



Subject card

Subject name and code	GREEN CHEMISTRY: MATERIAL AND ENERGY RECYCLING IN PRACTICE, PG_00064503						
Field of study	Chemistry						
Date of commencement of studies	October 2024		Academic year of realisation of subject		2026/2027		
Education level	first-cycle studies		Subject group		Optional subject group Humanistic-social subject group Subject group related to scientific research in the field of study		
Mode of study	Full-time studies		Mode of delivery		at the university		
Year of study	3		Language of instruction		Polish		
Semester of study	6		ECTS credits		4.0		
Learning profile	general academic profile		Assessment form		assessment		
Conducting unit	Department of Energy Conversion and Storage -> Faculty of Chemistry -> Faculties of Gdańsk University of Technology						
Name and surname of lecturer (lecturers)	Subject supervisor		dr hab. inż. Monika Wilamowska-Zawłocka				
	Teachers						
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	15.0	0.0	15.0	15.0	0.0	45
	E-learning hours included: 0.0						
Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan		Participation in consultation hours		Self-study	SUM
	Number of study hours	45		5.0		55.0	105
Subject objectives	The course aims to provide students with comprehensive knowledge of sustainable material production and advanced recycling technologies, focusing on both material and energy aspects. Students will acquire skills in the design and sustainable synthesis of materials, as well as in the planning, design, and analysis of recycling processes; they will also gain an understanding of the broader context of sustainable development and the role of technology in environmental protection.						

Learning outcomes	Course outcome	Subject outcome	Method of verification
	[K6_W04] identifies the conditions of chemical processes occurring in the analysed systems through the appropriate selection of methods to solve them, by taking into account the interdependence of the structure and properties of key materials in sustainable development technologies	has detailed knowledge of the chemical processes involved in technological processes. The student has knowledge of issues related to the selection of materials in sustainable, material- and energy-efficient technologies.	[SW1] Assessment of factual knowledge
	[K6_K02] is aware of the importance of non-technical aspects and consequences of engineering activities, including their impact on the environment, and of the related responsibility for the decisions to be taken	assesses the impact of sustainable materials synthesis technologies and material and energy recycling processes on the environment, the economy, and society, taking into account the principles of sustainable development and responsibility for design and technological decisions.	[SK5] Assessment of ability to solve problems that arise in practice [SK1] Assessment of group work skills
	[K6_U05] designs and performs experiments to confirm a hypothesis, recognises the wider, often non-technical context of the phenomena analysed	is able to independently plan, design, and conduct experiments to test a hypothesis. The student has the ability to analyze phenomena in a broader context, taking into account social, economic, ethical, and environmental aspects.	[SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject
	[K6_U09] is able to recognise hazards, counteract them and work with chemical reagents and basic technical apparatus in accordance with health and safety principles and the concept of sustainability	is able to effectively identify potential hazards associated with working with chemical reagents and basic laboratory equipment. The student possesses the skills to prevent hazards and conduct laboratory work in accordance with Occupational Safety and Health (OSH) regulations.	[SU2] Assessment of ability to analyse information [SU4] Assessment of ability to use methods and tools

Subject contents	Course content – lecture The course covers topics related to green chemistry, sustainable materials synthesis, and material and energy recycling technologies. The introductory part presents the fundamental concepts of recycling and waste treatment, material and energy recovery, circular economy principles, as well as the importance of critical raw materials, secondary resources, and sustainable material sourcing. Within the scope of material recycling technologies, the course discusses the principles of sustainable design of recycling processes and methods for the recovery of metals, plastics, glass, and cellulosic materials. Biological and thermochemical methods of biomass processing for material and energy recovery are also presented. The section devoted to energy recovery includes thermal and chemical processes used to obtain energy from waste streams, including technologies for the processing of refuse-derived fuel (RDF), as well as issues related to the energy efficiency of material cycles. An important element of the course is the design and synthesis of materials in accordance with circular economy principles. Students learn how to apply Life Cycle Assessment (LCA) to evaluate the environmental impacts of products and processes, as well as methods for designing manufacturing processes based on secondary raw materials. The course also covers the fundamentals of green engineering, environmental aspects of material synthesis and recycling, assessment of the energy efficiency of recycling technologies, and selected innovative solutions supporting sustainable development and responsible resource management. Course content – laboratory Laboratory classes focus on practical aspects of material recycling within the framework of the circular economy and the recovery of critical raw materials from end-of-life electrochemical devices. Students become familiar with the structure and operating principles of lithium-ion batteries, methods for identifying their components, and approaches to recovering materials of high economic value. The laboratory program includes exercises related to the preparation of spent batteries for recycling, including safe disassembly, component separation, and characterization of recovered materials. Students learn and perform selected stages of direct recycling, hydrometallurgical recycling, and pyrometallurgical recycling of lithium-ion batteries, while evaluating the recovery efficiency of individual active components. The laboratories also cover processes for recovering critical raw materials, particularly graphite and metals used in electrode materials. Students carry out basic technological operations related to the extraction, purification, and characterization of recovered materials and assess their quality and suitability for reuse. An important part of the laboratory work is the practical application of recycled materials in the production of new lithium-ion battery components. Students prepare selected electrode materials using recovered resources, perform basic material characterization studies, and evaluate the influence of recycling on the performance and environmental impact of the resulting products. The laboratory classes also address the environmental, energy-related, and economic aspects of recycling technologies, with particular emphasis on the principles of green chemistry, resource efficiency, and the reduction of the environmental footprint of manufacturing processes. Course content – project Project classes are dedicated to the practical application of Life Cycle Assessment (LCA) methodology for evaluating the environmental impacts of materials and technological processes. Students carry out projects focused on selected materials and products discussed during lectures, with particular emphasis on materials used in modern energy technologies, functional materials, and circular economy solutions. During the course, students learn the principles of defining the goal and scope of an LCA study, developing life cycle models, collecting and validating inventory data, and interpreting environmental impact results. Projects are conducted in a computer laboratory using professional LCA software and specialized environmental databases. Students perform life cycle modelling of selected materials, taking into account raw material extraction, manufacturing, use, recycling, and end-of-life management stages. The analyses consider the effects of using primary and secondary raw materials, as well as different recycling and energy recovery scenarios, on environmental indicators and resource consumption.
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	The final outcome of the project is a complete LCA study of a selected material or product, including the identification of life cycle stages responsible for the greatest environmental burdens and the development of recommendations for reducing environmental impacts in accordance with the principles of green chemistry, green engineering, and the circular economy.		
Prerequisites and co-requisites	Knowledge of the basics of inorganic and organic chemistry. Basic knowledge of mathematics.		
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	Lectures - exam	60.0%	40.0%
	Laboratories - report	60.0%	30.0%
	Project - finished project tasks	60.0%	30.0%
Recommended reading	Basic literature	1) N. J. Themelis, Recovery of Materials and Energy from Urban Waste, in R. A. Meyers (ed.), Encyclopedia of Sustainability Science and Technology, Springer Science+Business Media LLC, part of Springer Nature 2018 2) S. K. Ghosh, Energy Recovery Processes from Wastes, Springer Verlag, Singapore, 2020 3) C. Hubert, Handbook of Recycling Technology, Syrawood Publishing House, 2019 4) A. K. Błędzki, R. Jeziórska, J. Kijeński, Odzysk i recykling materiałów polimerowych, Wydawnictwo Naukowe PWN, Warszawa 2021 5) E. Klugmann-Radziemska, J. T. Haponiuk, J. Datta, K. Formela, M. Sienkiewicz, M. Włoch, Nowoczesne technologie recyklingu materiałowego, Wydawnictwo Politechniki Gdańskiej, Gdańsk 2017 6) T. Georgi-Maschler et al., Development of a recycling process for Li-ion batteries J. Power Sources 207 (2012) 173–182. 7) Odpady niebezpieczne. Przepisy i codzienność, Wiktoria Sobczyk, Wydawnictwo AGH, Kraków, 2019 8) Gospodarka odpadami niebezpiecznymi pod redakcją Krystyny Mędrzyckiej, Wydział Chemiczny Politechniki Gdańskiej, 1996	
	Supplementary literature	1) Basic hazardous waste management, William C. Blackman Jr., Lewis Publishers, New York, 2001 2) G. Harper et al., Recycling lithium-ion batteries from electric vehicles, Nature volume 575 (2019) 75–86. 3) I. A. Ignatyev et al., Recycling of Polymers: A Review, Chem. Sus. Chem, 7 (2014) 1579-1593. 4) O. Dogu et al., The chemistry of chemical recycling of solid plastic waste via pyrolysis and gasification: State-of-the-art, challenges, and future directions, Progress in Energy and Combustion Science, 84 (2021) 100901.	
	eResources addresses		

Example issues/ example questions/ tasks being completed	1. Describe the differences between material, raw material, and energy recycling. 2. Describe a selected material recycling technology. 3. Describe a selected energy recycling technology. 4. What are the methods for recovering metals from electronic waste?
Practical activities within the subject	Not applicable

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