**Strategy for research and doctoral education**
**in Resource Recovery**
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# WASTE IS A RESOURCE,

# BUT OUR KNOWLEDGE IS TOO LIMITED TO UTILIZE IT.

Resource Recovery at the University of Borås is leading the transformation of our current linear technology and economy into a sustainable and circular technology and bioeconomy. Through developing innovative methodologies and assessing its technological and societal aspects, Resource Recovery is contributing to accelerating conversion of a various range of wastes and residuals to value-added resources. Our motto is "waste is resource, but our knowledge is too limited to utilize it" and our vision is to become a global leader in sustainable resource recovery.

The University of Borås has developed research, education, and innovation in the field of Resource Recovery for over two decades. It all started with education in bachelor and master programs and in 2003, the University hired its first professor in the field. Since then, the Resource Recovery has continued to attract talented professors and researchers, resulting in its recognition as one of the top-priority research field at the University of Borås. In year 2007 the University of Borås received its license to award Degree of European MSc and then in 2010, it was granted to award Doctoral degree in Resource Recovery. All this has led to the creation of a **complete education, research, and innovation environment.** To emphasize this comprehensive education and research environment, the University of Borås created the *Swedish Centre for Resource Recovery* (SCRR) in 2010.

Resource Recovery is playing a crucial role in promoting a sustainable society by collaborating with a diverse group of universities, companies, and stakeholders both nationally and internationally. The impact of the research conducted by Resource Recovery goes beyond commercialized services and products, such as FOV Biogas in India and Mycorena and Millow in Sweden. Resource Recovery has also contributed to societal impact and knowledge, as demonstrated by the Waste Refinery in Indonesia and initiatives to minimize food waste in Brazil.

The PhD-program is organized as a Graduate School and underwent a quality evaluation in 2022. The program was considered to be of very high quality by external reviewers.

In 2022, Resource Recovery made a noteworthy contribution to UB's publication output by publishing 85 papers in international scientific journals, accounting for 30% of the university's total publications.

Resource Recovery's research environment is highly international, with PhD students and researchers from nearly 20 different countries represented.

For the year 2022, the internal research funding comprised SEK 14.5 million (of which SEK 11.1 million went to the Graduate School). The external research funding comprised SEK 16.3 million (excluding external funding of collaborative doctoral students and in-kind contributions by business in existing projects).

The research environment is organized into five research groups: Biotechnology, Combustion and Thermal Processes, Polymer Technology, Resource Management and Building Technology. There are currently 31 PhD students and approximately 30 researchers in Resource Recovery.

The development of the research and doctoral education is focused in five areas:

- Conducting high-quality research.
- Developing the Graduate School
- Spreading of knowledge
- External financing
- Marketing

## 1. PRIORITIZED RESEARCH AREA

Prioritized research area is Resource Recovery, with Research area representative Prof. Taherzadeh.
Research plans of the five research groups are presented in appendix. Further information can be found there.

## 2. RESEARCH PROFILE WITH A VISION

Resource Recovery has emerged as a crucial game changer in building a sustainable society. Resource Recovery is a dynamic field that aims to transform the current linear technology and economy into a more sustainable circular technology and bioeconomy. This is achieved through the development of innovative processes to accelerate the conversion of various wastes and residuals into value-added resources/products. With its holistic approach, Resource Recovery also aims to shift the attitudes and behaviors of users towards accepting these products and reducing waste. We mean that "*waste is a resource, but our knowledge is too limited to utilize it*". Therefore, moving the border of knowledge in this field is a key issue for sustainable development.

The University of Borås has for more than 20 years developed research, education, and innovation in the field of Resource Recovery. It started with bachelor and master programs which led to the first recruited professor in 2003. Since then, more professors and researchers have been recruited and the research has grown continuously. In year 2010 the University of Borås received its license to award Degree of Doctor in Resource Recovery. The doctoral program is very successful and 34 doctoral students have so far (March 2023) graduated.

To emphasize this environment of education, research, and innovation in Resource Recovery, the University of Borås created the *Swedish Centre for Resource Recovery* (SCRR) in 2010. This center is internationally known and helps in establishing new contacts with universities, researchers, companies, financiers, and prospective master and doctoral students.

**Our vision is that the University of Borås will become world-leading in sustainable resource recovery.**

## 3. RESEARCH ENVIRONMENT

The research environment in Resource Recovery is presently organized in five research groups with currently (March 2023) 31 PhD students in total. The number of researchers/supervisors is approximately 30, of which about ten are employed at other universities, in Sweden and abroad. Since 2014 around 500 papers have been published by peer-reviewed journals. University of Borås's goal is to make Resource Recovery into one of the world leading centers in its area. It is an international environment in terms of staff and collaborations, and it is also well-coordinated with its BSc, MSc, and PhD programs.

The five research groups:

The research group in Biotechnology develops various bioprocesses to refine or upgrade materials or wastes and residues into biofuels, biopolymers, feed, and food. The research group leader is Professor Mohammad Taherzadeh.

The research group in Combustion and Thermal Processes works with optimizing the efficiency and economy of power and heating plants as well as minimizing the use of natural resources and environmental impact. The research group leader is Associate Professor Anita Pettersson.

The research group in Polymer Technology develops environmentally sustainable polymeric materials from bio-based raw materials and waste streams. The group has a close collaboration with research groups at the Department of Textile Technology. The research group leader is Professor Mikael Skrifvars.

The research group in Resource Management focuses on integration of social aspects in resource recovery and to design and implement interventions to reduce waste and develop a circular economy. The research group leader is Associate Professor Kamran Rousta.

The research group in Building Technology is focused on the topics: Performance of hybrid structural elements. Optimization of structures and structural elements regarding structural performance, environmental footprint, and economy. Indoor climate and air quality including energy efficient demand-controlled ventilation. Recycling aggregates of concrete, $CO_2$ uptake of concrete waste prior re-use.

The research groups collaborate among themselves in several different ways, both in research projects as well as doctoral projects.

The research environment is characterized by researchers and students at different levels, from bachelor's and master's students to doctoral students and from junior researchers to professors, who all work together. The master's programs consist of three two-year programs tightly connected to the research works. The master's programs include a second year with a one-year thesis. This thesis work is carried out by the master's students together with doctoral students and postdocs. This work usually leads to a scientific publication.

The doctoral students are a central part of the research activities, and there are currently 31 within Resource Recovery. About half of the doctoral students come from a master's program at the University of Borås, while the rest come from other universities in Sweden as well as the rest of the world. About two-thirds of the doctoral students are externally employed doctoral students (i.e., financed by an external company), whilst the rest is financed directly by the university.

The research group leaders are responsible for developing the various research groups. They also have a joint responsibility to develop the research area Resource Recovery together with the area representative. This is done through applications for research funds, admission of new doctoral students, collaborations with other universities as well as companies, development of laboratories, etc. The number of researchers and supervisors in the field has increased continuously since the start and is now approximately 30. About half of them comes from our own PhD-program and about half of them are externally recruited. The research environment is very international and nearly 20 different countries are represented.

Postdoctoral positions are available subject to the availability of external funding. The postdocs conduct research under the supervision of one of the professors, and occasionally they can supervise doctoral and master's students. The postdocs can be externally or internally recruited. The number of currently active postdoctoral fellows is about five.

The number of women and men is approximately the same at doctoral level and younger researchers, however, the number of women in higher positions is low.

The research activity is mostly experimental, and an important prerequisite is well-equipped laboratories. The research groups use several different software for calculations and simulations but interviews and sensory analyzes in their research. The laboratory environment consists of approximately 1,500 square meters distributed among four laboratories: Biotechnology Lab, Building Technology Lab, Energy Technology Lab and Polymer Technology Lab.

The research groups collaborate with several national and international universities. Among the national universities are Chalmers, University of Gothenburg, Royal Institute of Technology (KTH), Kristianstad University, Linnaeus University, Luleå University of Technology, Swedish University of Agriculture, Umeå University and Uppsala University can be mentioned. International collaborations exist with universities in Austria, Brazil, China, Denmark, Finland, France, Germany, Great Britain, India, Indonesia, Iran, Norway, Portugal, Slovenia, Spain, Switzerland and Turkey. These collaborations lead, among other things, to a large number of scientific articles that are written in collaboration with researchers from these universities.

During the last five years, more than 30 guest researchers and guest doctoral students have been visiting the University of Borås for both longer and shorter periods of time. They have come from Brazil, Estonia, Ethiopia, Finland, Germany, Indonesia, Iran, Morocco, Nigeria, Poland, Slovenia, Thailand, and Turkey.

Resource Recovery places significant emphasis on innovation, which involves establishing enduring partnerships with both domestic and international industries, fostering the growth of small and medium-sized

spin-off businesses, hiring part-time researchers, and reinforcing the identification of research areas, all of which contribute to conducting research that is essential to society.

## 4. PRODUCTIVITY AND IMPACT

The researchers and doctoral students publish their results in international scientific journals with a peer-review system. The number of publications is presented in the table below. Note that the research area Resource Recovery accounted for 30 % of the publications from the University of Borås in 2022.

TABLE: Number of publications (peer review) per year 2017 – 2022 for the Swedish Center for Resource Recovery (SCRR) and in total for the University of Borås (UB) (according to SCOPUS).

| | SCRR | UB |
|---|---|---|
| 2017 | 31 | 186 |
| 2018 | 35 | 209 |
| 2019 | 45 | 252 |
| 2020 | 74 | 245 |
| 2021 | 86 | 229 |
| 2022 | 85 | 283 |

The researchers and doctoral students also present their research in books, TV, radio, popular press, competitions, social media, etc.

In 2022, the internal research funds comprised SEK 14.5 million, of which SEK 11.1 million went to the Graduate School. The external research funds comprised SEK 16.3 million. This amount does not include the external funding of collaborative doctoral students and in-kind contributions by business in the existing projects.

The external research financiers are the EU, the Swedish Research Council (Vetenskapsrådet), The Swedish Agency for Economic and Regional Growth (Tillväxtverket), the Swedish Energy Agency (Energimyndigheten), Vinnova, FORMAS, the Swedish Environmental Protection Agency (Naturvårdsverket), VGR, the KK foundation, Sparbanksstiftelsen Sjuhärad, Lantmännen, Åforsk, Kamprad Stiftelse, Gunnar Ivarson's foundation and various private companies.

## 5. EXTERNAL ENGAGEMENT

The research groups collaborate with many different external actors, such as Lantmännen, FOV Fabrics AB, Borås Energi och Miljö, The City of Borås, Renova, E.ON, Njudung Energi, Valmet OY (Finland), RISE, Albany, and Hedared Sand och Betong.

About 20 of the doctoral students are so-called collaborative doctoral students (industrial doctoral students). This means they are funded by a company or organization. Almost all our collaborative doctoral students carry out their research work in the premises of the University of Borås.

The research has resulted in several commercialized products through Waste Refinery in Indonesia, FOV Biogas in India and Mycorena and Millow in Sweden.

The research groups participate in various national networks such as LIGHTer, Bioinnovation, the West Sweden chemical and materials cluster, Treesearch and Textile & Fashion 2030 as well as in international networks such as the European Federation of Biotechnology, Bio-based Industries Consortium, and the International Bioprocessing Association.

## 6. DEVELOPMENT AND STRATEGY

Conducting high-quality research.

- Promote recruitment of postdocs and senior lectures with high reputation and scientific track record.
- Keep the best PhD-students as junior researchers.
- Promote career development for existing researchers.
- Inviting guest-students and guest-researchers to contribute to the research environment.
- Continue to invest in high quality lab equipment.
- Collaborate with researchers at other universities.

Developing the Graduate School

- Develop collaboration with graduate schools at other universities, nationally and internationally.
- Recruit the best Phd-students internationally.
- Increase the number of externally employed doctoral students.
- Develop relevant PhD-courses,

Spreading of knowledge

- Publish in high quality scientific journals.
- Publish results in books, TV, radio, popular press, social media etc.
- Cooperate with companies and other stakeholders to create networks and other collaborations.
- Promote patenting and commercialization of research results.

External financing

- Intensify work on seeking external research funding.
- Working with larger research applications, e.g., European Union and KK-foundation
- Increase the number of externally employed doctoral students.

Marketing

- Increase the marketing of Resource Recovery for external stakeholders together with professional marketers.
- Improve the communication skills of researchers and PhD students.

*Risk and Challenges*

The research area attracts scholars and students from various parts of the world, making it highly international. Thus, the Swedish Migration Agency plays a crucial role in ensuring that the migration process runs fast and smoothly.

The University of Borås (UB) currently lacks an international ranking, which poses a significant hurdle in terms of student recruitment and partnership establishment.

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