Review of Stefan Paulik's Open Online Course on Industrial Ecology (IEooc)

https://www.industrialecology.uni-freiburg.de/teaching.aspx/

By H. Scott Matthews (as of August 2025)

Following is a review of the materials organized on the listed website by Stefan Paulik of Freiburg University that is meant to support instruction on the topic of industrial ecology. It seems to be periodically updated.

Amongst the content is a significant amount of material on LCA, and on which this review focuses. This review does, however, mention various of the non-LCA resources, just in less detail. As such, this Review is focused on LCA-specific content areas.

A high-level benefit of this resource is that, given its open-access nature, it acknowledges but does not require non-open access resources (e.g., the new Graedel/Eckelman book as listed at the top). Thus, it can be paired in a course setting with other content to provide a useful course syllabus. However, as noted below, several modifications might be made to better enable that use case.

The overall collection of content represents an excellent collection of resources for the various concepts, tools, and methods of industrial ecology. Each section (called a background on the website) has links to video and/or PDF resources that are lectures or readings. Many of the video lectures and readings were prepared by Dr. Paulik himself, with externally linked videos which are often from global experts on the relevant topics. This content is all in English, however, the various videos that are posted to online channels like YouTube can be auto-translated into many other languages for users.

Following are detailed review comments for each Part and Background of the course.

Part I – Background Issues

Background 1 (Conceptual Foundations) – This section provides useful resources to define and introduce the field of industrial ecology, including three videos (about 1 hour in length) and about five linked readings. There is also a diagnostic exercise related to the topics of this Background, along with a sample worksheet and solution. This sample exercise is an excellent resource, providing a study on a current and potential re-design solution, but this exercise is fairly challenging as a first example in the first section of a course. That said, there are elements of the exercise (the first 3-4 questions) that provide excellent opportunities for a new learner to show their understanding. Perhaps the pieces could be

separated into simple/intermediate/basic questions to help students? Overall, this Background is a great introduction to the topic in this open access course.

Background 2 (Additional Related Concepts) – Similar to Background 1, this section provides useful resources to define and introduce related fields such as circular economy and sustainability, including six videos (about 3 hours in length). There are also three diagnostic exercises related to the topics of this Background, along with a sample solution for each. The first two are very accessible and appropriate questions for any student. The third comprises a much more advanced exercise related to the detailed calculation of global warming potential values, of which the final few parts are appropriate for an advanced undergraduate or graduate course. Overall, Background 2 provides a great connection to the topics of Background 1 in this open access course.

Background 3 (Open science for sustainability) – This Background contains five externally linked readings and one hour-long webinar from 2017 on openLCA (the globally available LCA software tool that was designed around being open) and Brightway (an emerging code-based tool for LCA). The admirable goal of this section is to inspire students to aim to produce open and transparent work when doing studies in this field, which is a clear goal by many researchers and this is a good opportunity to make that concept clear to new modelers. One of the readings is a highly relevant and useful "guide" on how to build transparent and reproducible models with a variety of software (from Excel to code). The readings discuss the goals and benefits of transparency and provide an excellent overview to the topic.

Overall, Part I of this open access course resource provides an excellent foundation for many parallel disciplines, such as industrial ecology, circular economy, life cycle assessment, etc., and could be used as is or with selected subsets of content to guide students towards a quick and easy basis of knowledge.

Part II – Methods

The second Part of this online resource is a detailed overview of six methods (one of them LCA, one is IOA, and another is method integration). Each Method section has suggested readings/videos and exercises. This review will focus on the three sections most relevant to LCA. The others are related to IE, MFA, DFA, etc.

Method 4 (LCA) – This section provides an excellent overview of the key foundations and methods of life cycle assessment. It is also the largest of the various sections of the course. Amongst the links provided are available resources from ILCA, UN LCI, and GreenDelta/openLCA, as well as additional readings and lecture videos.

In this section there is a mix of readings and video lectures from the website author and others, individually all are very good and relevant to LCA. The sequence of topics in this Method section is life cycle thinking, the basic method (i.e., the ISO standard definitions), bioenergy, and the LCA matrix approach. Given the context of supporting a broader course on industrial ecology (and not one focused on LCA), this Method section provides an adequate and focused introduction to the topic. It includes qualitative example, simple quantitative examples, and advanced examples using matrix math.

Given the co-dependence on self-produced and externally produced content, this section suffers a small bit by repetition due to reliance on multiple and parallel readings, but this is a small complaint and not one that affects a significant amount of time. It is the inevitable result of mixing resources that are not fully distinct.

The example questions in this LCA Method section are generally very good and encompass many of the important points one would want to know about LCA over the course of a 1-2 week introduction to the method (i.e., in the context of a much larger course on IE).

The next part of this Method section contains various useful exercises that intersect with other parts of the course. For example, there are examples on payback time in LCA, incorporating literature data into LCA models, and MEFA.

An additional section on doing LCA within the openLCA software is also quite good. It links to provided GreenDelta resources and tutorials, and provides small example problems on process modification, allocation, and recycling using openLCA. The examples are very good, but again tend towards being fairly complicated, and also require an ecoinvent license, which can be very expensive. The first example is a tutorial walkthrough and represents a good example of how to build a first openLCA model. Would suggest using a freely available dataset, even if not as regionally relevant for students (e.g., the US LCI database) to help with accessibility.

There is a final section on other advanced LCA exercises. The first is a quick synthesis on a popular LCA journal paper (which is not very advanced in complexity other than needing to follow a journal paper), the second is a linear algebra “proof” of LCA and IOA matrix equivalency (quite advanced), and the final is a calculus-based problem for radiative forcing (very advanced).

At the end of the section are two tutorials for the increasingly popular Brightway software.

Overall suggestion on Method 4 – There is a substantial base of information here, and probably the largest subsection of the entire course. It could easily be adopted by an instructor of many types of courses to introduce LCA. However, it could help to better streamline the provided content into Basic / Intermediate / Advanced subsections so that someone who is only looking for the basics could stop at a certain point, and others could go further. This would involve collecting/merging all of the listed content, as even the first openLCA tutorial example at the end could be listed in the "Basic" section. I would be concerned that a user does not even get to that part because it is presumed to all be Advanced content.

There are two suggestions from the more detailed review of this section on LCA. First, a small point (and suggestion) would be to better sequence the readings and examples on the website, as there is content on the computational structure/matrix math approach to LCA before the simple examples are provided. This could cause readers/students to not be able to test and appreciate their knowledge of the more basic concepts before moving to the more complex methods. However, a separate course instructor could easily make such an adjustment. The second suggestion is to add additional linked resources on the topic of Life Cycle Impact Assessment (LCIA), as there is a very good example question provided that may be hard for a student to complete with only the resources linked before it in this Section.

Method 5 (Input-Output Analysis) – This section is included in this review given the common overlap and use of IOA in LCA courses. There are about 40 minutes of linked video tutorials on the basics of IOA, and a 15-minute lecture on multi-regional IOA. There are several example questions provided also, which encompass a range of simple to complex problems (but taken, as a whole, are quite advanced).

A great addition to this section are examples in not only Excel, but python (via provided jupyter notebooks).

A student with any interest in IOA could quickly learn the basics and go as far as desired to MRIO, consumption footprints, etc., with the content in this section. It is an excellent overview to the topic of IOA and represents one of the best collections I have seen.

Method 6 (Model Integration) – This section is a collection of "other" connected topics related to the various methods introduced in the previous 5 method sections. Most

relevant to LCA are two topics, on process LCA-IOA integration, and linking MFA to LCA. Each of these has a linked reading (by Dr. Paulik) and helps to see how these models can support each other. As perhaps not a surprise, creating example problems for such settings is challenging, but the two relevant ones provided (on lightweighting and a repeat of the Advanced LCIA example from above) are quite good.

Overall suggestion on Part II – The provided resources are excellent but could still be slightly improved be adding several more links. In addition, it would benefit from more basic instructional examples (+ instead of ++ or +++, using the symbology on the page). Finally, many of the question examples would benefit from adding a "so what?" or reflection type question at the end. While these are hard to grade, they can be a good synthesis opportunity for students to ensure they are seeing the value or big picture perspective of their results.

Part III – Applications - This section of the course is meant to organize the various potential applications of industrial ecology and its supporting methods. The four individual application subsections vary in terms of the supporting content provided (videos or links or mostly examples).

The most relevant subsection (3) for this review is related to supply chain studies, which connects highly to LCA and IOA topics. Given the way the online course is organized, one could skim through the topics and choose to focus just on this application area and its readings, but then also go back and decide to better understand its foundations in the methods sections above.

That said, a suggested improvement would be to somehow add symbols or designations to the content (e.g., just a small icon?) to note which of the content here is shared/repeated from above in the course. For example, several of the examples in subsequent sections of the web page appear multiple times. By consistently using this icon, a student could more quickly realize this is a cross-cutting exercise (and possibly that they already had done it above).

Overall Summary of IEooc:

The content provided for this course is excellent and represents a catch-all compilation of all the relevant core topics for industrial ecology. For a student looking to learn the material, or a professor looking for a one-stop shop for strong content, it is an invaluable resource.

With respect to the LCA content specifically, the content in terms of readings and example questions is accessible, and useful, and supports a range of desired learning detail from basic to quite complex. The LCA methods section could be better formatted and organized to assist with the accumulated content from basic to complex, and to reduce duplication, but those are cosmetic suggestions and should not otherwise detract from the valuable material represented.