Resource Recovery
University of Borås

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Self-evaluation of Research in Resource Recovery

Background

As a part of the quality assurance system for research at the University of Borås an evaluation of the research activities within a specific research unit is performed every sixth year. The research unit is called a Unit of Assessment (UoA) and consists of one or more research groups.

The UoA of Resource Recovery consists of four research groups:

1. Biotechnology
2. Combustion and Thermal Processes
3. Polymer Technology
4. Resource Management

The Research and Education Board has established five criteria for evaluation

1. Research environment
2. Research (productivity and impact)
3. Collaboration
4. Connection between education and research
5. Development and strategy

Self-evaluation procedure

The Dean of Faculty for Textiles, Engineering and Business decided in September 2020 that the Unit of Assessment in Resource Recovery should consist of four research groups (see above). The Dean also appointed Tomas Wahnström as being the project leader for the self evaluation.

The self-evaluation report has been discussed in the different research groups by the researchers and the PhD-students. The main part of the work have been done by the four research group leaders and the project leader.

This report

The report is organized in nine sections:
1. UNITS OF ASSESSMENT
2. PROFILE OF THE UNIT OF ASSESSMENT
3. RESEARCH ENVIRONMENT
4. PRODUCTIVITY AND IMPACT
5. COLLABORATION
6. CONNECTION BETWEEN EDUCATION AND RESEARCH
7. ETHICS IN RESEARCH
8. DEVELOPMENT AND STRATEGY
9. DISCUSSION AND CONCLUSIVE EVALUATION

The UoA consists of four research groups within the Department of Resource Recovery and Building Technology. Important additional information connected to the four research groups is presented in their research plans. This report describes *the research* in Resource Recovery; the research education is only mentioned when appropriate.

A list of peer-reviewed publication per year 2016-2020 for Resource Recovery is presented in an Appendix.

The data presented in this report is updated to the current situation on December 31 2020.

1. UNIT OF ASSESSMENT (UoA)

1.1 Research area

Resource Recovery focuses on developing technical methods for recovering resources - energy and materials - from waste or residual products, and developing materials for improving recoverability, as well as materials with improved sustainability and durability.

In addition to technical methods, the field also includes research into logistical and social aspects linked to different solutions for recycling resources.

The research area is made up of four research groups: Biotechnology, Combustion and Thermal Processes, Polymer Technology and Resource Management.

1.2 Contact person for this report.

Tomas Wahnström

2. PROFILE OF THE UNIT OF ASSESSMENT

2.1 *Description of the UoA's recent history and organisational development.*

The University of Borås has since more than 20 years focused on developing research, education and innovation in the area of resource recovery. In connection to the expansion of research, Bachelor and Master Programs were developed and PhD-students in cooperation with other universities were admitted. The first professor was recruited in 2003 and in 2010 the University of Borås received its own right to give a PhD-program in Resource Recovery. The PhD-students receive their degree in the subject Resource Recovery with a specialization, which corresponds to the focus of the research groups.

The number of senior researchers has steadily increased and is now 20-25. Most of them have been externally recruited but some of the senior researchers have their background in our own PhD-program.

In parallel with the development of the research and the recruitment of seniors, four research groups have evolved, consisting of professors, docents, senior lecturers, postdocs, PhDs, visiting researchers and PhDs.

1. The Research Group in *Biotechnology* focuses on developing different bioprocesses in order to covert waste and residual products to valuable products such as biofuels, biopolymers, feed and food. Research Group Leader is Professor Mohammad Taherzadeh.

2. The Research Group in *Combustion and Thermal Processes* focuses on optimizing the efficiency and economy of heat and power plants and at the same time minimizing the usage of natural resources and the environmental impact. Research Group Leader is Professor Tobias Richards.

3. The Research Group in *Polymer Technology* focuses on the development of polymer materials (plastics, textiles and composites) for the circular economy. This includes polymers of biobased origin, polymers from recycled waste streams and polymers with improved environmental sustainability and structural performance. Research Group Leader is Professor Mikael Skrifvars.

4. The Research Group in *Resource Management* focuses on why waste occurs at all, and then implements innovations to reduce waste and improve sorting. The group has very recently begun to study social and environmental aspects associated with developing food products from food waste. Research Group Leader is Professor Kim Bolton.

The four research groups are collaborating in research in several ways.
- Biotechnology together with Polymer technology in developing biopolymers for textile applications (this collaboration also includes research groups in textile technology at the University of Borås).
- Biotechnology together with Resource Management in applying life-cycle analysis (LCA) and social aspects of fungal products.

- Biotechnology together with Combustion and Thermal Processes in gasification of materials and fermentation of syngas.

The four research groups have a joint responsibility to develop the research area and the PhD-program. The research groups are collaborating when it comes to research projects, PhD-projects, external research applications, lab equipment etc. This has been facilitated since the four research groups are organized within the same department.

The research in Resource Recovery is organized within the Department of Resource Recovery and Building Technology at the Faculty for Textiles, Engineering and Business. There is no formal management of the research area (UoA) in Resource Recovery. There are Group Leaders of the research groups and a Manager and a Director of Studies for the Research School. There are no special formal meeting places for the researchers in Resource Recovery. The formal meeting places are instead the Research Education Committee (FUU) and the so-called supervisor-meetings (handledarmöten). FUU meets once a month with representatives from the researchers and the PhD-students and deals with decisions connected to the PhD-program. All supervisors are invited to the supervisor-meetings, which are led by the Director of Studies and are held once a semester. The idea with these meetings is to discuss matters connected to the PhD-program. But during the years it has been requested that we should also discuss more general issues in connection with research.

The process when the direct government funding (fakultetsmedel) is to be allocated could be more transparent for the researchers.

The Research School applies in December every year to the Dean of Faculty for new internally financed PhD-students. The prioritizing is done together with the research groups. One to two internally financed PhD positions are allocated every year.

Each Research Group applies for funding for research from the Dean of Faculty after discussions with the Head of Department. The Head of Department negotiates with the The Dean of Faculty on the size of the budget for Resource Recovery and the Head of Department finally allocates the money to the different research groups. This funding covers consumables and materials for the research labs, as well as limited funding for conferences and travelling.

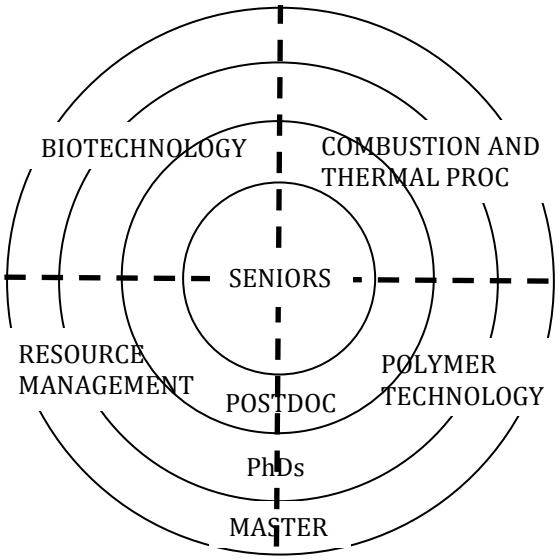
2.2 *Special factors that should be noted when assessing the research within the UoA.*

Nothing to add here.

3. RESEARCH ENVIRONMENT

3.1 *Description of the competences and the opportunities for merit and skills development within the UoA.*

The research in Resource Recovery is primarily performed within four research groups: Biotechnology, Combustion and Thermal Processes, Polymer Technology and Resource Management. The environment is characterized by having researchers and students on different levels, from bachelor and master students to PhD-students as well as junior and senior researchers, working closely together (see figure below).



The research group leaders have a responsibility to develop the different research groups. They also have a joint responsibility to develop the research area Resource Recovery by applying for research funds, recruiting new PhD-students, looking for collaboration with universities and companies, develop the laboratories etc. This work is done together with the other senior researchers. This collaboration gives the less experience seniors a possibility to develop their skills. For the senior researchers the main career development is becoming an associate professor (docent). The total number of senior researchers is 20-25.

The research group leaders are together with other senior researchers principal supervisors for the PhD-students. Less experienced senior researchers act as supervisors and by that they develop their skills in supervising. Supervisors from other research groups within the university or from other universities are also involved.

Post-doctor positions are available depending on external funding, normally for a short period. The post-doctors do research under supervision of the seniors and occasionally the supervise PhD or MSc students. The post-doctors can be externally or internally recruited. The number of active post-docs is around five.

The first PhD-student graduated in 2014 and until now (December 2020) in total 28 PhD-students have graduated with a degree in Resource Recovery from the University of

Borås. The number of PhD-students admitted and active today is 32. Around half of the PhD-students come from a master programme at the University of Borås, the rest come from universities all over the world.

The research environment is very international. The staff as well as the PhDs, visiting PhDs and visiting researchers are represented by several nationalities, today in total eleven different countries.

3.2 *Description of the research facilities and infrastructure.*

The lab environment consists of approx. 1200 square meters and is situated in the same building as the office spaces.

The research environment consists of three laboratories:

1. Biotechnology Lab
In the Biotechnology Lab, biotechnology studies focus on resource recycling through the processing of by-products and waste material into new products. Several different types of processes are investigated where organic waste becomes biofuel, feed, food and soil enrichment. Common to them is the pre-treatment and fermentation that different microorganisms grow in different conditions to perform the desired processes. The labs are divided into a biogas lab and a more general biotechnology lab where the reactors and analytical instruments are located.

2. Combustion and Thermal Treatment Lab
In the Combustion and Thermal Treatment lab investigations are made to understand the behaviour of materials (mainly wastes and renewables) during thermal processes. In addition, there are also studies regarding materials recycling after thermal treatment, which could either be by the gas and liquid products or by the solid reminders.

3. Polymer Technology Lab
The Polymer Technology Lab hosts studies of polymeric materials used in plastics, textiles and composites. In the studies, polymers are processed in different ways, after which the obtained properties are analysed regarding chemical and physical characteristics as well as mechanical strength and durability.. This work is largely concerned with studying how bio-based polymeric materials can replace non-renewable polymers, and can enhance material properties.

In the laboratories there are five lab technicians (3,5 full-year equivalents). Their duties are maintenance and handling of lab equipment and purchase of chemicals and other lab consumables. They instruct also students, visiting researchers and PhD students regarding the use and functioning of the research equipment.

The researchers have access to a well-equipped library at the University of Borås with physical and electronic books and databases (www.hb.se/Biblioteket). The researchers can influence which books and databases that are purchased. The researchers also have access to software, such as Aspen, HYSYS, SuperPro, SimaPro, FactSage, ChemDraw and MATLAB.

The Grants and Innovation Office (GIO) support the researchers regarding external funding, making deals and questions concerning innovations and patents. The collaboration between the researchers and GIO is today working well but it could be further developed.

The Communications Office, the IT Office and the Human Resources Office also support the researchers in several ways.

Issues concerning financing are handled by a Finance Officer who is placed very close to the researchers and in tight cooperation with them. This is working very good.

3.3 Description of research seminars.

Each research group has recurrent (monthly) group meetings where the focus is the group's future plans and presentations and feedback on on-going projects.

The Research School organizes a PhD-course called Research Seminar. In this course the PhD-students presents his or her research for the other PhD-students.

There are no special research seminars where all four research groups participate except two arrangements including the PhD-students; the mid seminars and seminars presented within a special PhD-course.

3.4 Description of the UoA's academic network and collaborations, publications, research mobility and exchanges.

The different research groups collaborate with several national and international universities. Among the national universities we find Chalmers, KTH, Linneaus University, SLU, University of Gothenburg and Luleå University of Technology. The international academic collaboration includes universities in Brazil, China, Finland, France, Germany, Great Britain, India, Indonesia, Iran and Turkey. These collaborations lead to numerous peer-reviewed articles that are co-authored with researchers from other national and international institutions.

During the last five years we have had around 30 visiting researchers and PhD-students. They have come from Brazil, China, Estonia, Finland, Indonesia, Iran, Morocco, Nigeria, Poland, Thailand and Turkey.

Details concerning the different forms of academic collaborations can be found in the research plans.

3.5 Description on how the UoA promotes equality and sustainability

Among the graduated PhD-students in the Research School there are 18 men and 10 women**.** Among the now admitted PhD-students there are 13 men and 19 women. So in total there are 31 men and 29 women.

Among the supervisors in the Research School there are 19 men and 12 women. But all professors are men. This has historical reasons; men are historically dominated the research subjects which are covered in Resource Recovery.

In the Research Education Committee (FUU) there are 3 men and 3 women (seniors and PhD-students combined).

When recruiting new researchers we aim to have external experts of both sexes and we encourage applicants of both sexes. We always have members of both sexes in the examining committees at PhD-defence.

The research in Resource Recovery focuses on sustainability and each PhD is recommended to have a section in the beginning of their theses where they reflect on sustainability in relation to their research work. There are also several courses in the PhD-program covering sustainability.

The relatively new research group in Resource Management has been created in order to also include social aspects of sustainability in the research and the research education. This group also includes gender aspects in their research, for example when identifying interventions to reduce waste and improve sorting of waste.

4. PRODUCTIVITY AND IMPACT

The researchers and the PhDs publish their results in international journals with a peer-review system with more than 310 publications. See the appendix that lists the publications for the years 2016-2020.

TABLE: Total number of peer-reviewed publications per year 2016-2020 in SCOPUS. See appendix for details.

2016	46
2017	35
2018	44
2019	45
2020	62

Professor Mohammad Taherzadeh and Tobias Richards were members (and Professor Taherzadeh even Chairman for three years) of panel in Biotechnology & Chemical Engineering, Swedish Research Council (Vetenskapsrådet) from 2013 until 2019.

Professor Mohammad Taherzadeh is Editor-In-Chief Bioengineered Taylor & Francis Group and Associate Editor Bioresource Technology Elsevier

The external research funding come from e.g. Vetenskapsrådet, Tillväxtverket, Energimyndigheten, Vinnova, FORMAS, VGR, KK-stiftelsen, Sparbanksstiftelsen Sjuhärad, Lantmännen and Naturvårdverket.

Details concerning the external funding can be found in the research plans.

5. COLLABORATION

The research groups have collaboration with many companies, such as Lantmännen, FOV Fabrics AB, Borås Energi och Miljö, Renova, RISE.

Details concerning the different forms of collaborations can be found in the research plans.

6. CONNECTION BETWEEN EDUCATION AND RESEARCH

The Research and Education Environment is made up of bachelor programs, a master program, a PhD-program and research. The second year of the master program consists of a one-year degree project performed in close collaboration with the researchers and the PhD-students. This project often generates an article in a scientific journal.

All researchers are also active as teachers or examiners in the BSc and MSc programs and there they can link their teaching to their research.

7. ETHICS IN RESEARCH

The research in Resource Recovery is mainly technical research and traditionally the research ethics has not been an important issue. But when we developed the research group in Research Management this has become more and more important. Ethical vetting has been sought for several research projects in Resource Management.

In Biotechnology more and more focus is on producing food from waste and this has also made it necessary to look into ethical issues.

8. DEVELOPMENT AND STRATEGY

The research groups will develop and widen their respective research topics within the research area resource recovery.

The collaboration between the research groups will be increased in order to develop the research area, for example by applying for common external research grants and starting common PhD-projects.

In order to broaden and deepen the research, collaboration with other research groups at the University of Borås will be developed, for example logistics, civil engineering and textile technology.

All this will be facilitated by developing the organization and government of the research area.

9. DISCUSSION AND CONCLUSIVE EVALUTATION

It is an advantage that the four research groups are situated in the vicinity of each other and organized within the same department. The laboratories are all situated in the same building. This facilitates collaboration.

The laboratories for the research groups within textile technology are situated in another building then the laboratories for resource recovery. This means that it is challenging to cooperate concerning investments and use of equipment.

The research groups are rather small (except Biotechnology) which could make them vulnerable.

The organization and government of the research area Resource Recovery is unclear and could be further developed. This is also dependent on the unclear organization and government of the research at the faculty level.

There is a good collaboration between the research groups despite the lack of formal government.

The PhD-program in Resource Recovery is an important part of the research activities.

The process when the direct government funding (fakultetsmedel) is to be allocated could be more transparent for the researchers.

Publications 2016- from SCOPUS

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13. Erdtman, E., et al., *A molecular-level computational study of the diffusion and solubility of water and oxygen in carbonaceous polyethylene nanocomposites.* Journal of Polymer Science, Part B: Polymer Physics, 2016. **54**(5): p. 589-602.
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