The University Senate of Michigan Technological University
Proposal 72-21
(Voting Units: Academic)

Establishment of a New Graduate Certificate in "Engineering Sustainability and Resilience"

Submitted by: The Department of Chemical Engineering
on Behalf of The Initiative on Sustainability & Resilience

1. **Proposal Date:**
   March 5, 2021

2. **Proposing Contacts and Department:**
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3. **Sponsor Department Approvals**
   Chemical Engineering Department approved on March 10, 2021

4. **General Description and Characteristics of Program:**

4.1 General Description of Certificate

Students will understand and develop skills in the application of sustainability principles in their different fields of study. This certificate includes courses that employ an interdisciplinary approach to graduate education in sustainability and resilience. The two required courses for the certificate are currently being delivered online, and most of the courses involved in the certificate are online-ready as well, with no additional development resources required. This certificate will provide exposure to concepts at the intersection of technology and the corresponding implications for sustainability and resilience of human and natural systems. While completing the certificate, students will learn and reflect on a number of related issues, such as:

- the origins of, and major advancements in, sustainable development, such as the United Nations' Sustainable Development Goals,
- systems analysis skills through application of environmental life cycle assessment (LCA),

- grand challenges in sustainability such as global climate change and the efficient utilization of materials through circular economy,
- environmental literacy, and
- policy and collective action in addressing challenges associated with sustainability and resilience.

The certificate will allow students to put sustainability and resilience thinking into practice within their chosen fields of study and careers. The skills developed in sustainability assessment will allow them to gain systems-level insights.

4.2 Catalog Description

Society, the environment, and economic/industrial development - the "triple bottom line" - are inherently interconnected, both domestically and worldwide. A high standard of living requires a sustainable future, one in which human and industrial systems support an enhanced quality of life by recognizing and seeking to understand this interconnectivity. This certificate will provide the student with the skills in systems analysis needed to understand, empirically examine, and contribute to a more sustainable and resilient society.

5. Rationale for Certificate:

In higher education, there is a growing recognition of the importance of instilling “T-shaped” skills in graduates. A ‘T-shaped’ education establishes a depth of knowledge in the required skills and expertise in a single discipline (the vertical segment in the “T”), while also enabling students to collaborate with experts from other disciplines and to apply multidisciplinary knowledge (the horizontal segment). A multidisciplinary education is central to this approach. In addition, themes of sustainability and resilience are gaining wide adoption in the companies who hire students from Michigan Tech. This is borne out by the fact that most Fortune 500 companies employ sustainability professionals and report annually on sustainability performance (see Ford Motor Company Sustainability site, https://corporate.ford.com/microsites/sustainability-report-2020/index.html). The World Business Council on Sustainable Development (WBCSD) places a high emphasis on sustainability education and partners with major universities on education programs (https://www.wbcsd.org/Projects/Education). The 2006 National Research Council report on Sustainability in the Chemical Industry (https://www.nap.edu/catalog/11437/sustainability-in-the-chemical-industry-grand-challenges-and-research-needs) maps steps toward an ideal future vision for the chemical industry, and emphasizes the crucial role of sustainability education. This graduate certificate is intending to address these priority needs in graduate education.

Sustainability in higher education is needed to meet the desire of students to share knowledge, gain understanding and develop skills that allow them to apply their disciplinary training while understanding its interconnected impact on other realms of social life. Within the companies and organizations that hire our students, sustainability is gaining prominence as they strive to achieve economic growth, environmental protection, and societal equity. Michigan Tech is in a position to

successfully develop and implement this graduate certificate because of its history in sustainability education programs such as the Interdisciplinary Graduate Certificate in Sustainability (IGCS) offered by the Sustainable Futures Institute (SFI). This new certificate is a replacement for the current 15-credit IGCS Graduate Certificate in Sustainability, which will be phased in favor of this new 9-credit model. The new certificate will include widely available online courses. Graduate students who may apply this certificate towards an MS or PhD degree or working professionals who want to expand their skills will benefit from this certificate. Similar courses to these proposed courses currently offered in the IGCS draw significant numbers of MTU students; in fact the two required classes for the certificate are revised versions of classes that have been offered at MTU for over 15 years, with a steady record of multi-disciplinary enrollment. The five-year average enrollment in the two required courses is 47 students and 22 students for ENG 5510 and ENG 5520, respectively. Offering them as part of a 9-credit certificate instead of a 15 credit certificate will likely increase enrollment. The proposed certificate may attract undergraduate students to enroll in graduate courses without having to commit to a full MS degree. In addition, the proposed certificate may attract working professionals who find working full time and getting an MS degree to be difficult to manage.

6. Related Programs:

Harvard Extension School – Corporate Sustainability and Innovation Graduate Certificate (4 courses)
https://www.extension.harvard.edu/academics/professional-graduate-certificates/corporate-sustainability-innovation-certificate
This graduate certificate must be completed within 3 years with a grade of B or better in each course. No information on prerequisites was found. Students must take between 2-4 core courses but can select between 0-2 elective courses.

Columbia University-The Earth Institute – Certification in Sustainability Analytics (12 credits)
https://www.sustainability.ei.columbia.edu/sustainability-analytics
The Certification in Sustainability Analytics addresses the need to train professionals in quantitative and technical skills central to the practice of sustainability. The certification (one of several) is part of the MS in Sustainability Management, but it is not clear whether students can take the certification without being in the MS program.

Colorado State University – Sustainable Military Lands Management (9 credits)
https://www.online.colostate.edu/certificates/sustainable-military-lands-management/

- Gain an overview of military lands in the United States in historical, geographical, and environmental contexts.
- Learn general practices and theory of land management and cultural anthropology.

- Study the ecological principles of military training and testing, and learn about the disturbances caused by these activities.
- Explore cultural resource laws, policies, management, and preservation as they apply to military lands.
- Prepare to lead stewardship-related matters on military lands.

University of Michigan, School for the Environment and Sustainability – Graduate Certificate Program in Sustainability (12 credits)
https://seas.umich.edu/academics/graduate-certificate-programs
This certificate is open to students enrolled in any University of Michigan graduate program and persons not currently enrolled in a University of Michigan graduate program. Applicants not enrolled in a University of Michigan graduate program must have earned a bachelor's degree or higher and can apply directly through standard admissions procedures. A person admitted to the certificate program must complete requirements within four years from the date of first enrollment in the program.

7. Projected Enrollments:

The courses proposed in section 9 are based on two courses (ENG5510, ENG5520) that exist already and typically have a combined enrollment of about 70 students/yr. These courses are core to the current 15-credit Interdisciplinary Graduate Certificate in Sustainability, which has averaged 5 awarded certificates per year over the past 5 years. This proposed 9-credit graduate certificate in Engineering Sustainability and Resilience will likely increase certificates completed per year. Online offerings of the courses could be attractive for professional students outside the campus with interests in career transitions for sustainability positions in their firms or in other firms. The two courses in this certificate may be taken independent of the certificate if space allows, which has often happened in the past for students who want a more limited exposure to concepts of sustainability and resilience.

Projected enrollments in the Certificate program

Semester	On-campus Enrollment	On-line Enrollment
Fall 2021	5	5
Fall 2022	10	10
Fall 2023	15	20
Fall 2024	20	25
Fall 2025	20	30

8. Scheduling Plans:

No change in the regular scheduling of the existing courses is anticipated. Courses will be available online throughout the academic year and some electives are available during summer semester.

9. Curriculum Design:

The certificate is designed to be completed in 2 to 3 semesters, depending on the chosen elective course. Students will likely begin in Fall semester, but could also begin by taking the second required course ENG 5520 in the spring, or an elective course in starting in the Spring or Summer semesters.

Required Pre-requisite courses:

There are no prerequisites for the required courses.

Required Coursework (9 credits, 2 required courses and 1 elective) Required Courses (2 courses, 6 credits)

ENG 5510 Introduction to Sustainability and Resilience (Fall semester, in-class and online)

ENG 5520 Systems Analysis for Sustainability and Resilience (Spring semester, in-class and online)

Elective Courses (students choose 1 from the list of potential courses, min. 3 credits)

Elective courses have been selected to represent a wide range of academic units, to address issues commonly associated with sustainability, and to provide additional sustainability assessment skills. All of these courses offer students the ability to evaluate issues from multiple sustainability perspectives. Elective course options will be re-evaluated regularly. Choose one course from one of the two lists below.

4000 Series Courses

1) CEE 4506 Sustainable Engineering
2) MEEM 4235 Wind Energy
3) FW 4111 Indigenous Natural Resource Management
4) SS 4700 Communities and Research

5000 Series Courses

5) CEE 5350 Life Cycle Engineering
6) CEE/CSE 5710 Modeling and Simulation Applications for Decision-Making in Complex Dynamic Systems
7) EE 5260 Wind Power
8) EE / MEEM 5275 - Energy Storage Systems
9) EC 4640 / EC 5640 - Natural Resource Economics
10) EC 4650 / EC 5650 - Environmental Economics
11) FW 5550 GIS and Spatial Analysis
12) MSE 5490 Solar Photovoltaic Science and Engineering
13) MSE 5760 Vehicle Battery Cells and Systems

14) SS 5313 Sustainability Policy
15) UN 5400 Climate Science and Policy

10. Course Descriptions Required

Courses (6 credits)

ENG 5510 Introduction to Sustainability and Resilience (3 credits)
Introduction to sustainable development, resilience, and global grand challenges with emphasis on socio-technical systems. Key topics include earth systems literacy, policy development, corporate social responsibility, ecological economics, sustainability indicators, and industrial / societal applications (e.g. agricultural, mining sustainability, etc.).

ENG 5520 Systems Analysis for Sustainability and Resilience (3 credits)
In-depth coverage of systems analysis using advanced tools and methods. Topics will include environmental life cycle assessments, social life cycle assessments, techno-economic assessments, material flow analysis, industrial ecology, and regional economic assessments.

Elective Courses (3 credits selected from the list below)

CEE 4506 Sustainable Engineering
Study of sustainability, engineering and design including systems analysis, life cycle analysis, biogeochemical cycles, energy balances, energy conservation and development, models for sustainable engineering, environmental regulations as sustainability instruments, sustainability in the build environment, and industrial ecology and compliance. Credits: 3.0 Lec-Rec-Lab: (0-3-0) Semesters Offered: Spring; Prerequisite(s): CEE 3501 or CEE 3503

CEE 5350 Life Cycle Engineering
The course examines how life cycle assessment (LCA), life cycle costing analysis (LCCA), green rating systems, value engineering and alternative project delivery systems influence design decisions and project outcomes. Topics will be discussed within the context of the underlying scientific principles and relevant standards. Credits: 3.0 Lec-Rec-Lab: (2-0-1) Semesters Offered: Spring - Offered alternate years beginning with the 2020- 2021 academic year; Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

CEE/CSE 5710 Modeling and Simulation Applications for Decision-Making in Complex Dynamic Systems
Introduces students to the theory and application of modeling techniques and simulations in the analysis of decision alternatives in complex engineering problems. Topics include queuing theory, system dynamics modeling, agent-based modeling, discrete event simulations, etc. Students will be required to conceptualize and implement an appropriate research/engineering problem of choice (this could be a dissertation/thesis problem). Credits: 3.0 Lec-Rec-Lab: (3-0-0) Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year.

Restrictions: Must be enrolled in one of the following Level(s): Graduate

MEEM 4235 Wind Energy

This course introduces students to the underlying principles of wind energy conversions, with an emphasis on engineering aspects of wind turbine design and construction, and the evaluation of wind resources. Credits: 3.0 Lec-Rec-Lab: (3-0-0) Semesters Offered: Fall; Prerequisite MEEM 3201 (introductory fluid mechanics and heat transfer)

EE 5260 Wind Power

Wind turbines are the fastest growing segment of the generator mix being added to power systems today. There is a growing need to understand the many issues caused by these additions. This course covers the theoretical background, regulations, integration experience, and modeling. Credits: 3.0 Lec-Rec-Lab: (3-0-0) Semesters Offered: On Demand; Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

EE / MEEM 5275 - Energy Storage Systems

Designing energy storage solutions for grid, vehicle and portable/autonomous systems. Quantitative and qualitative analysis of energy storage aging, cost, and performance improvement. Credits: 3.0 Lec-Rec-Lab: (0-3-0) Semesters Offered: Spring

EE 5290 - Selected Topics in Power Systems

Selected topics of current interest. Credits: variable to 4.0; May be repeated; Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering

EC 5640 - Natural Resource Economics

Analyzes the economic aspects of producing/using natural resources. Nonrenewable resources and renewable resources are discussed. The economics of land use, macroeconomic topics such as economic growth, sustainability and green accounting are considered. Credits: 3.0 Lec-Rec-Lab: (3-0-0) Semesters Offered: Fall; Restrictions: Must be enrolled in one of the following Level(s): Graduate Prerequisite(s): EC 2001 or EC 3002

EC 5650 - Environmental Economics

Considers the efficient and equitable use of environmental resources. Measures the benefits and costs of decreasing pollution and protecting scarce ecological resources; addresses market failures and the economic valuation of environmental amenities. Requires students to learn quantitative and technical techniques to determine the efficient use of resources. Credits: 3.0 Lec-Rec-Lab: (3-0-0) Semesters Offered: Fall; Restrictions: Must be enrolled in one of the following Level(s): Graduate Pre-Requisite(s): EC 2001 or EC 3002

FW 4111 Indigenous Natural Resource Management

In this course, students gain knowledge in indigenous history, culture, and policy to enhance understanding of the rights and privileges associated with treaties, government-to-government relationship, and diversity of people, practices and values. Students engage in multidisciplinary scholarship with relevance for today's shared management regime. Credits: 3.0 Lec-Rec-Lab: (3-0-0); Semesters Offered: Spring Restrictions: May not be enrolled in one of the following Class(es):

FreshmanPrerequisite(s): UN 1015 and (UN 1025 or Modern Language - 3000 level or higher)

FW 5550 Geographic Information Science and Spatial Analysis

Use of geographic information systems (GIS) in resource management. Studies various components of GIS in detail, as well as costs and benefits. Laboratory exercises use ArcGIS software package to solve resource management problems. Credits: 4.0 Lec-Rec-Lab: (3-0-3); Semesters Offered: Fall; Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior; Prerequisite(s): MA 2710 or MA 2720 or MA 3710

MSE 5490 Solar Photovoltaic Science and Engineering

Solar photovoltaic materials, the device physics of photovoltaic cells and practical applications of solar electric systems engineering. Credits: 3.0 Lec-Rec-Lab: (3-0-0); Semesters Offered: On Demand; Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

MSE 5760 Vehicle Battery Cells and Systems

The behavior and application of batteries will be examined by introducing concepts from thermodynamics, materials science, transport processes and equivalent circuits. Credits: 3.0 Lec-Rec-Lab: (3-0-0); Semesters Offered: Fall (alt years); Prior exposure to first-year chemistry, elementary electrical circuits, and elementary transport theory is assumed.

SS 4700 Communities and Research

A rural sociology course analyzing the sustainability of rural communities (socially, environmentally, economically, and culturally). The course involves participatory research conducted together with a local community organization. Students practice research skills while making a difference in improving community life. Credits: 3.0 Lec-Rec-Lab: (0-3-0); Semesters Offered: Fall; Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore; Prerequisite(s): UN 1015 and (UN 1025 or Modern Language - 3000 level or higher)

SS 5313 Sustainability Policy

Foundational scientific concepts (dynamic systems and catastrophe theory) as applied to socio ecological systems. Use of indicators and indices to track progress towards sustainability goals. Review of local, national, and global sustainability policies to avoid catastrophes and guide sustainable development. Credits: 3.0 Lec-Rec-Lab: (3-0-0); Semesters Offered: On Demand; Restrictions: Must be enrolled in one of the following Level(s): Graduate

UN 5400 - Climate Science and Policy

An interdisciplinary discussion format course covering the basic science of climate change and the development of international climate policy. Includes an analysis of policy targets in their scientific context and links to global sustainable development goals. Additional topics will be guided by the interests of the class and current events. Credits: 3.0; Repeatable to a Max of 6; Lec-Rec-Lab: (3-0-0); Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year; Restrictions: Must be enrolled in one of the following Level(s): Graduate

11. Model Schedule Demonstrating Completion Time

The certificate is designed to be completed in 2-3 semesters. Students can take 1-2 courses in the spring semester and one course in the fall or summer semesters. Both required courses will be offered both in person and online. Students can start any semester as shown in the table below:

Option			
A Fall start, 2 semester plan	Fall Y1: ENG 5510 Introduction to Sustainability & Resilience, and an Elective	Spring Y1: ENG 5520 Sys. Analys. for Sustainability & Resilience (and an Elective if not already done)	Summer:
B Spring start, 3 semester plan	Fall Y1: Fall Y2: ENG 5510 Introduction to Sustainability & Resilience	Spring Y1: Elective Spring Y2: ENG 5520 Sys. Analys. for Sustainability & Resilience	
C Summer start, 3 semester plan	Fall Y1: Fall Y2: ENG 5510 Introduction to Sustainability & Resilience	Spring Y1: Spring Y2: ENG 5520 Sys. Analys. for Sustainability & Resilience	Summer Y1: Elective

12. Library and other Learning Resources

No library or other learning resources are required at this time.

13. Faculty Resumes

The following faculty will be supporting the program.
Dr. David Shonnard, Professor of Chemical Engineering
https://www.mtu.edu/chemical/department/faculty/shonnard/
Dr. David Watkins, Professor of Civil and Environmental Engineering
https://www.mtu.edu/cee/people/faculty-staff/faculty/watkins/watkins-cv.pdf
Dr. Chelsea Schelly, Associate Professor, Social Sciences
https://www.mtu.edu/social-sciences/department/faculty/schelly/
Dr. Robert Handler, Sr. Research Engineer
https://www.mtu.edu/chemical/department/staff/handler/

14. Equipment

No additional equipment will be required.

15. Program Costs

Costs for offering the required courses in the certificate will be covered by the Department of Chemical Engineering, where the Robbins Chair in Sustainable Use of Materials currently resides. This department will receive any revenue returned from eligible online enrollment in the two required courses. The current holder of the Robbins Chair in Sustainable Use of Materials will be lead instructor of the two required courses in the certificate and will manage all aspects of the certificate. Students will be charged the chemical engineering tuition rate.

16. Space

There are no new space requirements. We envision a need to use a distance learning classroom to support this certificate.

17. Policies, Regulations, and Rules

Not applicable

18. Accreditation Requirements

Michigan Tech is accredited by the Higher Learning Commission (HLC). The proposed certificate will meet HLC criteria 3 and 4. The proposed certificate will not seek additional accreditation.

19. Planned Implementation Date

Fall 2021

20. Assessment

The learning objectives of the Certificate are as follows.

GLO1. Students receiving this certificate will be able to apply a holistic sustainability and resilience assessment to emerging technical and societal issues by integrating multiple complementary analysis frameworks to assess a specific issue.

GLO2. Students receiving this certificate will be able to communicate sustainability assessments to their peers.

Approval Process

College of Engineering: Approved 3/11/21

Graduate School

Provost's Office and Deans' Council

Approved by the Senate:

Approved by the President: