



M Industrial Ecology

Leiden University | Delft University of Technology

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# Contents

- Summary ..... 4
  - Score table ..... 5
- Introduction..... 6
  - Procedure..... 6
  - Panel ..... 7
  - Information on the programme ..... 8
- Description of the assessment..... 9
  - Recommendations previous accreditation panel ..... 9
  - Standard 1. Intended learning outcomes ..... 9
  - Standard 2. Teaching-learning environment..... 12
  - Standard 3. Student assessment ..... 16
  - Standard 4. Achieved learning outcomes ..... 17
  - General conclusion ..... 18
  - Development points ..... 18
- Appendix 1. Intended learning outcomes ..... 19
- Appendix 2. Programme curriculum..... 20
- Appendix 3. Programme of the site visit..... 21
- Appendix 4. Materials..... 22

## Summary

### Standard 1. Intended learning outcomes

The joint master's programme Industrial Ecology of Leiden University and TU Delft aims to empower students with the expertise and capabilities needed to identify, design, and critically assess sustainable solutions for global socio-ecological and technical challenges. The panel considers the exit qualifications to be well formulated, well aligned with the field of industrial ecology, and appropriate for the academic master's level. The panel appreciates the programme's interdisciplinary profile, integrating engineering, environmental, and social perspectives. The cooperation between the two universities, that both enjoy strong positions in their fields of expertise, enables the integration of the various disciplines. The joint degree is organized in an appropriate way with equal representation of both TU Delft and Leiden University. The 'Circular Economy' (CIRCLE) specialization is a relevant dual degree programme, according to the panel. Alignment and cooperation within the international consortium are well organized.

As the concept of 'industrial ecology' is subject to change through the years, increasingly including societal aspects and challenges, the programme needs to reflect on its desired position within the dilemma of the ideological aspirations that current students express and the business demands of the professional field. The panel advises the programme to make its position more explicit and communicate it more clearly to students. Also, the programme's narrative could be further strengthened. According to the panel, the programme's focus and narrative provide a strong identity that is highly relevant in the context of current (societal) developments. The panel advises the programme to communicate this narrative more effectively, and, while holding on to its core identity, explore possibilities to organically and gradually include broader current issues.

Throughout the programme and on various levels, there are many interactions with the professional field, allowing for good alignment with the demands and needs of the professional field. Interactions and alignment with the professional field include the teachers' own research projects, guest lectures, the involvement of external commissioners in the course 'Sustainability Challenge', and Leiden University's Institute of Environmental Sciences' Advisory Board.

### Standard 2. Teaching-learning environment

According to the panel, the curriculum is well structured, reflecting the interdisciplinary nature of the programme. The panel is pleased to see that the programme is responsive to student feedback, resulting in changes to the curriculum where possible. The curriculum offers a lot of possibilities for students to create individual pathways. Students are well guided in this process. The learning line for skills was strengthened during the past few years and is now coherent and clearly visible. The panel appreciates the involvement of the professional field in the courses through the guest lectures and the Sustainability Challenge. An idea to further strengthen this, is to have guest lecturers share about their company and give students a taste of 'the real world' of industrial ecology. The panel also thinks that students may benefit from more internship opportunities connected to the thesis. The curriculum of the CIRCLE specialization is coherent and highly relevant, according to the panel.

The programme is taught in English, which, according to the panel, follows logically from the international nature of the field of industrial ecology. The teaching methods applied in the programme are strongly student-centred. A variety of (interactive) teaching methods are used. Students engage in group projects, allowing them to learn interdisciplinary and international skills. The guidance with regard to group work and collaboration is well set up. The panel considers the admission criteria to be appropriate. Student guidance

is well organized, especially thanks to the commitment of the two dedicated study advisors. Additionally, first-year students participate in a mentor group. Although the programme is intensive, it is feasible in two years. The panel believes it may be helpful if students would have a dedicated physical community space on one of the campuses.

The core teaching team has sufficient expertise on all aspects of industrial ecology. The teachers are didactically qualified and have sufficient proficiency in English. The panel is impressed by the high engagement of the core teaching team. Teachers have strong connections within the global 'industrial ecology' research community and have an open and responsive attitude towards the students. Alignment within the teaching team is ensured by regular teacher meetings with teachers from both universities. The panel notes that some teachers of (restricted choice) electives at TU Delft are relatively less connected to the field of industrial ecology. It suggests to offer an introduction to the field of industrial ecology to these teachers, so that they are sufficiently aware of the background of students from this programme.

### Standard 3. Student assessment

Assessment in the programme is elaborated in the assessment plan, which demonstrates the relationship between the exit qualifications and the courses and assessment methods. For each course, the assessment is elaborated in an assessment matrix. The panel considers the assessment system to be clear, robust, and well documented, demonstrating a good balance between group and individual assignments and the use of diverse and appropriate assessments methods. The assessment procedure for the thesis is well thought out. The reliability of thesis assessment is enhanced by the four eyes principle. The assessment forms ensure that all criteria are taken into account and they allow for elaborate feedback. The panel was happy to learn that the form is mainly used as a decision-making tool rather than a rigid rubric to calculate the grade, allowing for a more holistic approach. The panel considers the BoE to be competent and in control. The BoE succeeds at safeguarding the quality of assessment and the exit level, amongst others by systematic reviews of assessment in courses and samples of theses and regular evaluation of the programme's assessment plan.

### Standard 4. Achieved learning outcomes

Based on the sample of 15 theses reviewed, the panel concludes that the level demonstrated in these theses is appropriate for an academic master's programme. The documentation and the interviews indicate that graduates of the programme are well prepared for and prove to be successful in the professional field. They are especially appreciated for their interdisciplinary skills and their ability to translate theory to practice.

### Score table

The panel assesses the programme as follows:

#### *Master's programme Industrial Ecology*

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Student assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard

General conclusion positive

Em. prof. dr. Hans Bressers, panel chair  
Date: 8 October 2024

drs. Anne-Lise Kamphuis, panel secretary

# Introduction

## Procedure

### Assessment

On 13 June 2024, the joint master's programme Industrial Ecology (IE) of Leiden University and TU Delft was assessed by an independent peer review panel as part of the cluster assessment Environmental Sciences. The assessment cluster consisted of 17 programmes, offered by the institutions Open Universiteit, University of Amsterdam, Wageningen University, Radboud University, Vrije Universiteit Amsterdam, University of Groningen, Maastricht University, Leiden University, Utrecht University, and Delft University of Technology. The assessment followed the procedure and standards of the NVAO Assessment Framework for the Higher Education Accreditation System of the Netherlands (September 2018). The Protocol Joint Degree Accreditation (2021) was applicable to the assessment.

Quality assurance agency Academion coordinated the assessment upon request of the cluster Environmental Sciences. Peter Hilderling and Jessica van Rossum acted as coordinators and as panel secretaries. Annemarie Venemans, Esther Poort, Anne-Lise Kamphuis, Linda te Marvelde, Carlijn Braam and Jessica van Rossum also acted as secretaries in the cluster assessment. They have been certified and registered by the NVAO. Anne-Lise Kamphuis acted as panel secretary in the assessment of the master's programme Industrial Ecology of Leiden University and TU Delft.

### Preparation

Academion composed the peer review panel in cooperation with the institutions and taking into account the expertise and independence of the members as well as the consistency within the cluster. On 15 December 2023, the NVAO approved the composition of the panel. The coordinator instructed the panel chair on his role in the site visit according to the Panel chair profile (NVAO 2016).

The programme composed a site visit schedule in consultation with the coordinator (see appendix 3). The programme selected representative partners for the various interviews. It also determined that the development dialogue would be made part of the site visit. A separate development report was made based on this dialogue. It was decided to organize the site visit in Leiden. This was both for practical reasons (the site visit was scheduled together with another programme of Leiden University) and because Leiden is the coordinating university of the joint degree. Participants from both Leiden and Delft, including teaching staff, programme committee and Board of Examiners, participated in all the interviews. Furthermore, the student interview included a student that followed the CIRCLE dual degree.

The programme provided the coordinator with a list of graduates from academic years 2021-2022 and 2022-2023. In consultation with the coordinator, the panel chair selected 15 theses from the programme. They took the diversity of final grades, locations and examiners into account. From academic year 2022-2023 10 theses were selected, from academic year 2021-2022 5 theses were selected. Care was taken to select students that did their research project in Delft as well as students that did their project in Leiden. For the dual degree CIRCLE, the selection included one thesis by an incoming student at UL/TUD, and one by an outgoing student at Chalmers University. Prior to the site visit, the programme provided the panel with the theses and the accompanying assessment forms. It also provided the panel with a self-evaluation report and additional materials (see appendix 4).

The panel members studied the information and sent their findings to the secretary. The secretary collected the panel's questions and remarks in a document and shared this with the panel members. In a preliminary meeting, the panel discussed the initial findings on the self-evaluation report and the theses, as well as the division of tasks during the site visit. The panel was also informed on the assessment framework, the working method and the planning of the site visits and reports.

#### Site visit

During the site visit, the panel interviewed various programme representatives (see appendix 3). The panel also offered students and staff members an opportunity for confidential discussion during a consultation hour. No consultation was requested. The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the preliminary findings.

#### Report

The secretary wrote a draft report based on the panel's findings and submitted it to the coordinator for peer assessment. Subsequently, the secretary sent the report to the panel for feedback. After processing this feedback, the secretary sent the draft report to the programme in order to have it checked for factual irregularities. The secretary discussed the ensuing comments with the panel chair and changes were implemented accordingly. The panel then finalized the report, and the coordinator sent it to the Faculty of Science of Leiden University and the Faculty of Technology, Policy and Management of TU Delft.

#### Panel

The following panel members were involved in the cluster assessment Environmental Sciences:

- Em. prof. dr. J.T.A. (Hans) Bressers, emeritus professor in Policy Studies and Environmental Policy at the University of Twente (chair);
- Prof. dr. A.C. (Arthur) Petersen, professor in Science, Technology and Public Policy at the University College London (United Kingdom);
- Dr. A.R. (Ana) Vasques, lecturer at the Erasmus University College of Erasmus University Rotterdam;
- Dr. S.E. (Sarah) Cornell, associate professor at the Stockholm Resilience Centre of Stockholm University (Sweden);
- Em. prof. dr. M.C. E. (Rietje) van Dam-Mieras, emeritus professor in Sustainable Development and Innovation of Education at Leiden University, and member of the Top Consortium for Knowledge and Innovation (TKI) Biobased Circular (focus Human Capacity Agenda);
- Dr. ir. T. (Thijs) Bosker, associate professor in Environmental Sciences at Leiden University;
- Prof. dr. ir. S.E. (Siegfried) Vlaeminck, professor in Microbial Cleantech and Environmental Systems Analyses at the Universiteit of Antwerpen (Belgium);
- Prof. dr. M.P.J. (Maarten) Loopmans, professor in Human Geography and Political Ecology at the KU Leuven (Belgium);
- Dr. ir. S.G. (Gerd) Weitkamp, associate professor in Health Geography, Mobility, and Geospatial Technologies at the University of Groningen;
- Prof. dr. P. (Paquita) Perez Salgado, professor in Natural Sciences at the Open Universiteit Nederland;
- Prof. dr. E. (Esther) Turnhout, professor in Science, Technology and Society at the University of Twente;
- Em. prof. dr. ir. J.T. (Hans) Mommaas, emeritus professor in Regional Sustainability Governance at Tilburg University, chair of the Netherlands Commission for Environmental Assessment and chair of the Netherlands Ecological Authority;
- Dr. P. (Patricia) de Cocq, director Living Environment and Nature at HAS Green Academy;
- Prof. dr. ir. Z. (Zofia) Lukszo, professor in Smart Energy Systems at the Delft University of Technology;

- M. M. (Marisa) Beunk MSc., alumn (March 2023) of the master's programme Environmental Sciences (Policy Track) of Wageningen University (student member);
- F.O. (Fenna) Oostrum, alumn (September 2023) of the master's programme Environment and Society Studies of Radboud University (student member).

The panel assessing the master's programme Industrial Ecology of Leiden University and TU Delft consisted of the following members:

- Em. prof. dr. J.T.A. (Hans) Bressers, emeritus professor in Policy Studies and Environmental Policy at the University of Twente (chair);
- Prof. dr. A.C. (Arthur) Petersen, professor in Science, Technology and Public Policy at the University College London (United Kingdom);
- Dr. S.E. (Sarah) Cornell, associate professor at the Stockholm Resilience Centre of Stockholm University (Sweden);
- Em. prof. dr. ir. J.T. (Hans) Mommaas, emeritus professor in Regional Sustainability Governance at Tilburg University, chair of the Netherlands Commission for Environmental Assessment and chair of the Netherlands Ecological Authority;
- M. M. (Marisa) Beunk MSc., alumn (March 2023) of the master's programme Environmental Sciences (Policy Track) of Wageningen University (student member).

## Information on the programme

Name of the institution:	Leiden University
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive
Name of the institution:	TU Delft
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive
Programme name:	Industrial Ecology
CROHO number:	65003
Level:	Master
Orientation:	Academic
Number of credits:	120 EC
Specializations or tracks:	Industrial Ecology Erasmus Mundus CIRCLE (dual degree with Norwegian University of Science and Technology, Chalmers University of Technology and University of Graz) – discontinued per 2024-2025
Location:	Leiden, Delft
Additional information:	joint degree (Leiden University/TU Delft)
Mode(s) of study:	Fulltime
Language of instruction:	English
Submission date NVAO:	1 November 2024



## Description of the assessment

### Recommendations previous accreditation panel

The previous accreditation of the programme took place in 2018. The panel assessed standards 1, 2, and 3 as satisfactory, and standard 4 as good. The panel gave several recommendations. In response to these recommendations, the programme implemented several improvements, including the reformulation of the exit qualifications, a revision of the curriculum and courses offered, a revision of the way skills are addressed and assessed, better embedment of guest lecturers, the introduction of intake meetings with the study advisors and a mentoring system, the introduction of study paths through bundles of electives, the renewal of the Thesis Preparation Course, the appointment of a graduation coordinator, the introduction of a mandatory assessment matrix for each course, the revision of the thesis rubric and introduction of a thesis supervision protocol, and the introduction of a yearly thesis market.

The panel examined the response of the programme to these recommendations and concludes that the recommendations have been seriously acted upon by the programme. The panel is generally content with the improvement measures taken. For some recommendations, it became clear that the programme is still in the process of addressing these. These issues will be described further on in this report.

### Standard 1. Intended learning outcomes

The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

### Findings

#### *Profile*

The master's programme Industrial Ecology aims to empower students with the expertise and capabilities needed to identify, design, and critically assess sustainable solutions for global socio-ecological and technical challenges. The programme is interdisciplinary, integrating engineering, environmental, and social perspectives. The panel is positive about the programme's interdisciplinary focus, which is achieved through the cooperation between the two universities. Whereas TU Delft's Faculty of Technology, Policy and Management (TPM) offers expertise on (the interaction between) the social and technological perspectives, Leiden University's Institute of Environmental Sciences (CML) has a strong position in the field of natural science, more specifically with regard to material and energy flows and quantitative sustainability assessment.

The concept of 'industrial ecology' was discussed in several interviews during the site visit. It became clear that the scientific field of industrial ecology, which has always been strongly connected to CML, has gradually changed over the years. Parallel to this, the educational programme has also seen a shift in focus. Originally, industrial ecology was mostly industry oriented and primarily concerned with the comparative analysis of the business value chains of products. Over the years, the scope has widened to include more societal aspects and challenges. The current students indicated that they would like to widen the scope even further to include topics such as decolonization and climate justice. The students the panel spoke with stressed the importance of critical thinking as they aspire to change the system instead of only improving it. They want to become change agents. On the other hand, the interview with alumni and representatives of the professional field showed that there may be some dissonance between the aspirations of students and the business

demands of the professional context wherein many alumni start working. The panel notes that the programme needs to think about how it wishes to position itself within this dilemma: to what extent are students educated to become business consultants or global/critical change agents? The panel advises the programme to reflect on this and make it more explicit in the communication to students, in order to better manage expectations.

The panel also wants to stress the importance of strengthening the storyline of the programme. According to the panel, the programme has a strong narrative, which starts with the material and energy flows of society's metabolism. Such focus is at the centre of the field of industrial ecology. From that starting point, the environmental effects of these flows are addressed which is then connected to the wider field of sustainability, including social and economic aspects. The panel encourages the programme to relate to this narrative more proactively, as it provides a strong identity. From there, the programme can explore possibilities to organically and gradually include broader current issues and challenges without losing its core identity. According to the panel, the diversity of tools for sustainability assessment, which is at the core of the programme, is still highly relevant and has proven its value throughout societal developments and political shifts. The panel advises to hold on to this core, but to explicitly relate it to current dilemmas and challenges. The programme's narrative should then also be communicated to students more clearly in light of expectation management.

#### *Exit qualifications*

The intended learning outcomes of the programme are elaborated in 14 exit qualifications (see Appendix 1 for an overview). The self-evaluation report describes how the exit qualifications relate to the Dublin descriptors and to the Dutch referential framework for academic programmes in Environment and Sustainability, a document that was developed by the Interuniversity Committee Environmental Sciences. The panel considers the exit qualifications to be well formulated. They are well-balanced, addressing both knowledge, understanding, application and skills, and correspond with the master's level as described in the Dublin descriptors. Also, they cover all important aspect of the field of industrial ecology.

#### *Joint degree*

The master's programme is offered as a joint degree programme by the Leiden University and TU Delft, with Leiden University in the role of coordinating university. The position of programme director alternates between the universities every four years, while the programme coordinators and study advisors are based at Leiden University. Decisions about the structure of the programme are jointly made by the relevant Faculty Boards of both universities. Within Leiden University, the programme is associated with CML of the Faculty of Science. Within TU Delft, TPM provides the main contribution to the programme. Both universities deliver an equivalent contribution to the overall teaching in the programme. Teaching activities take place in both Leiden and Delft. The panel examined the cooperation agreement for this joint degree programme and concludes that it is well thought out, demonstrating an appropriate division of responsibilities between both institutions.

#### *Specializations*

The programme offers two specializations: 'Industrial Ecology', which is the regular track, and 'Circular Economy' (CIRCLE), a dual degree programme. CIRCLE is an international Erasmus Mundus master's programme on Circular Economy. It was established in 2018, with the first cohort starting in 2019-2020. As the funding period ends in the summer of 2024, the last cohort of students started in September 2022. Students in the CIRCLE specialization take one year at Leiden University/TU Delft and one year at one of the partner host universities in the consortium (Norwegian University of Science and Technology (Norway), Chalmers University of Technology (Sweden) and University of Graz (Austria)). Additional mobility at one of

the associated partner universities (Waseda University Tokyo, Tsinghua University Beijing and Curtin University Perth) is possible in the second year. A joint summer school is organized each year in which all students get together. Students that participate through the master's programme Industrial Ecology receive two degrees: a MSc Industrial Ecology degree from Leiden University/TU Delft, and one of the partner institution that served as either their entry or exit university. CIRCLE does not have its own unique curriculum but is organized as an exchange programme. Students follow courses in the associated master's programmes, and care is being taken that the full curriculum meets the intended learning outcomes of both degrees.

The University of Graz is the coordinating university of the consortium. The consortium appointed a Program Board, in which all universities in the consortium are represented. The Program Board is responsible for the quality assurance of the dual degree programme (in addition to the local quality assurance systems), and for coordinating and supervising admission and examination. The CIRCLE specialization was approved by the relevant Faculty Boards and participatory bodies at Leiden University and TU Delft. It is included in the Course and Examination Regulations as a specialization of the master's programme Industrial Ecology. The panel considers the CIRCLE specialization to be a relevant dual degree programme. Also, alignment and cooperation within the consortium is well organized.

As the CIRCLE programme will end in the summer of 2024, a proposal for a new international Erasmus Mundus dual degree master's programme was submitted, called TRACE (Transitions to a Circular Economy). The submission was not successful and the TRACE programme will be resubmitted as a proposal to the Erasmus Mundus programme in 2025. Should the new proposal be approved, TRACE would be a specialization of the master's programme Industrial Ecology as of September 2026.

#### *Professional field*

According to the panel, the programme is well aligned with the professional field, as the programme management and teaching staff have ample connections in the professional field, partly in the context of their own research projects. Interactions with the professional field are further increased through regular guest lectures by alumni and professionals from the field. Moreover, in the second-year course 'Sustainability Challenge', students work on a project for an external commissioner from the professional field. Finally, CML has an Advisory Board, consisting of representatives from research institutes and the professional field. The Advisory Board meets with the department's Management Team, of which the programme director is a member, twice a year. The Board advises on the various educational programmes connected to CML. It is consulted about the overall profile and focus of the programmes in light of societal and political changes.

#### Considerations

The panel considers the exit qualifications to be well formulated, well aligned with the field of industrial ecology, and appropriate for the academic master's level. The panel appreciates the programme's interdisciplinary profile, integrating engineering, environmental, and social perspectives. The cooperation between the two universities, that both enjoy strong positions in their fields of expertise, enables the integration of the various disciplines. The joint degree is organized in an appropriate way with equal representation of both TU Delft and Leiden University. The CIRCLE specialization is a relevant dual degree programme, according to the panel. Alignment and cooperation within the international consortium are well organized.

As the concept of 'industrial ecology' is subject to change through the years, increasingly including societal aspects and challenges, the programme needs to reflect on its desired position within the dilemma of the

ideological aspirations that current students express and the business demands of the professional field. The panel advises the programme to make its position more explicit and communicate it more clearly to students. Also, the programme's narrative could be further strengthened. According to the panel, the programme's focus and narrative provide a strong identity that is highly relevant in the context of current (societal) developments. The panel advises the programme to communicate this narrative more effectively, and, while holding on to its core identity, explore possibilities to organically and gradually include broader current issues.

Throughout the programme and on various levels, there are many interactions with the professional field, allowing for good alignment with the demands and needs of the professional field. Interactions and alignment with the professional field include the teachers' own research projects, guest lectures, the involvement of external commissioners in the course 'Sustainability Challenge', and CML's Advisory Board.

### Conclusion

The panel concludes that the programme meets standard 1.

## Standard 2. Teaching-learning environment

The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

### Findings

#### *Curriculum*

The master's programme Industrial Ecology consists of 120 EC and is offered as a full-time, two-year programme (see Appendix 2 for a curriculum overview). In the first semester of the programme, all students follow the same six courses which form the foundation of the programme. The courses in the first quarter are offered in Leiden, while the courses in the second quarter are offered in Delft. In the second semester of the first year, students follow the interdisciplinary course 'Integrated Project'. Also, they have 20 EC in elective space. The first half of the second year includes 15 EC in elective space. Besides that, students follow the core courses 'Thesis Preparation Course' and 'Sustainability Challenge'. The Sustainability Challenge is a real-life group project for an external commissioner. In the Thesis Preparation Course, students write a literature review on their chosen topic and prepare a research proposal. To help students find a topic for their thesis, thesis markets are organized, in which staff members present their research projects. The final semester is dedicated to the 30 EC 'Thesis Research Project'. In the Thesis Research Project, students perform an individual interdisciplinary research project on the analysis of a sustainability challenge and the design and implementation of possible solutions. Students are supervised by two supervisors, representing different research groups, to emphasize the interdisciplinary nature of the project.

The panel considers the curriculum to be well structured. The panel appreciates the integrative courses offered in the first part of the programme, such as 'Society's Metabolism', and the way that interdisciplinarity is reflected in the curriculum, amongst others in the project courses and in the thesis. Also, the curriculum is thoroughly linked to research. The students the panel spoke with were positive about the curriculum. They appreciated the elective space and the possibilities they have to pursue individual pathways through the electives and projects. Students mentioned that they are well guided in the process of choosing their electives. To offer students consultation in their choice of electives, the programme organizes regular meetings in which potential 'specialization tracks' (bundles of electives) are presented to help students navigate their options. The panel is also pleased with the learning line for skills which was strengthened

during the past few years. It is clear where various skills are addressed in the curriculum, which is also visible in the course manuals. Input from the professional field is well incorporated in the curriculum, especially through the guest lectures and the Sustainability Challenge. The panel suggests that the professionals' contribution may be further enhanced by having guest lecturers share about the company they work for and give students a taste of what the field of industrial ecology is like 'in the real world'. The panel also thinks that students may benefit from more internship opportunities. At the moment, students have the possibility to do an internship on their own initiative. The panel suggests that the programme may support internship opportunities more proactively, especially connected to the thesis.

The panel was happy to learn how the programme is responsive to feedback from students. An example of this is the course on the topic of degrowth, which was first developed following a student initiative and is now offered as a regular elective. Students also indicated that they are interested in the topic of climate justice and would like to see more of this in the curriculum. The programme explained it is still considering whether or not to develop a specific course on this topic. So far, no special course was developed because there is no specific expertise and research experience on this topic among the teaching staff. The panel appreciates how the programme is aware of the issues connected to this topic, and explores possibilities to incorporate these into the curriculum while at the same time being realistic about what it can offer.

Information on the CIRCLE specialization (see standard 1) was provided in the documentation and on the CIRCLE website. The website includes information on the courses offered at the partner host universities. The students the panel spoke with included a student from the CIRCLE specialization who took the first year in Norway. The panel concludes that the curriculum for the CIRCLE specialization is well structured and coherent. The panel considers it to be highly relevant. The information and interviews made clear that the transfer from the first to the second host university runs smoothly. Moreover, the summer schools add to the integration and coherence of the dual degree programme as well as the sense of community among the students and staff.

#### *International focus*

The programme has an international focus, is taught in English, and uses an English-language name. According to the panel, this follows logically from the international nature of both the academic field and the professional field of industrial ecology. Challenges in this field are typically international and English is the common language in this field. The programme has a steady proportion of international students: nearly half of the students are international. Moreover, part of the teaching staff is non-Dutch. In the programme, a lot of attention is paid to international collaboration and international challenges.

#### *Didactic approach*

The panel is positive about the teaching methods applied, which are strongly student-centred and include various interactive approaches, such as flipped-classroom and 'Blue Engineering' principles. Besides lectures, teaching methods such as seminars and workshops are used. Students also work on group assignments and projects, which benefit from principles of problem-based learning. Group work provides students with the opportunity to learn interdisciplinary and international skills, as the groups include students from various disciplinary and cultural backgrounds. The panel appreciates the guidance students receive during the group projects. In this guidance, explicit attention is paid to the collaboration within the group. The panel notes that the students have an active and engaged attitude.

#### *Admission and guidance*

To apply for admission, students need to have a bachelor's degree from a research university in natural sciences, engineering sciences, or social sciences. They also need to have demonstrated experience in

multi/interdisciplinary education and research and knowledge of environmental sustainability challenges. Moreover, they need to have completed a minimum of 8 EC of courses on statistics, mathematics, and/or programming. Applications are evaluated by the Board of Admissions. The panel considers the admission criteria to be appropriate. The programme offers an online preparation module to students prior to the start of the programme.

The panel concludes that student guidance is well organized. The panel appreciates the commitment of the two dedicated study advisors for the programme. Students indicated that these are responsive and easily approachable. The study advisors are already available for upcoming students in the months before the start of the programme. During this period of time, the study advisors send newsletters and organize Q&A-sessions to help students prepare. After the start of the programme, all students have an individual intake meeting with one of the study advisors. Throughout the rest of the programme, the study advisors are available to students. They also proactively monitor student progress and initiate a meeting when appropriate. In the second year, the study advisors are involved in the thesis market and the Thesis Preparation Course. In addition to the guidance by the study advisors, first-year students are part of a mentor group. The mentor groups meet four times during the first year and are supervised by student-mentors (second-year students). The mentors are supervised by the study advisors.

The panel concludes that the curriculum is feasible. In the interview, the students explained that the programme is quite intense. According to the students, the workload is considerable and the group projects also challenge students in other areas than content-related topics, such as teamwork and time management. Even so, the students emphasized that, although the programme is intensive, it is doable in two years.

#### *Teaching staff*

The programme is taught by a core team of about 30 teachers from both institutions. All teachers hold the University Teaching Qualification (UTQ) or are in the process of obtaining one. The programme director also holds the Senior Teaching Qualification. All teachers are required to obtain the Basic Qualification Language Proficiency English. The panel is impressed by the qualified and highly engaged core teaching team. Teachers have strong connections within the global 'industrial ecology' research community. Moreover, the panel notes that the teachers have an open and responsive attitude towards the students. The panel also finds that there is good alignment within the core team, mainly thanks to regular teacher meetings with teachers from both universities.

The panel does note that the connection between the programme and the expertise of the teaching staff is somewhat stronger among teachers from Leiden University as compared to teachers from TU Delft, due to the nature of the field of industrial ecology. This is especially true for teachers of electives. According to the students, some teachers connected to electives hosted by TU Delft are not familiar with the field of industrial ecology. The panel believes it may be helpful to offer an introduction to the field of industrial ecology to teachers of electives included in the restricted choice list for the programme, so that these teachers are sufficiently aware of the background of students from this programme. The panel also thinks that the aspect of 'learning from each other' could be increased among the teaching team. For example, the students mentioned that some teachers have multiple evaluation moments during a course, instead of only having one evaluation moment at the end of the course. The students very much appreciate this more dynamic and continuous evaluation approach. The panel finds this is an example of a good practice that may be adopted by other teachers.

### *Facilities*

The students indicated that they are happy about the facilities offered by the programme at both locations. They do not experience problems with regard to travelling to the different locations (Leiden and Delft). The panel was happy to learn that students can use the facilities of both universities, which is an advantage of the joint degree programme. Students did point out that they miss a physical community space. They explained that the students form a close community: they often get together in between classes to share ideas and study. The panel believes it would be helpful if students would have a physical space where they could meet with other students from the programme.

### Considerations

According to the panel, the curriculum is well structured, reflecting the interdisciplinary nature of the programme. The panel is pleased to see that the programme is responsive to student feedback, resulting in changes to the curriculum where possible. The curriculum offers a lot of possibilities for students to create individual pathways. Students are well guided in this process. The learning line for skills was strengthened during the past few years and is now coherent and clearly visible. The panel appreciates the involvement of the professional field in the courses through the guest lectures and the Sustainability Challenge. An idea to further strengthen this, is to have guest lecturers share about their company and give students a taste of 'the real world' of industrial ecology. The panel also thinks that students may benefit from more internship opportunities connected to the thesis. The curriculum of the CIRCLE specialization is coherent and highly relevant, according to the panel.

The programme is taught in English, which, according to the panel, follows logically from the international nature of the field of industrial ecology. The teaching methods applied in the programme are strongly student-centred. A variety of (interactive) teaching methods are used. Students engage in group projects, allowing them to learn interdisciplinary and international skills. The guidance with regard to group work and collaboration is well set up. The panel considers the admission criteria to be appropriate. Student guidance is well organized, especially thanks to the commitment of the two dedicated study advisors. Additionally, first-year students participate in a mentor group. Although the programme is intensive, it is feasible in two years. The panel believes it may be helpful if students would have a dedicated physical community space on one of the campuses.

The core teaching team has sufficient expertise on all aspects of industrial ecology. The teachers are didactically qualified and have sufficient proficiency in English. The panel is impressed by the high engagement of the core teaching team. Teachers have strong connections within the global 'industrial ecology' research community and have an open and responsive attitude towards the students. Alignment within the teaching team is ensured by regular teacher meetings with teachers from both universities. The panel notes that some teachers of (restricted choice) electives at TU Delft are relatively less connected to the field of industrial ecology. It suggests to offer an introduction to the field of industrial ecology to these teachers, so that they are sufficiently aware of the background of students from this programme.

### Conclusion

The panel concludes that the programme meets standard 2.

### Standard 3. Student assessment

The programme has an adequate system of student assessment in place.

#### Findings

##### *Assessment system*

Assessment in the programme is elaborated in the assessment plan, which includes matrices demonstrating which exit qualifications are assessed in each course and which assessment methods are applied. For each course, an assessment matrix is developed by the course coordinator, which demonstrates the relationship between the course's learning objectives and assessment methods. The panel thinks that the assessment system is clear, robust, and well documented. There is a good balance between group and individual assignments and between formative and summative assessment methods. The used assessment methods are appropriate and diverse, including (take-home) exams, essays, papers, reports, practical assignments, presentations, and participation. To mitigate the risk of free rider behaviour in the case of group assessments, students are asked to evaluate the contributions of other group members. The panel is also pleased to see how interdisciplinary skills are assessed in various courses, especially in the Integrated Project and the Sustainability Challenge. To safeguard the reliability of assessment, grading models, assessment forms and/or rubrics are used by assessors. The use of artificial intelligence (AI) tools was discussed in several interviews. The panel learnt that, given the recent rapid developments in this area, the programme is still in the process of finetuning the regulations concerning the use of AI by students. The panel was pleased to hear that the programme recognizes the potential value of AI for students' learning process and aims to integrate AI tools in a responsible way.

##### *Thesis assessment*

Assessment of the Thesis Research Project is based on two components: 1) the research project and report, and 2) the oral defence, possibly complemented by a research product such as a design or piece of software. The Thesis Research Project is assessed by the two supervisors, representing different disciplines and/or research groups. The panel appreciates this approach since it enables the assessment of interdisciplinarity. Each assessor fills in the assessment form. Subsequently, the two assessors discuss their findings and determine a final grade. The interviews made clear that the thesis coordinator is appointed as a third assessor in case the first and second assessors' grades differ more than one point. The teachers indicated that this has not happened so far. One of the reasons for this is that the two supervisors already meet at the beginning of and halfway through the thesis project to align their findings. The panel considers the thesis assessment procedure to be well thought out.

One point of attention relates to the assessment of the thesis in the (now discontinued) CIRCLE specialization in the case that students take their second year at a partner host university. In that event, students write their thesis at the partner university, which provides the supervision and carries out the thesis assessment. In the interviews, the programme indicated that, so far, the teaching staff from Leiden University and/or TU Delft were not directly involved in the supervision and assessment of these theses. This is perceived as an issue that needs to be improved in order to be able to better safeguard the exit level of students in this specialization. The programme has already recognized this, and implemented a different procedure for the potential new TRACE programme, the possible successor of CIRCLE (see standard 1). If this programme is accepted, a procedure will be applied to ensure that there is always a supervisor from Leiden University or TU Delft involved in the assessment of theses from students in this IE specialization. The panel agrees with this new procedure and is positive that it will enhance the assessment quality.



As part of the preparation for the site visit, the panel reviewed 15 theses from the programme, including the completed assessment forms. The panel is satisfied with the way the forms were filled in. The grades awarded were well substantiated by the feedback given. The panel appreciates the elaborate assessment form as it ensures that all important criteria are taken into account. The panel was initially concerned that the form may be overly detailed. It was reassured, however, that the form is mainly used as a decision-making tool rather than a rigid rubric to calculate the grade. Assessors have sufficient freedom in how they use the form, allowing for a more holistic approach.

#### *Board of Examiners*

There is one Board of Examiners (BoE) for the programme, jointly appointed by the relevant Faculty Boards of the two institutions. Both institutions are represented in the members of the BoE. The BoE also has one external member. Besides appointing the examiners, the BoE performs systematic reviews of assessment in courses by examining the assessment matrices. Also, each year, the BoE checks a random sample of 5-6 theses to evaluate the grading reliability and exit level, including theses from the dual degree CIRCLE specialization. The programme's entire assessment plan is evaluated by the BoE every three years. Based on the documentation and the interviews, the panel is very positive about the BoE. The panel considers the BoE to be in control and aware of issues in the programme. The BoE is proactive with regard to evaluating the quality of assessment in the programme and the level of the theses. The panel also thinks that developments concerning AI are well considered and reflected on, resulting in well balanced policies.

#### Considerations

Assessment in the programme is elaborated in the assessment plan, which demonstrates the relationship between the exit qualifications and the courses and assessment methods. For each course, the assessment is elaborated in an assessment matrix. The panel considers the assessment system to be clear, robust, and well documented, demonstrating a good balance between group and individual assignments and the use of diverse and appropriate assessments methods. The assessment procedure for the thesis is well thought out. The reliability of thesis assessment is enhanced by the four eyes principle. The assessment forms ensure that all criteria are taken into account and they allow for elaborate feedback. The panel was happy to learn that the form is mainly used as a decision-making tool rather than a rigid rubric to calculate the grade, allowing for a more holistic approach. The panel considers the BoE to be competent and in control. The BoE succeeds at safeguarding the quality of assessment and the exit level, amongst others by systematic reviews of assessment in courses and samples of theses and regular evaluation of the programme's assessment plan.

#### Conclusion

The panel concludes that the programme meets standard 3.

### Standard 4. Achieved learning outcomes

The programme demonstrates that the intended learning outcomes are achieved.

#### Findings

##### *Theses*

The Thesis Research Project is regarded as the final student project, demonstrating the achieved level of students. The panel reviewed a sample of 15 theses from the programme. The panel concludes that the theses reviewed demonstrate a high level, appropriate for an academic master's programme. According to the panel, some of the theses seem to be suitable as the basis for scientific publications. This is consistent

with the figures provided in the documentation, demonstrating that a number of theses from the past few years have led to publications in scientific journals.

### *Alumni*

The documentation includes overviews of the current positions and employers of alumni. It is clear from the documentation and the interviews that graduates can find a job relatively easily. Alumni are positive about the programme and happy about how it prepared them for their current job. They especially appreciate the tools for sustainability assessment and the interdisciplinary skills and approach. Also, the guest lectures and projects (such as the Sustainability Challenge) helped them prepare for the labour market. The employers that the panel spoke with, appreciate graduates from this programme. They indicated that alumni from this programme are especially valuable because of their interdisciplinary skills and the ability to translate theory to practice. Based on the interviews and the figures included in the documentation, the panel concludes that alumni prove to be successful in the professional field and are able to contribute to society in a meaningful way.

### Considerations

Based on the sample of 15 theses reviewed, the panel concludes that the level demonstrated in these theses is appropriate for an academic master's programme. The documentation and the interviews indicate that graduates of the programme are well prepared for and prove to be successful in the professional field. They are especially appreciated for their interdisciplinary skills and their ability to translate theory to practice.

### Conclusion

The panel concludes that the programme meets standard 4.

## General conclusion

The panel's assessment of the master's programme Industrial Ecology is positive.

## Development points

1. Reflect on the programme's desired position within the dilemma of the ideological aspirations that current students express (becoming global change agents) and the business demands of the professional field (business consultants). Make this position more explicit and communicate it more clearly to students.
2. Strengthen the programme's storyline and relate it to the context of current (societal) developments. Communicate this narrative more effectively, and, while holding on to the programme's core identity, explore possibilities to organically and gradually include broader current issues.

## Appendix 1. Intended learning outcomes

### **Knowledge, understanding, integration and application**

The student has:

1. thorough understanding of society's metabolism, its role in sustainability issues and its drivers and impacts;
2. thorough knowledge of the most important approaches, hereby defined as theories, methods and tools, used in Industrial Ecology research;
3. in-depth knowledge of at least one approach used for analysing physical processes and one approach for analysing social processes, used in Industrial Ecology research.

The student is able to:

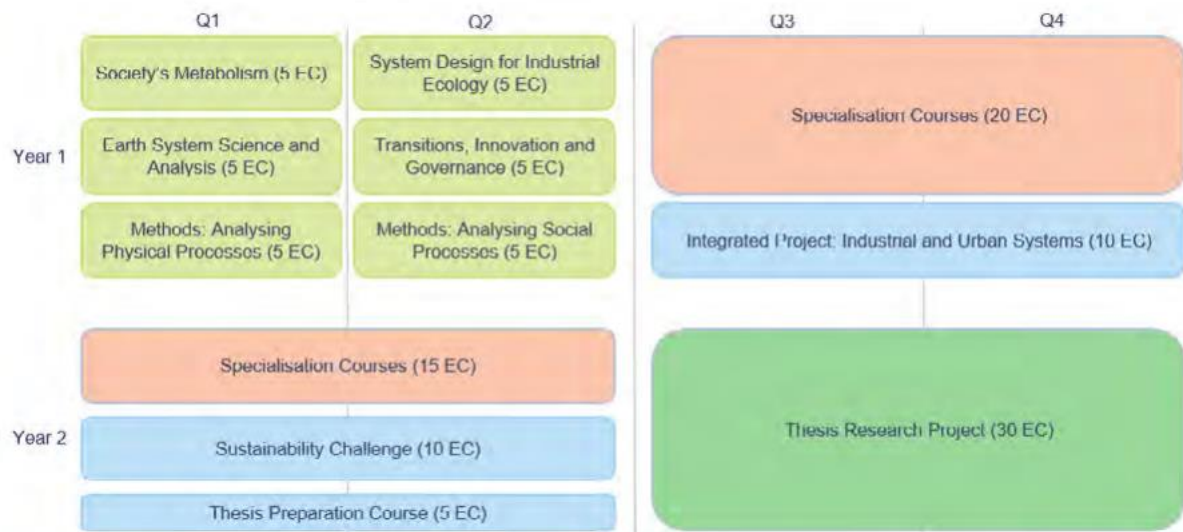
4. apply systems thinking in analysing society's metabolism and in evaluating and designing solutions to sustainability problems;
5. systematically combine and integrate knowledge, methods and tools from various disciplines relevant to Industrial Ecology;
6. formulate relevant research questions and choose the appropriate methods to answer these questions;
7. apply and critically evaluate at least one approach for analysing physical processes and one approach for analysing social processes, used in Industrial Ecology research ;
8. contribute to the further development and/or validation of theories, methods or tools in Industrial Ecology research.

### **Skills**

The student is able to:

9. constructively work and actively collaborate in multidisciplinary and international teams;
10. gather, use and integrate data from multiple sources;
11. independently plan, conduct and evaluate in-depth research, within an interdisciplinary context,
12. convincingly communicate results to specialist and non-specialist audiences, both verbally and in writing, with due attention to uncertainties;
13. design and plan their own learning processes through continuous reflection on personal knowledge, skills, attitudes and performance;
14. reflect on the ethical aspects of their research and to incorporate these reflections in setting up research and developing recommendations and/or sustainability solutions.

## Appendix 2. Programme curriculum



## Appendix 3. Programme of the site visit

**Thursday 13 June 2024, Leiden**

08.45	09.00	Arrival and welcome
09.00	09.30	Panel preparation
09.30	10.15	Interview programme management IE
10.30	11.15	Interview students IE
11.30	12.15	Interview teaching staff IE
12.15	13.00	Lunch break
13.00	13.30	Interview alumni + professional field IE
13.45	14.15	Interview Board of Examiners IE
14.30	15.30	Thematic sessions IE
15.30	16.30	Panel deliberation
16.30	17.00	Final meeting with management IE
17.00	17.30	Panel deliberation
17.30	18.00	Oral feedback and closing

## Appendix 4. Materials

Prior to the site visit, the panel studied 15 theses of the master's programme Industrial Ecology. Information on the theses is available from Academion upon request. The panel also studied other materials, which included:

- Self-evaluation report, including:
  - Student chapter
  - SWOT analysis
  - Reflection questions for site visit
- Reading guide
- Exit qualifications
- Dutch referential framework cluster ICM
- Programme metrics (*Opleidingskaart*) 2022-2023
- Results Nationale Studenten Enquete 2023
- Cooperation agreement Leiden University and TU Delft
- Curriculum overview
  - Short description of core courses
  - List of specialisation course 2023-2024
  - Curriculum renewal 2018-2020 summary
  - Contents and future improvements online preparation module
  - First ideas elective bundles
  - Overview commissioners Sustainability Challenge 2021-2023
- Previous accreditation report
- Overview recommendations and actions accreditation 2018 and midterm 2021
- Regulations
  - Course and Examination regulations 2023-2024
  - Implementation Regulations 2023-2024 (appendix CER / IR)
  - Rules and Guidelines of the Board of Examiners 2023-2024
- Overview of the teaching team
- Members of Boards and Committees
- Quality assurance
  - Annual report programme 2022-2023
  - Quality assurance cycle
  - Course evaluation example
  - Reflection Programme Committee and course coordinator example
  - Example of minute PC meetings and diversity memo
  - Description CIRCLE programme and quality assurance
- Assessment plan
  - Overview of exit qualifications vs. courses
  - Overview of courses and their assessment
  - Rubric Sustainability Challenge
  - Example report Sustainability Challenge
- Quality assurance
  - Annual report Board of Examiners 2022-2023
  - List of IE core examiners 2023-2024
  - Course assessment and thesis review procedure

- Course assessment review form
  - Thesis review form
  - Course assessment review example
  - Thesis review example
  - Thesis review summary
  - Grades analysis Board of Examiners 2023
- Thesis
  - Thesis protocol
  - Thesis supervision protocol
  - Thesis rubric and assessment form
  - List of thesis titles 2021-2023
- Alumni
  - National Alumni Survey 2021
  - Exit survey
  - Profession after graduation
  - Alumni booklet
  - List of publications based on MSc IE theses 2021-2024

During the site visit the panel had access to the online learning environment Brightspace. Also, the exam archives of two courses ('LCA Practice and Reporting' and 'Methods Analysing Physical Processes') were made available.