

# Sustainability and Research Integrated in Engineering Courses at Dalarna University, Sweden

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## PRESENTATION

### Introduction

The department of Technology and Science at Dalarna University (DU) includes, as well as engineering, courses in energy technology. There are undergraduate programmes in Building Engineering as well in Energy Engineering and master's programmes in Solar Energy Engineering. The master's programmes are held in English and attract students from all around the world. These programmes collaborate, contributing with lectures in each other's courses, having common department meetings and common goals.

However, the University of Dalarna as a whole has a number of principal goals, one of which concerns sustainability. Having a goal on sustainability is a directive from Ministry of Education issued to all Swedish universities. The overall sustainability goals are to encourage the implementation of concrete measures that promote sustainable development. There are three sustainability documents giving overall guidelines at DU:

- A Formal Environmental/Sustainability Review
- An Environmental Policy
- Environmental Goals

**The Environmental Review** (Miljöutredning Högskolan Dalarna, Dnr: DUC 2011/577/10) is a detailed document which aims to map the direct and indirect effects on the environment of activities at Dalarna University. Direct effects on the environment are those caused by staff and their activities, including their travel routines and, their use of energy or water. Indirect environmental effects can come from our teaching, if these aspects are included in the courses, from carrying out research or from interaction with society when we contribute our expert knowledge in external activities.

**The Environmental Policy** (Miljömål för Högskolan Dalarna 2013 – 2015. 2013) is based on the Environmental Review and our routines are directly linked to it. One example is the change introduced on the production of course catalogues. These used to be printed every year. Now they are created in a digital format and handed out in paper only on request. The paper products created at Dalarna University that weighed 8,440 kg in 2009 were reduced to 272 kg in 2010. All travel routines have also been regulated, and thorough calculations on the reduction of CO<sub>2</sub> emissions have been carried out, to justify the changes. The university premises are also heated and maintained with energy from renewable sources, using low-energy lamps, recycling as much waste as possible, etc.

The Environmental Policy also includes directives concerning education at the university. A questionnaire has been sent to all students seeking their opinions on sustainable development in their education. The goal is not only to ask about the course

content, but also make students aware of how their habits contribute to a sustainable development.

**The Environmental Goals** at Dalarna University could be summarized as follows (<http://www.du.se/Global/dokument/Styrdokument-ny/Milj%C3%B6/Policydokument/Milj%C3%B6policy.pdf>) :

- High numbers of students shall attain a basic understanding of and insight into the significance of changes towards a sustainable society and shall be able to relate this knowledge in their future careers.
- The negative effects of travel shall be reduced as a result of the well-planned choice of transport, the use of environmental service vehicles, and increased access to so-called virtual meetings.
- Purchasing of goods and services shall be of a high environmental standard and goods shall be increasingly eco-labelled.

### *The Building Engineering Programme*

Turning to course content, the Building Engineering and especially the Energy Engineering programmes at Dalarna include sustainability in most courses. The goal at the Building Engineering is to focus on this even more and to prepare the students to meet the current Swedish building code and legislation when they graduate. The environmental goals in Sweden are constantly being revised and this concerns all sectors. In the building sector, the focus has until now mainly concerned heating costs, but a change is coming. Now discussions on sustainability more often includes the effect on climate change and how the production of different building materials, as well as the building process as a whole affects CO<sub>2</sub> emissions. We do not yet have a common Life Cycle Analysis (LCA) for each material. But all producers know that this information will soon be part of legal requirements, so they are already now handing out information of climate and environmental effects of their products.

However, being a university, we have to teach our students to be able to check this kind of information. Looking more closely at the information and comparing it with science-based knowledge, and so on, we can see that what is handed out by companies and producers on their websites is often misleading. To give one easy example: in the common LCA *'list'* **steel** is listed as using 80 % recycled steel in its production (SSAB and [http://www.jernkontoret.se/ladda\\_hem\\_och\\_bestall/publikationer/stalforskning/Stalkretsloppet\\_slutrapport\\_miljohandbok\\_svensk\\_web.pdf](http://www.jernkontoret.se/ladda_hem_och_bestall/publikationer/stalforskning/Stalkretsloppet_slutrapport_miljohandbok_svensk_web.pdf)). This looks very good and environmentally friendly. But checking steel production as a whole, only a small percentage of production can recycle this large amount!

So, we want our students to obtain a critical, independent and professional attitude after attending our courses and consider the education as a base for life-long learning.

### *Courses in Sustainable Re-building/retrofitting*

I am responsible for the courses in Sustainable Re-building/retrofitting. These courses take place on the last year of the undergraduate programme and aim to tie together what students have learned from the previous courses with added knowledge, using this to solve a re-

building project in a specific context. The course aims at not only at connecting previous knowledge, but also to train students how to link theory with practice. The theory I am talking about here is not related to building physics, but more to ideological approaches and societal aspects that includes value analyses and analyses of environmental impacts including social and economic issues. The course stresses a comprehensive understanding of specific buildings, how their statics, history, identity and context are related and to understand the impact of the choices of particular actions, including repair, change of function, extension of function, etc.

This is the first course where the knowledge acquired from earlier courses in a specific area connects and combines all knowledge and skills as a professional.

The sustainable approach in the course is based on existing legislation as well as expected future legislation. Changes in legislation are announced in advance, to enable industry adaption. The courses at the university must be in tune with these changes, since our students will face these new demands when they graduate. Most changes to the Swedish building code concern the environment, security and availability.

To make the course more comprehensive all issues are connected to a project including theory and value analysis, and changes in the project are based upon documentation and investigation of the building, assessing the existing situation with regard to damage, its history and earlier stages and a justification based on a theoretical approach and environmental impact.

The projects chosen for this course include quite different types of buildings. The buildings are of historical value, but not monuments or listed buildings. In the Swedish building code ALL buildings must be considered valuable ( 8 kap 17§ PBL), even if they are not listed. Changes are not allowed without a justified motivation. This means that any re-building project has to respect the work of earlier generations, following in a way the doctrines of John Ruskin and William Morris of the British Arts and Crafts Movement (The Seven lamps of Architecture, John Ruskins. 1849) which stresses that all interventions on a building must respect the knowledge, engagement and hard work of the initial and earlier builders and clients. Later generations have no right to change anything, according to these principles. This is a very rigid approach but it forces decision makers to think twice and base the argumentation of why changes are needed on serious grounds. This is not always easy for young professionals to understand. These grounds must be based on a reasonable adaption to new legislation, and to changes of function when old ones are obsolete since a building must be in use to survive. To make these judgements students must learn professional value criteria on which to base their argumentation.

The basic sustainable approach is that it is more environmentally friendly to re-use a building than to tear it down and build a new one. So sustainability supports the approach of the Swedish building code that emphasizes respect for all existing buildings.

The actual building projects chosen for the courses vary from year to year. Sometimes all buildings are historical. When this is the case, it is easier for the students to understand the need for careful interventions and respect. They can sometimes become so emotionally involved with the building that they want to continue the project as a professional.

Other years the projects are from the Modernist period and sometimes even later, from the 60's and 70's. In this case students are asked to work with the mass housing which was constructed in Sweden between 1965–1975 as part of the so-called Million Programme. During this ten year period 100,000 apartments were built each year, leading to one million apartments all together. This was a very important political program to improve and modernize housing in Sweden, and the speed forced a rapid industrialization of building

modules to develop. However, the speed with which this project was implemented, led to a set of detrimental decisions such as levelling the ground on buildings were to be constructed, removing all existing vegetation, and not always having time for all parts of the process to be carried out in a qualitative way, etc.

Even if housing standards were quickly raised and people marvelled at the modern kitchens and bathrooms in every flat, the new estates faced criticism for being inhuman and boring. It was difficult to rent all these apartments and today, with large numbers of immigrants now living across Sweden, the large developments from this era are where they are mostly housed. At this moment, these areas are the major challenge for renewal in Sweden. The estimated cost of modernizing them to contemporary standards, taking into account that a significant part of them were poorly built due to the speed with which they were constructed, is estimated at about 330 million euros (Facts 2013 Sveriges Byggindustrier).

Last year all projects in the course concerned this problem. Some of the students live in these types of buildings and are able to enrich the course with valuable contributions. Since these areas have such a bad reputation it has been interesting to notice how added knowledge can change attitudes. When considering the history and context of such areas, in proposing a sustainable approach, the student projects show how a different approach with new creative ideas for improvement, and can change minds after an initial negative attitude.

A course in re-building has also to focus on building materials. Here students cannot learn only about concrete and steel, a little wood and the calculation of forces. They must learn about historic building materials and learn how damage should be repaired and when to repair and when to change. All materials have different characteristics which rule which changes and repairs can be made and how. It is important to consider the LCA of the proposed materials and to avoid choosing a universal solution if it is not appropriate.

In all projects in the courses the university collaborates with local authorities and tries to find a problem of common interest so that the sense of a real project is present as well as an external interest in the results. If there are issues such as air and temperature movement in the walls, for instance, the students can use any of the research facilities at the university. Our researchers are always interested in participating and helping students if there is a shared interest.

### *Collaboration with Local Industry*

Dalarna University is located in western Sweden, in a rural setting in one of the wooden building districts. The university is rather new, especially the Building Engineering Programme. A university in this area is very visible and Dalarna University has used this situation to create an important and positive role for itself, leading to the development of the following goals for the university as a whole ([www.du.se/Omhögskolan/Hållbarutveckling](http://www.du.se/Omhögskolan/Hållbarutveckling)):

- To contribute to the development of the market, products and the process of existing and new enterprises with the help of researchers, teachers, students and coaches from the Foundation Teknikdalen
- To coach alumni students in the network of former students working at enterprises in the region, across the country or internationally
- To promote good ideas
- To disseminate interesting research in a popular scientific way

- To contribute to the commercial realization of research results
- To contribute to the raising of competence and further education of local enterprises with modern pedagogy
- To contribute to internationalization, among other ways with the help of the international students at the university, and with the help of the language and business culture sector
- To demonstrate the possibilities the research laboratories and facilities and testing environments at the university can provide for local and regional enterprises

Many research projects in our department concern solar energy as well as district heating systems. The research on district heating, for instance, is a collaboration with the local district heating company. This has also generated collaboration and a sustainable approach to all engineering courses provided at Dalarna University. Sustainability itself is not a separate subject but a general base for education as a whole. Many researchers are also engaged in teaching students with contributions on this topic which strengthens and supports this important approach.

### *The Research Project*

In the research project I will show here there has been collaboration between the departments of Building Engineering and Energy Engineering. The research question was a solid wood construction built as a passive house. One aim of this research project was pragmatic, involving collaboration with local enterprises. Here a three party collaboration was established, between the university, Stora Enso, one of the world's biggest wood and paper companies, and a local building company. We chose to collaborate with Stora Enso because they had a newly developed building system which they wanted to test for a passive house and we wanted to use this robust building system. The third partner, the builder, HMB Construction, participated with their long building experience, and at the same time they wanted to see if special skills were needed for this type of construction.

The building system we used as a basis for the research project was based on a standard product Stora Enso was developing using CLT (Cross laminated timber) boards as the structural material. We developed the solution of Stora Enso further, to fit the Swedish passive house standard which means that we calculated the dimensions for insulation to achieve a specific energy consumption in kW/h and year. This was done by one of the students as his final report for his bachelor's degree.

The developed solutions of this building system have been tested on a small experimental building constructed in Borlänge. The system tested in a small scale can likewise be used for a larger multi-story building.

The innovation in the solution we introduced as a development of the standard by Stora Enso concerned mainly the three first and the last aspects (Passive Cross Laminated Timber Buildings, Cerbof-project no 76, Henrik Janols, Mats Rönnelid, Tina Wik. Dalarna University 2013):

- a) How to achieve air tight connections between different elements or building components
- b) How to solve energy efficiency in a modern design with large windows
- c) To study the performance of alternative, climate friendly materials as alternatives to ones used normally used in the building production.

- d) The fourth difference to the standard solution is no novelty, only a difference: we used thicker measurements of insulation to meet the passive house standards.
- e) Industrial and economically efficient production
- f) A new foundation system initiated by the builder

To achieve air tight connections we designed new solutions where air was not able to have straight access through the building but was always caught in a so-called S curve. This is a completely new way to insert windows and doors.

Large sliding doors are very popular but always considered impossible to use in passive houses due to air leakage. Here we introduced a double groove system which we wanted to test to see if it could meet the requirements for air tightness for a passive house.

Since we used walls of solid timber we excluded the normally used plastic coating to achieve a vapor barrier. We also used mineral wool insulation in half of the building and pulp based insulation in the other half (the same wall) to measure differences in air and humidity movements.

The last innovation was the rejection of concrete in the foundation. The building is based on packed gravel, with foam insulation under the solid wooden board. We were afraid that humidity would penetrate the wooden board. After two year in one location in Borlänge the building was moved to a site adjacent to the university building. Doing this we measured the underside of the wooden floor board and discovered that it was completely dry. This simple foundation method functions for small scale buildings (up to two floors), it is simple, cheap and environmentally friendly!

We have been measuring the building for more than two years now and we can conclude that the changes we introduced to the standard building system were enough to reach the set goals of achieving a passive house. From our measurements we now have proofs that pulp-based insulation has a better performance compared to mineral wool insulation, since its curve has fewer variations. This means that mineral wool reacts more quickly to changes in temperature and humidity. The success of the foundation method is a bonus we had not calculated on and this will most likely be the main innovation with this research project. We can now prove that a foundation made directly on the ground does not need concrete. We are currently in the process of writing the final report from this research project. Meanwhile students are checking and measuring different facts on this test building and reporting their results as a final exam in their programme. One of their reports received the award for the best exam report in Sweden last year! (Moisture Analysis of Solid Wood Construction, Robert Eriksson, Johan Olsson Thor. Dalarna University 2014)



The building industry is a complex one, being performed in an existing context, using a lot of energy in production and even more during its life time, due to the Swedish climate. The end product will form people's lives and existential issues, and contribute to planning, good or bad. Even if education at Dalarna University cannot embrace all of this, we want our students to understand that they are part of a larger context and that their future role will be the one of a team player.

The challenge of retrofitting the Million Programme areas which is in focus both in research as well as in our courses, and often considered as non-valuable housing areas, will be one of the most demanding assignments for everyone working in the Swedish building sector in the near future. We at Dalarna University will participate in this difficult and on-going debate on how to be able to evaluate, develop and maintain this problematic modern heritage.



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