy, and economic value for Gen-II solar photovoltaics at end-of-life.
- Exploring the environmental and economic trade-offs associated with end-of-life (EOL) decisions for consumer products.
- Evaluation of eco-design tools for implementation in product design and development processes and product sectors.
- Economic and environmental impacts of reforming bio-fuel and bio/petro blends to produce hydrogen for solid oxide fuel cell (SOFC)-based auxiliary power units (APUs).
- Water management in proton exchange membrane (PEM) fuel cells, with particular focus on economic trade-offs among strategies for mitigating water accumulation at the channel-to-manifold interface.
- Analysis of the integration of waste-to-energy technologies in the New York State dairy farm and food manufacturing industries using multi-criteria decision strategies to optimize renewable energy generation.
- Material flow analysis of lithium ion batteries, specifically for emerging EV technologies, including industrial ecology (material flow analysis, life-cycle assessment) and technology forecasting, with an emphasis on energy, material and waste management implications.
- Developing new sustainability models based on community ecology principles and optimal foraging theory to more effectively characterize and manage life-cycle impacts of a group of rapidly evolving products (i.e., consumer electronics) owned by a household.
- Service Life-cycle Decision Framework, and True Savings of Remanufacturing.
- The environmental risk and opportunities associated with end-of-life lithium-ion batteries, by quantifying nano-particle exposure risks during recycling processes and applying life-cycle assessment methodology to evaluate the environmental impacts.

**ISUS-877 Research Internship**

The Research Internship is designed to enhance the educational experience of PhD students through full-time employment (Enrollment restricted to students enrolled in the Sustainability PhD program. Requires Department approval). Credit 0 (F,S,Su)

**ISUS-890 Dissertation Research**

Research fulfillment of Sustainability Ph.D. dissertation requirements. (Enrollment restricted to students in the Sustainability Ph.D. program who have successfully completed qualifying exam.) Credit variable (F,S,Su)
Dr. Nabil Nasr  
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Dr. Gabrielle Gaustad  
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Dr. Thomas A. Trabold  
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Dr. Michael Thurston  
Research Faculty and Technical Director, Systems  
Modernization and Sustainment Center  
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Expertise: Life-cycle Engineering, Asset Health Management, Product Design

Dr. Eric Williams  
Associate Professor  
exwgis@rit.edu • 585-475-7211 • 81-2171  
Expertise: Industrial Ecology, Life-cycle Assessment, Macro-assessment of Energy Supply and Demand

Dr. Anahita Williamson  
Research Faculty and Director,  
New York State Pollution Prevention Institute  
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Expertise: Manufacturing Process Modification for Improved Material Recovery and Reuse, Design for the Environment, Life-cycle Assessment (LCA)
Additional Information

Online

Golisano Institute for Sustainability website
www.rit.edu/gis

Sustainable Systems M.S. program webpage
www.rit.edu/gis/academics/ms-sustainability/

Sustainability Ph.D. webpage
www.rit.edu/gis/academics/ph.d-sustainability/

Program Office Contacts

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