

# Slutrapport

## Utvärdering av forskningsområde Resursåtervinning vid Borås Högskola våren 2021

Utvärderingen har gjorts av en bedömagrupp med interna och externa medlemmar. Bedömningarna är baserade på självvärderingar av de fyra forskargrupporna, en samman-ställning av verksamheten gjord av Tomas Wahnström och en utfrågning av doktorander, forskare och forskargrupsledare.

### **Medlemmarna i bedömagruppen är som följer:**

Sakkunnig representant från annat lärosäte, tillika Ordförande för bedömagruppen.

– Prof. Bengt Andersson, Chalmers

Sakkunnig representant från annat lärosäte

– Prof. Marianne Thomsen, Dept. Environmental Science, Århus, Danmark

Sakkunnig representant från professionen/arbetslivet:

– Prof. Thomas Hjertberg, Borealis AB

Forskargrupsledare från annat akademiskt område vid Högskolan i Borås:

– Prof. Jan Nolin, Biblioteks- och informationsvetenskap

Studentrepresentant:

– Emanuel Gunnarsson, doktorand, textilteknologi utsedd av studentkåren i Borås

Sekreterare/handläggare:

– Olof Harbecke (Utbildningsstöd)

## Research Environment

Overall, the Resource Recovery research area 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. The research for all research groups are in fields that have been recognized as areas with high potential. Resource recovery is demanded by the society and the Swedish industry is showing an increased interest.

There is a close cooperation between the research groups and 20% to 80% of the projects are financed from joint research proposals. The group Resource Management with 80% joint projects sense that they are too dependent on the other groups. The group needs a broader and more independent research base. The researchers find the present informal structure for Resource Recovery sufficient and do not wish for a formal structure with an externally appointed area manager, but they seemed positive towards an internal appointed coordinator representative to drive a common strategy.

The PhD-students primarily identify themselves with their research group, but they also sense that they belong to the Resource Recovery area.

The groups have common labs where the equipment is available for all research groups. The PhD-students find it easy to borrow equipment and get help from their fellow PhD-students and technicians on how to handle the equipment. Laboratory technicians are responsible for technical skills development of student as well as maintenance. Regular lab meetings are the backbone for maintaining the labs optimal potential for research activities. There is also good support from IT whenever they have IT problems related to the labs. Some new instruments for material characterization are wished for but, in general, the groups have the necessary experimental equipment and the technical support is good.

The groups are unbalanced in size and financial strengths. Resource Management has only been functioning for 3-4 years and with a professor that has changed his research from a very different field and a young senior researcher (PhD 2018). One new senior researcher will be employed with focus on Life Cycle Analysis (LCA). So far, Resource Management has been very dependent on joint research projects. Polymer technology has only two senior researchers and they have had large administrative and teaching duties. They are now starting three new projects. Combustion and Thermal Processes is a larger group with 4.5 senior researchers and 5 PhD-students. Two of the professors will soon retire and the financial base for the group has been weak. Only Biotechnology is large enough to have sufficient number of senior researchers and a reasonable balance between basic and applied research including financing from VR and Formas.

The researchers are encouraged to apply for external funding and develop their own research fields. There is good support for the younger researchers in how to write research proposals. However, finances for fundamental research are limited and the

smaller groups are very dependent on the base funding from Borås University for basic research. All groups include some fundamental research in their applied projects.

All groups have extensive external collaboration, both with industry and academia. This is an important base for joint research projects and for obtaining new competences into the projects and for supervision of the PhD-students.

#### Gender equality

The groups are a good mixture of men and women with Swedish and non-Swedish background. Most of the PhD-students have non-Swedish background. The younger faculty members are mainly recruited from the PhD-students at Borås University.

The gender equality varies between the research groups but in total the mix is acceptable, but all research leaders are men.

#### Research

The groups within Resource Recovery are very different and has different traditions. All groups are strong in applied research and they address many of the most important fields within resource recovery in Sweden.

Fundamental research is very dependent on the funding and only Biotechnology has obtained a continuous funding of fundamental research. They have much more publications than the other groups and publish more in high impact journals. Polymer Technology has also many publications/scientist but the publications are in more applied journals. The Combustion and Thermal Processes group has a reasonable number of publications. Resource Management are still developing their own profile.

Biotechnology has a very good fundamental base and has been able the change the focus of their applied research as the demand in society change and still publish in high impact journals.

Polymer Technology and Combustion and Thermal Processes have developed very good experimental equipment and methods to also approach new areas. Polymer Technology has good international collaboration that broaden their competence base which may help them into participation in larger international projects. They also plan to more actively use their Swedish network to raise external funding.

Combustion and Thermal Processes has identified that they need more modeling in their research to obtain a more fundamental understanding in their research. They also need more international collaborations both for additional competences and to enable participation in international projects.

Resource Management still has to identify their role within the Resource Recovery research area. So far, this has been difficult since almost all their research is in joint

projects. Their ambition is to cover many areas from behavior science to LCA requires additional staff and extensive external collaboration. It is not clear from their presentations and existing projects if the focus is on consumer behavior or system analysis. However, prospective upscaling from lab to full industrial scale of emerging technologies is needed to support policy and business decision support. Equally important is the part of the research addressing behavioral aspects and support for raising awareness and societal readiness level for a transition into sustainable consumption patterns through acceptance of Resource Recovery products certified and labelled accordingly.

### Collaboration

There is a close cooperation between the research groups within Resource Recovery and 20% to 80% of the projects are financed from joint research proposals. The group Resource Management with 80% joint projects sense that they are too dependent on the other groups. The group wants a broader and more independent research base.

All groups have extensive external collaboration both in joint research projects and due to necessary external competences in ongoing projects. There is a very good use of external supervisors/consultants in existing project to overcome the lack of internal competences in the small research groups

### Exchange between research and education

All master programs include 1 year master thesis work that is closely connected to the ongoing research and all senior researchers teach.

Most PhD-students consider teaching as an advantage, it gives them an extra year and they also learn to communicate their research methodologies, tools and concepts on a fundamental level. For some students that are aiming for an academic career is one year of teaching an extra boost in their CV.

### Development and strategy

The research leaders have no common strategy for Resource Recovery. The research leaders decide, after discussion with the senior researchers, the strategy for each research area. The younger researchers are encouraged to develop their own niche within the general field for their research group.

Most groups only present a wish list of new recruitments and competencies they need. There is no strategy presented for how to obtain more funding or how to use existing resources to reach specific objectives.

All groups are strong in applied research and they need to be recognized by industry for direct financing and for support of their applications for federal funding. Resource Recovery need more visibility and Resource Recovery wish that Borås University should recognize Resource Recovery and give them a profile like The Swedish School of Textile.

The smaller groups are very dependent on Borås University but cannot forecast future support. They wish for a more transparent financing from Borås University including a running five-year plan for support and overhead. Such change would enable a stronger strategy with associated goals for recruitment of the needed skills to strengthen the profile of the Resource Recovery research area

#### Funding

It is difficult to obtain an overview of the financial situation for the different research groups. The rent and all faculty members are financed by Borås University but the faculty members are required to teach and do administrative tasks. It is not clear how much time each researcher has available for research and writhing research applications. Each research group obtain rewards for production of PhD:s and articles. Are there additional funding for projects that are underfinanced e.g. VR and EU projects?

## Recommendations

[Update the objectives for Resource Recovery regularly.](#)

There is no need for a more structured organization of the Centre, but the researchers must have a continuous discussion among themselves and with the University of Borås about the objectives.

*Make “Swedish Centre for Resource Recovery, University of Borås” more visible.*

The group needs projects that are noticed by industry and the media.

- Prospective upscaling from lab to full industrial scale of emerging technologies is needed to support policy and business decision support.
- Research addressing behavioral aspects and support for raising awareness and societal readiness level for a transition into sustainable consumption patterns through acceptance of Resource Recovery products certified and labelled accordingly.

### More contacts with industry from Resource Recovery group.

Several of the individual research groups have very good collaboration with industry but the Resource Recovery Center is not that visible.

- Form a Center for Resource Recovery similar to Center Process Engineering at Chalmers or the national center for multiphase research SIAMUF
  - Provide courses in resource recovery for industry
  - Present the research results from Borås University, invited researchers worldwide as well as from participating industry e.g. twice a year.
  - Use the board of the center as an expert team to identify the research the industry needs 3-5 years into the future.
  - Make seminars, Master thesis and PhD presentations available on Zoom
- Use more adjunct professors.
- Involve the engineers at the collaborating industry as assistant supervisors and involve them in writing articles.
- Make your equipment available for industry.

### Build a global research network.

- Make it possible for 6-12 months sabbatical leave for the researchers. With the salary paid by Borås University they are welcome to spend some time at the top research groups worldwide. They will come home with new knowledge and a very valuable research network.
- Use more post docs. They will provide new knowledge and a network with the research group that they graduated from.

### Increase the communication skills of the PhD-students and post docs.

- The joint seminars within the center and with industry will be more valuable for the audience when the students are aware of how the non-experts can gain from the presentations.

### Assessment of research (groups) in Resource Recovery, University of Borås

The self-reports give a good introduction into the research objectives and organization of each research group. However, some issues are not reported in the self-reports and clearer instructions on the expectations of the reports may improve the self-reports in the future.

1. First of all, the quality of the self-reports are not completely satisfactory. In general, they tend to describe only positive aspects. Truly little of weaknesses are included.
2. Only one of the groups has written something about one of the criteria, connection education – research.
3. When it comes to gender equality all groups are only mentioning the numerical. Nothing is said, e.g. about what is done to present role models for young female researchers.
4. All groups have presented plans for their development and strategy, in some cases these are quite ambitious. However, in general there are few details about what should be done to reach such high goals.
5. There are obviously some collaborations between the groups although mainly related to specific projects. It is difficult to estimate the distribution of resources to the different researchers in the joint projects.
6. The financial figures given to the assessment group cannot be used seriously. Obviously, the figures only describe the funds that comes to the groups. We have understood that the rent and a lot of the positions are financed by the university. This means that it is difficult to get a good picture of the financial evolution. We leave it to University of Borås to evaluate productivity of the Centre in relation to the support from the University of Borås.

## Resource Management

### *Research environment*

This group is quite small, today 1 professor, 1 senior lecturer and 4 PhD students. The PI, Kim Bolton, worked earlier with computational chemistry but changed direction forming the Research management group in 2015. The senior lecturer, Kamran Rousta, defended his thesis in 2018.

The direction of the group involves the interface between social actors, e.g. households, retailers, primary production and schools and the technical waste management system. The ultimate goal is to design interventions that would both reduce and improve management of waste for better resource usage in society.

The group uses a number of different techniques, e.g. pick analysis, Life Cycle Analysis (LCA), economic analysis, and interviews and questionnaires that enable an interdisciplinary approach. Frequently, these methods are included in the *recycling behaviour transition* (RBT) procedure developed in the group to identify interventions (innovations) that can lead to reduction and the improved sorting of waste.

At present the group does not have all competences that are needed for the research outlined above. To compensate for this the group has close cooperation with three senior researchers: Dr. Greta Häggblom from the University of Gothenburg (GU), Ph.D., Mattias Eriksson from the Swedish University of Agricultural Sciences (SLU,) and Mohammad Razzaghi from the University of Art, Tehran. They act as assistant supervisors for the PhD students. It can be concluded that the group is functional as a unit for the education of PhD students.

Due to the nature of the work the group does not need experimental resources but are strongly dependant on computational tools for LCA.

The ongoing projects give a good indication of the research profile

- The Role of Packaging Design to Reduce the Total Amount of Packaging Waste.
- Waste Prevention and Valorization Assessment within Life Cycle Analysis (LCA).
- Recycling bread – an occupational perspective on fermenting leftover bread.
- Waste-repurposed foods: public views and biotechnological perspective of using food waste to produce food.

### *Research – productivity and quality*

Being a quite new group, the total productivity is not large. One PhD thesis has been produced but two more are expected this year. The total number of publications 2015 – 2020 within the research theme of the group is 21. Although the number might seem small it is acceptable considering that the group only had one PI for the first 4 years.

The papers have been published in respected journals in the field, e.g. Recycling, Waste management and Sustainability, among others. It can also be noted that



cooperation with other groups has led to papers in journals outside the “waste management” field.

Kim Bolton has published many papers that are cited. However, the majority of these originates from his earlier research area, computational chemistry. For the papers related to waste management the number of citations is not too high. The papers supplied for judgement can all be said to be of good quality. In conclusion it can be stated that the research is of good quality although the output so far is limited, mainly due to the size and the short lifetime of the group.

#### *Collaboration*

The collaborations with GU, SLU and University of Art, Teheran, have already been mentioned. They are essential as they contribute with competences that are missing in the group.

In the self-report a project concerning wood waste in Sao Paolo, Brazil funded by Naturvårdsverket was mentioned. There is also some cooperation with other groups at the University of Borås. These include Biotechnology and Civil Engineering but seem to be limited to specific projects.

#### *Connection education – research*

In the self-report a good interaction between the research in the group and education is described. Research results are used in LCA courses and in a Master level course in Resource recovery. Likewise, the research is benefiting from work done by master students in their thesis work. The exposure of the group in education has also led to recruitments as project employee and as PhD students.

#### *Development & strategy*

The overall strategy of the group is stated that it should be an independent, internationally known and sought-after group with Resource Recovery. Realizing that the group is small a defined sub-goal is to expand from four to six PhD students, one more senior researcher and a post-doc by 2023. To finance this expansion the group aims to send in at least three applications each year. It is, indeed, necessary to expand the group as a pre-requisite for reaching the overall goal. However, the description does not point to a clear pathway on how to do this.

#### *Conclusions and Recommendations*

The group should expand to become an important player in the field. This would include more senior researchers encompassing a broader competence profile e.g. LCA. Behavioural science is a large part of the research and this competence may be

included as part time employed by the group. A full time employment may be an odd person in the group and limit his/her competence development.

Apart from creating a more complete research environment it would make the group less vulnerable to changes in staffing and create better opportunities for attracting research funds. The research topic in this group is not standard academic topics and the group cannot wait for research calls from traditional financiers. The group has already identified a need for creating a demand for their competences by becoming more visible. Increasing the size of the group would, of course, yield increased visibility. Another way would be to cooperate with other groups working with different technical issues and apply the tools of the Resource Management group to those issues. The group will be more visible to industry if they can provide prospective upscaling from lab to full industrial scale of emerging technologies to support policy and business decision.

In the self-report it is stressed that the group has a clear wish to extend the cooperation within the university, also including other groups, e.g. within the textile area. This is something the reviewers strongly recommend.

## Polymer technology

### *Research environment*

At present the group includes two senior researchers, two post-docs and six PhD students. In addition, there are five “department external members” whereof two are engaged as assistant supervisors. This is a clear change compared to the situation two to three years ago. Due to administrative/leadership position the two senior researchers spent less time on research 2015 - 2018 and at a time there was even no PhD student in the group. From 2019 the research activities have been restarted, after a relaunch of more systematic research activities and planning during 2018. This involved recruitment of PhD students and postdocs, and reorganisation of the lab facilities including improvement of lab equipment.

Research has so far focused on:

- Recycling, re-use and biodegradation of polymeric materials
- Synthesis and processing of bio-based thermosets for use in fibre composites
- Processing and functionalisation of bio-based thermoplastics
- Manufacture of natural fibre composites for structural applications.
- Manufacture and functionalisation of polymer fibres for smart textiles
- Processing of polymeric materials by additive manufacturing (3D printing)

The two senior researcher cover most of the competences needed but the groups also has close cooperation with other groups including people acting as assistant supervisors, e.g. at University of Portsmouth (prof. Hom Dhakal) and Department of Textile Technology (prof. Nawar Kadi and senior lecturer Lena Berglin).

The lab resources include equipment for polymer processing, sample preparation, fibre filament spinning, thermoset resin processing as well as equipment for the characterisation of polymers (DSC, TGA, DMTA, FT-IR spectrometer). In 2019, an investment was made using the Faculty’s own resources (A1) into new equipment for the extrusion and injection moulding of polymer materials on a larger scale.

### *Research – productivity and quality*

Since 2009 the group has produced ten PhD theses and one more is expected in 2021. The total number of publications 2015 – 2020 is quite high, 74. Partly, this has been made possible by the active cooperation with other groups. The papers have been published in international journals. Considering the applied nature of the research these are not among the highest ranking journals. The senior researchers have published relatively many papers having a decent number of citations.

The papers included for judgement show that the research is conducted with relevant techniques to obtain samples to study and that proper analytical methods are applied to investigate their properties. It is also clear that the work is of a more or less experimental nature.

### *Collaboration*

The Polymer Technology group has an extensive network, both national and international. This has indeed been a contributing factor to the large number of papers and conference proceedings. These interactions include both direct research cooperation and membership in knowledge networks.

Apart from the more academic contacts the group also has many industrial contacts. In one way, this is natural considering the applied nature of the research in the group. However, this has not led to substantial grants from companies as can be judged from the financial records (summary of external funding).

Within the university the group has close collaboration with the Biotechnology group and the Department of Textile Technology. As a surprise it can be noted that the interaction with Chalmers and RISE, which both have substantial polymer activities, is limited.

### *Connection education – research*

Surprisingly, the self-report does not include any information on this issue.

### *Development & strategy*

The overall goal of the Polymer Technology goal is ambitious: The goal for the polymer research group is to within 3 years be a significant academic research player in Sweden that contributes to a more sustainable society by developing polymer materials so that they are adapted to the circular economy.

In the self-report they stated that the size of the group, two senior researchers, 2 post-docs and six PhD students, should be constant. They have identified that they need a few larger research grants (2-3MSEK) to reach their objective but also indicate that it is difficult to write more applications due to the teaching duties.

### *Conclusions and Recommendations*

The amount and nature of collaboration of this group is excellent and should be continued and contacts with Chalmers and RISE should be extended. The group has a good structure with both senior researchers and post-docs. From a long-term perspective more senior researchers would be an advantage, but this is to a large part compensated with the structure of department's external members and the interaction of other external supervisors. After the upgrade in 2019 the experimental resources are adequate although additional capacities always can be added.

In conclusion it can be stated that the research done in this group is of good quality based on thorough experimental work. The large number of cooperation's has

contributed to the extensive number of papers as well as to the international visibility of the group. For the future, it is recommended that the group also include modelling as an additional tool, either by cooperation or by including that competence in the group.

## Combustion and Thermal Processes

### *Research environment*

At present the group involves five senior researchers, whereof one is shared with the biotechnology group, and four PhD students (one is starting, and one will graduate 2021). Two of the senior researchers will go into retirement within five years. One of these, Lars Åmand, is active as assistant supervisor for several of the PhD students.

The group conducts research primarily linked to thermal processes for waste treatment. It includes fundamental studies at the molecular level through computer calculations and laboratory studies. In addition, full-scale trials and modelling of reactivity, system effects and management, reprocessing and recycling of residue materials such as ash and gasification residues are carried out.

The present projects are:

- Recovery of phosphorus from sewage sludge ashes.
- Developing a general model for pyrolysis oil production mechanics.
- Development of a kinetic model for optimization of waste/biomass pyrolysis.
- Pyrolysis of sewage sludge to remove heavy metals and recover phosphorous

One more project will start 2021.

At present the group has the competences it considers necessary, as well as the supervisor capacity needed. The group has several specially made high temperature equipment. The most recent addition is a conversion of a rotary kiln to enable continuous feeding of pellets and handling of formed pyrolysis gases. Initial use is sludge pyrolysis to recover phosphorous. In addition, there are three different TGA units, ranging from small (mg level) to larger (g level) scale, and possibilities of handling pressurized conditions as well as steam atmosphere. There is a Py-GC/MS/FID for very rapid heating rates together with direct analysis of produced gases, an AAS for inorganic species analysis, and a MP-AES shared with the Biotechnology group.

### *Research – productivity and quality*

Since 2015 the group has produced 4 PhD thesis and one more is expected 2021. For the period 2015 – 2020 the group has listed 27 publications (one as conference proceeding), a normal figure for a group of this size. It can be noted that a few of the papers do not concern the core theme of the group but rather the Biotechnology group.

The papers are published in international journals. Looking at the number of publications and citations in particular, it can be noted that the most cited researchers will retire within short.

In conclusion, it can be stated that the research in the group is based on thorough experimental work that also includes a more fundamental approach. In some papers modelling is introduced.

#### *Collaboration*

The group has several different collaborations both within academia and with institutes, organisations, and companies. In Sweden these include RISE, Chalmers, KTH, Borås Energi och Miljö AB, Renova, Energiforsk, E.ON, UMU, Njudung Energi and Re:Source. Some interactions has also started with the forestry industry, so far in smaller projects.

In the self-report it is also mentioned that the group has several international collaborations and have had postdocs and guest researchers from Brazil, Nigeria, Finland, and Iran. However, no specifics of these collaborations are mentioned.

Within the university there is a clear collaboration with the Biotechnology group involving a senior researcher and a PhD student.

#### *Connection education – research*

Surprisingly, the self-report does not include any information on this issue. However, the publications include one paper with this title: *A conceptual model of how research can influence student development; / Connecting Higher Education*

#### *Development & strategy*

The group has not presented a strategy to develop toward a defined goal. Instead the direction of the research is discussed:

*The strategy is to uphold a competence within mechanistic understanding of the phenomenon during thermal treatment of waste materials (mainly organic structures) in combination with post treatment to system analysis. Up until now, much of the focus has been on the fundamental understand but it is directed towards a more product and process oriented phase. Development and analysis of new processes (either as new raw material or new products) will be important.*

In addition, it has also been stated that the group must grow in size. The number of PhD students should grow from the present 4 to 5 – 10 and there should be 1 – 2 post-docs. This is also expected to increase the number of publications from the present level of less than 4 per year to at least 10 per year.

#### *Conclusions and Recommendations*

It can be concluded that the group is a well-functioning research unit with enough supervisor capacity for the present situation. There are few other groups in Sweden that perform similar type of basic research in this relevant area and the group has a

well-equipped laboratory environment with some unique set-ups. However, with respect to the upcoming retirements planning for new recruitments should start now. Their ambition to include ash chemistry into their field should be encouraged. The ash contains many valuable products and toxic compounds that must be removed before the ash can be used as land fill. If their application to KK for a guest professor is not approved, they should make it possible for one of the younger researchers to visit one of the leading academic research groups for an extended stay (6-12 months). This will add new networks and competences to the group and boost the CV for the researcher. With the ambition to include fundamental research in the projects, the group would also benefit from more post-docs and fewer PhD-students.

Based on the presented material it is difficult to judge the extent and quality of the collaborations. There are joint publications with academic institutions in Sweden but no external co-supervisors from academia or industry are listed. It is recommended that the external scientists should be more involved in the research projects. An adjunct professor from industry can provide ideas for new research areas and open for more industry financed projects.

The increase in the number of PhD students is ambitious. But it must also be combined with a clear strategy to recruit more senior researchers, especially considering the upcoming retirements. The success will also depend on the funding situation. The presented material is difficult to penetrate in a clear way but the tendency in funding cannot be said to support an increase to 10 PhD students.



## Biotechnology

### *Research environment*

At present the group consists of 7 senior researchers, 2 post-docs and 16 PhD students. One of the seniors is shared with the Combusting and Thermal Processes group, 2 PhD students with Polymer Technology, 2 PhD students with Resource Management and 1 PhD student with Textile Technology. In addition, there is a constant stream of guest researchers at different levels.

The Biotechnology research group originally worked with research in fermentation for ethanol production from ligno-cellulose. In order to establish a unique niche in Sweden, the research has been further developed towards "bioprocesses" to convert organic waste and residual matter into valuable products such as biofuel, biopolymers, animal feedstock, and even food. The aim is to create various bioeconomic innovations to contribute to a sustainable society.

When discussing the need of competences, the self-report does not mention specific needs. Instead, it discusses the need/wish to expand the size of the group (see below). The group is very well equipped with experimental resources. This includes different types of bioreactors of different sizes, analytical instruments, and equipment for separation and post- and pre-treatment.

In conclusion it can be stated that this is a group that has an exceptionally good research environment. Apart from the relatively large group of senior researchers the in-flux of guest researchers ensure that there can be a fruitful research climate. The group has also a structured way to deal with career development.

### *Research – productivity and quality*

This group started 2004 and expanded until it reached its present level ca six years ago. It has been very productive with 29 PhD thesis since 2010. Also, the number of publications is impressive, the group has listed 178 papers in the period 2015 – 2020. There are a few conference proceedings and some book chapters.

The papers have been published in international journals. The group leader, prof. Mohammad Taherzadeh, has published 320+ papers that are cited a lot leading to an excellent h-index, 67. Also the other senior researchers have published many papers that are cited frequently considering their level of seniority.

Of the five papers sent in for judgement two were critical reviews while the three others were original research papers. They are all of a high standard showing that this group performs excellent research, and that the senior researchers have an exceptionally good overview of the research field.

In conclusion it can be stated that the research of this group is excellent, both in terms of quality and productivity.

### *Collaboration*

The group has developed exceptionally good collaborations with universities and research institutes in Sweden and abroad including many companies. In Sweden, the group has developed strategic collaborations with Lantmännen and also FOV Fabrics AB to develop two concepts regarding fungi and textile reactors. Both concepts are approaching commercialisation.

There are several ongoing collaborations with universities and institutes in Sweden, e.g. Chalmers, KTH, Linnaeus University, RISE and SLU. The contact with universities abroad encompasses France, Spain, Portugal, Finland, Norway, Belgium, Indonesia, China, Turkey, and Iran. One measure of the international visibility of the group is the high number of visiting PhD students, 23 in the period 2014 – 2020.

The high number of collaborations and visiting PhD students is a clear indication that the group has reached a high international status.

### *Connection education – research*

Surprisingly, the self-report does not include any information on this issue.

### *Development & strategy*

In the self-report the group stresses some scientific research niches, where the group aims to remain or become a leader in Sweden within five years in:

- Fermentation with filamentous fungi
- Membrane bioreactors for the production of various products
- Innovative food and feed
- Development of biopolymers, bioplastics and biotextiles

Apart from this a highlighted goal is to expand the size of the groups; senior researchers from 7 to 8 – 9, post-docs from 2 to 5, and PhD students from 16 to 20. Coupled to this a goal of increased publication has been set from ca 30 to 40 – 50 publications per year.

In addition, the group plans to be active when it comes to outreach with public seminars, websites, public and social media.

It can be noted that the group has done several changes with respect to changing the direction of the research. Had it stayed with the original theme, fermentation for cellulose ethanol production, it would have been less relevant today. The changes done have ensured that it has stayed or even become more relevant.

The planned expansion in size looks reasonable at first hand but must be matched with increased funding as well, which mainly means external funding. As written in the self-report the level of external funding has been more or less constant, 5 – 6 MSEK/year for more than

10 years. To increase the staff as planned the group would have to increase the funding with at least 5 MSEK/year which could be challenging.

#### *Conclusions and Recommendations*

The Biotechnology group have created an exceptionally good research environment and are one of the leading groups in bioprocess engineering in Sweden and well recognized internationally. They have a very good production of PhD's and an outstanding production of articles.

The new focus of the Biotechnology with animal and human food as well as biofibres are well within the objectives for a sustainable future. A system approach ranging from LCA to consumer acceptance as well as use of biofibres and treatment of the waste from the bioprocesses are already in place. The group could gain from a larger visibility of the Resource Recovery Centre as such.

## SWOT analysis of unit of assessment Resource Recovery [2021-05-17]

## Strengths

- All groups perform very good applied research.
- The research is in very relevant research areas today and the expectation is that these areas will be even more important in the future.
- The groups have a good organization of the infrastructure with shared equipment and technicians.
- The Centre has an informal way of collaboration and way for joint research applications.
- The groups have many interactions with local community and companies and extensive possibilities to expand joint research with industry.
- The trade name “Swedish Centre for Resource Recovery, University of Borås”, used in all articles and presentations is recognized internationally, leads to many visitors and guest researchers.
- The groups have many joint projects with research groups outside Sweden.

## Weakness

- Resource Recovery should gain from more visibility, but they have no common strategy for outreach.
- The researchers view is that the research area Resource Recovery is not recognized by the University of Borås as an area for future development.
- Unbalanced size and financial strengths between the groups.
  - Only Biotechnology is large enough to have a reasonable balance between fundamental and applied research.
  - The research groups Polymer Technology & Combustion and Thermal Processes are too small.
  - Resource Management is subcritical in size.
- The limited resources for fundamental research introduce a barrier for groundbreaking research and hence the University of Borås as a key player within the global scientific community in resource recovery. This limitation leads to:
  - Limiting the research areas to the traditional.
  - Makes it very difficult for the smaller groups to obtain external funding for basic research.
  - It is difficult to obtain a longer time period free from teaching and it is not possible to take a sabbatical leave for a few months or a year.
  - Post docs are only used to a limited extent to include new competences into the research groups. Post docs are important for building international networks.

- The bulk of Swedish industry has not yet recognized the need for Resource Recovery.
- It is very difficult to find support for joint projects when the research groups are from the same university which underlines the importance of internal funding for in-house interdisciplinary skills development.
- The attendance in common seminars with Resource Recovery is limited. This is to a large extent due to limited training for the PhD students to present their material to non-experts in their field.

#### Opportunities

- Their research areas have a very strong societal pull with an increasing demand from the society.
- Increased political pressure to reach climate neutral production and sustainable consumption will increase public funding.
- Legislation may pave the way in a positive direction for this research area, especially for recycling. Recycling of textile is a research area that will increase when the new legislation for textile recycling is in place.
- Increased pressure on industry to contribute to environmental restoration and climate change mitigation will increase the collaboration between universities and industry.
- The surrounding industry of University of Borås may constitute an opportunity for showcasing local research and industrial innovation demonstration activities attractive for industrial marketing strategies as well as RR demonstration hub opening up opportunities for attracting international networks and future international project funding.

#### Threats

- Knowledge is international and many new groups internationally will go into this research area shortly, resulting in an increased competition.
- The Resource Management group is sub-critical and may disappear – the holistic possibilities will be gone.
- International companies in recycling are established in Sweden and the processes are developed outside Sweden.
- Basic funding is based on the number of students and the present decrease in number of students will reduce the funding.
- Not enough funding for basic research.
- Too few Swedish companies are active in recycling.