COURSE DESCRIPTION CARD - SYLLABUS

Course name

MATERIAL METABOLISM AND RESOURCE LOOP CLOSURE IN THE LIFE CYCLE OF BUILDING STRUCTURES AND TRANSPORT INFRASTRUCTURE [S5ILGIT>MMZP]

Course

Proposed by Discipline
–

Year/Semester
3/6

Level of study
Doctoral School

Course offered in
English

Form of study
full-time

Requirements
elective

Number of hours

Lecture
8

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

dr hab. inż. Anna Knitter-Piątkowska
anna.knitter-piatkowska@put.poznan.pl

Lecturers

dr hab. inż. Anna Knitter-Piątkowska
anna.knitter-piatkowska@put.poznan.pl

Prerequisites

Knowledge: the PhD student possesses advanced knowledge in the field of civil engineering or a related engineering discipline; is familiar with the fundamental processes involved in the design, construction and maintenance of building structures and transport infrastructure; and has a general understanding of environmental protection and sustainable development in the construction sector. Skills: the PhD student is able to independently analyse academic literature, formulate research questions within their own discipline, and use academic databases as well as computational and analytical tools. Social competences: the PhD student is prepared to work in an interdisciplinary research team, is able to present the results of analyses and participate in substantive academic discussion.

Course objective

To acquire knowledge, skills and competences in the principles and tools of material flow analysis in building structures and transport infrastructure, life cycle assessment (LCA) methodology, resource loop-closing strategies, and the regulatory and research context of the circular transformation of the construction sector. The course supports PhD students in identifying research gaps relevant to their own theses.

Course-related learning outcomes

KNOWLEDGE

A doctoral student knows and understands:

W1. The theoretical foundations of industrial ecology and material metabolism as analytical frameworks for quantifying resource flows in building structures and transport infrastructure.
P8S_WG / SzD_W01, SzD_W02

W2. The methodology of Life Cycle Assessment (LCA) in accordance with ISO 14040/14044 and EN 15804/15978, including system boundaries, functional unit, impact categories and computational tools applicable to infrastructure contexts.
P8S_WG / SzD_W01, SzD_W03

W3. Methods for quantifying material flows (MFA, SFA) and circularity indicators (MCI, CEI, RMI) applied to the construction and transport infrastructure sector.
P8S_WG / SzD_W01, SzD_W03

W4. Strategies for resource loop closure, including Design for Disassembly (DfD), recycling and upcycling of construction materials, decarbonisation of material production, and digital material passports.
P8S_WG / SzD_W01, SzD_W02

W5. Current EU regulatory and policy frameworks for circularity in construction (Circular Economy Action Plan, revised CPR, Green Public Procurement) and circular business models in infrastructure.
P8S_WK / SzD_W05, SzD_W06, SzD_W07

SKILLS
A doctoral student can:

U1. Apply MFA methodology to map material flows for a selected building structure or transport infrastructure category, identifying key loss points and potential feedback loops.
P8S_UW / SzD_U01

U2. Critically evaluate the methodological quality of a published LCA study in the field of construction or transport infrastructure, including assessment of system boundaries, data quality and interpretability of results.
P8S_UW / SzD_U02

U3. Identify and assess resource loop closure strategies for a selected object, applying the waste management hierarchy and estimating a simplified circularity indicator.
P8S_UW / SzD_U01, SzD_U02

U4. Formulate a research gap in the field of material metabolism and circular construction in relation to their own doctoral dissertation, and present it in scientific discourse.
P8S_UW / SzD_U01, SzD_U02 / P8S_UK / SzD_U06, SzD_U07 / P8S_UO / SzD_U09

SOCIAL COMPETENCIES
A doctoral student is ready to:

K1. Critically assess current achievements in the field of circular construction and resource management in infrastructure, and evaluate their own potential contribution to the development of the discipline.
P8S_KK / SzD_K01, SzD_K02, SzD_K03

K2. Engage in interdisciplinary scientific debate combining technical, environmental and regulatory perspectives, and recognize the significance of circular economy principles in addressing contemporary civilizational challenges.
P8S_KO / SzD_K04, SzD_K05 / P8S_KK / SzD_K03

K3. Maintain the ethos of scientific activity by ensuring rigor and transparency in conducted analyses and taking responsibility for the reliability of presented results.
P8S_KR / SzD_K07

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Passing the course is based on the assessment of a mini-research project carried out by the PhD student throughout the entire lecture series. The project involves analysing a selected building or category of transport infrastructure from the perspective of material metabolism, life-cycle assessment, resource loop-closing strategies and the identification of research gaps. The final output is a report (6–8 pages) or a presentation (15 minutes).

Assessment criteria: methodological soundness of the MFA and LCA analyses, the appropriateness of the proposed circular strategies, the quality of the research gap identification, and active participation in lectures.

When assessing learning outcomes for the purposes of course credit, the following grading scale based on percentage ranges applies:
over 50% – 60.0%: 3.0
over 60% – 70.0%: 3.5
over 70% – 80.0%: 4.0
over 80% – 90.0%: 4.5
over 90% – 100%: 5.0

Programme content

Industrial ecology and material metabolism as a theoretical framework for circularity in construction. Analysis of material flows (MFA, SFA) in building structures and transport infrastructure. Life cycle assessment (LCA) methodology in infrastructure applications. Strategies for closing resource loops, including design for disassembly (DfD), recycling of construction materials, decarbonisation of production and digital material passports. Implementation of circularity in the construction sector in terms of EU regulations, green public procurement, circular business models and research perspectives within the discipline.

Course topics

Lecture 1. Material metabolism (theoretical foundations and analytical frameworks). The resource crisis as the context for the transformation of the construction sector. Industrial ecology as the founding discipline. Material metabolism as an operational model. Material Flow Analysis (MFA) and Substance Flow Analysis (SFA). Taxonomy of resources in construction and transport infrastructure. Circulation metrics (CEI, MCI, RMI). The EU policy framework.

Lecture 2. Life cycle assessment in construction and transport infrastructure. LCA methodology in accordance with ISO 14040/14044 and EN 15804/15978. LCA phases. System boundaries and functional unit. Environmental indicators (GWP, ADP, EP, AP). Applications of LCA in bridge, road and tunnel infrastructure. Databases and calculation tools (Ecoinvent, OpenLCA, SimaPro). Methodological limitations and uncertainty of results.

Lecture 3. Resource loop-closing strategies (design, deconstruction and reuse). The waste hierarchy in the construction sector. Design for Dismantling (DfD). Recycling and upcycling of construction materials (concrete, steel, asphalt). Decarbonisation of materials production. Digital material passports, BIM and digital twins.

Lecture 4. Implementation, management and research prospects. Barriers and drivers for implementing circularity in infrastructure. EU legal and regulatory frameworks. Green public procurement (GPP). Circular business models. Research gaps and future directions for the discipline.

Teaching methods

An informative lecture with a multimedia presentation.
Workshop activities integrated into each lecture (material flow mapping, critical analysis of a published LCA, DfD design workshop, debate on regulation and implementation).
A mini-research project carried out throughout the lecture series.

Bibliography

Basic:
1. Graedel, T.E., Allenby, B.R. (2010). Industrial Ecology and Sustainable Engineering. Prentice Hall.
2. Hauschild, M.Z. et al. (2018). Life Cycle Assessment: Theory and Practice. Springer.
3. Ellen MacArthur Foundation (2021). Completing the Picture: How the Circular Economy Tackles Climate Change.
4. European Commission (2020). A New Circular Economy Action Plan. COM(2020) 98 final.

Additional:
1. Fischer-Kowalski, M., Hüttler, W. (1998). Society's Metabolism. Journal of Industrial Ecology, 2(4).
2. Pomponi, F., Moncaster, A. (2017). Circular economy for the built environment: A research framework. Journal of Cleaner Production, 143.
3. Geissdoerfer, M. et al. (2017). The Circular Economy: A new sustainability paradigm? Journal of Cleaner Production, 143.
4. ISO 14040:2006. Environmental management. Life cycle assessment. Principles and framework.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	8	0,00
Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation)	42	2,00