ES99L-15 Industrial Ecology and Sustainable Engineering

22/23

Department
School of Engineering
Level
Taught Postgraduate Level
Module leader
Taofeeq Ibn-Mohammed
Credit value
15
Module duration
1 week
Assessment
100% coursework
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Contemporary global economic challenges, which are exacerbated by intensive competition through international trade and the rapid growth in population has led to negative impact on environmental systems (such as the diminishing finite natural resources and environmental impacts) as well as on socioeconomic systems. Addressing these challenges, without destabilising industrial and business processes whilst operating within the safe operating zone of the planetary boundaries has, therefore, become a matter of global concern and urgency. The associated complexities of these challenges including technology development, economic growth, environmental management, and social change have led to a surge in demand for the requisite knowledge and skills in the area of Industrial Ecology and Sustainable Engineering.

Industrial Ecology is an emergent interdisciplinary scientific discipline of developing nearly closed-loop industrial ecosystems of material exchange and efficient energy cascading by mimicking natural systems. Sustainable Engineering, on the other hand, supports the development of products and processes through the lens of the triple bottom line (TBL) framework, based on a balanced view of economic, environmental and social aspects. As such, sustainable engineering could be considered the operational aspects of industrial ecology in that it adopts industrial ecology tools such as lifecycle, input-output, techno-economic and material flow analyses across a range of environmental, economic, and social sustainability indices. It then adopts sustainable engineering methods to integrate that knowledge into products, processes, and services design and management. These analyses form the basis of industrial ecology and sustainable engineering that seeks to develop and manage products, processes and services that satisfies human needs in a sustainable manner.

This module is designed for students from diverse disciplinary backgrounds and aims to provide them with critical knowledge and skills to analyse and contribute to sustainable technical solutions in industry, consultancy, governmental agencies, and research. The module covers aspects including but not limited to key concepts of industrial ecology (industrial ecosystems, industrial symbiosis, and industrial metabolism), industrial ecology tools (lifecycle, input-output, techno-economic, and material flow analyses), sustainable engineering and design for environment, environmental impact assessment, sustainable production and consumption, resource/material efficiency and circular economy strategies (e.g. reuse, repair, remanufacturing and recycling), pairing disruptive digital technologies with the circular economy, sustainability in the supply chain, multi-criteria decision analysis, energy and transportation (e.g. battery systems and electric vehicles) amongst others.

Module aims

The module aims to provide students with a rich understanding of how industrial ecology and sustainable engineering serve as a framework for the consideration of environmental and sustainability-related aspects of products and processes. Drawing from multiple disciplines, including engineering, management and sustainability sciences, students will garner knowledge on underlying principles and visions as well as theory and tools that support the establishment and assessment of resource-efficient and circular measures. By exploring real-world examples, students will be able to synthesize and apply the knowledge acquired. In doing so, students would have gained broad awareness and profound understanding of the environmental, economic, social and ethical challenges as well as opportunities facing humankind.

A further module aim is that students will gain knowledge and skills about some of the analytical tools and methods applied in industrial ecology and sustainable engineering to support them to assess critical aspects of sustainability, focus on environmental impacts and resource constraints, and to suggest measures towards sustainable development.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

The module will be delivered across five days sessions and covers aspects including but not limited to key concepts of industrial ecology (industrial ecosystems, industrial symbiosis and industrial metabolism); industrial ecology tools (lifecycle, input-output, techno-economic and materials flows analyses; environmental impact assessment); resource/material efficiency and circular economy strategies (e.g. reuse, repair, remanufacturing and recycling); pairing disruptive digital technologies with circular economy; sustainability in the supply chain; energy and transportation (e.g. battery systems and electric vehicles) amongst others. Indicative delivery plan across the five days are detailed below:

Day 1:
Welcome and introduction to the module. Climate change and the need for mitigation strategies; industrial and natural ecosystem metaphor; ecosystems classifications; introduction, definition, goals, analytical components of industrial ecology framework (industrial ecosystems, industrial symbiosis and industrial metabolism); social dimension of industrial ecology; Eco Industrial Parks; IPAT equation (population and carrying capacity, consumption patterns and technology). Guest lecturers are invited.
Day 2:
Perspectives on the concept of sustainable development and humankind's interaction with nature; definition and drivers of sustainability; sustainability indicators; resource sustainability challenges and opportunities (materials, energy, water); roots, rationales and core elements of resource-efficiency and the circular economy including strategies such as reuse, repair, remanufacturing and recycling; pairing disruptive digital technologies with circular economy. Real-world examples of resource-efficient and circular solutions will be explored through various lenses, aiming for gradual synthesis and applications.
Day 3:
Introduction to industrial ecology and sustainable engineering tools including lifecycle, input-output, techno-economic and material flow analyses to model product's environmental impacts and resource constraints; case studies application of lifecycle assessment; Hands-on practical application of the tools using spreadsheet to create simple models. Overview of environmental impact assessment (EIA) and Strategic Environmental Assessments (SEA).
Day 4:
Hands-on practical application of the tools using spreadsheet to create simple models continued.
Day 5:
Energy and transportation. This will focus on battery systems and electric vehicles covering the rationale, supply chain complexities, challenges, environmental impact, recycling, opportunities and outlook. Battery electric vehicles vs. internal combustion engine vehicles. Societal attitudes to electric vehicles; recharging infrastructure. Review of the module content and discussion on the individual report.

Learning outcomes

By the end of the module, students should be able to:

- Comprehend and synthesise the concepts of industrial ecology & sustainable engineering as frameworks for the consideration of the triple bottom line based on a balanced view of economic, environmental and social aspects of science, technology, and policy
- Apply industrial ecology & sustainable engineering tools and techniques including lifecycle, input-output, techno-economic and material flow analyses across a range of environmental, economic, and social sustainability indices
- Demonstrate that industrial ecology & sustainable engineering provide a solution-oriented approach to environmental and sustainability problems and understand the relationships among production, consumption, sustainability, and industrial ecology
- Understand how the private sector, government, and NGOs can consider the values and trade-offs associated with various sustainability goals, with other quantitative analyses when approaching business, investing and policy decisions
- Communicate orally and in writing the knowledge and skills acquired

Indicative reading list

Günther, H.-O., Kannegiesser, M., Autenrieb, N., 2015. The role of electric vehicles for supply chain sustainability in the automotive industry. Journal of Cleaner Production 90, 220-233.
Hao, H., Liu, Z., Zhao, F., Geng, Y., Sarkis, J., 2017. Material flow analysis of lithium in China. Resources Policy 51, 100-106.
Ibn-Mohammed, T., Koh, S.C.L, Reaney, I.M, Acquaye, A., Wang, D., Taylor, S., Genovese, A., 2016. Integrated hybrid life cycle assessment and supply chain environmental profile evaluations of lead-based (lead zirconate titanate) versus lead-free (potassium sodium niobate) piezoelectric ceramics. Energy & Environmental Science 9, 3495-3520.
Jelinski, L.W., Graedel, T.E., Laudise, R.A., McCall, D.W., Patel, C.K., 1992. Industrial ecology: concepts and approaches. Proceedings of the National Academy of Sciences 89, 793-797.
Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resources, conservation and recycling 127, 221-232.
Li, X., 2017. Industrial Ecology and Industry Symbiosis for Environmental Sustainability: Definitions, Frameworks and Applications. Springer.
Lowe, E.A., Evans, L.K., 1995. Industrial ecology and industrial ecosystems. Journal of cleaner production 3, 47-53.
Mihelcic, J.R., Crittenden, J.C., Small, M.J., Shonnard, D.R., Hokanson, D.R., Zhang, Q., Chen, H., Sorby, S.A., James, V.U., Sutherland, J.W., 2003. Sustainability science and engineering: the emergence of a new metadiscipline. Environmental science & technology 37, 5314-5324.
Olivetti, E.A., Ceder, G., Gaustad, G.G., Fu, X., 2017. Lithium-ion battery supply chain considerations: analysis of potential bottlenecks in critical metals. Joule 1, 229-243.

Interdisciplinary

This module is designed for students from diverse disciplinary backgrounds and aims to provide students with critical knowledge and skills to analyse and contribute to sustainable technical solutions in industry, consultancy, governmental agencies, and research.

Subject specific skills

Students will develop: a broad awareness and profound understanding of the environmental, economic, social and ethical challenges as well as opportunities facing humankind; understanding how environmental assessment and improvements are conducted using industrial ecology & sustainable engineering tools and techniques such as lifecycle, input-output, techno-economic and materials flows, risk, and eco-efficiency analyses; and understanding of the relationships among technologies and the connections between technology and other fields of study.

Transferable skills

i. Critical thinking: gain an understanding of systems analysis applied to sustainability-related problems, acquire methods to quantify the use of energy, materials, water, and land for industrial production, and the comparative evaluation of different products, services or processes
ii. Technological and environmental awareness: Integrate topics learnt and skills acquired, gaining

exposure to design processes, make choices informed by the TBL, in the application and development of technology. Gain an understanding of the effects of technology on the environment.
iii. Problem solving: Learn about how engineers, technologists and allied professionals employ mathematical and scientific principles in the solution of society's problems
iv. Communication and presentation: develop excellent communication skills and present arguments, knowledge and ideas across a wide range of formats
v. Teamwork: Learn excellent collaborative and team work through group tasks and assessment
vi. Judgement and creativity: Enhanced creativity with flexibility to assess and assemble numerous alternatives in tackling sustainability-related issues
vii. Data collection and analysis: Critical awareness of how data is collected, used, managed and synthesised towards analysing industrial ecology and sustainable engineering related problems.
viii. Sustainability: Understands the concept of the triple bottom line and their interconnectedness in addressing sustainability-related issues.
ix. Professionalism: acquire the skills, status, methods, character or standards to become a distinguished industrial ecologist and sustainability engineer. Students will be encouraged to join the International Society for Industrial Ecology and the Institute of Environmental Management and Assessment (IEMA).
x. Employability: Acquire transferable skills for employment in corporate sustainability and environment, environmental consultancies and think-tanks, Academia, NGOs, and governmental and multilateral agencies.

Study

Study time

Type	Required
Lectures	13 sessions of 1 hour (9%)
Seminars	5 sessions of 1 hour (3%)
Demonstrations	4 sessions of 1 hour (3%)
Practical classes	6 sessions of 1 hour (4%)
Online learning (independent)	2 sessions of 1 hour (1%)
Private study	120 hours (80%)
Total	150 hours

Private study description

120 hours of self-study and independent learning in order to complete all aspects of the assessments for the module.

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Assessment group A

	Weighting	Study time	Eligible for self-certification
Coursework	80%		Yes (extension)

3000 words report based on contemporary topics in industrial ecology and sustainable engineering from a humanitarian engineering perspective. This will entail basic application of tools and techniques learnt to address key environmental and economic decision making.

	Weighting	Study time	Eligible for self-certification
Computer-based take home test	20%		No

This will be based on multiple choice questions covering all aspects and contents of the module. The test will take place two weeks after the completion of all lectures pertaining the module and it will be administered via Moodle under timed conditions.

Feedback on assessment

Provision of comments on submitted individual reports by way of summative feedback. Informal feedback during class discussions and practical/demonstration sessions. Support through office hours.

Availability

Courses

This module is Core optional for:

- Year 1 of TESA-H1C1 Postgraduate Taught in Humanitarian Engineering

This module is Optional for:

- TESA-H1C1 Postgraduate Taught in Humanitarian Engineering
  - Year 1 of H1C1 Humanitarian Engineering
  - Year 1 of H1C3 Humanitarian Engineering (with Management)