WO-master Industrial Ecology
Leiden University
Delft University of Technology

Report of the panel for re-accreditation of the program

August, 2015

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1 Summary

Re-accreditation
June 2015 a panel for re-accreditation visited the WO master program Industrial Ecology, jointly offered by Leiden University and Delft University of Technology.
In this report the panel presents its findings. The standard procedure for the limited program accreditation was applicable. The findings are based upon study of the Self-evaluation report and appendices, course materials, including assessments, a selection of theses and
upon various meetings with the Vice Deans of the Faculties, Program Management, Program Council, Board of Examiners, staff, students and alumni.
The documentation provided by the program was complete, informative and transparent and the preparation and organization of the site visit were excellent. The panel very much appreciated the open discussion in the various meetings.

Programme profile
Industrial Ecology is an academic field that takes a systemic approach to environmental problems. This approach combines technical, environmental and social frames of reference, which are considered essential in the eventual transition to sustainable development. For that reason Industrial Ecology is sometimes referred to as the 'toolbox for sustainable development' or the 'science of sustainability'. Industrial Ecology takes a positive approach to sustainable development: 'industry's answer to the environmental challenge'. The analogy between natural and technical systems and processes is a core element. Processes in nature, where cycles are closed and waste from one process is input for another, serve as models for socio-technological processes. The term 'industrial' does not refer only to the industrial complexes or industrial process systems, it is used for all kinds of technological systems used in the exploration-production-consumption chain.

Standard 1. Learning outcomes
The intended learning outcomes focus on the analysis, design, and implementation of industrial systems on the analogy of ecological systems and with the least possible adverse sustainability impacts. They comply evidently with both the Dublin descriptors and the Dutch-Flemish domain specific referential framework.
Industrial ecology is a relatively young program. Like related programs regarding sustainability and the environment it relates to a complex and rapidly evolving field (in terms of research, theoretical concepts, practical applications and student body). The current articulation of the intended learning outcomes (dating from 2009) is overambitious and runs the risk of extending the field or scope of Industrial Ecology too broadly. Given the current state of development in the field of Industrial Ecology and related fields the panel recommends a rearticulation of the learning outcomes.

The panel assesses standard 1 as 'satisfactory'.

Standard 2. Teaching-learning environment
Industrial Ecology is a two-year master program. The first year focuses on acquiring the knowledge and skills that an Industrial Ecologist needs (covering the three basic areas of Industrial Ecology (Natural Sciences, Social Science and Engineering) with some room for specialization modules. The second year is primarily about applying the knowledge and skills that have been taught in the first year of the programme and consists of interdisciplinary group projects, specialization modules (of which about 25 are on offer) and an individual thesis research project. The panel notes some tension between a multidisciplinary and a truly interdisciplinary approach in the program.

The program succeeds in attracting a student body that is well-balanced in terms of relevant background disciplines: Natural Sciences, Social Science and Engineering. All students are required to master a core level of these three areas. There is some study delay and early drop-out of students due to this and because many students do internships for which no credits are awarded.

Given the complexity and dynamic development of the field, the panel doubts that the basic tenet of the program (that all students should have a common understanding of the three core disciplines) is sustainable in the long run and suggests implementing a system of 'tracks' (implying a 'T-structure' of the curriculum).

All staff members have both a teaching and a research task, because the philosophy of both involved faculties is that education should be based on scientific research. Most staff members are involved in research relevant to the theme of the program. The panel considers a total of 6 fte for the program and the number of students to be rather low, but still satisfactory now.
There is one full professor of Industrial Ecology in Leiden. Given then international ambitions of the program and the development of the field of Industrial Ecology, it would be advantageous to also have a full professor of Industrial Ecology at Delft University of Technology.

The program specific facilities are adequate.

The panel assesses Standard 2 as 'satisfactory'.

Standard 3. Assessment
The assessment system of the program is in (a final stage of) development and some of the standard measures for quality control of assessment have only relatively recently been implemented. Still, given the material studied by the panel and the general impression of rigor in the program, the percentage of retakes in natural sciences exams for students with a social science background, and the improvements that have been realised with regard to the thesis assessment (see also standard 4) the panel concludes that the assessments are overall sufficiently transparent, valid and reliable.

The panel assesses Standard 3 as 'satisfactory'.

Standard 4. Achieved learning outcomes
The panel has paid much attention to the theses, both in terms of level and content. Initially, the panel had (on the basis of a sample of 15 theses) doubts about the relevance of the research topics in relation to the field of Industrial Ecology and about the grading. This has intensively been discussed in the various meetings, and the panel has studied additional theses and thesis research proposals.
The panel concludes that the original sample of theses was not wholly representative and that, while the thesis grading tends to be generally somewhat too high, the level of the theses is sufficient.

The program has provided a list showing the jobs of graduates (n= 72). Of these 28% work in research and 69% in 'industry' (including consultancy, government). Only 3% are unemployed.
Clearly graduates are in demand.

The panel assesses Standard 4 as 'satisfactory'.

General conclusion
Following the NVAO assessment rules the final conclusion of the panel regarding the WO master program Industrial Ecology, offered by Leiden University and Delft University is 'satisfactory'.

The Hague, August 11, 2015

Prof.dr. Wim Hafkamp
Chairman

Drs. Carlo Hover
Secretary

2 Introduction

In this report, the panel for the re-accreditation of the WO master program Industrial Ecology, a joint program between Leiden University and Delft University of Technology, presents its findings, based on the study of documents, theses and a site visit in June 2015.

The program was offered for the first time in the academic year 2010-2011. The initial accreditation decision by the NVAO dates from December 22, 2009. One of the current panel members (prof.dr. H. Moll) was chairman of the panel for the initial accreditation (site visit October 2, 2009).

2.1 Panel

The composition of the panel for the re-accreditation is as follows:

- Prof. dr. Wim Hafkamp, Erasmus University Rotterdam (EUR), domain expert, chairman.
- Prof. dr. Henk Moll, State University Groningen (RUG), domain expert, member.
- Prof. dr. Andrew Jamison, Aalborg University, domain expert, member.
- Prof. dr. Harrie Eijkelhof, Utrecht University, education expert, member.
- Ir. Wouter van Gerwen, Department Manager Industrial Projects Tebodin, professional field, member.
- Thomas Mason BSc, Utrecht University, student member (master Sustainable Development).
- Drs. Carlo Hover, Smets & Hover Adviseurs, secretary.

The panel composition is in compliance with the *Requirements regarding panel composition within the framework of the accreditation system* (August 2011). All panel members have signed a declaration of independence and confidentiality.

2.2 Content and structure of the report

The report complies with the requirements as formulated in the NVAO Limited program assessment framework (December 2014) and is structured on the basis of the standards and their explanations recorded in said framework.

2.3 Process of the program assessment

On June 15 and 16, 2015 the panel visited the program in the process of the limited program assessment. In preparation for the site visit, panel members have studied the critical self-evaluation report and its various appendices as required conform to the NVAO assessment framework. The panel members also assessed, prior to the site visit, a number of theses; see appendix 7.5 for the list.

On the day before the actual site-visit, the panel had a preparatory meeting. In this meeting the members exchanged their general impressions of the program, discussed the quality of the theses and their grading and made an inventory of questions and discussion points for the various meetings.

During the site visit, the panel has spoken with the vice deans of the faculties involved, the scientific director of the Institute of Environmental Science, the program management, members of the Education committee (‘opleidingscommissie’), Board of Examiners, academic staff, students, alumni and two representatives of the professional field. Time for open consultations with students and staff members was provided. Nobody made use of this opportunity.
Appendix 7.3 presents the schedule of the site visit.

During the site visit the panel studied additional documents (theses, course material, exams, quality assurance reports and board and committee minutes) in compliance with the NVAO assessment framework.
In judging the various standards and in formulating the final conclusion the panel adhered to the assessment scales and rules of the NVAO Assessment frameworks as well as the NVAO Guideline for the assessment of final projects (February 2015).

The panel greatly appreciates the support provided by program management and staff in preparing and organizing the visit. The discussions in the various meetings all had a very open and lively character.

2.4 Administrative data

Table 1 provides the mandatory administrative data about the program.

Table 1. Administrative data

Country	**The Netherlands**
Institutions	Universiteit Leiden (Leiden University) Technische Universiteit Delft (Delft University of Technology)
Title of the program (as registered in CROHO)	M Industrial Ecology
Registration number in CROHO	60415
Orientation and level of the program	Academic orientation, Master's level
Number of credits	120 EC
Language of instruction	English
Location	Delft and Leiden, The Netherlands
Mode of study	Full time
Institution	Leiden University
Status	State funded
Outcome institutional quality assurance audit	Leiden University positive assessment July 2nd, 2013. Delft University of Technology positive assessment November 21, 2011

2.5 Program profile

The Master Program Industrial Ecology is a joint program between Leiden University and Delft University of Technology. Leiden University is the leading partner and is responsible for the administration of the program.

Industrial Ecology is an academic field that takes a systemic approach to environmental problems. This approach combines technical, environmental and social frames of reference, which are considered essential in the eventual transition to sustainable development. For that reason Industrial Ecology is sometimes referred to as the 'toolbox for sustainable development' or the 'science of sustainability'. Industrial Ecology takes a positive approach to sustainable development: 'industry's answer to the environmental challenge'. The analogy between natural and technical systems and processes is a core element. Processes in nature, where cycles are closed and waste from one process is input for another, serve as models for socio-technological processes. The term 'industrial' does not refer only to the industrial complexes or industrial process systems, it is used for all kinds of technological systems used in the exploration-production-consumption chain.

The programme is home to a diverse group of students, both in disciplinary backgrounds and in nationality, and therefore also in cultural terms. Within the program problem-oriented education is important and offered in combination with conducting academic research, individually or in groups.

2.6 Basic program data

Table 2. Study yield

Cohort	2009	2010	2011
Study yield	65%	61%	48%

Table 3. Academic staff quality

Degree	Ma	PhD	Teaching qualification (BKO)
Percentage	7%	93%	70%

Table 4. Student staff ratio

Ratio	24

Table 5. Contact hours

Year	1	2
Contact hours	586	120

2.7 Ambitions

The Industrial Ecology program will undergo some changes during the coming years. The most important ones are:

- Link with Rotterdam School of Management (RSM). By working closely together with RSM, Industrial Ecology will strengthen the business aspect of the program. In the next academic year Dr. Erwin van de Laan of RSM will become an Industrial Ecology lecturer.
- Official Joint Degree. In September 2016 the program will be an official joint degree between Leiden University and Delft University of Technology.
- Moving to the faculty of Technology, Policy and Management. It has been decided that the placement of the program within Delft University of Technology will shift from Applied Sciences to Technology, Policy and Management in order to enhance the connection with research groups, such as Energy & Industry and Policy, Organization, Law and Gaming that are currently already involved in the IE program.
- Curriculum renewal, necessary to handle the growth of student numbers (annual intake from 20 – 65).

3 Standard 1. Intended learning outcomes

The intended learning outcomes of the program have been concretized with regard to content, level and orientation; they meet international requirements.
Explanation: As for level and orientation (bachelor's or master's; professional or academic), the intended learning outcomes fit into the Dutch qualifications framework. In addition, they tie in with the international perspective of the requirements currently set by the professional field and the discipline with regard to the contents of the program.

3.1 Findings

Industrial Ecology is a multidisciplinary scientific field aiming at analysing sustainability problems and designing and implementing solutions for such problems. In almost all cases, flows of energy and materials are the connection between economic activities and environmental problems. These flows of energy and material are the core object of Industrial Ecology, as well as the technologies generating these flows and the socio-economic context driving technology development and diffusions.
The intended learning outcomes focus on the analysis, design, and implementation of industrial systems on the analogy of ecological systems and with the least possible adverse sustainability impacts.

Typical learning outcomes are for instance: "(graduates will) have a thorough knowledge of and insight into the main sustainability issues, their causes in society and the technosphere, the currently available Industrial Ecology solutions, their potential and limitations." Or: "(graduates will) be able to contribute to the technological design of industrial systems, industrial processes and consumer products, aiming at environmental protection and sustainability, and to identify threats and opportunities for current and new processes for life cycle stages like the extraction of raw materials, production, consumption, and waste treatment." See appendix 7.4 for the complete list of intended learning outcomes.

The self-evaluation report corroborates the intended learning outcomes with regard to the Dublin descriptors and the Dutch-Flemish referential framework for academic environmental education (ICM 2012). In the development of the intended learning outcomes the program has taken international examples into account.

3.2 Considerations

Industrial ecology is a relatively young program. Like related programs regarding sustainability and the environment it relates to a complex and rapidly evolving field (in terms of research, theoretical concepts, practical applications and student body). In a sense, the panel feels as if it is assessing a 'moving target'. It is not easy to clearly delineate what is (or should be) the exact subject matter of industrial ecology as a basis for appraising the intended learning outcomes.

The panel spent quite some time (in internal discussions and in the various meetings) to come to grips with this. This was also important because it reflects upon the research topic of the theses. The panel concludes as follows:

- The intended learning outcomes comply evidently with both the Dublin descriptors and the Dutch-Flemish domain specific referential framework.
- As said, the field is quite dynamic and there are various, more or less related programs. The multidisciplinary setup of the program stressing (as few programs do) the industrial/engineering aspect can certainly retain its added value in a field where the focus is laid more and more on 'sustainability' and 'transition', but (from a linear to a circular economy) requires clear differentiation and more focus. The current articulation of the intended learning outcomes is overambitious and runs the risk of extending the field or scope of Industrial Ecology too broadly. That was, given the state of the field, certainly justifiable in 2009 but for the future a rethinking seems in order.
- Students and alumni were generally able to identify the core of what Industrial Ecology is, stressing as most important elements: a very strong systemic approach, solution orientation and a pragmatic focus on applications.

3.3 Assessment

In terms of level, orientation and international perspective the panel regards the intended learning outcomes as satisfactory. The panel recommends a rearticulation of the intended learning outcomes given the rapid state of development of the field and a clearer representation of what the program actually includes.
Therefore the panel assesses Master standard 1 as ‘satisfactory’.

4 Standard 2. Teaching learning environment

The curriculum, staff and program-specific services and facilities enable the incoming students to achieve the intended learning outcomes.
Explanation: The contents and structure of the curriculum enable the students admitted to achieve the intended learning outcomes. The quality of the staff and of the program-specific services and facilities is essential to that end. Curriculum, staff, services and facilities constitute a coherent teaching-learning environment for the students.

4.1 Findings

Industrial Ecology is a two-year master program. Students can enter the program twice a year (September and February).
The first year focuses on acquiring the knowledge and skills that an Industrial Ecologist needs. It mainly contains compulsory core modules covering the three basic areas of Industrial Ecology (Natural Sciences, Social Science and Engineering, comprising in total 54 EC) with some room for specialization modules (6 EC). Students starting the programme and lacking background in certain topics are recommended to take (before they start the program) selected online courses.
The second year is primarily about applying the knowledge and skills that have been taught in the first year of the programme and consists of compulsory interdisciplinary group projects, specialization modules (of which about 25 are on offer) and an individual thesis research project. See Table 6 for an overview of the program.

Table 6. Overview of the program (September intake)

First Semester	Analytical Methodologies and Tools (6 EC)	Fundamentals of Systems, Data, Models, and Computational Thinking (6 EC)	General Introduction to Industrial Ecology (6 EC)	Renewable Energy Systems (6 EC)	Social Systems - Policy and Management (6 EC)
Second Semester	Design of Sustainable Technological Systems (6 EC)	Sustainable Innovation and Social Change (6 EC)	Urban Environments and Infrastructures (6 EC)	System Earth (6 EC)	Specialisation modules (6 EC)
Third Semester	Interdisciplinary Project Groups (12 EC)	Thesis Preparation (6 EC)	Specialisation modules (12 EC)		
Fourth Semester	Thesis Research Project (30 EC)				

4.1.1 Content and structure of the curriculum

The program self-assessment report has provided a table linking the intended learning outcomes to the various courses of the curriculum, on the basis of which the panel concludes that there is a reasonably clear relationship between intended learning outcomes and content.

The curriculum develops from a *multi*disciplinary approach in the first year (addressing the three core disciplines of Industrial Ecology) into an *inter*disciplinary one in the second year (Interdisciplinary Project Groups). Amongst others, the instructional strategy of the *flipped classroom* is being used. The panel considers the course material (handbooks) as relevant and up to date.

Students especially appreciate the multi- and interdisciplinary character of the program (and also the multicultural composition of the student body) as well as the systemic approach to industrial ecology problems and the focus on a practical problem solving.
As points of improvement students suggest enhanced attention for economics and for implementation in a business environment (they regard the current program as more governmentally oriented) and the possibility of internships for credit within the curriculum.

The study load is considered tough, caused partly by the fact that every student has to master the basics of one or two new (to him/her) areas. This leads to some drop-outs (especially in the first semester) and a good deal of study delay. Students mention that delay is partly caused by doing voluntary internships (no credits) and in finding the right thesis supervisor (in relation to the research question). Students themselves in fact organize forms of 'remedial teaching' where social sciences students are being taught math and science, for instance, by natural science students who in turn receive help in social science oriented subjects and skills (e.g. writing a paper).

In the Evasys survey, students rate the course overall 7.2 (on a ten-point scale).

4.1.2 Incoming students

The program attracts students from various disciplinary backgrounds: engineering (38%), natural sciences (20%) and social sciences (42%), a well balanced mix. Furthermore there is a multicultural mix of students.

An admission committee assesses the applications on the basis of diplomas, motivation and affinity with interdisciplinary work and sustainable development. The students are assessed in relation to the level of knowledge and understanding in the field of sustainable development and environmental issues, technology or technical design, public administration and business processes. Sometimes a minor is required that is related to the environment or sustainability or students are advised to (voluntarily) follow an online course before entering the program. An additional requirement is sufficient proficiency in English.

4.1.3 Quantity and quality of staff

The program counts 13 teaching staff members (amounting to 6 fte). For thesis supervision many more staff members of the universities can be deployed. There is one full professor of Industrial Ecology in Leiden.

All staff members have both a teaching and a research task, because the philosophy of both involved faculties is that education should be based on scientific research. In order to provide the students with a broad background in environmental science, process technology, product design, economics and organizational management, teachers come from a range of institutions:

- Delft University of Technology, Faculty of Technology, Policy and Management and Faculty of Applied Sciences.
- Leiden University, Institute of Environmental Sciences.
- Erasmus University Rotterdam, Faculty of Social Sciences and Rotterdam School of Management. These staff members deliver socio-economic content.

With the exception of one teacher who is still working on his PhD project all teachers have at least a PhD degree. Of the teachers 70% is BKO qualified. Teachers who are not yet qualified are encouraged to become qualified and teach together with a BKO qualified teacher.
Based on the resumes the panel concludes that most staff members are involved in research relevant to the theme of the program.

Students show appreciation of the teaching staff, which they perceive as competent and dedicated and as upholding a coherent vision of Industrial Ecology. In the Evasys survey lecturers receive an average rating of 3.7 (on a 5-point scale).

4.1.4 Program specific services and facilities

The panel has seen the facilities in the Leiden location. During the visit and in the period before panel members have studied some of the online courses and video lectures that are available for students. The chairman and the secretary have visited the facilities in the Delft location and have attended part of a lecture being given.

Delft and Leiden share the same online learning environment: Blackboard. The program has a dedicated study advisor who helps students with study or administrative issues (e.g., admission requirements). Also, they regularly discuss study progress with students.

Student surveys show there has been a drop in student satisfaction about the facilities in Leiden, but that may have been caused by extensive renovations. The panel heard no complaints about the facilities during the meeting with students.

4.1.5 Coherence

Although there is some tension between the various ambitions and approaches taught in the program, students state they experience a coherent program. They appreciate being brought up to some level of mastery of the constituting disciplines so as to be able to function professionally. Furthermore, they note that the interdisciplinarity of the program is in fact not so much brought in by the (mainly disciplinary trained) staff but is created as it were by the students themselves, in the Interdisciplinary Project Groups and discussions outside of the classroom. Coherence is also brought about by the act that a systemic, solution oriented approach runs as a thread through the entire curriculum.

4.1.6 Curriculum innovation and quality assurance

The initial accreditation panel indicated some areas for improvement regarding the teaching-learning environment. The former panel:

- Was dissatisfied with the lack of a Full professor of Industrial Ecology. As per October 2013 Professor dr. Arnold Tukker has been appointed as professor of Industrial Ecology at Leiden University.
- Noted that the programme appeared to be more multidisciplinary rather than interdisciplinary. The interdisciplinary character of the program has meanwhile been enlarged, especially during the Integrated Project Groups.
- Recommended increasing coordination of and meetings between teachers. This has been somewhat improved, but still merits attention according to the Self Evaluation Report.
- Begrudged the limited admission from social sciences students. According to the current panel, there is now a quite balanced spread of students over the various relevant disciplines.
- Recommended to lay more emphasis on *designing* models (instead of only *applying* them) and more attention for business management in the curriculum.

The program has an active Education Committee (‘opleidingscommissie’) that meets regularly and impresses the panel (on the basis of meeting minutes) as operating very conscientiously.

Recently scenarios have been developed for a redesign of the curriculum given the growth of student numbers.

The program as a whole is evaluated through a survey (Evasys). Course evaluations are done both through surveys and in lunch meetings with teachers and students where they discuss not only single courses but also the relationships between them. A study of the minutes of these meeting shows that this approach is effective.

4.2 Considerations

4.2.1 Content and structure of the curriculum

The panel takes note that there are a number of tensions in the program particularly concerning the relation between particular areas of specialization on the part of teachers and the intended multidisciplinarity/interdisciplinarity of the program. Students however seem content with the structure of a multidisciplinary first year and a more interdisciplinary second year. They seem to take it for granted furthermore that integration is their responsibility rather than the programs. This is certainly sympathetic but does not release the program from its own responsibility with regards to integration.

The format of the curriculum is strongly determined by the basic assumption that all students should have a common understanding of the core disciplines. Given the complexity and dynamic development of the field, the panel doubts that this is sustainable in the long run and suggests implementing a system of 'tracks' (implying a 'T-structure' of the curriculum).
This could also address the criticism of some students that the electives are sometimes lacking in depth.
Preferably these tracks should not be disciplinary oriented, but oriented to different problem areas or to different problem 'scales' (e.g. local, regional/national and global). Given the growing number of students a system of tracks can be considered necessary.

4.2.2 Incoming students

The panel is impressed by the 'biodiversity' of the student body, both in terms of academic background, nationality and culture. Because the program demands that all students reach a certain level of competence with regard to the three constituting disciplines, this implies for some science-based courses relatively many exam retakes and it also (as the panel concludes from some exams) sets limits with regard to the level that can be reached - although overall the panel has no doubts concerning the academic level of the program.

Given the growing number of applicants, the programme might consider becoming more selective. The number of retakes of exams in some science courses might be reduced if the required pre-knowledge of these courses is made more specific.

4.2.3 Quantity and quality of staff

The panel considers a total of 6 fte for the program and the number of students to be rather low, but still satisfactory now. In the future the growth of the number of students should concur with an expansion of the responsible staff.
Students voiced no complaints regarding staff quality and quantity, except for the fact that finding a supervisor fitting with the thesis topic is sometimes cumbersome (but that is not directly related to the number of fte).

Given the international ambitions of the program and the development of the field of Industrial Ecology, it would be advantageous to also have a full professor of Industrial Ecology at Delft University of Technology to strengthen the balance between the two universities, to improve further the identity and quality of the program and to keep the program attractive for top international students. The fact that more professors are already involved in the program (in the role of supervisor) is of course very positive and beneficial to students, but does not address the issue fully.

The amount of meetings and interaction between staff members has increased somewhat and the panel has understood that the students do experience staff coherence. Recently the Board of Examiners has proposed the establishment of a core team of teachers to develop and guard the Industrial Ecology identity. The panel supports this proposition. Additionally the program management should also stimulate an increase of such interaction meetings on staff level.

4.2.4 Program specific services and facilities

The panel concludes that the program specific services and facilities are adequate and facilitate students in achieving the intended learning outcomes.

4.2.5 Coherence

The program is coherent if even only in retrospect, like one of the alumni said: "It gets together in the end, but is quite confusing in the beginning." Few things beat a deliberate confusion as an educational strategy, but still the panel feels that its fruits can be harvested earlier in the program.

4.2.6 Curriculum innovation and quality assurance

The panel concludes that all in all, the recommendations of the panel for the initial accreditation have sufficiently been carried out and that the program is constantly evolving on the basis of adequate evaluations.

The panel agrees that the growth of student numbers implies changes to the curriculum. It is prudent that the program is now exploring different scenarios in this. The panel would suggest considering the scenario of making the intake more selective so as to maintain the current volume while strengthening the quality and the level of the program.

4.3 Assessment

The panel has described and discusses various items with regard to standard 2. The panel has formulated some recommendations for improvement. The teaching-learning environment is certainly adequate but cannot be considered to be systematically and evidently above average in comparison to other programmes.
Therefore the panel assesses Master standard 2 as ‘satisfactory’.

5 Standard 3. Assessment

The program has an adequate assessment system in place.
Explanation: The tests and assessments are valid, reliable and transparent to the students. The program's examining board safeguards the quality of the interim and final tests administered.

5.1 Findings

The panel has studied exams, theses, grading sheets, course evaluations and meeting minutes of the Board of Examiners.

Transparency of assessment is achieved by:
- course guides providing the necessary information about the examinations;
- various rules and regulations by the Board of Examiners;
- the use of a thesis grading scheme;
- the use of pre-set norms ('antwoordmodellen') for assessments.

The validity of the assessment is achieved by:
- having examinations reviewed beforehand by a different staff member to the appointed examiner; of the study component (monitored by the Board of Examiners);
- the use of assessment matrices ('toetsmatrijzen').

Reliability of assessment is achieved by:
- enabling students with a disability to take examinations in a manner that has been adjusted to their particular disability (while not affecting the quality or level of difficulty of the examination);
- assessing theses always by a primary and secondary examiner, both of whom are connected to one of the institutions;
- assessing students individually in the case of presentations, research, reports or other study activities that are performed as part of a group;
- using plagiary detection programs;
- using a thesis grading scheme.

The Board of Examiners meets four times per year and recently produced a very interesting report ('Kwaliteitstoetsing Masteropleiding Industrial Ecology') with various recommendations to enhance the quality (control) of the program.

Students rate assessment 3.8 on a 5-point scale

5.2 Considerations

The assessment system of the program is in (a final stage of) development. A number of measures have recently been taken by the Board of Examiners, apparently in anticipation of the accreditation, and some rules (for instance with regard to the use of pre-set norms and assessment matrices) are in fact not yet fully (i.e. in all cases by all teachers) adhered to.

The Board is however, as became clear in the meeting (and as evidenced by the above mentioned report) aware of, and addresses these problems. Their observations on the need to have the program and the (disciplinary) core courses of the program reflect (more) upon the interdisciplinary field of Industrial Ecology resonate quite well with observations by the panel. Given the overview in said report and based on the panel's own observations the conclusion can be that the quality control of the assessment generally meets the set criteria.

Moreover, given the material studied by the panel and the general impression of rigor in the program, the percentage of retakes in natural sciences exams for students with a social science background, and the improvements that have been made with regard to the thesis assessment (see also standard 4) the panel has no doubt that the assessments are overall sufficiently transparent, valid and reliable.

5.3 Assessment

The panel assesses Master standard 3 as ‘satisfactory’.

6 Standard 4. Achieved learning outcomes

The program demonstrates that the intended learning outcomes are achieved.

Explanation: The level achieved is demonstrated by interim and final tests, final projects and the performance of graduates in actual practice or in postgraduate programs.

6.1 Findings

6.1.1 Study yield

The study yield has been presented in Table 2. The study yield is relatively low and has been dropping. The drop-out rate is moderate and drop-out occurs mainly in the first semester of the program.

From the data it appears that students get delayed in the period before and during the Thesis Research Project. According to students this delay is caused by other activities (e.g. internships for which no the current program allows no credits) as well as by the fact that it can take a while to find the right supervisor for the thesis.

Meanwhile measures have been taken to improve the study yield and decrease the amount of delay. Student progress is monitored more closely and proactively by the study advisor and before and during the Thesis Research Project more guidance is provided. A thesis research protocol is in place as well as a project registration form. Monthly meetings in which students present their provisional findings help motivate to finish the thesis in time.
These program adjustments fit in well with comments by students that more guidance is desirable.

6.1.2 Theses

Complying with the NVAO regulations panel members have studied 15 theses selected by the chairman and the secretary out of a complete list. In the preparatory meeting of the panel, the findings were discussed extensively. Initially, three of the theses (all theses that were marked a 6, in one of which a plagiarism case was discovered after graduation and still in procedure) were deemed unsatisfactory. Furthermore, the panel notes that the grading tends to be generally somewhat too high.

The three theses were then each read by another panel member and discussed again the following day. There remained two unsatisfactory theses. In the third case there was a difference of opinion whether the thesis subject was sufficiently related to the field of Industrial Ecology.

Thereupon the panel has studied, during lunch break and the open consultation hour, several more theses and a number of recent thesis research proposals. The panel is satisfied with the thesis research proposals, which are substantial – showing the use of the Thesis Research Protocol is effective. The additional theses that were read were all considered to be in order.

6.1.3 Performance of graduates

The program has provided a list showing the jobs of graduates (n= 72). Of these 28% work in research and 69% in ‘industry’ (including consultancy, government). Only 3% are unemployed.
Clearly graduates are in demand.

The alumni requested to be more involved in the program, with regard to the further development of the program, but also as resources for students.

6.2 Considerations

The panel has given ample attention to the quality of the theses, both in terms of level and content (in relation to the field of Industrial Ecology). The topic has of course been extensively discussed in the meetings. The panel considers the following:

- In hindsight, the plagiarism case (that was chosen to be able to discuss the procedure with the Board of Examiners), would better not have been included in the sample.

- As stated already, Industrial Ecology and related fields are strongly in flux. It is not easy to make sharp delineations. In fact, the panel members themselves reflect somewhat differing positions. However, just because this is the case, theses could and should reflect more upon the relationship between the research topic and (developments in) the field of Industrial Ecology.
  So it is strongly recommended that the program aims at a sharper delineation of the thesis subject of Industrial Ecology as recommended by the panel with regard to standard 1.
- In some cases (including of course the theses deemed unsatisfactory) the grading by the thesis supervisors was considered by the panel to be too high. However the panel found no consistent deviation.
- Clearly, adaptations to the (preparation of) the Thesis Research Project appear to bear fruit. The meeting with the teaching staff showed that thesis supervision is indeed concerned with linking the research topic to the Industrial Ecology profile. The Thesis Research Proposals show that this had indeed improved.

Although there is room for improvement (and measures in that direction are projected), the panel in the final analysis concludes that the theses are satisfactory in terms of level and content.

6.3 Assessment

The panel assesses Master standard 4 as ‘satisfactory’.

7 Appendices

7.1 Composition of the panel

The composition of the re-accreditation panel is as follows:
Prof. dr. Wim Hafkamp, Erasmus University Rotterdam (EUR), domain expert, chairman
Prof. dr. Henk Moll, State University Groningen (RUG), domain expert, member
Prof. dr. Andrew Jamison, Aalborg University, domain expert, member
Prof. dr. Harrie Eijkelhof, Utrecht University, education expert, member
Ir. Wouter van Gerwen, Department Manager Industrial Projects Tebodin, professional field, member
Thomas Mason BSc, Utrecht University, student member (master Sustainable Development).
Drs. Carlo Hover, Smets & Hover Adviseurs, secretary

7.2 Score tables of panel

Table 7. Score table master standards

Standard	Assessment
1. Intended learning outcomes	Satisfactory
2. Learning-teaching environment	Satisfactory
3. Assessment	Satisfactory
4. Achieved learning outcomes	Satisfactory
Final conclusion	Satisfactory

7.3 Schedule of the site visit

Date	Time	Meeting	Participants
jun-15	14:30-15.30	Site visit TU Delft (TNW and TPM): facilities and class visit	René Kleijn (Director of Education) Jaco Quist (Chair Education Committee)
	17:00-19:30	Panel Preparatory meeting	
	20:00-22:00	Panel Diner	
jun-16	08:30-09:30	Panel studies course material and exams on site	Anne van Bruggen, a student assistant, will be available to demonstrate our online learning environment Blackboard and USIS
	09:30-10:15	Interview with organisational staff	René Kleijn (Dir. Of Education) Petra Oosthoek (Study coordinator) Els Kroon (Study advisor)
	10:30-11:15	Interview with students	Imme Groet (Sep 14) (EduComm) Jochem de Jong (Sep 14) Anne van Bruggen (Sep 14) (EduComm) Zev Stramans (Sep 14) Spyros Ntemiris (Sep 14) Jorinde Vernooij (Feb 14) Joris Bouwens (Sep 13) Natalia Uribe (Sep 13) (EduComm) Maarten Bruinsma (Sep 13) Wesley Crock (Feb 13)
	11:15-12:15	Open consultation hour	No one used the opportunity

12:15-13:00	Lunch break	
13:00-13:30	Interview with vice deans and director of CML	Rob Mudde (vice dean Applied Sciences, TU-Delft) Ernst ten Heuvelhof (vice dean Technology, Policy and Management, TU-Delft) Han de Winde (vice dean Science, Leiden University) Arnold Tukker (Scientific Director, Institute of Environmental Science)
13:30-14:30	Interview with academic staff	Jaco Quist (TPM TU-Delft (Chair EduComm) Gijsbert Korevaar (TPM TU-Delft) Chris Davis (TPM TU-Delft, now RUG) Ellen van Bueren (TPM TU-Delft now Architecture TU-Delft) (EduComm) Eefje Cuppen (TPM TU-Delft, new per Sep15) Harrie van de Akker (AS TU-Delft) Ester van der Voet (Science, Leiden University) Ruben Huele (Science, Leiden University) Jeroen Guinée (Science, Leiden University) (EduComm) Coen van der Giesen (Science, Leiden University) René Kleijn (Science, Leiden university)
14:30-15:15	Interview with Board of Examiners	Harrie van den Akker (Chair, AS TU-Delft) Mark van Loosdrecht (AS TU-Delft)) Ester van der Voet (Science Leiden University) Arnold Tukker (Science Leiden University) secr. Petra Oosthoek (Science Leiden University)
15:30-16:15	Interview with Alumni and professional field	**Alumni** Maja Valstar (Rijkstrainee Ministry Infrastructure and Environment I&M) Marlies Meijer (consultant & trainer at ARN) Pau Hueget (consultant, Ecomatters) Chris Davis (assistent professor RUG, did a PhD at TU-Delft) Noortje Schrauwen (consultant Search) Thijs Kamperman (Developer Data services at Stedin) Jan Bergen (PhD student at TU Delft) Angelica Mendoza (PhD student, Leiden University, former PBL) **professional field** Hector Timmers (ARN) Pau Hueget (Ecomatters) (double)
16:30-16:45	Interview with organisational staff	René Kleijn (Dir. Of Education) Petra Oosthoek (Study coordinator) Els Kroon (Study advisor)
16:45-18:00	Panel Break	
18:00-18:15	Feedback	

7.4 Intended learning outcomes WO Master Industrial Ecology

Graduates from the master's program Industrial Ecology will:

1. have a general knowledge of the main disciplines relevant to Industrial Ecology, i.e. environmental science, process technology, product design, economics and organizational management;
2. have a thorough knowledge of the Industrial Ecology field, including its theories and concepts, its methodologies and its object, the technosphere;
3. have a thorough knowledge of and insight into the main sustainability issues, their causes in society and the technosphere, the currently available Industrial Ecology solutions, their potential and limitations;
4. have an understanding of the societal sustainability debate regarding the three dimensions (people, planet, and profit) and the ability to contribute to this debate, relating Industrial Ecology expertise to input from the natural, technical, and social sciences;
5. have the ability to identify issues and to generate new solutions based on their knowledge of Industrial Ecology;
6. be capable of using, improving, and applying the methods, techniques and tools of Industrial Ecology, including system analysis, life cycle assessment, substance and material flow analysis, energy balances, input-output analysis, stakeholder analysis and involvement, transition management and system dynamics, agent-based modelling, and the implementation, monitoring and management of innovation processes;
7. be able to contribute to the technological design of industrial systems, industrial processes and consumer products, aiming at environmental protection and sustainability, and to identify threats and opportunities for current and new processes for life cycle stages like the extraction of raw materials, production, consumption, and waste treatment;
8. have acquired general academic skills, including the usage of research methods and tools such as statistical data analysis, collecting and interpreting data, modelling techniques, critical application and evaluation of theories, concepts, and principles;
9. be capable of conceiving and conducting research in the interdisciplinary field of Industrial Ecology;
10. be capable of analysing and synthesizing information, including research results, and of presenting them using text, presentation techniques, and graphic tools to both specialist and non-specialist audiences.

7.5 List of theses and grades

The table below shows the theses (and their grading) that have been studied and assessed by the panel members.

	Studno Leiden	Family Name	First Name	Diploma	Grade	Title Thesis Research Project Report
1	1234935	Figueroa Ortega	Fernando	19-8-2013	6,0	Technological life cycles for foresight of performance and price development in residential heating and cogeneration technologies: the EcoGenie House study.
2	1392409	Chu	Trista (Pao-Hsuan)	29-8-2014	6,0	Building Up A Closed-Loop Economy. Exploring the possibilities to recycle neodymium magnets from wind turbines in China
3	1190431	Groot, de	Sanne	31-10-2014	6,0	Method development and proposal for assessing the environmental footprint of organisations
4	0988669	Vlieg	Mathilde	6-3-2012	6,5	Tendering the 'street of the future': A research into sustainable procurement

5	1031295	Oliva Avancine	Felipe	14-6-2013	6,5	Analysis of Brazilian Industrial Symbiosis Program
6	1201166	Stevens	Sarina	6-3-2014	7,0	Assessing the environmental impact of business models: The case of peer-to-peer car sharing in The Netherlands
7	1181009	Gout	Marloes	14-1-2014	7,5	Extending bee habitat in urban area: How green roofs can foster bee populations in the Netherlands
8	0847658	Wijsman	Katinka (Kim)	31-8-2012	8,0	Making Sense of Cityscapes – Ecosystem and Metabolism Metaphors in Grasping the City
9	1233343	Zhu	Ben	30-8-2013	8,0	Life cycle assessment and simplified life cycle costing on Industrial Symbiosis
10	1452959	Krotova	Anna	29-8-2014	8,0	Potential For Industrial Symbiosis Development in Russia.
11	0727822	Verheul	Rhea	29-8-2014	8,0	WHAT'S THE DEAL WITH CITIZENS? How frames influence policy strategies for citizen involvement in Green Deals in the Netherlands
12	0641790	Schrauwen	Noortje	19-12-2012	8,5	The effect of social institutions on innovation practices in the Westland horticulture sector
13	1197479	Tammes	Pim	24-12-2014	8,5	Life Cycle Assessment of a short-use tent for music festivals
14	0940372	Herms	Sarah	22-8-2011	9,0	Energy Flows in Product Life Cycles: Analyzing thermodynamic improvement potential of cardboard life cycles
15	0967386	Bergen	Jan	3-7-2012	9,5	On the Role of Government in Transition Management: Three Different Discourses and their Validation with Dutch Energy Transition Project Professionals

7.6 List of documents

Apart from the mandatory appendices to the Self-Assessment, the panel has studied the following documents:

- Adviesrapport over Universiteit Leiden. Instellingstoets kwaliteitszorg NVAO, May 23 2013.
- Course materials, including a MOOC and video lectures.
- Course evaluations
- Course exams
- Board Of Examiners meeting minutes
- Educational Committee meeting minutes
- Report of the Curriculum Renewal Committee for the Industrial Ecology course program (May 10, 2015)
- Kwaliteitstoetsing Masteropleiding Industrial Ecology. Final draft. Inventarisatie en aanbevelingen van de Examencommissie van de MSc Industrial Ecology (May 21, 2015)

7.7 Recommendations

Below the panel formulates a number of recommendations. These are meant to contribute to quality enhancement. The recommendations are in no way conditional with regard to the assessments of the panel with regard to the respective standards.

Standard 1. Intended learning outcomes

Reformulate the intended learning outcomes on the basis of:

- A renewed delineation of the field of Industrial Ecology. Consider organizing a seminar in which papers by staff members about the scope of Industrial Ecology are being discussed on the basis of what (according to students and alumni) are the really strong points of the programme (i.e. systemic orientation, solution oriented, pragmatic/applicability orientation).

Standard 2. Teaching-learning environment

- Restructure the curriculum according to the 'T-model', combining breadth ánd depth by the use of 'tracks'. Design these tracks not on the basis of disciplines but on the basis of problem fields or 'challenges'.
- Create in the curriculum the possibility for students to do an internship for credits.
- Make the program more selective so as to improve study yield. Given the growing interest in the program selectivity is possible while maintaining the current size of the student population (instead of growing).
- Appoint a full professor of Industrial Ecology at Delft University of Technology.
- Make arrangements to avoid that the search for a thesis supervisor leads to study delay (e.g. by offering tracks; limiting somewhat the current freedom of choice of thesis research topics).
- Reduce the number of retakes of exams in some science courses by specifying the required pre-knowledge more in detail.

Standard 3. Assessment

- Implement the improvement measures as proposed by the Board of Examiners (in their May report) promptly and monitor adherence (regarding mandatory use of pre-set norms, assessment matrices, use of grading sheets).
- Periodically discuss thesis grading among staff to enhance inter-assessment reliability.
- Arrange for a second reviewer of the thesis proposal (to enhance interdisciplinarity and embedding within the scope of Industrial Ecology).
- Let students reflect explicitly in their theses upon the relation between the thesis research topic and (developments in) the field of Industrial Ecology (this relates to the recommendations regarding standard 1).

Standard 4. Achieved learning outcomes

- Increase Alumni involvement (in the evaluation of the program, for outside-in input, as resources for students).

Ambitions for the future

- Give priority to program quality over student quantity.

7.8 List of abbreviations

BKO	Basiskwalificatie Onderwijs (Basic Teaching Qualification)
EC	European Credit
FTE	Full-time Equivalent
MOOC	Massive Open Online Course
NVAO	Nederlands-Vlaamse Accreditatie Organisatie (Accreditation Organisation of the Netherlands and Flanders)
CROHO	Centraal Register Opleidingen Hoger Onderwijs (Central Register of Higher Education Programs)