Guidelines for Good Scientific Practice and Supervision in the Industrial Ecology Group in Freiburg (IEF)

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Research projects, student assignments, the bachelor thesis, and the master thesis are major steps in academic education. Their completion requires a wide spectrum of new skills and professional interaction with academic supervisors and advisors. Specific challenges arise as the time spent with supervisors and other experienced academics is limited and the educational and cultural background of the students is diverse. This document lists the quality standards for research and thesis work conducted in the industrial ecology group. It explains the requirements for becoming a student in the group. It shall help students and becoming researchers to understand what is expected of them and what role their supervisors and advisors play in their work. This document complements the official study and exam regulations of the respective study programs.

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[1] For feedback and questions, please contact stefan.pauliuk@indecol.uni-freiburg.de

Good scientific practice in the industrial ecology group in Freiburg

The University of Freiburg has issued guidelines and regulations for good scientific practice, which apply to everybody working in the industrial ecology group.
https://uni-freiburg.de/forschung/redlichkeit-in-der-wissenschaft/

Next to the general rules of good scientific conduct the following guidelines apply for Industrial Ecology Research in general:
https://www.industrialecology.uni-freiburg.de/Content/IEooc_Methods_Good_Scientific_Practice.pdf
This material also contains recommendation about the report/thesis structure and the writing style, and is considered mandatory reading for all thesis students in the industrial ecology group.

In particular:

All researchers and students in the industrial ecology group develop a professional workflow including regular backups, archiving of results, and dissemination of finished work. Ongoing work needs regular backups, at least once a week. Finished projects, including MSc theses, BSc theses, and project assignments need to be archived in electronic form on the group's internal repository, their online publication is voluntary. The archived data and procedures shall be comprehensive so as to allow the research staff and future students to trace the data to their original source and to replicate the analysis.

All raw data, software scripts, and other models (incl. Excel files) that were part of the work need to be archived. MSc and BSc students must make an effort to make the archived material useful for others, e.g., by providing written explanations for how to use the material. If work done by the student gets re-used by others of the group, proper credit needs to be given.

It's OK to use automated text generation tools based on large language models, such as ChatGTP, as long as the generated material (code, calculations) is duly verified and the generated text is not directly used in academic writing but merely serves as inspiration for writing one's own text. Text generated from AI, machine learning, or similar algorithmic tools cannot be used in journal papers!

Research group infrastructure and exchange formats: Information for researchers

Meetings and seminars: Regular individual advisory meetings are the key scientific exchange between researchers of different levels of experience. The meeting frequency varies, and there are typically more meetings when new projects start or (doctoral) research proposals are being developed. Also, there are regular group meetings, and each researcher is expected to present and discuss her work in the group meeting at least three times per year. Members of the group organize research seminars on a regular basis.

Research infrastructure: The group hosts substantial research infrastructure that is available to all colleagues in the group and where all are expected to contribute to. Our research infrastructure includes:
- The data, result, literature, and organizational material folders on our group's shared network drive (login details will be shared with all new colleagues)
- Calendar (link will be shared via email with new colleagues)
- Equipment booking table (mostly for teaching)
- Issue tracker on GitHub (link will be sent separately)
- The group's Wiki on the shared network drive

Documentation: As part of good scientific practice, all researchers are obliged to archive their work and to supply the group with relevant information. This includes:
- Keep the group's calendar up to date
- Archive raw data and other data that are input to your research
- Archive intermediate research material and all completed research projects on the group's shared network drive (see policy document in the main folder)
- Archive all teaching material on the on group's shared network drive
- Archive central conference/seminar presentations on the group's shared network drive

How to get assigned a thesis topic in the industrial ecology group

We expect all MSc thesis candidates who wish to write their thesis in the industrial ecology group to participate in at least one of our master-level classes, before starting their thesis work in the industrial ecology group with either Stefan Pauliuk or Johan Vélez as their main advisor.

To enable high quality research in our group, all project, BSc and MSc thesis topics need to fit into the group's research profile. **Project and thesis topics can be either defined by more senior researchers (default) or be self-chosen (in justified cases).**

Pre-defined topics: These topics have been carefully chosen to enable students to contribute to cutting edge and relevant research. High quality work on these topics can sometimes lead to a peer-reviewed publication afterwards. **A list of current thesis topics with detailed descriptions is distributed to interested students at the beginning of each year, and students are asked to apply by the end of January of each year for the thesis topics of the current year.**

If you are interested, contact stefan.pauliuk@indecol.uni-freiburg.de. Please attach your grades and list previous topic-related experience (relevant courses or practical training).

Self-defined topics: We also offer the possibility to define a self-chosen topic in dialogue with the future supervisor. This pathway to the thesis requires special engagement, the capability to autonomously scope the topic after studying the literature, and the involvement of external experts on the topic.

If you are interested in a specific topic of your own interest, please apply by sending an email to stefan.pauliuk@indecol.uni-freiburg.de. Applicants please attach your grades and list previous topic-related experience (relevant courses). Most importantly, you need to prepare a detailed description of the topic of interest including an overview of the literature, goal and scope, and choice of methods (1500-2000 words). I reserve the right to reject a proposal if I get the impression that the student may not have the required competence, that the work proposed is too difficult, or if there isn't enough overlap with my own competence. **If in doubt, contact me beforehand.**

We decline requests for thesis supervision once we have reached our capacity of how many students and topics we can handle in a given year.

Moreover, I do in general not act as main supervisor of theses carried out at other research institutions, including non-university institutes such as Fraunhofer Institutes, which usually have own supervision rights. A role as second reviewer is possible, though.

Research questions and method choice

This section contains specific guidelines for carrying out thesis-related research in industrial ecology. See https://www.industrialecology.uni-freiburg.de/Content/IEooc_Methods_Good_Scientific_Practice.pdf for more general guidelines. This material also contains recommendation about the report/thesis structure and the writing style, and is considered mandatory reading for all thesis students in the industrial ecology group.

Which literature to use:

The available amount of relevant literature is huge and very diverse. Students need to be able to find, read and assess, store, select, and cite the relevant literature. All literature used needs to be assessed critically. Students need to be aware of the difference between peer-reviewed and non-peer-reviewed reports. Not that some reports, like the IPCC Assessment Reports or the major reports of the IEA are also peer-reviewed. Guides for literature search are listed at the end of this document under 'Further reading'.

The standard journals of the field include: Journal of Industrial Ecology, Environmental Science and Technology, International Journal of LCA, Journal of Cleaner Production, Global Environmental Change, Environmental Research Letters, Ecological Economics, Resources, Conservation, and Recycling.

Formulation of research questions, scope:

As a result of the literature review, a research gap shall be identified and one or more research question(s) to fill that gap shall be posed. The research question(s) can be a bit general, and in a second step, the students defines the scope of the work by narrowing down the topic or by specifying for which special cases the research question shall be answered. The sequence gap-questions-scope is the central part of the framing of a research project and needs to be dealt with great care.

The thesis supervisor will give advice on research gap, question, and scope, but since the array of possible questions and the literature is very broad, the student needs to make an own effort to justify his or her choice based on the literature review and data availability.

Choice of methods:

If a topic involves quantitative environmental systems analysis, the established quantitative methods of industrial ecology (material flow analysis, input-output analysis, and life cycle assessment) need to be used.

The roles of student and supervisor

In this section I describe my understanding of the roles of student and supervisor during the thesis/project work and explain the different supervision steps.

The role of the student: A thesis or project is an independent piece of work according to scientific standards. The student is responsible for monitoring the progress of the work, for her or his own motivation, for finding a second referee (Zweitgutachter), and for keeping up to date with the different deadlines and regulations. Taking responsibility for one's thesis or project means to own your work and its intellectual framing, to hold your views and decisions as your own, and to be in charge of the whole process. Being in charge is especially important, and as the person responsible for your project or thesis, you are responsible for all the different steps, including the reflection about what to do and why and how, the actual work and its documentation, and the process of seeking feedback from the supervisor and others. Being in charge also means to carry the decisions made during the different steps, which are often strongly influenced by the supervisor because of his or her longer experience.

All students who write their thesis are responsible for finding a second reviewer ('Zweitgutachter').

Last but not least, the student is responsible for making good use of the time the supervisor dedicates for the thesis or project topic, by preparing well for each meeting, by communicating which input is needed, and by preparing the minutes of each meeting.

The role of the supervisor and the time schedule of MSc and BSc thesis work:

During the thesis and project period, the role of the supervisor is not to be a 'boss' but to be an advisor offering guidance through the work. The supervisor makes an effort to understand the state of the student's work and the pending problems and he offers solutions, further ideas, literature sources, and technical advice. Interaction between supervisor and students happens in meetings as described below.

How does the supervision work?

My goal is to offer professional assistance during the thesis time and to treat all candidates in a fair manner with a reasonable amount of time dedicated to each student.

Our exam regulations distinguish between thesis advisors and referees. The first referee (the person reviewing and grading your thesis) is by definition also your thesis advisor. The second reviewer does not have such formal duties, and it is up to them how much they want to become engaged in the supervision of the work. In practice, there is not much involvement of the second referees in the actual thesis work. Please check beforehand what you can expect from your second referee.

1) Mandatory thesis proposal

Before starting, all thesis candidates must prepare a written thesis proposal of typically 4-6 pages that covers the following points: the topic of the thesis and why it is important, a survey of the core relevant literature and the identification of the research gaps, formulation of research questions (goal), specification of the scope of the work and the choice of methods, an overview of the expected results, and a reference list. The proposal is revised at least once after feedback from the advisor. After the proposal is accepted, you can register your thesis at any time, i.e., right away or 1, or 2, or 6, or 9 months later. The start date of your thesis is up to you. After the proposal is accepted and the thesis supervision agreement is signed, an individual kickoff meeting marks the start of the thesis.

I never give my consent to being the 2nd referee of a thesis without having seen and accepted a detailed research proposal.

2) Supervision during the working period

Work carried out in the industrial ecology group:

Thesis work carried out within the group is structured as alternation of group meetings in the student research seminar and individual meetings (Figure 1). The student research seminars are an offer to all thesis students.

For the first thesis seminar, I recommend to all candidates to prepare a 10-15 min talk and presents their research proposal, followed by a 15 min discussion. During the subsequent seminars, the candidates may report their progress and will receive feedback from the entire group (Figure 1). Each candidate has up to 30 min at their disposal.
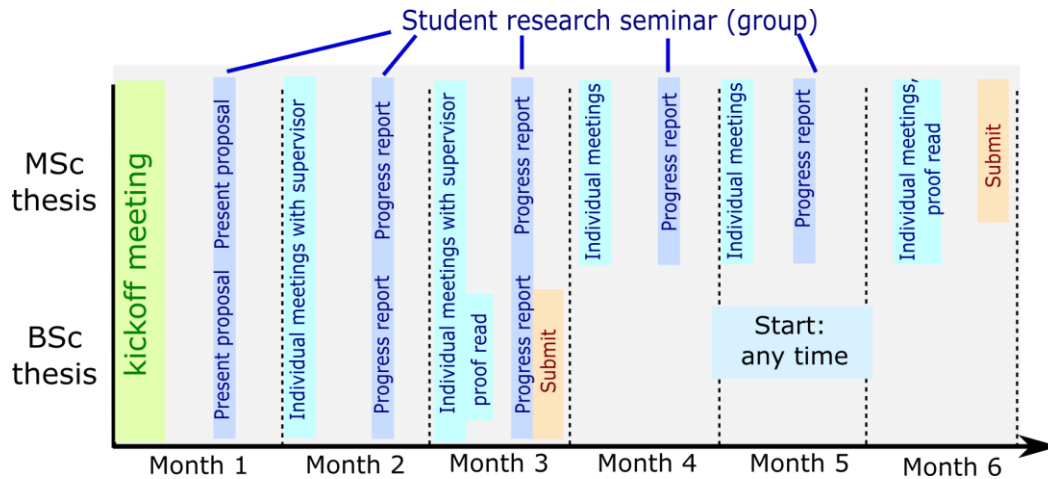
Figure 1: Thesis and project timelines in the industrial ecology group. During the semester break, there are no research seminars. Individual meetings can be held via Zoom. Both MSc and BSc theses can start at any time.

Theses for which I am the second referee.

Unless some special interest warrants more engagement from my side, students get one meeting throughout the course of their work, and I leave it up to the student to decide when to come back to that offer. Note that I am often not available on short notice.

The finalization period

Candidates should schedule at least one month for writing the thesis.

I offer to proof-read one chapter of your choice of the thesis prior to submission, but may not be able to do so on short notice.

Choice of language and timing:

Theses and projects can be carried out in English or German. The thesis candidate seminar has an English and a German part.

Once the thesis proposal is accepted, any start date is possible for MSc and BSc theses.

Theses and project reports are graded within six week after submission and the grade is submitted to the exam office.

Master and Bachelor thesis archive

Once you sign up for the thesis project in industrial ecology (TPIE) module, you'll get access to the group's archive of previous master thesis, database, and standards under
https://www.industrialecology.uni-freiburg.de/internal_login

Formal requirements and assessment criteria for MSc/BSc theses and written assignments

Next to the formal requirements for project reports, BSc theses, and MSc theses stated in the study regulations of the respective programs, some additional requirements are posed.

+ **Length restriction:** The following restrictions of page numbers for the main thesis/report body apply for all theses and project reports with SP as main advisor:

Project reports/term papers:	20 pages,
BSc theses:	30 pages,
MSc theses:	50 pages.

These pages limits exclude cover pages and references. Annexes and appendices (no length restriction applies) may be attached to provide full documentation of the work conducted. These will be checked during the grading as well, in particular, if the documentation in the main report is not clear enough or if doubts arise. Erroneous and incomplete supplementary material may lead to lower grades.

+ **References and citation style:** All references cited need to be official documents that can be attributed to individual authors and organizations. That excludes the Wikipedia and similar sources. The Wikipedia can of course be used during research, but all information provided there needs to be traced back to the original literature sources. There is no prescribed citation style, but the style chosen needs to be one of the recognized official ones. An overview can be found here: https://www.citethisforme.com/guides
Reference management programs are listed in the final section.

+ **Abstract, table of content, list of figures and tables:** BSc and MSc theses need to have a table of contents that shows the structure of the report in a meaningful way. A TOC is not required for project reports. A list of figures and a list of tables are not mandatory.
BSc and MSc theses need an abstract of 1-2 pages in the language the thesis is written. An additional abstract in another language is optional.

All the best for your work!

The industrial ecology scientific writing quick fix table

So, you've written up a great research piece and want the world to know about it. Great! Please be mindful of your readers and make your work accessible and understandable to them. Therefore: everyone, wherever you are and whatever you do: Before you submit/publish something in quantitative industrial ecology and socio-metabolic research, please make the following checks:

- Introduction: Cite major established findings (e.g., on energy use, climate change, resource use) from authoritative sources, reviews, and synthesis reports, such as the IPCC, IPBES, IEA, or the UNEP-IRP, not from individual papers.
- Methods: When using different colors in system diagrams, schematic drawings, and figures: If the meaning of the different colors is not completely obvious, explain the color coding in the figure's legend or caption!
- Methods and overall consistency: Check that your system definition/system boundary and choice of indicators matches your research question. Adapt your system definition to the different research questions if needed! Check that your display of results is done in a way that directly addresses the research question(s)!
- System definitions: In a proper MFA diagram, the trio material/region/time frame is always displayed. This also applies to process diagrams (box-flow drawings) of unit processes in LCA.
- Results: Plausibility-check the correct order of magnitude of all reported indicators (compare with national total production, waste flows, stocks, GHG, etc.)
- Results: In plots: Each axis is labelled with an indicator and a unit.
- Plots: Consider accessibility: try to use colors in a way that won't create problems for the many readers with some form of color blindness (for a good discussion and design suggestions).[2]
- Results: Link your numerical results to your system definition: E.g., "Fig. 4a reports the scenario results for flow F_6_7 (final consumption), Fig. 4b the GHG emissions of the use phase (scope 1, F_7_0)."
- Proper rounding of numerical results: if no error range is given, round to 2-3 significant digits. If you have an error range, round main result to the same precision as the error value rounded up to 1 or 2 digits precision.
- For time-dependent results: Always make clear (in text, indicator label, and unit) whether you report annual (for which year?) or cumulative (for which time range?) values. Annual values come as amount/yr, cumulative values as amount.
- General: Check all instances where you report changes (absolute or in %): Is the reference value clear? (E.g., "Indicator x improved by 5%. -> 5 % compared to what?)

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[2] See http://www.somersault1824.com/tips-for-designing-scientific-figures-for-color-blind-readers/

- Check that you use % when you report a relative change of a value in any unit and pp (percentage points) when you report an absolute change of a % value.
- Writing: Unless you apply statistical significance tests: Replace 'significant' by 'substantial' or simply 'large', and, even better, provide concrete numbers (your results or from the literature) instead of writing 'substantial'. So, based on your own findings, the readers can judge by themselves about the magnitude of your results. The same holds for phrases such as 'relatively limited', 'important', or 'major'.
- Writing: We are generally flexible regarding which tense the text should be written in. But please be consistent, at least within each chapter (introduction, methods, results, discussion).
- Writing: Avoid subjective wording: reviewers will often object to words/phrases like "unprecedented", "paradigm shift", "amazing", "dramatic", and "remarkable". Best to present your results, and let the readers make up their minds about the magnitude of the advance.
- Writing: It's CO_2 and H_2O etc. and NEVER CO2 or H2O!

Further reading

Next to the general rules of good scientific conduct, the following guidelines apply for Industrial Ecology Research in general:
https://www.industrialecology.uni-freiburg.de/Content/IEooc_Methods_Good_Scientific_Practice.pdf
This material also contains recommendation about the report/thesis structure and the writing style, and is mandatory reading for all thesis students in our group.

Good scientific practice:

+ Guidelines of the University of Freiburg
https://uni-freiburg.de/forschung/redlichkeit-in-der-wissenschaft/
+ Guidelines of the German Research Council
https://www.dfg.de/foerderung/grundlagen_rahmenbedingungen/gwp/
+ Guidelines of the International Society for Industrial Ecology
https://is4ie.org/data

Citation styles and reference management:

+ Guide to citation styles
https://www.citethisforme.com/guides
+ Zotero citation manager
https://www.zotero.org/
+ Bibtex citation style
http://www.bibtex.org/

Guides to scientific work on the BSc and MSc thesis level:

Jürgen Huss: "*Schreiben und Präsentieren in den angewandten Naturwissenschaften*". Verlag Kessel, 2015. ISBN: 978-3-941300-94-1. Erhältlich für 10 Euro im Sekretariat Waldbau
http://www.sciencebuddies.org/science-fair-projects/top_science-fair_finding_scientific_papers.shtml

Guides to scientific writing:

https://www.e-education.psu.edu/styleforstudents/c10_p6.html
Jürgen Huss (2015, reference above).
https://www.butte.edu/departments/cas/tipsheets/style_purpose_strategy/writing_clearly.html