91. Pre-assessment Projects for Practice Based Learning

An interdisciplinary and project based course for ecological assessment at the Graz Technical University

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Abstract

The interdisciplinary course for ecological assessment at TU-Graz is a one-semester course (3 ECTS). It aims at improving the critical thinking skills of future engineers for a sustainable development. Participants are students in the Erasmus Programme (EuRopean Community Action Scheme for the Mobility of University Students) and graduate students at TU-Graz, who are working on their thesis. Students come from different engineering disciplines. During the first meeting of the class students take part in a creative workshop and start thinking about the relevant R&D issues in the next 20 years. This workshop helps them select a topic for their project, which is a pre-assessment for a real assessment project. The creative workshop also motivates students from different disciplines and countries to discuss among themselves the short- and long-term impacts of technical solutions such as waste-water-treatment, biogas production, waste incineration, smart packages, etc. Participants apply the theoretical framework of the assessment on their specific case and learn from experiences of their colleagues in other fields. One of the most important factors is the selection of an appropriate system boundary and a functional unit for the assessment.

In this contribution details of the interdisciplinary and project based course for ecological assessment and the course pre-assessment projects will be presented.

1 Introduction

The theoretical part of the course describes ecological assessment methods in the broader context of impact assessment for sustainable development. This part is used as a framework for all pre-assessment projects and is divided into five main chapters based on (Sotoudeh 2009):

1) Background of ecological assessment in the context of sustainable development
2) Terminology and definitions (process, closed cycles, socio-technical systems, etc.)
3) Differences between qualitative and quantitative methods and standards for ecological assessment
4) Environmental challenges, environmental impact categories and their connection to socio-economic challenges
5) Technology Assessment for a sustainable development and trade-off between benefits and risks of processes.

As an example students learn the concept of Life-Cycle Analysis (LCA, Figure 1) of products and processes including the consideration of material and energy consumption as well as certain impacts (such as acidification, climate change, etc.).

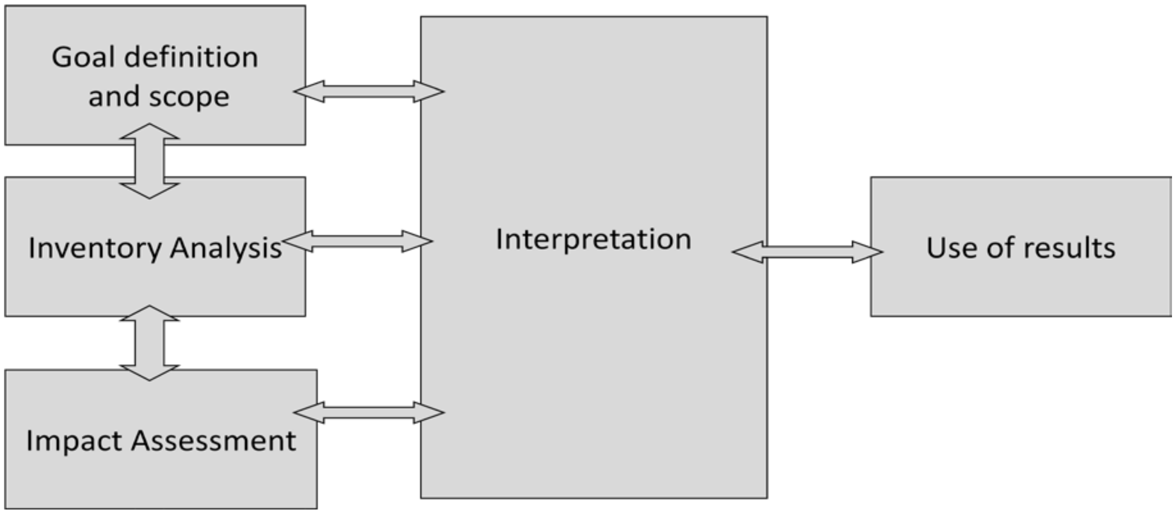

Figure 1: LCA concept in ISO 14040, 14041, 14042, 14043

Different examples introduce the Life Cycle Thinking concept in a sustainable development for consideration of raw material extraction, preparation and conversion, production processes of different elements in different industrial sectors, transport of elements to the integration process, use of products as well as repairmen and recycling steps. The practical part of the course is about scoping of a case by each participant and selection of appropriate functional unit for the inventory analysis. Some examples are given in this paper on the students' projects.

Since students are usually from chemical engineering, mechanical engineering and industrial management, the interdisciplinary discussions need a facilitator during the introduction of examples. At this phase the facilitator (in this case the lecturer) points out similarities and differences of projects as well as cooperation possibilities between projects.

The theoretical part includes also broader concepts such as Environmental Impact Assessment (EIA), which does not only takes the LCA aspects of a project into account but also involves a comprehensive evaluation of industrial products, processes and services within diverse projects at local level. Porter (1980) defined the central questions of EIA as:

What are the beneficial and detrimental impacts on the physical environment?

Which adverse effects cannot be avoided and why?

What alternatives exist?

What irreversible and irretrievable resources are committed?

Evaluation of industrial projects often requires decisions on acceptable levels of emissions and risks. Engineers need understanding of social and cultural mechanisms on acceptability of risks. Different perspectives should be regarded in the company, its surrounding and in the society (Figure 2). The technical knowledge provide in such cases is only one input to the discussions and negotiations between relevant actors. Engineers need negotiation skills for communicating with their local community in such cases.

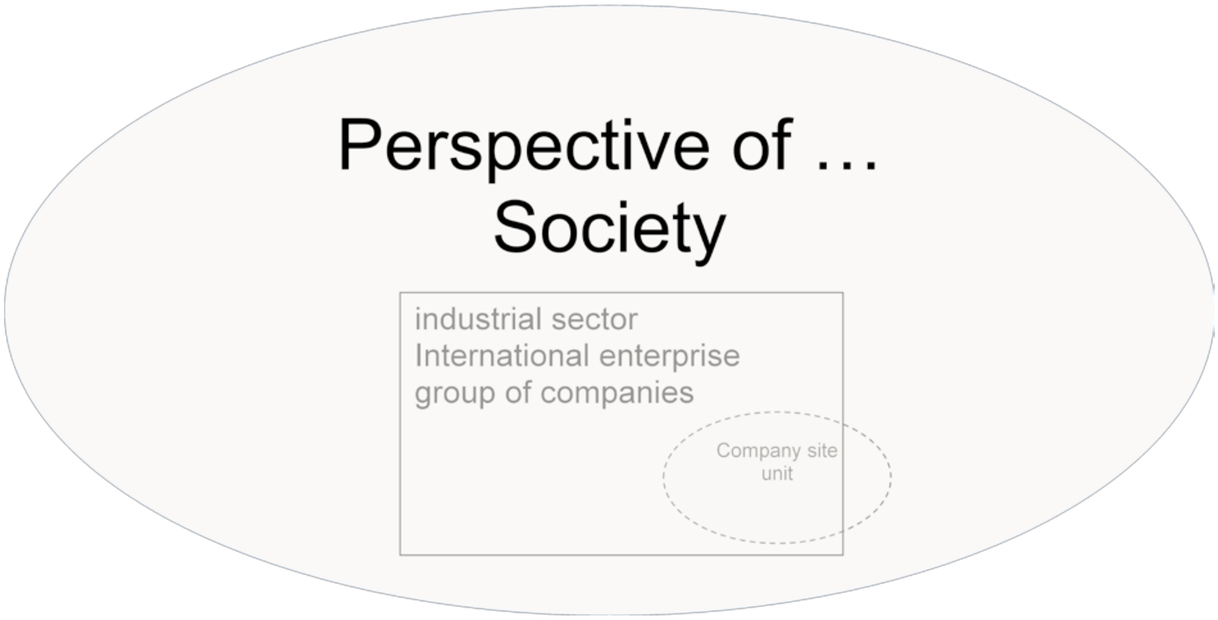

Figure 2: different perspectives, which should be regarded in a broader ecological assessment

The course includes discussions on the interdisciplinary trade-off between risks and benefits of processes. The example on debates on climate change shows the controversy in pro and contra arguments on risks and benefits of the technology. The pro and contra arguments on impacts of climate change since the 1990s among experts (including engineers) show that most of the controversial opinions are present at the boundaries of disciplines and organisations. Taking part in decision-making processes and discussions regarding controversial issues in participatory processes imply new challenges to engineers and their needs for gaining new skills. In this way students understand the importance of their communication and negotiation skills in an interdisciplinary group.

2 Pre-assessment projects

Pre-assessment projects are mini projects that are required prior to a comprehensive assessment in the real engineering work. Each student or if desired each team performs a pre-assessment project during the course on a selected topic and presents the findings once a month. A pre-assessment project aims at:

- defining the aims of the main assessment– what shall be accomplished by the assessment project?
- A short analysis of the status quo – what is the current situation like, are there any environmental, social or economic problems, etc. at local or global level for the given thematic field at the moment?
- defining the scope of the assessment – what should be assessed (what are the alternative solutions ; what are the corresponding environmental, social and economic effects)?
- performing a mini-Assessment of alternatives – pros & cons, strengths/weaknesses.

Students have an opportunity to select an assessment project depending on their own interests, receive support for the conceptual design of the assessment, present their results and take part in interdisciplinary discussions, and last but not least learn to deal with critics.

Some examples from winter semester 2012/2013 are presented in this paper to show different goals for an ecological assessment and different strategies for selection of the system boundaries and functional units. The assessment procedure and results are out of scope of this paper.

In winter semester 21012/2013 students worked individually. In five cases students have been already involved in a research project in the field of their pre-assessment project. This close connection to the practical work was very useful for the structuring of their analysis.

Sustainable mobility by wind energy (Gerda Gahleitner; the case is related to her research field)

The goal of this project was finding a way to provide sustainable mobility from wind energy with the least effect on the environment. Therefore three different pathways with different production steps, energy vectors and vehicle types are compared. Every system obtains the electricity from a wind turbine and the fuel production is taking place on-site at the refuelling station so that no transport is required in between. It has to be remarked that the transport from the production site to the refuelling station could have significant impact but is not regarded in this assessment, as the distances are hard to compare.

The considered output parameter is the driven distance and so the functional unit is determined to be 100 km. All of the components are assumed to be state-of-the-art technology and the values are taken from detailed described literature sources.

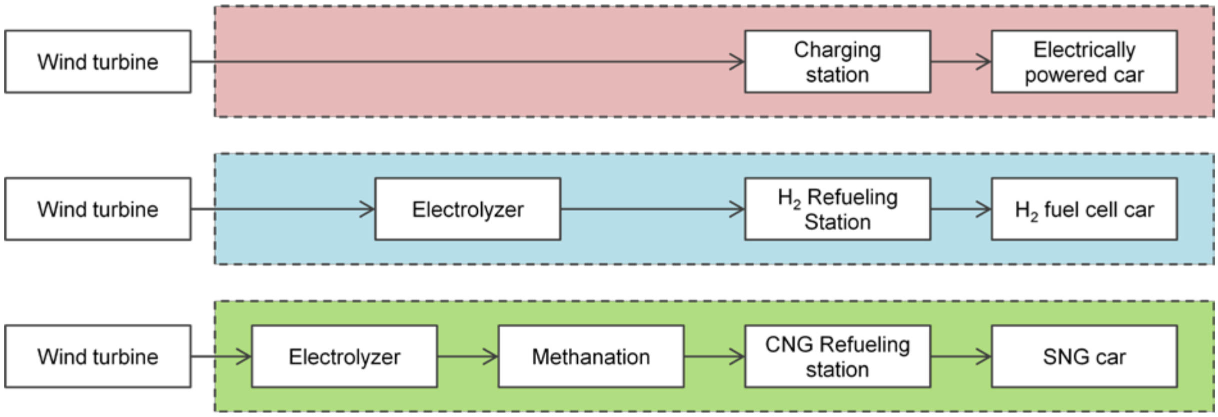

Figure 3: System boundaries for the three pathways

Environmental performance for production of olive oil (Sara Arias Martin)

The goal of the study was to assess the environmental performance of olive oil in order to use it as sustainable agriculture. A second, equally significant goal was to identify the best ideas to do a continuous improvement procedure with regard to the environment, by identifying the areas with the most significant impacts, and by taking measures for their control.

The functional unit of the study is 0.75 l extra virgin olive oil, packed in a glass bottle to be sold. The impact categories are global warming, emissions to the air, water used, solid waste, and material consumption.

Biogas production from corn (Khurram Shahzad; the case is related to his research field)

The aim of the study was to compare biogas and ultimately energy production using combined heat power (CHP) unit. The 1st scenario is about bio-ethanol production integrated with biogas production.

The 2nd scenario is biogas production utilizing the same input material. The comparative life Cycle Impact Assessment (LCIA) study deals with ecological as well as economic assessment of the process. The boundary conditions are cradle to gate. It includes all process from production of the renewable material to production of products bio-ethanol and energy.

The functional units for bio-ethanol are kg or ton and for energy KWh while the footprint allocation is made using market price of the products in €. The calculated ecological footprint can be further divided into seven discrete sub areas corresponding to different ecological pressure aspects: renewable resources, non-renewable resources, fossil resources, land occupation and emissions to water, soil and air.

Pre-assessment LCA for wood ash utilization as a binder in soil stabilization for road construction in comparison with burnt lime (Klaus Supancic; the case is related to his research field)

The main goal of the assessment was the evaluation of the ecological impacts of soil stabilisation with wood ashes in comparison to soil stabilisation with burnt lime (comparison of two different products fulfilling the same function). The results of the assessment shall establish ecological baseline information for the process and provide information and direction to decision-makers (authorities) as well as to end users of the product (construction companies). The information and direction of construction companies is of great importance because except for a few innovative companies, none is considering wood ashes as an interesting alternative to burnt lime.

The ecological assessment covers the evaluation of the whole process (from mining to application for burnt lime, from ash generation to application for wood ash). Depending on the quality of the data available, the fuel preparation processes for all fuels and energy used during the process will also be included. The impact assessment covers global impacts (global warming, renewable and non-renewable resources, land use) as well as local impacts (environmental toxicity, nuisance, final solid waste). The data used within the study shall be based on scientific papers, technical and environmental reports as well as recently performed research.

Functional unit: Area of 1,000 m^2 of stabilized soil at a thickness of 30 cm and a density of 1,800 kg/m^3 (dry basis) for a lifetime of 50 years.

Incinerator as a possible solution to recycling or treatment of the waste (Lara Trentadue)

The study contains the baseline information about the process and a calculation of the potential negative environmental impacts of an incinerator. Data is provided by existing rules applied to protect the environment, as well as research on the best available technologies (BAT) in order to obtain the lowest environmental impact.

The functional unit used in this case is the environmental impacts for one tonne of waste burned and the electricity produced in KWh.

Main environmental impacts of the incinerator are largely related to emissions by the fireplace of the plant and the production phase of solid residues (such as fly ash and slag that are harmful to human health and to the environment). Among the minor impacts, but not to be neglected for this, include the production of unpleasant odours, noises and vibrations, and water and reagent consumption during the process of waste disposal.

Application of membrane technology in the Methyl Acetate Synthesis (Thomas Winkler; the case is related to his research field)

Methyl acetate (MeOAc) is a highly volatile solvent. It is used in the pure state or mixed with alcohols or other esters to reduce the viscosity of certain products. The synthesis and isolation of MeOAc is challenging due to the formation of azeotropes. MeOAc forms low boiling azeotropes with the by-product water and with methanol. It is not possible to overcome these thermodynamic limitations by applying conventional distillation. The goal of this assessment was to support decision-makers to find a new state-of-the-art process for the MeOAc synthesis. The following pathways are investigated regarding impact on environment and process economy: conventional approach (9 distillation columns); Eastman Kodak process (reactive distillation); membrane reactor + rectification (pervaporation).

The functional unit for this assessment is determined by a production rate of 100 tons MeOAc per year. The system boundaries are set to be the process itself including the impact of the raw materials on the environment. It is assumed that all of the required equipment is already available in the chemical plant. The assessment mainly focuses on the environmental impact categories global warming and the toxicity of the disposal. The data quality is based on published papers in approved scientific journals. Additional data was gained through experimental investigations as part of the own research work.

3 First Reflection on outcomes of the course

The outcomes of the course "ecological assessment" are evaluated in this paper on two different classification schemes related to sustainable development in (Kastenhofer *et al.*, 2010).

The Declaration of Barcelona presents a long list (EESD 2004), including the ability to "understand how engineers' work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks, and impacts"; to "understand the contribution of their work in different cultural, social, and political contexts and take those differences into account"; to "work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management"; to "apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts"; to "participate actively in the discussion and definition of economic, so cial, and technological policies to help redirect society towards more sustainable development"; to "apply professional knowledge according to deontological principles and universal values and ethics"; and to "listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures".

The course addresses directly and mainly the abilities required in this scheme. The examples of the pre-assessment projects and the quality of discussions during the course shows that students improve their understanding for the meaning and influence of their work in a broader social context.

The second selected scheme is based on the European "Dublin" Descriptors (Joint Quality Initiative 2004). They distinguish learning outcomes along the categories "knowledge and understanding", "applying knowledge and understanding", "making judgements", "communication skills", and "learning skills".

The course aims to contribute to all of mentioned categories. Some indicators for the success is the final presentation of students, the quality of their handouts on their projects, the interdisciplinary character of discussions and the productive and useful feedbacks of students on the presentations of their colleagues.

In general all of pre-assessment projects led to a trade-off between different production processes and discussions improved the ability to review the work of colleagues. In some cases students produced well-elaborated recommendations for further research. In case of sustainable wind energy by mobility in the first calculations the production of the cars has not been considered but as the vehicle types differ quite significantly from each other, the production may influence the ecological impact. There is a great variance of components in each pathway and so it was recommended to also include electrolyser and methane production respectively. Furthermore, the infrastructure for fuel transportation should be included, as it differs significantly for the three evaluated pathways.

Through the olive tree pre-assessment project students realised the uncertainty of results of an assessment and the importance to make judgements in absence of complete certainty. Results between 2.5 to 3.6 Kg CO2 eq. of fossil origin have been achieved for any bottle of the present extra virgin olive oil that has been produced, packed and transported to the markets of northern Europe according to different references.

The project on wood-ash utilization pointed out the lack of data and the importance of the impact of environmental toxicity of the material as well as the need for the consideration of other gaseous emissions (NOx, SOx, PM10) than CO_2 and leaching from the stabilized soil.

Improvements are still needed for selection of project topics, application of new methods of learning as well as a comprehensive external evaluation of projects through experts at different fields.

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