UAB
Universitat Autònoma de Barcelona

Industrial Ecology

Code: 42405
ECTS Credits: 9

2024/2025

Degree	Type	Year
4313784 Interdisciplinary Studies in Environmental, Economic and Social Sustainability	OT	0

Contact

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Teachers

Anna Petit Boix

Teaching groups languages

You can view this information at the end of this document.

Prerequisites

NO REQUIREMENTS

Objectives and Contextualisation

This course is an introduction to the field of Industrial Ecology (IE) as a multidisciplinary effort to evaluate anthropogenic systems, minimizing their negative effect on our planet. The students are taught the methods, tools, and strategies within IE, aimed to recreate our industrial system in such a way that it can be sustainable and in harmony with the rest of the natural ecosystem. To achieve this general objective, we will learn about:

- Understand the concepts of IE, its framework as a multidisciplinary area of research based on system theory; resources: environmental goods and services, externalities.
- Understand Material Flow Analysis (MFA), and be able to apply this tool to different systems, such as a product, process, or region.
- Understand the concepts of urban metabolism, carbon footprint, including differences in scope, results, and policy implications.
- Understand both process-based approach, MFA-LCA (or Material Flow Analysis coupled with Life-Cycle Assessment) and EIO-LCA (or Economic Input-Output coupled with Life-Cycle Assessment); apply the fundamentals of these approaches to be used for various analyses (e.g., GHG, pollution, water, land, toxics, materials use, etc.)
- Understand the concept of LCA, its applications and the global framework for its use.

- Understand the main steps of LCA (i.e., goal and scope definition, inventory analysis, impact assessment and interpretation) and be able to apply them to different real-life cases, such as products or services.
- Learn how to evaluate and interpret the results, assumptions and uncertainties in case studies from a critical point of view.
- Learn how to use the Open LCA software and its basic functionalities and be able tocalculate the environmental impacts of a system by means of it.

Competences

- Analyse, summarise, organise and plan projects related to the environmental improvement of product, processes and services.
- Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of Environmental Studies.
- Solve problems in new or little-known situations within broader (or multidisciplinary) contexts related to the field of study.
- Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.
- Work in an international, multidisciplinary context.

Learning Outcomes

1. Analyse research results to obtain new products or processes, assessing their industrial and commercial viability with a view to transferring them to society.
2. Apply knowledge of the different tools of industrial ecology to systems independently of scale.
3. Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of Environmental Studies.
4. Apply the concepts learnt in class, make assessments and take decisions based on results.
5. Interpret and develop life-cycle analyses for products and processes.
6. Know the main elements of industrial ecology: systems theory, thermodynamics, material flow analysis and resource consumption.
7. Know the tools of eco-innovation that are applicable to urban environments.
8. Know urban systems and their indicators in order to evaluate them.
9. Work in an international, multidisciplinary context.

Content

The contents of the course can be summarized as follows:

- Industrial Ecology and Technological change.
- Introduction to material flow analysis.
- Introduction to urban metabolism, carbon footprint and case studies.
- Introduction to process-based approach, MFA-LCA (or Material Flow Analysis coupled with Life-Cycle Assessment), using actual energy use data to model systems; and EIO-LCA (or Economic Input-Output coupled with Life-Cycle Assessment), which adopts IO tables to study the inter-dependencies of economies. The fundamentals of these approaches will be used for various analyses (e.g., GHG, pollution, water, land, toxics, materials use, etc.
- Introduction to LCA
- Interpretation and uncertainty
- introduction to LCA software, case study project.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
LCA computer lab	12	0.48	1, 2, 3, 6, 8, 7, 5, 4, 9
Theory Classes	36.5	1.46	1, 2, 3, 6, 8, 7, 5, 4, 9
Type: Supervised			
Work on LCA project using guidelines	60	2.4	1, 2, 3, 6, 8, 7, 5, 4, 9
Type: Autonomous			
Input-Output tables and LCA	16	0.64	
LCA project	78	3.12	1, 2, 3, 6, 8, 7, 5, 4, 9
Readings, study, work in groups and preparation for presentations	17	0.68	

The key concepts of this class will be transferred through theory classes (36.5 hours), hands-on exercises in lab classes (12 hours), and a hefty load of autonomous and group work (111 hours).

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Final Exam	50%	2	0.08	1, 2, 3, 8, 7, 5, 4, 9
LCA exercise	10%	0	0	2, 6, 5, 4
LCA project presentation	30%	2	0.08	2, 6, 5, 4
input output exercise	10%	1.5	0.06	2, 3, 5, 4

Non-evaluable: The student can only apply for recovery if he has done the following:
-delivered all the assignments for the subject that are requested in class and delivered through the moodle space.
- having taken the final exam
-having participated in group work during the course
-having worked on the LCA project and having made a presentation of your project at the end of the subject.
Recovery: The student will only be able to recover a grade with a second chance for the final exam, and the final grade for the subject will not be higher than a 6.

Bibliography

Industrial Ecology General

Saavedra, Y.M.B., Iritani, D.R., Pavan, A.L.R., Ometto, A.R., 2018. Theoretical contribution of industrial ecology to circular economy. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2017.09.260

Dayeen, F.R., Sharma, A.S., Derrible, S., 2020. A text mining analysis of the climate change literature in industrial ecology . J. Ind. Ecol. 24, 276-284. https://doi.org/10.1111/jiec.12998

Kennedy, C., 2020. The energy embodied in the first and second industrial revolutions. J. Ind. Ecol. 24, 887-898. https://doi.org/10.1111/jiec.12994

Goldstein, B., Newell, J.P., 2019. Why academics should study the supply chains of individual corporations. J. Ind. Ecol. 23, 1316-1327. https://doi.org/10.1111/jiec.12932

Lindgreen, E.R., Salomone, R., Reyes, T., 2020. A critical review of academic approaches, methods and tools to assess circular economy at the micro level. Sustain. https://doi.org/10.3390/su12124973

Mallawaarachchi, H., Sandanayake, Y., Karunasena, G., Liu, C., 2020. Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.120618

Cordella, M., Alfieri, F., Sanfelix, J., Donatello, S., Kaps, R., Wolf, O., 2020. Improving material efficiency in the life cycle of products: a review of EU Ecolabel criteria. Int. J. Life Cycle Assess. 25, 921-935. https://doi.org/10.1007/s11367-019-01608-8

Ayres, R., and Ayres, L. Accounting for Resources, volumes I and II, Cheltenham, UK: Edward Elgar, 1998.

Ayres, R. Industrial Ecology: Towards Closing the Material Cycle. London: Edward Elgar, 1996.

Bringezu, S. And Y. Moriguchi, Material flow analysis, in A handbook of Industrial Ecology, RU Ayres, and LW Ayres, eds, Cheltenham, UK: Ewards Elgar, pp79-90, 2002.

Chertow, M.R., Esty, d.C. Thinking Ecologically. New Haven: Yale University Press, 1997.

Classics in systems theory:

Bertalanffy, L. Von: General Systems Theory, New York, George Braziller, 1968 and 1980.

Forrester, Jay W. Industrial Dynamics, MIT Press, Cambridge, MA 1961.

Boulding, K. General Systems Theory, the Skeleton of a Science, in Buckley W. (Ed) Modern Systems Research for the Behavioral Scientist, Chicago: Alaine, 1968.

Thermodynamics

Smith and Van Ness. Introduction to Chemical Engineering Thermodynamics. New York: McGraw Hill, 1996.

Szargut, Jan. Exergy analysis of thermal, chemical, and metallurgical processes. Hemisphere Publishing Corporation, 1988.

Ayres Robert U., and Leslie W. Ayres. 1999. Accounting for resources 2: The life cycle of materials. Cheltenham, UK and Lyme MA: Edward Elgar.

Baumgärtner Stefan. 2002. Thermodynamics of waste generation. In Waste in Ecological Economics, edited by K. P. Bisson, J. Cheltenham, UK and Nothampton, MA,USA: Edward Elgar.

Szargut, J.;, D.R.; Morris, and F. R.; Steward. 1988. Exergy analysis of thermal, chemical, and metallurgical processes. New York: Hemisphere Publishing Corporation.

Conelly, Ll. and C.; Koshland. 2001. Exergy and industrial ecology. Part 2: A nondimensional analysis of means to reduce resource depletion. Exergy, an International Journal 1 (4):234-255.

Ayres Robert U., Katalin Martinás, and Leslie W. Ayres. 1998. Exergy, waste accounting and life cycle analysis. Energy 23 (5):355-363.

Ayres, Robert U., Andrea Masini, and Leslie W. Ayres. 2001. An Application of Exergy Accounting to Five Basic Metal Industries. Fontainebleau, France: INSEAD.

Van Gool, W. 1992. Exergy analysis of industrial processes. Energy 17 (8):791-803.

Szargut, J.;, A.; Ziebik, and W. Stanek. 2002. Depletion of the non-renewable natural exergy resources as a measure of the ecological cost Energy conversion and management 43:1149-1163.

MFA

Matthews, E., Amann, C., Bringezu, S., Hüttler, W., Ottke, C., Rodenburg, E., Rogich, D., Schandl, H., Van, E., Voet, D., Weisz, H., Billings, H., 2000. The Weight of Nations - Material Outflows from Industrial Economies. WORLD RESOURCES INSTITUTE.

Eurostat, 2013. Economy-wide Material Flow Accounts (EW-MFA) Compilation Guide. European Commission, Office for Official Publications of the European Communities, Luxembourg.

Graedel, T.E., 2019. Material Flow Analysis from Origin to Evolution. Environ. Sci. Technol. 53, 12188-12196. https://doi.org/10.1021/acs.est.9b03413

Persson, L., Arvidsson, R., Berglund, M., Cederberg, C., Finnveden, G., Palm, V., Sörme, L., Schmidt, S., Wood, R., 2019. Indicators for national consumption-based accounting of chemicals. J. Clean. Prod. 215, 1-12. https://doi.org/10.1016/j.jclepro.2018.12.294

Calvo, G., Valero, Alicia, Valero, Antonio, 2018. Thermodynamic Approach to Evaluate the Criticality of Raw Materials and Its Application through a Material Flow Analysis in Europe. J. Ind. Ecol. 22, 839-852. https://doi.org/10.1111/jiec.12624

LCA

Klöpffer, W., Grahl, B. 2014. Life Cycle Assessment (LCA): A Guide to Best Practice | Wiley.

Finkbeiner, M., Ackermann, R., Bach, V., Berger, M., Brankatschk, G., Chang, Y.-J., Grinberg, M., Lehmann, A., Martínez-Blanco, J., Minkov, N., Neugebauer, S., Scheumann, R., Schneider, L., Wolf, K., 2014. Challenges in Life Cycle Assessment: An Overview of Current Gaps and Research Needs. Springer, Dordrecht, pp. 207-258. https://doi.org/10.1007/978-94-017-8697-3_7

Guinée, J. B., Heijungs, R., Huppes, G., Zamagni, A., Masoni, P., Buonamici, R., Ekvall, T., & Rydberg, T. (2011). Life Cycle Assessment: Past, Present, and Future. Environmental Science & Technology, 45(1), 90-96. https://doi.org/10.1021/es101316v

Visentin, C., Trentin, A.W. da S., Braun, A.B., Thomé, A., 2020. Life cycle sustainability assessment: A systematic literature review through the application perspective, indicators, and methodologies. J. Clean. Prod. https://doi.org/10.1016/j.jclepro.2020.122509

Palazzo, J., Geyer, R., Suh, S., 2020. A review of methods for characterizing the environmental consequences of actions in life cycle assessment. J. Ind. Ecol. 24, 815-829. https://doi.org/10.1111/jiec.12983

Beloin-Saint-Pierre, D., Albers, A., Hélias, A., Tiruta-Barna, L., Fantke, P., Levasseur, A., Benetto, E., Benoist, A., Collet, P., 2020. Addressing temporal considerations in life cycle assessment. Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2020.140700

Mendoza Beltran, A., Cox, B., Mutel, C., Vuuren, D.P., Font Vivanco, D., Deetman, S., Edelenbosch, O.Y., Guinée, J., Tukker, A., 2020. When the Background Matters: Using Scenarios from Integrated Assessment Models in Prospective Life Cycle Assessment. J. Ind. Ecol. 24, 64-79. https://doi.org/10.1111/jiec.12825

García-Pérez, S., Sierra-Pérez, J., Boschmonart-Rives, J., 2018. Environmental assessment at the urban level combining LCA-GISmethodologies: A case study of energy retrofits in the Barcelona metropolitan area. Build. Environ. 134, 191-204. https://doi.org/10.1016/j.buildenv.2018.01.041

Urban metabolism

Wolman, A., 1965. The metabolism of cities. Sci. Am. 213, 179-190.

González-García, S., Dias, A.C., 2019. Integrating lifecycle assessment and urban metabolism at city level: Comparison between Spanish cities. J. Ind. Ecol. 23, 1062-1076. https://doi.org/10.1111/jiec.12844

Jeong, S., Park, J., 2020. Evaluating urban water management using a water metabolism framework: A comparative analysis of three regions in Korea. Resour. Conserv. Recycl. 155, 104597. https://doi.org/10.1016/j.resconrec.2019.104597

Hu, G., Mu, X., 2019. Analysis of urban energy metabolic system: An ecological network framework and a case study for Beijing. J. Clean. Prod. 210, 958-969. https://doi.org/10.1016/j.jclepro.2018.11.088

Chen, Q., Su, M., Meng, F., Liu, Y., Cai, Y., Zhou, Y., Yang, Z., 2020. Analysis of urban carbon metabolism characteristics based on provincial input-output tables. J. Environ. Manage. 265, 110561. https://doi.org/10.1016/j.jenvman.2020.110561

Bibliography- more specific

Adriaanse, A., S. Bringezu, A. Hammond, Y. Moriguchi, E. Rodenburg, D. Rogich, H. Schütz 1997. Resource Flows: The Material Basis of Industrial Economies. Washington DC: World Resources Institute.

Ayres, R. U. (1978): Resources, Environment and Economics. Applications of the Materials/ Energy Balance Principle. New York: John Wiley & Sons

Ayres, R. U. and Kneese, A. V. (1969): Production, Consumption and Externalities. In: American Economic Review 59(3), pp. 282-297

Ayres, R. U. and U. E. Simonis 1994. Industrial Metabolism: Restructuring for Sustainable Development. Tokyo, New York, Paris: United Nations University Press.

Ayres,R.U. and Ayres,L.W., 1999. Accounting for Resources, 2, The Life Cycle of Materials. Edward Elgar, Cheltenham, UK and Lyme, US.

Baccini, Peter and Brunner, Paul H. (1991): The metabolism of the anthroposphere. Berlin: Springer.

Barbiero, G., Camponeschi, S., Femia, A., Greca, G., Tudini, A., and Vannozzi, M. (2003): 1980-1998 Material-Input-Based Indicators Time series and 1997 Material Balances of the Italian Economy. Rome: ISTAT

Brunner, Paul H. and Rechberger, Helmut (2004): Practical Handbook of Material Flow Analysis. New York: Lewis Publishers.

Bullard, C. and Herendeen, R. A. (1975): The Energy Costs of Goods and Services. In: Energy Policy 3(4), pp. 268-278

Dietzenbacher, E., 2005. Waste Treatment in Physical Input-Output Analysis. Ecological Economics, 55, 11-23.

Duchin, F. (1992): Industrial Input-Output Analysis. Implications for Industrial Ecology. In: Proceedings of the National Academy of Science 89, pp. 1-5

Duchin, F. (1998): Structural Economics: Measuring Change in Technology, Lifestyles, and the Environment. Washington: Island Press

Eurostat 2001. Economy-wide Material Flow Accounts and Derived Indicators. A methodological guide. Luxembourg: Eurostat, European Commission, Office for Official Publications of the European Communities.

Eurostat (2002): Material use in the European Union 1980-2000. Indicators and Analysis. Luxembourg: Eurostat, Office for Official Publications of the European Communities, prepared by Weisz, H., Amann, C., Eisenmenger, N., Hubacek, K., and Krausmann, F.

Fischer-Kowalski, Marina (1998): Society's Metabolism. The Intellectual History of Material Flow Analysis, Part I, 1860 - 1970. In: Journal of Industrial Ecology 2(1), pp. 61-78.

Fischer-Kowalski, Marina and Haberl, Helmut (1993): Metabolism and Colonization. Modes of Production and the Physical Exchange between Societies and Nature. In: Innovation - The European Journal of Social Sciences 6(4), pp. 415-442.

Fischer-Kowalski, Marina and Hüttler, Walter (1999): Society's Metabolism. The Intellectual History of Material Flow Analysis, Part II: 1970-1998. In: Journal of Industrial Ecology 2(4), pp. 107-137.

Fleissner, P., Böhme, W., Brautzsch, H. U., Höhne, J., Siassi, J., and Stark, K. (1993): Input-Output-Analyse. Eine Einführung in Theorie und Anwendungen. Wien, New York: Springer Verlag

Giljum, S. and Hubacek, K., 2004. Alternative Approaches of Physical Input-Output Analysis to Estimate Primary Material Inputs of Production and Consumption Activities. Economics Systems Research, 16 (3): 301-310.

Giljum, S., Hubacek, K., and Sun, L. (2004): Beyond the simple material balance: a reply to Sangwon Suh's note on physical input-output analysis. In: Ecological Economics 48(1), pp. 19-22

Griffin, J. (1976): Energy Input-Output Modeling. Palo Alto: Electric Power Research Institute

Haberl, Helmut, Fischer-Kowalski, Marina, Krausmann, Fridolin, Weisz, Helga, and Winiwarter, Verena (2004): Progress Towards Sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. In: Land Use Policy 21(3), pp. 199-213.

Hubacek, K. and Giljum, S. (2003): Applying physical input-output analysis to estimate land appropriation (ecological footprints) of international trade activities. In: Ecological Economics 44(1), pp. 137-151

Japan Environment Agency (1992): Quality of the Environment in Japan 1992. Tokyo: Japan Environment Association.

Konijn, P. J. A., de Boer, S., and van Dalen, J. (1997): Input-Output analysis of Material flows with applications to iron, steel and zinc. In: Structural Change and Economic Dynamics 8, pp. 129-153

Leontief, W. (1936): Quantitative input-output relations in the economic system. In: Review of Economics and Statistics 18, pp. 105-125

Leontief, W. (1941): The Structure of American Economy. New York: Oxford University Press

Leontief, W. (1970): Environmental Repercussions and the Economic Structure. An Input-Output-Approach. In: Review of Economics and Statistics 52, pp. 262-271

Machado, G., Schaeffer, R., and Worrel, E. (2001): Energy and Carbon embodied in the international trade of Brazil: an input - output approach. In: Ecological Economics 39(3), pp. 409-424

Mäenpää, I. and Muukkonen, J. (2001): Physical Input-Output in Finland: Methods, Preliminary Results and Tasks Ahead. Paper presented at Workshop on Economic growth, material flows and environmental pressure, 25th - 27th April, Stockholm, Sweden.

Matthews, E., C. Amann, M. Fischer-Kowalski, S. Bringezu, W. Hüttler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, D. Rogich, H. Schandl, H. Schütz, E. van der Voet, H. Weisz 2000. The Weight of Nations: Material Outflows from Industrial Economies. Washington, D.C.: World Resources Institute.

Miller, R. E. and Blair, P. D. (1985): Input-Output Analysis: Foundations and Extensions. New Jersey: Prentice Hall Inc.

Pedersen, O. G. (1999): Physical Input-Ouput Tables for Denmark. Products and Materials 1990. Air Emissions 1990-92. Kopenhagen: Statistics Denmark

Pedersen, O. G. (2002): DMI and TMR for Denmark 1981, 1990, 1997. An assessment of the Material Requirements of the Danish Economy. Statistics Denmark

Proops, J. L. R. (1977): Input-output analysis and energy intensities: a comparison of some methodologies. In: Applied Mathematical Modelling 1(March), pp. 181-186

Stahmer, C., Kuhn, M., and Braun, N., 1998. Physical Input-Output Tables for Germany, 1990. Eurostat Working Paper No 2/1998/B/1, European Commission , Luxembourg.

Suh, S. (2004): A note on the calculus for physical input-output analysis and its application to land appropriation of international trade activities. In: Ecological Economics 48(1), pp. 9-17

Weisz, Helga and Duchin, Faye (2006): Physical and monetary input-output analysis: What makes the difference? In: Ecological Economics 57(3), pp. 534-541.

Software

LCA software (Open LCA, simapro, Gabi)

Language list

Name	Group	Language	Semester	Turn
(PAULm) Classroom practices (master)	1	English	first semester	afternoon
(TEm) Theory (master)	1	English	first semester	afternoon