Mittuniversitetet
MID SWEDEN UNIVERSITY

Progress Report 2022

Transformative Technologies

Mid Sweden University in partnership with

Knowledge Foundation

Progress Report 2022
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Photo: Olle Melkerhed

Executive Summary

Reported here are the results of the development during 2021 in the Research Environment of Transformative Technologies (TransTech) at Mid Sweden University. The process is supported by the Knowledge Foundation and aims at building a strong research profile for the university in line with the regional vision *Transforming the Industrial Ecosystem* (*TIE Vision*).

The reporting period completes the implementation of the 4-Year Plan 2018–2021. In the beginning of 2021, we had already fulfilled six of the nine 4-Year Goals, including the high-priority goals of <u>*Higher scientific ambition*</u> and <u>*International projects*</u> of the 4-Year Plan. In the Work Plan 2021, we put emphasis on <u>*National programs*</u>, which was the third high-priority goal of the 4-Year Plan, as well as on <u>*Support to individuals and teams*</u> (professor recruitments) and <u>*Funding*</u> where new challenges had arisen during autumn 2020. We made good progress last year in these areas although we did not reach all our goals:

- Our schedule for two national collaboration programs and one excellence centre by 2021 was too ambitious but the goal itself is fully realistic when we have run **NIIT** and **NeoPulp** for a while.
- Out of the planned professor recruitments, one should be ready before summer while we postponed the other two and instead recruited assistant professors to avoid delays in projects.
- For 2022 funding, we submitted a record number of applications and reached 92% of our target despite reduced research volume in important industry sectors.

A systematic comparison with our starting point in 2012 is outside the scope of this report, but even a brief glance on our first Work Plans makes it clear that the ten-year development period that now ends has radically strengthened our research and education programs, quality processes and ways of working.

The next steps in our development will be guided by the Transformative Technologies Strategy 2022-2024. When preparing it, we made use of the conclusions reported here.

Contents

1. Introduction

Reported here are the development results achieved by the end of 2021 in the Research Environment of Transformative Technologies (TransTech) at Mid Sweden University (MIUN). The work done last year concluded the 10-year long program of a Knowledge and Competence Centre at MIUN that was supported by the Knowledge Foundation and aimed at a strong research profile for the university in line with the regional vision *Transforming the Industrial Ecosystem (TIE Vision)*. The common annual Indicators of all Knowledge and Competence Centres (according to Appendix D in KKS Guidelines) are embedded in Tables 2–5. The values of all indicators are in a separate Appendix E.

The overall plan for the last program period was presented in the 4-Year Plan 2018–2021 and its implementation in Work Plan 2021. In this report we will compare our results to these plans. The development status of capabilities is presented in Chapter 4. Our plans for the continuation of TransTech's development are described in the separate Strategy 2022-2024.

Please note that we write **Research Actions** in bold, key concepts with Capital Initials, and goals with *italics and underlining*. We use the following acronyms for the Strategic Actions:

- **EISS** = Embedded Industrial Sensor Systems, especially connecting sensors to the Internet of Things
- **InFibra** = Integrating new technology in Fibre materials, especially industrial manufacturing
- **KM2** = "square kilometres", developing large surfaces and power electronics for green electricity
- **XGeMS** = Next Generation Measurement Systems, especially to support **EISS** and **InFibra**

Please also note that although we in the beginning of 2022 started to use **NIIT** and **NeoPulp** instead of **EISS** and **InFibra**, in this Progress Report we still employ the latter acronyms.

2. Development work in 2021

Implementation of Work Plan 2021

Last year we continued the development of TransTech according to the Work Plan 2021. Among other things, the Work Plan specified a number of important actions, shown in Table 1 (next page). These actions were performed during 2021, and in most cases (those indicated by green in Table 1) the goals were achieved. Funding and Personnel (senior recruitments) were the two areas where we could not fully reach our goals but nevertheless could improve our operations. We return to this in Chapter 3 where all the results of 2021 are presented. In their statement about the Work Plan in December 2020, the Expert Group had also noted that we must have plans on how to handle the any effects of possible delays in recruitments on proposed or already running projects. This risk was the greatest in senior AI-competence. Having made two attempts, first to hire two professors and then two associate professors in the area, we decided instead to hire three assistant professors to get projects in **EISS** and **XGeMS** going. The professor recruitments in **InFibra** and **KM2** were not time critical. The senior level capacity of **KM2** decreased unexpectedly last summer when the research leader became seriously ill, but his colleagues have done a very good job handling all his operational responsibilities. However, strategic developments in **KM2**, such as the professor recruitment, were put on hold.

Table 1: *Main development actions from Work Plan 2021 and the results obtained in 2021, green indicating good fulfilment of the goals.*

Development action	Goals and Results	Comments
InFibra: Establish **NeoPulp** and prepare further collaboration with SLU	Goal: 2 projects running in August 2021. Result: 3 projects in Nov 2021 Goals: First meeting of Scientific Advisory Board *and* planning with SLU start in 2021. Result: Planning with UEF (Guest Prof. Haapala) instead of SLU started March 2022. SAB postponed to October 2022.	Focus has been on project planning with companies. SAB after the new professor starts.
InFibra: Higher production	Goal: 45 papers submitted in 2021. Result: 50 papers published in 2021	
EISS: Vinnova Competence Centre application	Result: Prestudy for large national initiatives started in Nov 2021 with a large consortium of companies, Luleå Technical University and RISE.	Good collaboration with LTU has started
XGeMS: Project applications with Swedish universities	Result: Three new collaborative projects approved in 2021	
Personnel: Follow plan for senior (professor & assoc. professor) recruitments	Goal: 3 new prof or assoc. prof appointed by the end of 2022. Result: - Professor (Mechanical Eng.) to **InFibra** in progress, on schedule - Associate professor (AI) to **XGeMS** delayed to 2023 - Professor (Material Science) to **KM2** will be reconsidered in 2022	We will aim for other recruitments rather than full professors
Funding: Secure funding for 2022 in parallel with good production	Goal 120 MSEK in funding for 2022. Results: 103 applications during 2021 and 111 MSEK of funding granted by March 2022.	We have an efficient process for applications
KM2: Large companies and RISE as partners	Goal: Project applications with two large companies and RISE. Results: HÖG applications with Kubal and Nouryon, and coating infrastructure in planning with RISE	Collaboration with Kubal is at risk because of the war in Ukraine
TransTech after KK Environment	Result: TransTech became a KK Strategic Environment in March 2022	

Important management decisions during 2021

- MIUN decided to continue to develop TransTech after 2021 using the Quality System and in collaboration with the Knowledge Foundation.
- NMT Faculty decided to prepare a new organisation as of 2023 for better efficiency and transparency.
- TransTech's management invited the Additive Manufacturing (AM) group of the Sports Tech Research Centre to join TransTech starting 2022.

Quality System and Management Structure

The focus in the Quality System during 2021 was in the Strategic Process of preparing for the next stage of TransTech's development from 2022 forward. Discussions and planning the role of the Additive Manufacturing (AM) group within TransTech took place throughout the autumn of 2021. We also started to set up all the components of TransTech's Quality System for the AM group. This is nontrivial because the group is located in Östersund, however, this makes TransTech relevant for the entire mid-Sweden region and increases its importance for the university.

A valuable extra input to the Strategy Process was ARC21 evaluation of all MIUN Research Centres. We received the external reviewers' recommendations in November 2021, which helped us to refresh our development goals and consolidate them in a new set of main priorities in TransTech's Strategy 2022–2024.

In the Quality Assurance Process, we adapted the Quality System for new KK project applications to match the Knowledge Foundation's the regular biannual calls. This meant a new annual schedule and slightly reduced timing of some parts of the process. In other respects, the Quality Assurance System continues to meet its purpose of ensuring the quality of our research projects well.

In the Reporting Process we revised the list of indicators so that it matches our new Strategy.

Regarding TransTech's management, the revision of the Faculty organisation is in part motivated by the need to improve synergies and coordination between the line organisation (Departments) and Research Centres (and TransTech).

Status in Industrial graduate schools

The status reports of **FORIC/FORIC+** and **Smart industry** are found in Appendix B and C, respectively.

Changes and deviations in ongoing projects

As requested by project managers and after discussion and review within the management group regarding conditions and how the changes would affect the Research Groups, the management group of TransTech has approved the following changes in projects funded by the Knowledge Foundation:

- **CELLREC, registration no. KKS 20180176**: six-month extension of the project until 2023-12-31 due to delayed appointment of the position and workload in terms of teaching.
- **RECCHE, registration no. KKS 20180175**: extension of the project by six months until 2023-12-31 due to delayed appointment of the position and additional unplanned assignments.
- **MILANESE, registration no. KKS 20200186**: change of start date from 2021-10-01 to 2022-10-01 and thus a change of end date to 2026-09-30. Changes made due to late drop-out of suitable candidate and restart of the recruitment process.
- **LEEDS, registration no. KKS 20200177**: change of start date from 2021-09-01 to 2023-01-01 and thus a change of end date to 2026-12-31. Same reason as above: changes made due to late drop-out of suitable candidate and restart of the recruitment process.
- **FORIC and FORIC+, registration no. 20130319 and 20160260**: extension of the FORIC project until 2022-05-31, transfer of funds from FORIC to FORIC+ and new admission of doctoral students. All changes have been made after discussion with and approval from the Knowledge Foundation.
- **NeoPulp, registration no. KKS 20210009**: Change of business partner, Kvarnsveden paper mill is replaced by Hylte mill. The change does not affect the project.

3. Results and discussion

This section reports the progress made during 2021, the fulfilment of the goals of our 4-Year Plan 2018–2021 and the conclusions that we used in the preparation of TransTech's Strategy 2022–24. The plans and goals of the new Strategy are not repeated here. Table 2 (next page) summarises the following discussion of the results and conclusions for each of the nine 4-Year Goals. Among them, the 4-Year Plan placed at the highest priority to achieve the following three goals by the end of 2021:

- *National programs*: Gain influence through two large national collaboration projects and one national excellence centre
- *Higher scientific ambition*: Achieve an aggregated H-Index 25 and council funding of SEK 5 million per year
- *International projects*: Grow to an international volume of SEK 8 million and 10 international guest professors each year

As we will describe below (see TransTech's profile), the first goal remained unfulfilled whereas results were good in the other two.

Table 2. *Summary of the fulfilment of our goals set in the 4-Year Plan 2018–2021 and conclusions for the Strategy 2022–2024. In the green areas we reached the goals, but in the white areas only partially.*

4-Year Goals and target values	Goal fulfilment at the end of 2021	Conclusions for Strategy 2022–2024
Higher scientific ambition - Impact, H = 25 - Council funding 5 MSEK per year - Production 160 papers per year	Good results except for council funding: - Impact, H = 31 - Council funding 1.1 MSEK - Production 256 papers	For progress also in council funding: - Keep up application numbers - Increase academic collaborations - Support exciting new scientific opportunities for impact and renewal
National collaboration programs - 2 large collaboration programs - 1 academic excellence centre	Goals not reached despite two Competence Centre applications/initiatives and two Excellence Centre applications in 2018–21.	Stronger foundation with academic collaborations and track record of **NIIT** and **NeoPulp**.
Profiling of research - Each Strategic Action has a large project for a clear scientific identity	Good results in 3 out of 4 Strategic Actions: **NIIT** in **EISS**, **NeoPulp** in **InFibra**, and **STORE** (= KK Synergy) in **KM2**	Update plans for **KM2** and **XGeMS**
International projects - Volume 8 MSEK per year - 10 guest professors, 2 per Strategic Action	Good results, except international funding: - Volume 6 MSEK - 15 guest profs, at least 2 per Strat. Action	More support from guest professors to early-career researchers and dynamic academic environment
Industry networks and co-production - Large projects with companies in each Strategic Action - 70% of industry collaborations within Edge	Good results: - Large projects in all Strategic Actions - 92% of project volume within Edge	- Engage strong companies also in **KM2** and **XGeMS.** - Monitoring of Core-Edge is no longer useful.
Collaboration with institutes - Strong regional innovation structures - Many projects with institutes - 12 adjunct professors	Good results: - Good structures for regional collaboration - 18 projects with RISE - 8 adjunct profs	Expect growth in joint projects and publications
Individuals & teams - Recruit 5 new profs/assoc. profs 2018–21 - Support junior researchers in career progress - Support senior researchers in large projects	Mixed results: - Good progress with support (see below) - No new professors or assoc. professors	- More dynamic academic environment - New organisation —> better operations - Shift recruitment focus to assoc. profs
Synergy of education and research - Increased research – education benefits - New connections research – education - Better competence support to industry	Good results: - 4 MSc programs connected to the 4 Strategic Actions will be in place in 2022 - Expert Competence Stage 2 in 2022	Continue to develop new MSc programs and Expert competence activities
Funding (discussed in Chapter 5) - Balanced funding profile in Strategic Actions - 120 MSEK p.a. total funding, in-kind excluded	Reasonably good results: - Better balance: ERDF's share smaller - 111 MSEK for 2022 granted by now	- Broader relevance for industry & region - More applications to non-KKS foundations

Scientific production: Strong progress continued during 2021

One of our three main goals in the 4-Year Plan was *Higher scientific ambition*. We especially focused on following (1) publication volume, (2) scientific impact, and (3) funding from research councils and other highly-competed sources. We knew from the beginning that the last one (3) posed the biggest challenge. We did not win any new council projects in 2020 or 2021, despite many applications (15 last year). The outlook is that these strong efforts are bound to result in new council projects. We will additionally improve our chances through new academic collaborations and exciting new opportunities that may give high scientific impact and renew our research program.

In contrast to competitive funding, our scientific production continued to improve last year, cf. Table 3 and Fig. 1, and we surpassed our goals for 2021. The publication volume continued to grow even though the person-years in research (FTE) decreased. This was possible because of the help and contributions of the growing numbers of guest professors. From now on, we will include only papers with MIUN as affiliation so that the publication volume more accurately reflects the efforts of our full-time researchers.

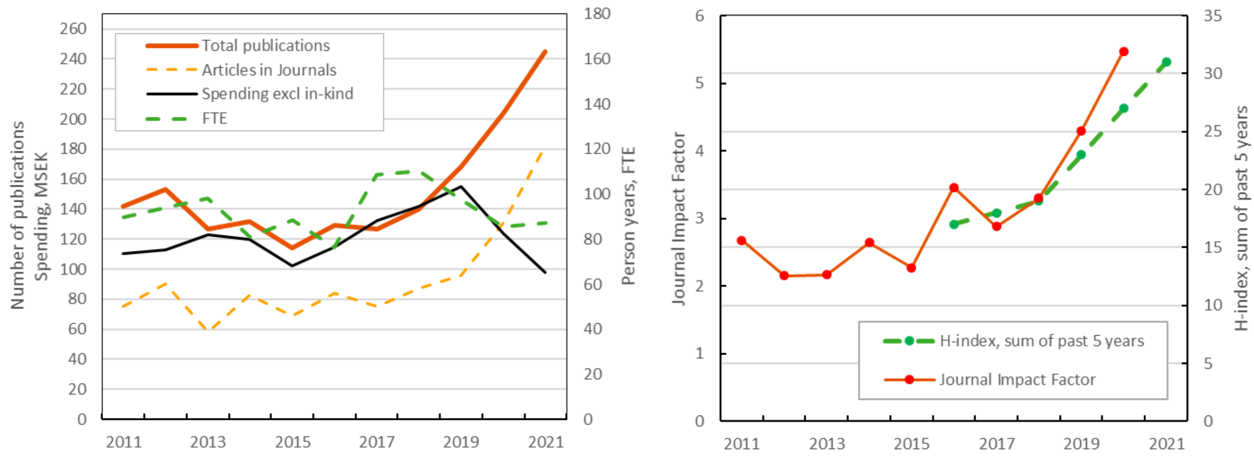

Figure 1: *On the left, the number of publications of TransTech, research spending, and person-years in research (= FTE). On the right, the Journal Impact Factor and H-index of the publications produced by TransTech. For each year, the H-index comes from the papers we published that year and the four preceding years.*

In addition to publication volume, a number of other indicators of our scientific production also show good results (Table 3 and Fig. 1). For the H-index our goal was 25 by 2021, but the final result by the end of last year was H = 31. These 31 publications are given in Appendix A. Thirteen of them are from 2017 and will therefore be excluded from the next listing. In comparison, last year the list included eleven publications from 2016. They were compensated by fourteen new publications in the list this year. We should thus be able to roughly maintain the current level of H = ca. 30 and any further increase would signify extra strong performance. Also, the Journal Impact Factor and the share of papers published in journals (rather than at conferences) continued to increase. In addition to the indicators in Table 3, CiteScore qualitatively follows the same curve as the Journal Impact Factor. SNIP reached a value of 1.62 and SJR 1.4 (both highest values since 2011), the share of publications in Web of Science remained at 69% and that of Scopus increased to 93%. SNIP was 1.51 and SJR 1.15. Our conclusion is that this will be enough to follow three indicators H-index, Journal Impact Factor and publication volume.

Table 3. *Number of scientific publications, H-index and mean impact factor of the journals where we publish.*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Articles in Journals	75	90	58	83	69	84	75	87	96	131	186
Conference Articles	67	63	69	49	45	45	52	53	72	73	70
Total Articles	142	153	127	132	114	129	127	140	168	204	256
H-index of past 5 years						17	18	19	23	27	31
Journal Impact Factor	2,68	2,15	2,17	2,64	2,27	3,46	2,88	3,3	4.3	5,44	

The results for the Strategic Actions shown on the next page (Fig. 2) demonstrate that **EISS** stands for much of TransTech's improvement in production. Part of the increase in **EISS** last year resulted from the move of a Research Group from **XGeMS** to **EISS**. This also explains last year's drop of publication in **XGeMS**. Also **KM2** has performed very well – the publication volume in 2021 was three-fold that of 2015. In 2022, we need to stabilise the situation for the Research Groups in **XGeMS** and **KM2** so that the good level of scientific production can continue. The modest development in **InFibra** can be explained by the major changes we made a few years ago. Now that the production in **InFibra** has recovered, it is growing towards 60 publications in 2024 that is the target set in the Research Profile **NeoPulp. InFibra** is the area where we can benefit the most from increased academic collaborations and more dynamic academic environment.

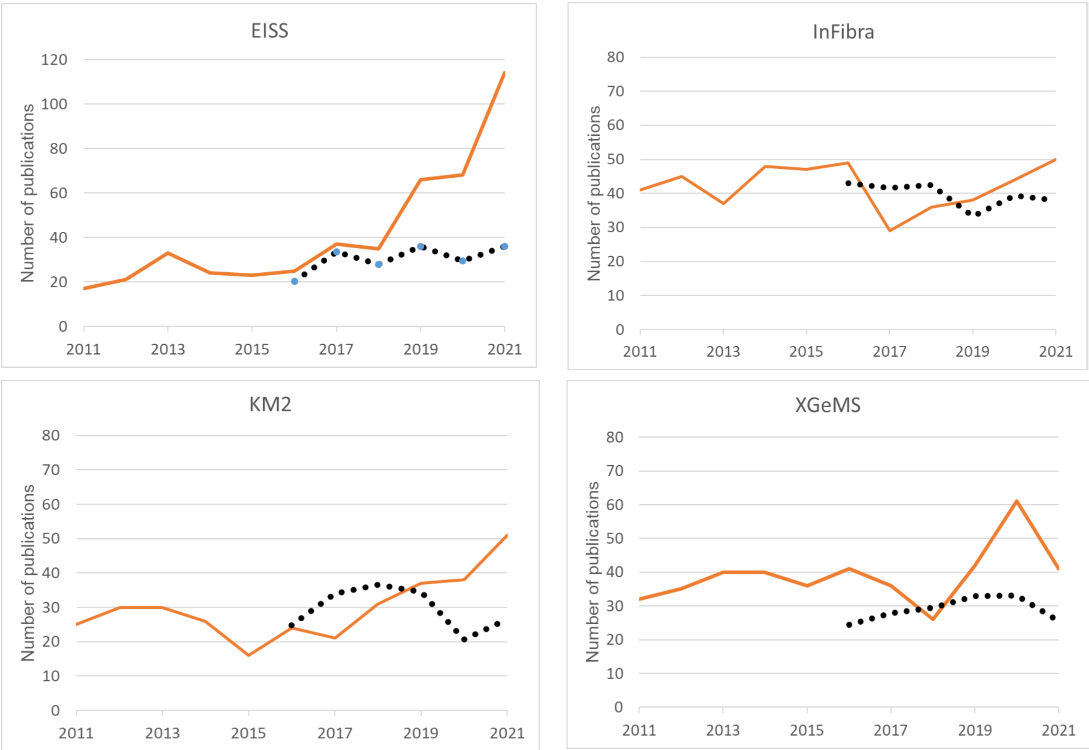

Figure 2. Publication volumes in the Strategic Actions. Dotted lines show the mean level of 1.5 publications per FTE that roughly agrees with the total of TransTech's publications in the early years, as can be seen in Fig. 1.

Significant new research results achieved in 2021

Since we want to improve our scientific production, we also want to give credit to important research results. Here are some of the highlights of 2021:

- Lignin enhances cellulose dissolution in cold alkali, which is most certainly attributed to the natural amphiphilic properties these two wood polymers share[1]
- Variable reluctance energy harvester for powering IoT nodes in industrial context with slowly rotating objects[2]
- The first self-assembly (from cellulose and nanocellulose) of artificial plant cell walls with catalytic activity that can be used for asymmetric catalysis and synthesis[3]
- Machine learning methods for interference mapping for industrial IoT networks over unlicensed bands[4]
- Temporal enhanced deep learning model for detection of small objects in complex backgrounds[5]
- A scalable route for production of anodes containing Silicon nanoparticles that exhibit high stability and high capacity retention after 500 cycles[6]

1 Costa, C.; Medronho, B.; Eivazi, A.; Svanedal, I.; Lindman, B.; Edlund, H.; Norgren, M. (2021) Lignin enhances cellulose dissolution in cold alkali. Carbohydr. Polym., Vol. 274, 118661; https://doi.org/10.1016/j.carbpol.2021.118661

2 Xu, Y. , Bader, S. , Magno, M. , Mayer, P. & Oelmann, B. (2021). System Implementation Trade-Offs for Low-Speed Rotational Variable Reluctance Energy Harvesters. Sensors, vol. 21: 18

3 Deiana, L.; Rafi, A. A.; Naidu, V. R.; Tai, C.-W.; Bäckvall, J.-E.; Córdova, A. Artificial plant cell walls as multi-catalysts systems for enzymatic cooperative asymmetric catalysis in non-aqueous media. Chem. Commun. 2021, 57, 8814.

4 Grimaldi, S. , Mahmood, A. , Hassan, S. A. , Hancke, G. P. & Gidlund, M. (2021). Autonomous Interference Mapping for Industrial IoT Networks over Unlicensed Bands. IEEE Industrial Electronics Magazine, vol. 15: 1, pp. 67-78.

5 Alqaysi, H. , Fedorov, I. , Qureshi, F. Z. & O'Nils, M. (2021). A temporal boosted yolo-based model for birds detection around wind farms. Journal of Imaging, vol. 7: 11

6 Patil, R. , Phadatare, M. R. , Blomquist, N. , Örtegren, J. , Hummelgård, M. , Meshram, J. , Dubal, D. & Olin, H. (2021). Highly Stable Cycling of Silicon-Nanographite Aerogel-Based Anode for Lithium-Ion Batteries. ACS Omega, vol. 6: 10, ss. 6600-6606.

- Measurement methods for underwater X-ray fluorescence spectrometer for characterization of heavy metal contamination[7]
- Visualised effect of pulp rheology and groove geometry on rotating pulp flow in an LC-refiner[8]
- Ultrasonic spray pyrolysis process for production of H_2S gas sensors based on SnO_2 thin films[9]
- Shorter sampling intervals improve refiner pulp quality control even for intervals that are shorter than chest residence time for the pulp or the delay of analyser[10]

TransTech's profile and national position

The establishment of two large national programs and one excellence centre was another main goal (i.e., *National programs*) in the 4-Year Plan, which turned out to be too ambitious. We need more time to establish the track record and academic recognition that leading such programs requires. However, the outlook is good with the Research Profiles **NIIT** and **NeoPulp** now running. In **NIIT**, we continued very strong research last year (cf. Fig. 2) and started a large initiative with a consortium of companies, RISE and Luleå Technical University, where our aim is to make **NIIT** nationally well-known in Industrial Internet of Things. We also had a collaboration with Mälardalen University (MDU) and the joint Industrial Graduate School **Smart industry** with four other universities.

Within **NeoPulp**, we started the first three Research Profile projects in November, prepared a complementary HÖG proposal (**HH-KK** on chemical pulping that had to be left outside the Research Profile), with MDU as a partner even here, and received other funding for four projects to start in Q1/2022. Collaboration with RISE/MoRe Research was intense, and the employment of three new guest researchers from foreign universities is soon ready. In addition to MDU, we have contacts with all Swedish universities active in the area, but the scientific agenda of **NeoPulp** is not yet far enough gone to discuss concrete new collaborations with them.

Given the unique opportunity that we have for making TransTech and MIUN known for Data-Driven Process R&D, we decided to simplify our communication, and in the beginning of 2022 we started using **NIIT** and **NeoPulp** instead of **EISS** and **InFibra** as the names of the Strategic Actions (yet in this report we mostly use **EISS** and **InFibra** for clarity). We also started to build a joint Stage 2 proposal Expert Competence for Data-Driven Industrial Transformation – **Driven** which will further strengthen our position.

The Strategic Actions **KM2** and **XGeMS** have not yet come as far as **NIIT** and **NeoPulp** in their development of a strong focused research program and clear scientific identity (a 4-Year Goal). **KM2** has the Synergy project **STORE**, and **KM2** has several possible focus areas. In terms of personnel **KM2** and **XGeMS** are smaller (about 30 researchers each) than **NIIT** and **NeoPulp** (about 50). Furthermore, **KM2** is in a special situation because its leader became seriously ill last summer. Fortunately, the other researchers did excellent work so that research production, project planning, and the development of academic and industrial collaborations did not suffer much. During 2022 they will need to discuss the future of **KM2**, including synergies with the AM Research Group.

For **XGeMS** we concluded last year that the research would develop better in connection to other Strategic Actions rather than trying to create a separate agenda for **XGeMS**. Two groups are already collaborating with **NIIT**-researchers and three with **NeoPulp**-researchers, and one Research Group moved to the Research Profile **NIIT**. By dropping the ambition of a separate agenda and profile for **XGeMS** we can focus development efforts to increasing international collaborations and innovation

7 An, S. , Zeeshan, F. , Norlin, B. & Thungström, G. (2021). Effects of Water Absorption on Mercury Contamination in Fiberbank Sediments using X-ray Fluorescence Spectrometer. In IOP Conference Series: Earth and Environmental Science

8 Jouybari, NF., Engberg, B., Persson, J. and Berg J-E. (2021). Investigation of pulp flow helicity in rotating and non-rotating grooves. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 235(6):2045-2058. doi:10.1177/09544089211027421

9 Akbari-Saatlu, M. , Procek, M. , Thungström, G. , Mattsson, C. & Radamson, H. H. (2021). H2S gas sensing based on SnO2thin films deposited by ultrasonic spray pyrolysis on Al2O3substrate. In 2021 IEEE Sensors Applications Symposium (SAS).

10 Sund, J., Sandberg, C., Karlström, A., Thungström, G. & Engstrand, P. (2021). The effect of process design on refiner pulp quality control performance. Nordic Pulp & Paper Research Journal, 36(4), 594-607. https://doi.org/10.1515/npprj-2021-0011

projects. For TransTech such results would be more valuable than another profile not far from Data-Driven Process R&D. In summary, during 2022 we want to find new roles for the **XGeMS** Research Groups.

Figure 3 shows the updated structure of Strategic Actions in the beginning of 2022 with **NIIT** and **NeoPulp** together making up the main profile of TransTech. **KM2** and **XGeMS** are shown without clear "boundaries" since their position will be reconsidered. Also shown are all our groups and the collaborations they had in 2021 relative to the Strategic Actions. A large share of our scientific impact and production came from Research Groups that are not part of **NIIT** and **NeoPulp**.

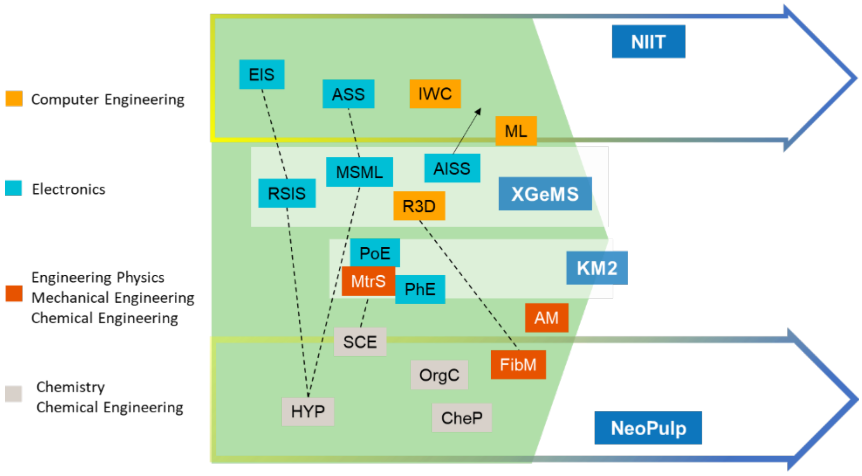

Figure 3: *Strategic Actions and Research Groups (see Appendix D for full group names) in the beginning of 2022. The Research Groups that have a longer history in TransTech are to the left and the "newcomers" to the right. Proximity and lines indicate collaborations.*

Comprehensive approach to partnerships

Throughout the development of TransTech, co-production with industry has been very strong and therefore we have put most efforts in the latest four-year period into increasing international collaborations. At the same time, academic collaborations in Sweden are central for our aims to build a national position and recognition as well as collaborations with institutes for the transformative effects of our research. These four kinds of partnerships are discussed in this section. Most of the collaborations concern research, but their importance in education and competence development has increased. Adjunct professors are now complemented with adjunct lecturers and affiliated researchers from industry and RISE institutes. This development has brought valuable complements to our own research and education capacity and industrial relevance.

Co-production and industry networks

Table 4 shows that the number of industrial organisations that collaborate with us has grown more than two-fold since 2012, from 34 to 85 in 2021. Unlike the initial situation, all research groups now have many industrial partners. One of the 4-Year Goals was that each of the four Strategic Actions would have at least one large co-production project with a number of companies, and this was maintained also in 2021. The fact that indirect funding has not followed the same trend reflects reductions in the research volume of industry. The effects of the pandemic in 2020 and 2021 were particularly clear.

The definition of what constitutes a partner company has varied during the years, with a range of qualitative judgments. In the next phase, it is important for us to be able to follow the different kinds of partnerships effectively and objectively. We therefore decided that starting 2022, we will record all partnerships in the same way with the number of current projects and joint publications. Especially for industry and other non-academic partners, we will complement these numbers with indirect funding and doctoral students employed by them. Networking and relation-building is naturally a crucial requirement of these concrete forms of collaboration, but at the same time very tedious to follow objectively. We will test one approach to that in parts of our operations.

Another 4-Year Goal related to co-production was to increase the share of industrial Edge issues (as opposed to Core) to 70% when it had been 60 in 2014 (cf. Progress Report 2015). The result for last year was 92%, with only small differences between the Strategic Actions. We had no projects left that consider pure Core-questions, such as pure process improvements. In the process industry context, the relevant concept has become "Competence" rather than "Core". Recognising New Competence as a desired effect of our research can further improve the connection of research to education programs and other forms of life-long learning such as the Expert Competence program.

Table 4. *Co-production with companies (adjunct professors and researchers in part from institutes)*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of partner companies	32	34	43	42	53	(105)	(105)	78	84	87	85
Indirect funding (MSEK)	20,98	27,40	35,40	26,98	33,18	36,75	33,38	29.79	30,17	23,66	22,32
Adjunct professors	4	5	10	10	9	9	12	11	10	9	7
FTE	0,86	1,6	1,63	1,7	1,7	1,85	2,52	1,6	1,82	1,57	2,05
Adjunct researchers		3	3	10	8	9	14	14	10	9	11

International interaction and projects

This was the third of our main goals in the 4-Year Plan. The good performance of 2020 continued last year. Only research missions (In and Out) were almost absent because of the pandemic travel restrictions (Table 5). The number of 15 international guest professors exceeded the target level of 10 and project spending remained a bit below the target level. We expect that the current high level of guest professors will start to increase the international project volume and the Faculty has established a program to systematically engage guest professors in the supervision and mentoring of early-career researchers. Activities with guest professors and other visiting researchers will be central in the strengthening of our academic environments that the ARC reviewers called for.

Table 5. *International interactions. Guest professors and postdocs at year-end, the rest total number per year.*

Year	2015	2016	2017	2018	2019	2020	2021
Number of international guest professors	1	2	2	6	5	10	15
FTE	0,25	0,33	0,41	0,8	0,58	1,2	2,84
Number of international postdocs at MIUN	1	6	10	12	19	28	21
FTE	0,33	2,25	7,95	10,4	12,27	12,49	11,68
Number of international research missions - In	34	24	31	35	21	6	5
Accumulated duration of international research missions (no. of days) - In	262	393	914	1513	229	109	287
Number of international research missions - Out	45	45	46	47	30	11	3
Accumulated duration of international research missions (no. of days) - Out; Conferences excluded	293	303	713	950	252	441	14
Spending in international projects (kSEK)	1 757	4 605	5 406	5 317	1 857	3 633	5 704
Number of publications with international co-authors	33	54	71	60	94	149	184

Collaboration with institutes

For a few years now, we have had regular planning meetings with a number of RISE operations for the purpose of strengthening the regional innovation system and improving resource sharing. We received funding (especially from Vinnova) for several new joint projects and their total number grew to 18 last year. A few researchers from TransTech are now employed by the RISE units in the region and several RISE researchers are affiliated to MIUN. Such personal relations make it much easier to ideate and build new joint projects but also education and competence development programs. The level we reached last year in institute collaboration meets the corresponding 4-Year Goal well in all other aspects except adjunct professors: we had 7 last year (see Table 4 above) when the goal was 12. However, the number increases to 12 if we add up adjunct professors and researchers. The latter increasingly act as teachers, which was not considered in the 4-Year Plan.

Partnerships in Strategic Actions

The balance of industrial, national academic and international collaboration projects of the Strategic Actions in 2021 is shown in Fig. 4. Institute projects were not included in this follow-up. The figure reiterates the different stages of the research program in **EISS/NIIT** and **InFibra/NeoPulp** vs **KM2** and **XGeMS**. It also clearly demonstrates how the national academic collaborations were fewer than the other forms of collaboration. We had no goal in the 4-Year Plan to increase them, but have included them in the new Strategy since they are central for our aims to build a national position and recognition.

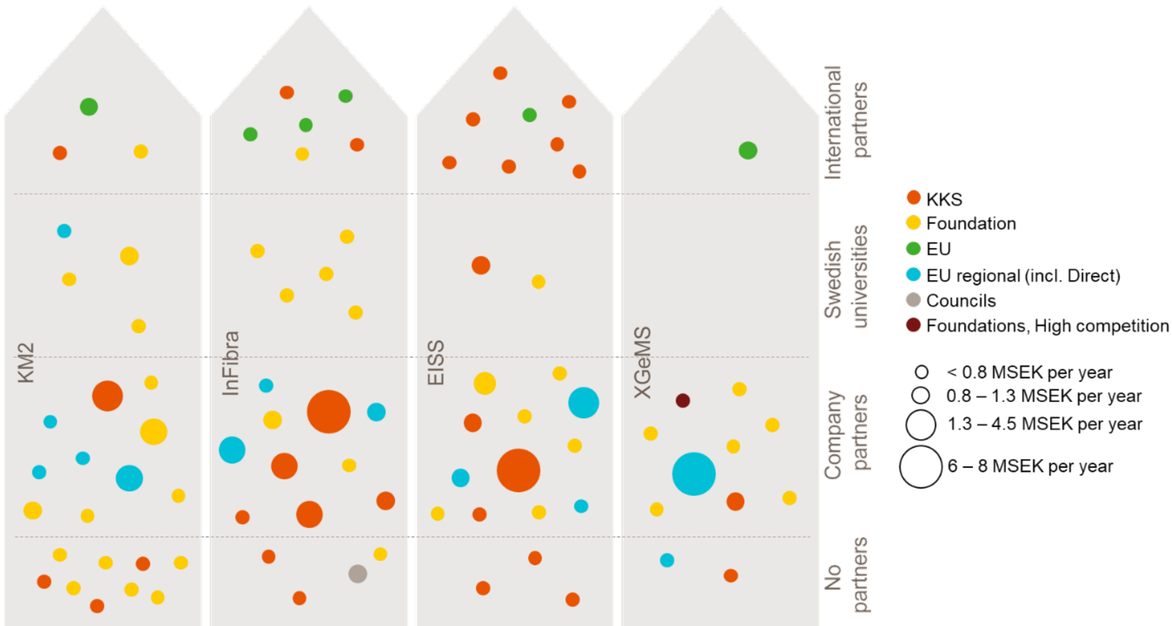

Figure 4: *Externally funded projects in 2021 for each Strategic Action, divided into four groups so that projects with international partners are at the top, followed by projects with Swedish universities, Swedish companies but no universities, and at the bottom projects without partners. Colours correspond to different financiers and symbol sizes to annual project volume. One* ***XGeMS*** *project with funding from SSF is distinguished from the rest as Foundations, High competition because the project was won in high competition.*

The conclusions for the development of partnerships are the following:

- Increase collaboration in competence development and education with companies and institutes
- Deeper international partnerships for career development and joint funding applications
- More collaborations with other Swedish universities to win recognition for our research

Personnel: Support to individuals and teams

For personnel development our original goals in the 4-Year Plan were to recruit new professors and improve career support to junior researchers and project management support to senior researchers. We achieved the latter two aspects quite well. New funding was granted last year from a faculty program that aims at career support with the help of guest professors. We aligned our other guest professor recruitments (e.g., with Knowledge Founation funding) with it, thus creating a significant effort to support early-career researchers. For senior researchers, two professional project managers were recruited already in 2020 to help them in the running of large projects.

For senior recruitments, our original target in the 4-Year Plan was to recruit three new professors to compensate for retirements. We later increased this to five new professors (full or associate) by the end of 2021. The current outlook is that we will hire one new professor this summer. As was explained in Chapter 2 (Implementation of the Work Plan), we put the position in **KM2** on hold and decided to hire three assistant professors in AI to get projects in **EISS** and **XGeMS** going. The competition for senior-level researchers is in many areas so hard that we decided to shift from professor recruitments to associate professors, which the ARC21-reviewers also recommended.

The ARC21-reviewers also advised both STC and FSCN to create more dynamic academic environments – increase the number of visiting scientists, postdocs, and above all more doctoral students interacting – and avoid small research groups with just one professor in each. This is another argument against hiring senior-level professors who may want to start building yet another research group.

We did not have a growth target for the number of researchers in the 4-Year Plan, but our personnel volume did grow before 2018 (Table 6). In view of the funding uncertainties that emerged in 2020 (one consequence of Covid-19) it was fortunate that we had before that been cautious with recruitments.

Table 6: *Total number of researchers and graduate students*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
No. of researchers	134	143	144	132	142	150	166	170	180	173	162
FTE	89,62	93,95	98,02	80,98	88,49	76,37	108,6	110,13	97,72	85,61	85,61
Graduate students	57	63	60	47	54	53	55	58	57	54	53
FTE	42,57	47,56	46,55	31,9	36,72	39,28	44,05	44,7	33,51	37,32	37,61
Doctoral and licentiate exams	20	17	26	19	15	9	3	7	17	11	14

Continuous development of synergies between education and research

The academic environment of TransTech includes MSc programs that we develop continuously and the 4-Year Plan included corresponding targets for the *Synergy of education and research*: (1) improved benefits between education and research, (2) new potential synergies, and (3) better competence development for industry. The programs in Electrical Engineering and Computer Engineering (connected to **EISS** and **XGeMS**) were running already prior to the establishment of TransTech, but have been renewed to match the increasing needs of companies in machine learning and Industrial Internet of Things. A new program in Engineering Chemistry (**InFibra**) was created early on in TransTech as a response to requests from the forest, energy, and chemical process industries in the region, and Engineering Physics (**KM2**) started more recently for similar reasons, with the first intake to 5th year this fall. With that, we have a complete match between the four education programs and the four Strategic Actions.

In addition to the above four programs, we have several efforts in progress to connect the MSc program in Mechanical Engineering (= Technical Design) to our research in **InFibra;** the recruitment of a new professor, new laboratory instrumentation and the creation of data-driven methodologies for this can strengthen the scientific foundation of Technical Design and allow updates to its scope. This will become the fifth education program within TransTech, and yet another will be developed by the AM group and others in Östersund.

One of our two Expert Competence Stage 1 projects (related to **EISS**) was completed last year and the other related to in **InFibra** will be completed this spring. We also started to build a joint Stage 2 proposal Expert Competence for Data-Driven Industrial Transformation – **Driven** – which will be submitted in April. The main idea of **Driven** is to develop industrial competence to *apply* IoT/AI tools (from **EISS**) in bio-based industrial processes (from **InFibra**). Such course modules are also useful for students in Computer and Electrical Engineering and Engineering Chemistry and they are perfectly in line with the profiling of TransTech in Data-Driven Process R&D.

4. Assessment of capabilities

Table 7 summarises our assessment of the capabilities that TransTech has acquired by the end of 2021. The ability to *Secure resources* is the area where improvement is most needed, to be able to reach a better funding balance and succeed with senior recruitments. In the ability to *Build scientific profile* it remains for us to establish a national position, and in the ability to *Integrate research and education* to reach a good level of enrolment in the programs that we have developed. The improvement needs in the remaining four capabilities are minor.

Table 7: *Development status of TransTech in the capabilities followed in the Knowledge and Competence Centre program. Critical areas are shown in white, those with stable improvement in lighter green and those with good status in darker green.*

Capability, the level achieved (1-4; 4= best)	Main strengths	Improvement needs	External risks and opportunities
Can develop and implement strategy: 4	Good and legitimate process to plan, implement and evaluate strategy from vision to plans and follow-up	The spread of strategic ability should increase in the new faculty organisation	
Can build scientific Profile: 3	Iterative process to define and implement a renewed profile, using systematic assessment of the research field when relevant	Reach the desired national position. Better collaboration of Strategic Actions and Departments in project implementation	Opportunity: Shared supervision of graduate students with external professors
Can co-produce: 4	Can interact on all time scales with a few large companies, and on project level with many (> 100)	Clarify expected benefits for MIUN from the collaboration with RISE	Opportunity for MIUN + the regional RISE: Competitive offer for education and new technology
Can integrate research and education: 3	Can build complete academic environments in all areas	Attract more students for better balance between income and expected deliveries	Opportunity: Education combined with research co-production
Can secure quality: 4	Good, continuously improving processes from strategic level to individual projects Clearly improved scientific production	Strengthen the academic environment to support scientific ambition, from PhD studies onward	Opportunity: Guest professors co-supervise PhD students and work with early career researchers
Can build organisation: 4 (*concerns faculty level*)	Two well-established research centres combined with good leadership and support from the Faculty	More support to Departments in research and education	Opportunity: New faculty organisation enables good collaboration with TransTech
Can secure resources: 2 *(level = 2 because of funding profile)*	Can attract strong international guest professors and postdocs. Improving support to funding applications	Better ability to succeed with senior recruitments and to balance funding profile	Risk: Less national research funding accessible Opportunity: Invitations to EU consortia are growing

5. Funding

Figures 5 and 6 show the used and received funding of TransTech as a whole and each Strategic Action separately. Shown in Fig. 5 is the actual annual spending of funds for 2011–2021, whereas Fig. 6 shows research funding according to original project budgets. The difference between the perspectives (spending vs budgets) was particularly great in 2020-21 when Covid-19 required extra resources in education, which caused delays in research. This lies behind the apparent strong increase of KKS funding from 2021 to 2022 in Fig. 5 that cannot be seen in Fig. 6 with project budgets.

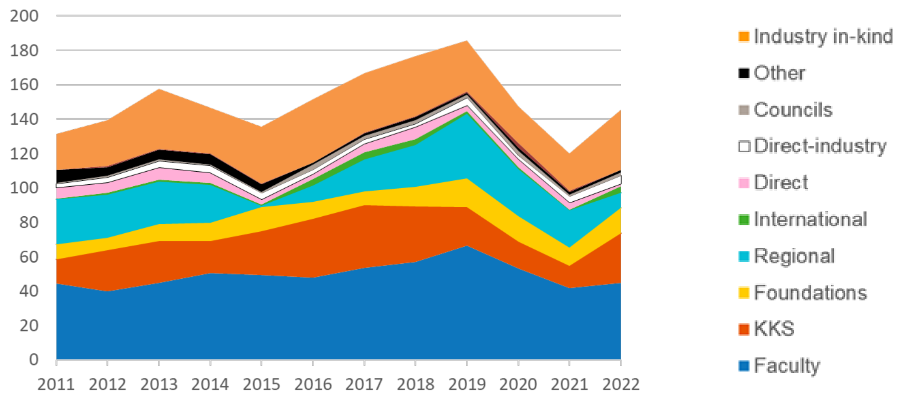

Figure 5. *Funding (MSEK) of Transformative Technologies. From 2011 to 2021, we show the actual spending of funds, and for 2022 the budget of approved projects.*

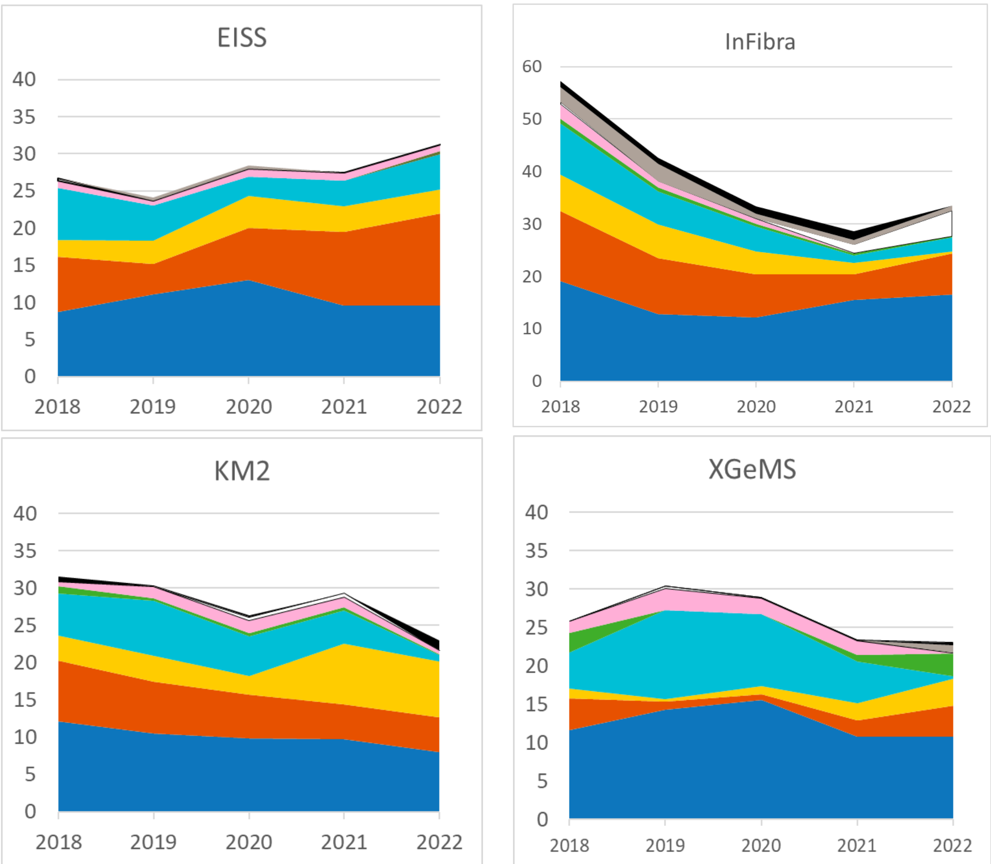

Figure 6. *Funding (MSEK) in each of the Strategic Actions according to approved project budgets.*

Already in 2019, we noted that the approach of the end of the current program of the European Regional Development Fund (ERDF) would lead to funding challenges. We started then to develop an externally staffed support process for submitting more project applications. Last year the number of our applications was twice that of 2019 (cf. Table 8), and at the time of writing the funding granted for 2022 is just 10% below the 120 MSEK that we had as a goal in Work Plan 2021. The result is good in light of the fact that research volume has gone down in some important industry sectors (pulp and paper, chemicals).

Table 8. *Success rate (the number approved over the number submitted) of applications to different financiers.*

Year	2015	2016	2017	2018	2019	2020	2021
Research Councils (VR, FAS, Formas etc.)	3 / 4	0 / 1	0 / 3	2 / 5	0/4	0/7	0/15
Swedish Foundations (e.g., Wallenberg, SSF, Vinnova, RJ, Knowledge Foundation, Swedish Energy Agency etc.)	16 / 22	17 / 23	15 / 32	22 / 39	17/30	23/59	33/74
EU, regional funds	0 / 2	4 / 6	3 / 4	4 / 5	2/8	2/3	0/6
EU, international funds	1 / 1	1 / 10	2 / 5	2 / 3	1/2	1/5	2/3
Direct funding from non-industrial organizations in society	13 / 23	12 / 16	10 / 12	7 / 10	1/4	8/8	0/0
Direct external funding from industry	0 / 0	5 / 6	1 / 1	1 / 1	3/3	1/2	1/1
Other	0 / 0	0 / 0	2 / 2	5 / 9	3/3	0/0	2/4
Total number applications submitted	52	62	59	72	54	84	103

In the 4-Year Plan we had growth targets also for international project volume (8 MSEK available during 2021) and council funding (5 MSEK) shown in Fig. 7. In the 4-Year Plan we used them as indicators of progress in *International projects* and *Higher scientific ambition*, not funding volume or funding profile. We did not fully reach these targets, but the outlook is nevertheless promising. Our international project volume is increasing for the fourth year in a row and we have now started to receive invitations to join EU consortia. Council funding consists of only 1-3 projects and therefore has a high-risk level. Despite no new council projects in the last three years, we are optimistic that the build-up of strong scientific track records by many younger researchers and our large application numbers are bound to give results sooner or later.

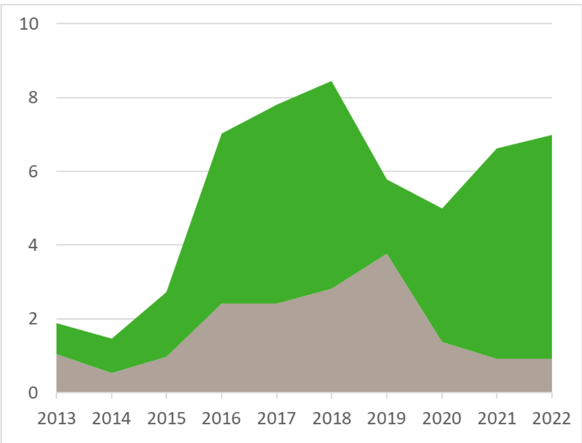

Figure 7. *Funding (in million SEK) granted by high-competition sources (grey) and for international collaboration projects (green).*

Appendix A: List of the articles in 2017–2021 that made H-index = 31 in 2021

	Number of citations
Sisinni E, Saifullah A, Han S, Jennehag U, Gidlund M. Industrial Internet of Things : Challenges, Opportunities, and Directions. IEEE Transactions on Industrial Informatics. 2018;14(11):4724-4734.	420
Vuorinen V, Aarnio M, Alava M, Alopaeus V, Atanasova N, Auvinen M, et al. Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors. . Safety Science. 2020;130:104866.	124
Butun I, Österberg P, Song H. Security of the Internet of Things: Vulnerabilities, Attacks, and Countermeasures. IEEE Communications Surveys and Tutorials. 2020;22(1):616-644. :8897627.	95
Lindman B, Medronho B, Alves L, Costa C, Edlund H, Norgren M. The relevance of structural features of cellulose and its interactions to dissolution, regeneration, gelation and plasticization phenomena. Physical Chemistry, Chemical Physics - PCCP. 2017;19(35):23704-23718.	92
Wiedorn M O, Oberthuer D, Bean R, Schubert R, Werner N, Abbey B, et al. Megahertz serial crystallography. Nature Communications. 2018;9:4025.	90
Rizzi M, Ferrari P, Flammini A, Sisinni E. Evaluation of the IoT LoRaWAN Solution for Distributed Measurement Applications. IEEE Transactions on Instrumentation and Measurement. 2017;66(12):3340-3349. :8036410.	89
Vijeh M, Rezanejad M, Samadaei E, Bertilsson K. A General Review of Multilevel Inverters Based on Main Submodules: Structural Point of View. IEEE transactions on power electronics. 2019;34(10):9479-9502.	88
Molina-Lopez F, Gao T Z, Kraft U, Zhu C, Öhlund T, Pfattner R, et al. Inkjet-printed stretchable and low voltage synaptic transistor array. Nature Communications. 2019;10(1):2676.	72
Samadaei E, Kaviani M, Bertilsson K. A 13-levels Module (K-Type) with two DC sources for Multilevel Inverters. IEEE transactions on industrial electronics (1982. Print). 2019;66(7):5186-5196.	71
Mahmood A, Sisinni E, Guntupalli L, Rondón R, Hassan S A, Gidlund M. Scalability Analysis of a LoRa Network under Imperfect Orthogonality. IEEE Transactions on Industrial Informatics. 2019;15(3):1425-1436.	70
Barhoum A, Samyn P, Öhlund T, Dufresne A. Review of recent research on flexible multifunctional nanopapers. Nanoscale. 2017;9(40):15181-15205.	65
Samyn P, Barhoum A, Öhlund T, Dufresne A. Review: Nanoparticles and Nanostructured Materials in Papermaking. Journal of Materials Science. 2018;53(1):146-184.	62
Blomquist N, Wells T, Andres B, Bäckström J, Forsberg S, Olin H. Metal-free supercapacitor with aqueous electrolyte and low-cost carbon materials. Nature Publishing Group; Scientific Reports. 2017;7:39836.	59
Engelke U, Darcy D, Mulliken G, Bosse S, Martini M, Arndt S, et al. Psychophysiology-based QoE Assessment : A Survey. IEEE Journal on Selected Topics in Signal Processing. 2017;11(1):6-21. :7569001.	51
Wang C, Wang X, Li Y, Xia Z, Zhang C. Quaternion polar harmonic Fourier moments for color images. Information Sciences. 2018;450:141-156.	50
Hu J, Shao J, Yang H, Lin G, Chen Y, Wang X, et al. Co-gasification of coal and biomass : Synergy, characterization and reactivity of the residual char. Bioresource Technology. 2017;244:1-7.	49
Cuomo F, Cofelice M, Venditti F, Ceglie A, Miguel M, Lindman B, et al. In-vitro digestion of curcumin loaded chitosan-coated liposomes. Colloids and Surfaces B: Biointerfaces. 2018;168:29-34.	46
Singh P, Magalhaes S, Alves L, Antunes F, Miguel M, Lindman B, et al. Cellulose-based edible films for probiotic entrapment. Food Hydrocolloids. 2019;88:68-74.	44
Radamson H H, He X, Zhang Q, Liu J, Cui H, Xiang J, et al. Miniaturization of CMOS. Micromachines. 2019;10(5):293.	42
Liu H, Chen Y, Yang H, Gentili F G, Söderlind U, Wang X, et al. Hydrothermal carbonization of natural microalgae containing a high ash content. 6th International Conference on Biomass Energy (ICBE), Wuhan, PEOPLES R CHINA, OCT 16-19, 2018. Fuel. 2019;249:441-448.	42

Singh P, Medronho B, Alves L, da Silva G J, Miguel M G, Lindman B. Development of carboxymethyl cellulose-chitosan hybrid micro- and macroparticles for encapsulation of probiotic bacteria. Carbohydrate Polymers. 2017;175:87-95.	40
Zhang R, Engholm M. Recent Progress on the Fabrication and Properties of Silver Nanowire-Based Transparent Electrodes. MDPI; Nanomaterials. 2018;8(8):628.	38
Thapa A, Soares A C, Soares J C, Awan I T, Volpati D, Melendez M E, et al. Carbon Nanotube Matrix for Highly Sensitive Biosensors To Detect Pancreatic Cancer Biomarker CA19-9. ACS Applied Materials and Interfaces. 2017;9(31):25878-25886.	37
Chen X, Yang H, Chen Y, Chen W, Lei T, Zhang W, et al. Catalytic fast pyrolysis of biomass to produce furfural using heterogeneous catalysts. Journal of Analytical and Applied Pyrolysis. 2017;127:292-298.	37
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Allahgholi A, Becker J, Delfs A, Dinapoli R, Goettlicher P, Greiffenberg D, et al. The Adaptive Gain Integrating Pixel Detector at the European XFEL. Journal of Synchrotron Radiation. 2019;26:74-82.	34
Lebreton S, Borrer-Echeverry F, Gonzalez F, Solum M, Wallin E, Hedenström E, et al. A Drosophila female pheromone elicits species-specific long-range attraction via an olfactory channel with dual specificity for sex and food. BMC Biology. 2017;15(1):88.	34
Paudyal P, Battisti F, Sjöström M, Olsson R, Carli M. Towards the Perceptual Quality Evaluation of Compressed Light Field Images. IEEE transactions on broadcasting. 2017;63(3):507-522. :7938323.	34
Ahmad W, Olsson R, Sjöström M. Interpreting Plenoptic Images as Multi-View Sequences for Improved Compression. In: ICIP 2017: . 24TH IEEE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING (ICIP), Beijing, China 17-20 September 2017. IEEE; 2017. p. 4557-4561.	34
Radamson H H, Zhu H, Wu Z, He X, Lin H, Liu J, et al. State of the Art and Future Perspectives in Advanced CMOS Technology. Nanomaterials. 2020;10(8):1555.	33
Eivazihollagh A, Bäckström J, Dahlström C, Carlsson F, Ibrahem I, Lindman B, et al. One-pot synthesis of cellulose-templated copper nanoparticles with antibacterial properties. Materials letters (General ed.). 2017;187:170-172.	31
Costa C, Medronho B, Filipe A, Mira I, Lindman B, Edlund H, et al. Emulsion formation and stabilization by biomolecules : The leading role of cellulose. Polymers. 2019;11(10):1570.	31

Appendix B: Status report of the industrial graduate school **FORIC & FORIC+**

Table 1: Progression of studies

Samtliga forskarstuderande inom Företagsforskarskolan FORIC samt FORIC+ **Projektperiod: 2014-06-01 t.o.m 2024-05-31**

Namn	Arbetsgivare/ Medfinansiär	Program	Antagnings-datum	Doktorandens utgångsläge vid start** *(tillgodoräknan* Veckor / hp / ekvivalent	Planerad examen	Publika-tioner tom 2021	Progression* under året hp 2021	Progression totalt från start % enl FDB MIUN	Ekv.	Förbrukad doktorandtid, månader (omräknat till heltid)	Inrapporterad aktivitet 2021
Aktiva doktorander											
Alexander Hedlund	Frontway AB	FORIC	2014-11-18		Lic vt 2022	1	7,5	66%	0,6	15,8	VT saknas, HT saknas
Bakhram Gaynullin	SenseAir AB	FORIC	2014-12-16	6v	Dr 2023	6	34	64%	1,28	30,7	VT 50%, HT 50%
Olof Ferritsius	Mittuniversitetet/Stora Enso Kvarnsveden	FORIC	2014-12-16	27v / 41hp	Dr 210604	26	14	89%	1,78	42,7	VT 70%, HT saknas
Robert Norgren	Ragn-Sells AB	FORIC	2014-12-16/ 2017-12-05		Dr 220225	6	2	93%	1,86	44,6	VT saknas, HT saknas
Tove Joelsson	MoRe Research	FORIC+	2017-09-11		Dr 211215	10	63,5	92%	1,84	44,2	VT 100%, HT 100%
Sara Starrsjö	SCA R&D Center	FORIC+	2017-12-05		Lic 210913	3	44,5	87%	0,87	20,9	VT 50%, HT saknas
Johanna Enström	Skogforsk	FORIC+	2017-12-05		Dr vt 2022	3	31,5	53%	1,92	25,4	VT 100%, HT saknas
Anna Thoring	Norrskog	FORIC+	2018-01-22		Lic vt 2022	2	15	66%	0,66	15,8	VT 50% HT50%
Malin Nejström (From)	Nouryon	FORIC+	2017-12-05		Lic vt 2022	2	35	64%	0,64	15,4	VT 50%, HT saknas
Shiromini Gamage	Colabitoil	FORIC+	2017-12-05		Dr 2022	0	55	83%	1,66	39,8	VT 90%, HT 100%
Christer Sandberg	Holmen	FORIC+	2014-05-22	1 (Lic)	Dr vt 2022	21	0	96%	1,92	46,1	VT 25%, HT 10%
Johan Sund	Holmen	FORIC+	2019-10-23		Lic vt 2022	4	0	67%	0,67	16,1	VT 100%, HT 100%
Doktorander med studieuppehåll/ej aktiva											
Anna-Karin Stengard	Sundsvall Energi AB	FORIC	2014-12-16		Lic 2020	1	0	69%	0,69	16,6	
Magnus Larsson	Skogforsk	FORIC	2015-01-01	47v / 81hp	Dr 2021	2	0	90%	1,8	43,2	
Mathias Lundberg	PulpEye AB	FORIC	2014-10-21		Lic 2020	2	0	80%	0,8	19,2	
Magnus Hörnsten	Domsjö Fabriker	FORIC+	2017-06-13		Dr 2023	0	0	23%	0,46	11,0	
Tommy Nordin	MoRe Research	FORIC+	2017-09-11		Lic 2020	1	0	86%	0,86	20,6	
Doktorander som lämnat forskarskolan efter examen											
Elisabeth Björk	RISE Bioekonomi (f.d Innventia AB)	FORIC	2014-12-16		Lic 201124	10	19	100%	1	24,0	
Jonas Johansson	SCA Timber AB	FORIC	2014-12-16		Lic 170614	1		100%	1	24,0	
Sinke Henshaw Osong	Mittuniversitetet/MoRe Research	FORIC	2011-11-15	1 (Lic)	Dr 160422	11		100%	2	48,0	
Hafizur Rahman	SCA Forest Products AB, SCA R&D Centre	FORIC	2015-04-14		Lic 180322	6		100%	1	24,0	
Doktorander som avslutat studierna utan examen											
Mats Paulson	Sylvestris AB	FORIC	2014-06-24	2v	Lic 2016						
Carl Moser	Valmet AB	FORIC	2014-12-16	6v	Dr 2019						

*Progression anges i examensekvivalenter. Doktorsexamen motsvarar 2 examensekvivalenter, Lic.examen 1 examensekvivalent och dokorsexamen med tidigare avlagd licentiatexamen räknas som 1 examensekvivalent.

**När en forskarstuderande vid antagningstillfället har poäng från tidigare utbildning (tillgodoräknande).

Table 2: Resources during 2019

Namn	Arbetsgivare	Befattning	Roll i projektet	Andel i projektet (% av heltid alt. timmar)	
Anders Kihl	RagnSells AB	Strategi och utvecklingschef	Handledare, industri	20 tim	FORIC
Anders Nilsson	Frontway AB	Director	Handledare, industri	13,5	FORIC
Anna Svedberg	MoRe Research AB	Forskningschef	Handledare, industri	35 tim	FORIC+
Aron Larsson	Mittuniversitetet	Docent	Handledare	9%	FORIC+
Bo Andreasson	Nouyron AB	Forskningsspecialist	Handledare, industri	50 tim	FORIC+
Christer Sandberg	Holmen Paper AB	R&D specialist	Handledare, industri	62 tim	FORIC+
Erik Hedenström	Mittuniversitetet	Prefekt	Handledare	11%	FORIC+
Edith Andresen	Mittuniversitetet	Lektor	Handledare	0%	FORIC
Feixiang Long	Colabitoil		Handledare, industri	236 tim	FORIC+
Folke Österberg	F.Österberg konsulting	Director	Ordförande styrgrupp	110 tim	FORIC och FORIC+
Gunilla Pettersson	Mittuniversitetet	Forskare	Biträdande handledare	10%	FORIC+
Henrik Flore´n	Mittuniversitetet	Forskare	Handledare	3%	FORIC+
Henrik Rödjegård	SenseAir AB	Research manager	Handledare, industri	33 tim	FORIC
Håkan Edlund	Mittuniversitetet	Professor	Handledare	0%	FORIC
Jan Andersson	Holmen Paper AB	Technical Sales and product	Handledare, industri	34 tim	FORIC
Jan-Erik Berg	Mittuniversitetet	Forskningsingenjör	Biträdande handledare	0%	FORIC+
Kaarlo Niskanen	Mittuniversitetet	Vice Dekan	Styrelseledamot	0%	FORIC
Katarina Eriksson	Mittuniversitetet	Handläggare	Projektadministratör	23%	FORIC
Lars Eliasson/(Anders	SLU/Skogforsk		Handledare	56 tim	FORIC+
Leif Olsson	Mittuniversitetet	Lektor	Handledare	2%	FORIC
Magnus Norgren	Mittuniversitetet	Professor	Handledare	0%	FORIC+
Maria Iwarsson Wide	Skogforsk	Programchef	Handledare, industri	0 tim	FORIC+
Olof Björkqvist	Mittuniversitetet	Lektor	Koordinator och handledare	13%	FORIC
Per Engstrand	Mittuniversitetet	Professor	Projektledare och handledare	5%	FORIC+
Per Engstrand	Mittuniversitetet	Professor	Projektledare och handledare	10%	FORIC
Maria Boman	SCA	Forskningsspecialist	Handledare, industri	102 tim	FORIC+
Peter Öhman	Mittuniversitetet	Professor	Biträdande handledare	6%	FORIC+
Yvonne von Friedrichs	Mittuniversitetet	Professor	Handledare	6%	FORIC+
Timmar är framräknat via kostnadsredovisningarna (lön handledare/800kr)					

Table 3: PhD students and supervisors

Namn			Lärosäte	Anställd	Projekt	Huvudhandledare	Adj. Handledare	Kontakt partnerföretag
Robert	Norgren	FORIC	MIUN	Ragn-Sells AB	New use of bio sludge from pulp and paper industry	Anders Jonsson	Olof Björkqvist	Anders Kihl
Bakhram	Gaynullin	FORIC	MIUN	SenseAir AB	Methane measurement system and analysis	Göran Thungström	Claes Mattsson	Henrik Rödjegård
Alexander	Hedlund	FORIC	MIUN	Frontway AB	Technical and economical systems modelling of a mechanical pulping based bio-refinery	Per Engstrand	Olof Björkqvist, Aron Larsson, Leif Olsson	Anders Nilsson
Mathias	Lundberg	FORIC	MIUN	PulpEye AB	Improved fines material control	Håkan Edlund	Magnus Norgren, Per Engstrand	Öivind Sundvall Thomas Storsjö
Anna-Karin	Stengard	FORIC	MIUN	Sundsvall Energi AB	Integrated energy solutions	Per Engstrand	Olof Björkqvist	Anders Jonsson Anette Rhodin
Olof	Ferritsius	FORIC	MIUN	Mittuniversitetet	Connecting high yield pulp properties with functional product properties	Birgitta Engberg	Per Engstrand	Jonas Sjans
Elisabeth	Björk	FORIC	MIUN	Innventia AB	Fibrillar chemical pulp fines to enhance paper board strength	Per Engstrand	Myat Htun	Tomas Anderson
Magnus	Larsson	FORIC	MIUN/SLU	Skogforsk	Efficient wood supply logistics adopted to combinates including modern saw mills and bio-refineries	Aron Larsson	Matti Stendahl, SLU	Gert Andersson Magnus Thor
Tommy	Nordin	FORIC+	MIUN	MoRe Research	Industrianpassad produktin av lika typer av nanocellulosameterial optimerade för ökad styrka hos förpackningstryckpapper.	Per Engstrand	Sven Norgren	Anna Svedberg
Tove	Joelsson	FORIC+	MIUN	MoRe Researech	Strong High Yield Pulping Technology	Per Engstrand	Gunilla Pettersson	Anna Svedberg
Magnus	Hörnsten	FORIC+	MIUN	Domsjö Fabriker	Transport and chemical rate phenomena in transition from cellulose into alkali-cellulose	Magnus Norgren	Håkan Edlund	Kristina Elg Christoffersen Roland Agnemo
Christer	Sandberg	FORIC+	MIUN	Holmen	Process efficiency aspects of high and low consistency refining in mechanical pulping systems	Per Engstrand	Jan-Erik Berg	Jan Andersson
Malin	Nejström	FORIC+	MIUN	Nouryon	Cellulosabaserade termoplastiska barriärmaterial	Magnus Norgren	Håkan Edlund, Ida Svanedal	Anna Kron, Bo Andreasson
Shiromini	Gamage	FORIC+	MIUN	Colabitoil	Utveckla biokatalytiska processer för produktion av fettsyror passande till HVO diesel	Erik Hedenström	Erika Wallin	Feixiang Long
Anna	Thorning	FORIC+	MIUN	Norrskog/Skogforsk	Modeller och verktyg för hållbara värdekedjor i skogssektorn	Yvonne von Friedr	Peter Öhman	Magnus Larsson
Johanna	Enström	FORIC+	MIUN	Skogforsk	Ta fram metoder för att beskriva och visualisera försörjningskedjans olika strategier, från skog till produkt.	Aron Larsson	Leif Olsson	Lars Eliasson/Anders Eriksso
Sara	Starrsjö	FORIC+	MIUN	SCA	Utvecka och optimera blekningssystem för state-of-the-art sulfatmassa	Per Engstrand	Juha Fiskari	Maria Boman
Johan	Sund	FORIC+	MIUN	Holmen Paper	Automatic control of mechanical pulp refiners	Per Engstrand	Göran Thungström	Christer Sandberg

Scientific results

We started FORIC in 2015 and FORIC+ in 2017. The industrial research college involved 16 PhD students during 2021.

Up until the end of 2021 six PhD students have left FORIC with exams: Sinke Henshaw Osong (today at Valmet) graduated with a PhD in April 2016, Johan Johansson (SCA Timber) graduated with a Licentiate degree in June 2017 and Hafizur Rahman (SCA Research) graduated with a Licentiate degree in April 2018, and a PhD in June 2021 (FSCN-MIUN), Elisabeth Björk (RISE Bioeconomy) graduated with a Licentiate degree in November 2020, Olof Ferritsius (FSCN-MIUN) graduated with a PhD in June 2021, Tove Joelsson (MoRe Research) graduated with a Licentiate degree in February 2020, and a PhD in December 2021. One PhD student left without a degree in 2017. Some students continue on to PhD after the Licentiate degree: Bahkram Gaynullin (SenseAir) graduated with a Licentiate degree in October 2019, and Sara Starrsjö graduated with a Licentiate degree in September 2021. The publication rate has been according to the individual study plans of the PhD students.

Some examples from the research presented at dissertations in 2021

Olof Ferritsius performed research to achieve a more profound understanding of how mechanical pulping processes work, in this case it is essential to have a relevant description of the material being processed. With this description, it will be easier to evaluate and control processes to produce more uniform products with the right properties. The focus of this thesis is on how to describe mechanical pulps in ways that reflect its character.

Mechanical pulps are made from wood, a highly heterogeneous material. Common practice within the pulping industry and academy is to describe mechanical pulps and its wide variety of particles in terms of averages. The energy efficiency of the mechanical pulping process is usually calculated without considering the characteristics of the wood fed to the process. The main objective of the thesis is to explore ways to make more detailed descriptions of mechanical pulps. A second objective is to propose useful ways to visualise these descriptions.

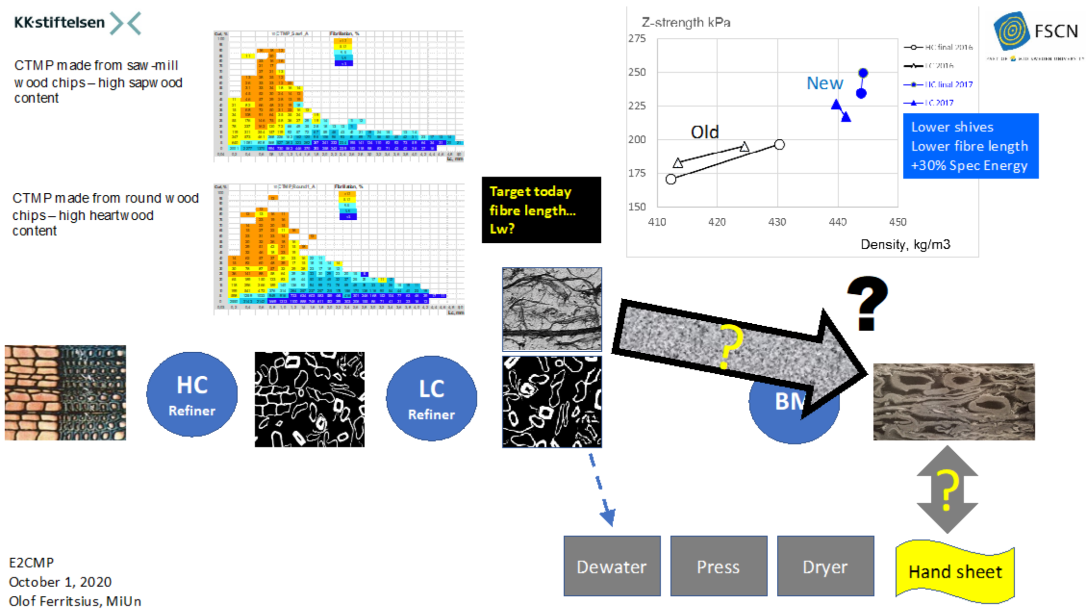
The studies were carried out in full-scale mill operations for TMP of publication grades and CTMP for board grades with Norwegian spruce as raw material. The particles in the pulps were analysed in an optical particle analyser for several properties such as length, curl, wall thickness, diameter, and external fibrillation for 10,000 to 60,000 particles per sample to cover their wide property variation. The data was analysed by factor analysis, a method used to reduce the multidimensional data space, and compared with data simulations.

Several examples were identified where averages based on wide and skewed distributions may hide useful information and therefore result in misleading conclusions regarding the fibrous material and process performance.

It was demonstrated that the average length-length-weighted fibre length, commonly referred to as the average weight-weighted fibre length, is a relevant way to express the number of long fibres, i.e., the "length factor". The commonly used average length-weighted fibre length may lead to erroneous conclusions. Through data simulations of curl and fibre length on particle level it was found that today's analysers may underestimate the true length of the particles, especially if they are prone to be curled. As a result, the ranking of pulps may be altered.

The main contribution of this study is the finding that a highly heterogeneous material such as mechanical pulps could be described in new ways through visualisation of data in 4D maps. These maps reveal casual connections and more pertinent questions may be raised in the communication along the chain from pulpwood to products.

Going beyond averages may reveal discrepancies in the process and material that were previously unknown, and lead to a more profound understanding. It seems that the mechanical pulping process can be even further simplified than previously expected. It has been concluded that to operate the process more efficiently, and to make products with just the right quality, the focus should be on the raw material and the primary refiner stage from a heterogeneity point of view.



Robert Norgren at RagnSells AB presented his research "Valorization of Low Value Organic Waste using Black Soldier Fly Larvae – Bioconversion of Sludge from the Pulp and Paper Industry". The circular economy has been suggested as a vision for how to organize production and consumption by reducing waste and supplying sustainable resources. In a circular economy, materials should always be kept at their highest utility and value. As an example, wet waste such as sludge from wastewater treatment facilities for household and industry sewage contains valuable resources. However, it is a challenge to valorise because of its low energy value, content of potential pathogens, pesticides, and heavy metals. Pulp and paper bio-sludge (PPBS) is an example of this kind of difficult waste for which the current management methods only recover low values such as energy and compost.

Valorisation of PPBS into protein by black soldier fly larvae (BSFL. Hermetia illucens) was assessed by lab-scale rearing. However, the nutrients in PPBS are not readily available to the larvae. Simplexmanipulations such as adding reference diet leachate (nutrient solution) mixed into the PPBS or as free liquid surface did not significantly increase larvae weight gain or bioconversion rate. Low nutrient availability, the occurrence of toxic substances such as pesticides and other organic toxins, toxic elements such as heavy metals and pathogenic and/or competing microbes inhibit the growth of BSFL. PPBS therefore needs pre-treatment to improve its feasibility as feed for BSFL.

Hydrothermal pre-treatment of PPBS reduces microbial occurrence and increases nutrient availability. The growth of the larvae improves, which leads to increased weight of BSFL, thus the PPBS's feasibility as feed for BSFL improves.

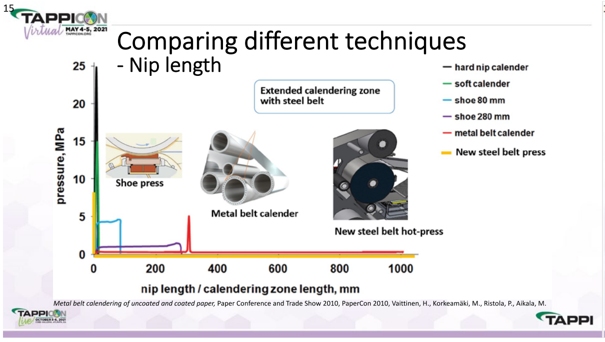
Tove Joelsson studied the potential of hot-pressing technology for manufacturing of strong, wet stable materials based on eco-friendly renewable and recyclable materials from lignocellulose. The purpose of this work was to study how the pulp fibre characteristics and the hot-pressing conditions affect the dry and wet strength properties of paper. Two different devices for hot-pressing were used. One using felted nip and a heated cylinder with a temperature limit at 200°C and one new design using a hard nip and an IR-heated steel belt with a temperature limit of 300°C.

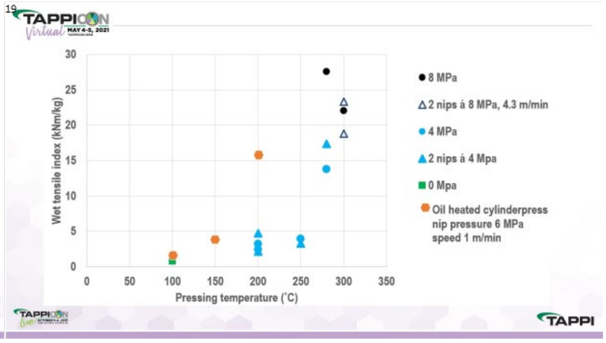
The results showed that dry strength can increase up to 150% for high yield pulp (HYP) based sheets at pressing temperatures well above the softening temperature of lignin. The maximum dry tensile strength obtained was 70 kNm/kg at 200°C pressing temperature and the corresponding value for a lignin-rich kraft pulp was about 130 kNm/kg, an increase of 30%. For all lignin-rich pulps the dry strength increased linearly with a density up to 200°C after which it levelled off and was reduced.

Dry strength of lignin-rich paper is enhanced by improved fibre-fibre contact that can be improved by compression at high temperature, well above softening temperature (Tg) of moist lignin, native or chemically modified. It is known that sulfonation of lignin lowers the Tg in moist conditions. It was observed that at a 150°C temperature the dry strength increased by 15% to a level of 71 kNm/kg for the high sulfonated pulp compared to the lower sulfonated pulp that had a dry strength of 60 kNm/kg at the same density. The level of wet strength was, however, not found to be affected by the sulfonation.

It was found that the ratio wet:dry strength was about 35–60% for all lignin containing pulp grades. A rule of thumb for an efficient wet strength resin is that the wet:dry strength ratios are 15%. This means that it should be possible to manufacture wet-strong paper from lignin-rich pulps by means of hot-pressing without using wet strength chemicals. The concern regarding repulpability of such material led to an initial test to disintegrate this paper showing that re-pulping under vigorous mixing at room temperature is possible.

The connection between dry and wet strength, high pressing temperature, and lignin content of pulp fibres is suggested to be related to some redistribution mechanisms of surface lignin between adjacent fibres. The improved wet strength and water resistance could be due to intermixing of lignin polymers across the interface between contacting fibre surfaces, or it could be lignin sufficient to cover the fibre-fibre bonds and/or chemical modifications, but these remain open questions.





Co-production process

Due to the Covid-19 pandemic, during 2020–21 General Assembly meetings, several board meetings, and courses have had to be conducted digitally. After March 2022 we will return to physical meetings, as this enhances creativity in the different research projects run within FORIC.

Deviations

The Covid-19 pandemic has of course influenced the PhD-projects within FORIC and FORIC+. To cope with this, we asked TransTech's management to extend FORIC by one year, i.e., completion by 2022-06-30, which was approved. Whether we will have to extend FORIC+ is still not clear. It was not until the beginning of 2022 before lab studies, pilot plant and full-scale studies could start in an efficient way. One PhD student will graduate with a Licentiate degree in 2022 instead of a PhD in 2023 due to reorganizations at her company Nouryon in Sundsvall. To utilize the budget to for as many PhD degrees as possible, we plan to take on a new PhD student in a project relevant for FORIC with Holmen Iggesund. Two PhD students have been ill for a large part of the year, which means that it will take longer than planned for them to complete their studies. One PhD-project at Aditya Birla Domsjö has been put on hold and the PhD student has started at AFRY. We are looking into possibilities for him to continue his studies in 2022.

Strategic impact

FORIC is an important instrument to operationalise the *TIE Vision* and to promote and facilitate implementation of research results in the industry. The holistic approach of FORIC/FORIC+ stimulates new multi-disciplinary collaborations within the university and seems to improve Mid Sweden University's ability to participate and support the ongoing industrial transformation. It is likely that this will lead to new collaborations and deeper co-production with companies related to the forest industry, e.g., in the area of business development and organizational change.

We can see a benefit in combining more fundamental technological research with research concerning business models and value creating chains as a working model for securing the industrial relevance of the research focus, specifically in the long term.

The **FORIC/FORIC+** program has also increased Mid Sweden University's interaction with other related Swedish universities; some PhD projects are included in their companies' broader academic network. As a result of this we see an increased interest from researchers from other universities to collaborate with Mid Sweden University.

Articles published or submitted for publication in journals 2021

1. Väätäinen, K., Anttila, P., Eliasson, L., Enström, J., Laitila, J., Prinz, R., & Routa, J. (2021). Roundwood and Biomass Logistics in Finland and Sweden. Croatian Journal of Forest Engineering, volume: 42, 24. doi:doi: 10.5552/crojfe.2021.803
2. Enström, J., Eriksson, A., Eliasson, L., Larsson, A., Olsson, L. Wood chip supply from forest to port of loading – a simulation study.
3. Ferritsius, O., Ferritsius, R., Rundlöf, M., Ferritsius, J., Daniel, G., Engberg, B.A. (2021). Heterogeneity of Mechanical Pulp Particles- Variations and Correlations Beyond Averages. Submitted to BioResources Nov 2021 (21 pages).
4. Ferritsius, O., Beyond Averages – Some Aspects of How to Describe a heterogeneous Material, on Particle Level (2021). Doctoral Thesis, Mid Sweden University. ISSN 1652-893X, ISBN 978-91-89341-09-8. Seven papers are included in the thesis.
5. Norgren R, Jonsson A, Björkqvist O (2021) Original article: fermented pulp and paper bio-sludge as feed for black soldier fly larvae. Biomass Conv Bioref In Press. https://doi.org/10.1007/s13399-021-01564-0
6. Sara Starrsjö, Maria Boman, Olena Sevastyanova, Mikael E. Lindström and Juha Fiskari, Assessment of Q(OP)D(PO) bleachability of softwood kraft pulp. Accepted for publication in Nordic Pulp and Paper Research Journal.
7. Sund, J., Sandberg C., Karlström A., Thungström, G. & Engstrand, P. (2021). The effect of process design on refiner pulp quality control performance. Nordic Pulp and Paper Research Journal.
8. Sandberg, C. (2021) Fibre development in an intensified mechanical pulping process. Holzforschung 75(9):824–837.
9. Sandberg, C, Ferritsius, O. and Ferritsius, R. (2021) Energy efficiency in mechanical pulping - – Definitions and considerations. Accepted for publication in NPPRJ.

Conference papers 2021: No conferences because of the pandemic.

Thesis since the beginning of FORIC

1. Osong, S. H. (2016). *Mechanical Pulp-Based Nanocellulose: Processing and applications relating to paper and paperboard, composite films, and foams* (PhD dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-29076
2. Johansson, J. (2017). *The Swedish durable wood materials market - industry structure and consumer perceptions* (Licentiate dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-30739
3. Rahman, H. (2018). *Modifying kraft pulping to produce a softwood pulp requiring less energy in tissue paper production* (Licentiate dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-32833
4. Gaynullin, B. (2019). *High accuracy low-cost NDIR sensing* (Licentiate dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-37948
5. Joelsson, T. (2020). *High strength paper from high yield pulps by means of hot-pressing* (Licentiate dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-38333
6. Björk, E. (2020). *Production and application of fine fractions made of chemical pulp for enhanced paperboard strength* (Licentiate dissertation, Mittuniversitetet). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-40246
7. Ferritsius, O. (2021). *Beyond averages - some aspects of how to describe a heterogeneous material, mechanical pulp, on particle level* (PhD dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-42060

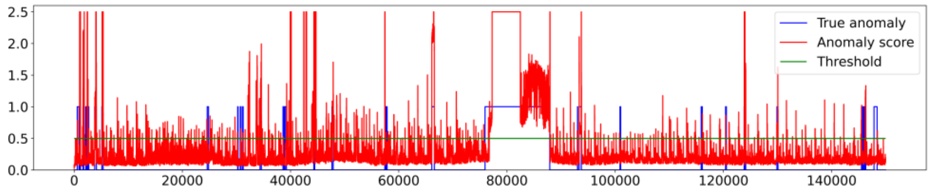
8. Rahman, H. (2021). *Aspects of optimizing pulp fibre properties for tissue and packaging materials* (PhD dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-42090
9. Starrsjö, S. (2021). *On the Process Development of an ECF Light Bleaching Sequence for the Production of High Quality Softwood Kraft Pulp and Low AOX Formation* (Licentiate dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-42380
10. Joelsson, T. (2021). *The influence of Pulp Type and Hot-pressing Conditions on Paper Strength Development* (PhD dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-43707
11. Norgren, R. (2022). *Valorization of Low Value Organic Waste by the use of Black Soldier Fly Larvae â€" Bioconversion of Sludge from the Pulp and Paper Industry* (PhD dissertation, Mid Sweden University). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:miun:diva-44067

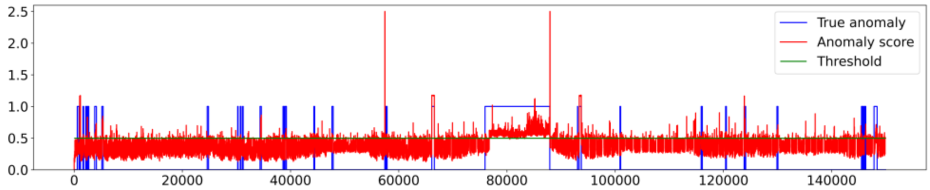
Appendix C: Status report of the industrial graduate school **Smart industry**

During the year, one more student started in the Smart industry Sweden, in the area of Smart electricity production. This means that there are two students active at Mid Sweden University within the graduate school. There are no deviations for Mid Sweden University's part of the graduate school and the progress for both students follow the plan. So far, no published papers, but the first student has several manuscripts that are about to be finalized.

Some examples of research activities

Adam Lundström investigates improved methods for anomaly detection based on hybrid unsupervised deep learning methods, where additionally to the normal behaviour for training the anomaly detection can be boosted with any additional knowledge that is available. The initial results of this, shown in the figure below, show superior behaviour to the state-of-the-art methods presented in literature. The results of this are about to be published.





Smart Industry Sweden+

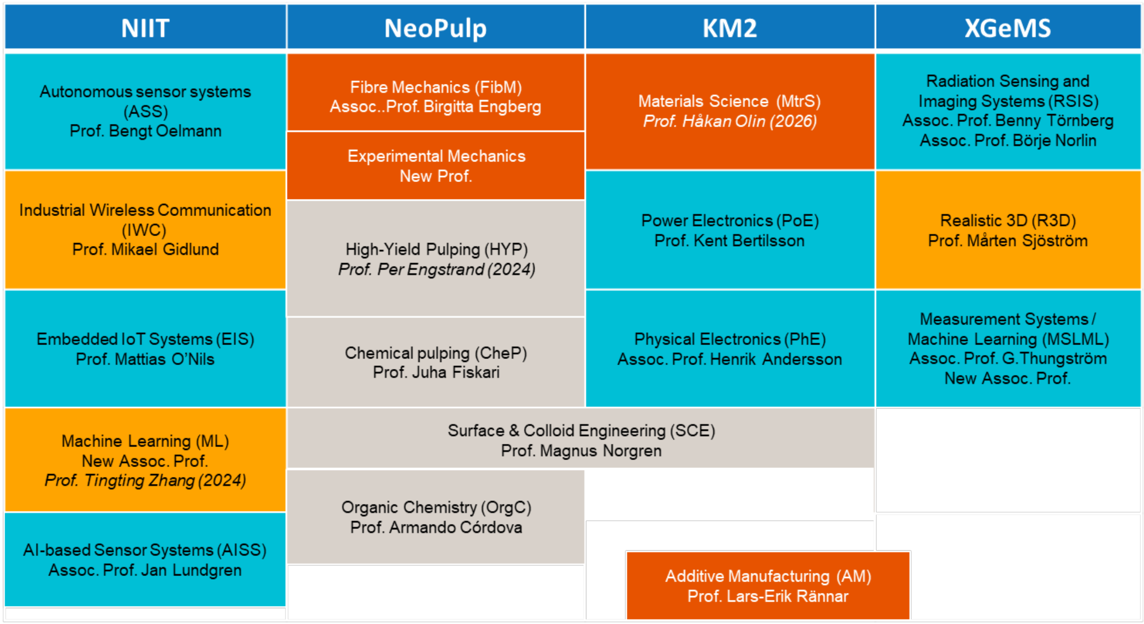
The process of accepting new students to the second stage of the graduate school has started, where discussions are currently ongoing with ten companies, with a target to reach 4 new students in the second stage of Smart Industry Sweden.

PhD students

Name and company	Start	Area
Adam Lundström, SCA	1 September 2020	Machine learning-based predictive maintenance
Viktor Döhlen, Sollefteåforsens kraftverk	1 September 2021	Smart electricity production

Appendix D: Research Groups of TransTech

Research Groups in each Strategic Action with their scientific disciplines indicated by the colour codes. The Additive Manufacturing group joined in the end of 2021. The acronyms are used in Fig. 3 of Chapter 3.



Electronics   Chemistry & Chemical Engineering   Computer Engineering   Eng. Physics, Mechanical Eng., Chemical Eng.

Contact

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