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Boosting business with science

Roadmaps toward the future bioeconomy

Sweden's forests have a higher growth rate today than ever before in modern history. About 50% of this growth is used to manufacture forest-based products such as solid wood, pulp and paper.

The forests are an invaluable natural resource that provides ecosystem services such as carbon sequestration, recreation and biodiversity. On-going research and development shows that forests can also provide cutting edge and exciting value-added products and create many new job opportunities in rural areas.

The development of value chains for these innovative products requires a multidisciplinary approach and close collaboration between research institutes, universities, industry and government. For Research Institutes of Sweden (RISE) – which consists of Innventia, SP, Swerea and Swedish ICT – the forest-based and agricultural-based components of the bioeconomy are key priorities. In a joint project, coordinated by Peter Axegård, Innventia, the RISE institutes have produced eight complementary roadmaps for how to reach the future bioeconomy. ●

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Roadmaps for the period 2015-2025
- The pulp mill biorefinery
- Lignin-based carbon fibre
- Materials from nanocellulose
- Textile materials from cellulose
- Bio-based composites
- Food industry and pulp mills in symbiosis
- Biofuels for low-carbon steel industry
- Sensors for increased resource efficiency

The roadmaps are available at www.innventia.com

Cutting cost of CO2 capture in process industry

To reduce greenhouse gas emissions is one the most important challenges of our time. The CO2stCap project will investigate where and how CO2 capture may be applied cost efficiently to the process industry. The working hypothesis is that cost reductions of at least 20% should be possible to achieve through implementing partial capture and technological optimizations.

The energy intensive process industry has a series of tools to reduce their emissions of CO2: increased use of solar and wind power as well as biomass, energy efficiency measures, and carbon capture and storage (CCS). The CO2stCap project will investigate where and how partial CO2 capture may be applied cost efficiently to emission intensive industry, focusing on cement, pulp and paper, steel and ferroalloys.

The project will take into account that individual plants may have several scattered CO2-sources of varying quality, that the possibilities for heat supply differs between plants, and the possibility to capture from bio-energy. The project will investigate if targeting the most suitable CO2 sources at individual sites could drastically reduce the cost of CO2 capture.

In process industry, utilization of waste heat energy may reduce the need for additional energy supply, or even eliminate the need completely. The project's working hypothesis is that cost reductions of around at least 20% should be possible to achieve through implementing partial capture including associated technological optimizations. Even if waste heat amounts are limited on a given site, capture cost may be reduced. The overall aim is, thus, to suggest a cost effective carbon capture strategy for future CCS systems considering utilization of waste heat and intermittent power generation, a more efficient use of biomass resources, different capture technologies and optimization, as well as changed market conditions.

The CO2stCap project, coordinated by Tel-Tek, will focus strongly on developing tools for technical-economic analyses and cost estimation of CO2 capture technologies in different industries.

Innventia has developed simulation models built up in the software WinGEMS to simulate the performance of modern market pulp mills. The model allows for estimations of effects on material and energy balances of the paper mill when implementing different types of modifications or when adding new equipment and/or material flows to or from the mill such as adding a unit for capture of CO2 from one or several of the flue gases from the mill. This information is essential when evaluating the techno-economic effects of making these modifications.

"One specific challenge for the pulp mill is that the available low temperature steam possible to use for CO2 capture has a relatively high use and value compared to other industries, and that the excess heat is at too low temperature," says Marie Anheden, Innventia. "Ways to overcome this challenge will be investigated in the project. An additional challenge is that the economic incentives for capture of CO2 which originates from biomass, which is the case in the pulp and paper industry, are unclear." ●

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CO2stCap runs for four years with funding from CLIMIT-Demo, The Swedish Energy Agency and participating industry and research partners.

Marie Anheden

Att minska utsläppen av växthusgaser är en av de viktigaste utmaningarna i vår tid. I det fyraåriga projektet CO2stCap undersöks var och hur CO2-fångst kan tillämpas kostnadseffektivt kostnadseffektivt på utsläppsintensiv industri, med fokus på cement, papper och massa, stål och ferrolegeringar. I processindustrin kan utnyttjande av spillvärmeenergi minska behovet av ytterligare energitillförsel, eller till och med eliminera behovet helt. Projektets arbetshypotes är att kostnadsminskningar på omkring minst 20 procent ska vara möjligt att uppnå genom att genomföra partiell avskiljning inklusive tillhörande tekniska optimeringar.

The lightweight, fuel-efficient cars of the future can be made using materials from our Swedish forests. The raw material can also be used in batteries, which reduces the use of fossil-based materials and fuel. A team from Innventia, Swerea, KTH Royal Institute of Technology and Blatraden is now demonstrating this by means of a model car.

The fossil-free car of the future is in the forest

Innventia, Swerea, Blatraden and KTH are now able to present the first model car with a roof made of a composite using carbon fibre based 100 per cent on softwood lignin. The car has also been equipped with a battery in which lignin-based carbon fibre is used as the electrode material. The car is toy size, a demonstrator manufactured on a small pilot scale, but this is a major step towards realising the vision of new lightweight materials from the forest as part of the future bioeconomy.

Carbon fibre composites are strong and light, with many applications. Today, demand is mainly limited by the high cost. As a result, carbon fibre is currently used primarily in products where performance is the priority. Lignin is a by-product of paper pulp manufacturing and can be produced cost-effectively. Using lignin would lead to significantly increased access to a raw material that is also biobased. Even 'ordinary' cars and other everyday products could be produced from carbon fibre. Lighter cars lead to lower fuel consumption or longer ranges for electric cars.

Lignin fibre produced at Innventia carbon fibre laboratory, a test bed with equipment for both single and multi-filament extrusion.

In 2014, Innventia and Swerea launched a plan for how Swedish lignin-based carbon fibre could be available within a ten-year period. The next step according to researchers is a process line on a pilot scale with continuous production in order to identify the challenges that always arise when scaling up. In addition, larger quantities of carbon fibre are required to evaluate composites and composite components.

"Further efforts are required to achieve our goal. This demonstrator is a clear example of how cooperation between our test beds and R&D infrastructure helps us to move forward. Our work on various projects is aimed at using lignin in as valuable a way as possible," says Per Tomani, Team Leader for Lignin & Carbon Fibres at Innventia.

"Collaboration has definitely been a success factor for development. With the knowledge of lignin as a raw material possessed by Innventia, plus Swerea's knowledge of composites and the electrochemistry know-how of KTH, led by Professor Göran Lindbergh, we have been able to assemble the puzzle from three different quarters," says Project Manager Anders Uhlin at Innventia. ●

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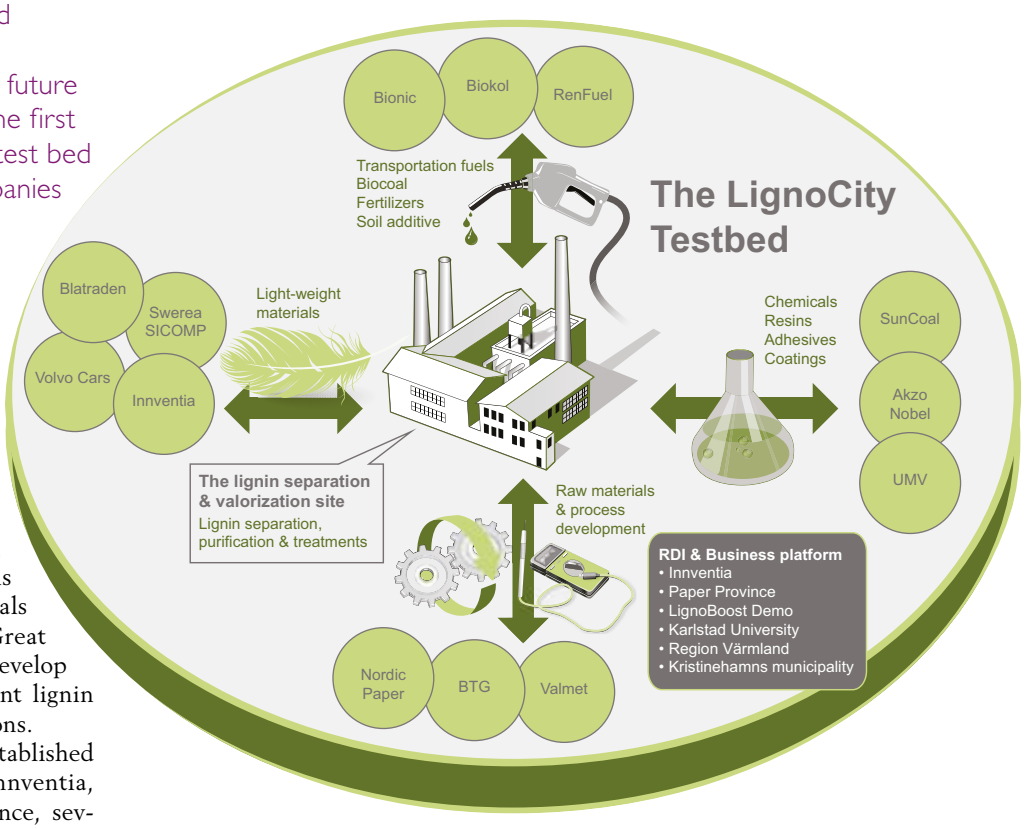
The work has been carried out as part of the BioInnovation strategic innovation programme, a joint venture on the part of Vinnova, Formas and the Swedish Energy Agency. The demonstration project involved Innventia (coordinator), Swerea SICOMP, KTH Royal Institute of Sweden, Blatraden, and industrial partners in Innventia Research Programme 2015-2017.

Innventia, Swerea, Blatraden och KTH kan nu visa upp den första modellbilen med ett tak tillverkat av en komposit där kolfibern är baserad på 100 procent barrvedslignin. Bilen har även försetts med ett batteri där ligninbaserad kolfiber används som elektrodmaterial. Bilen är i leksaksstorlek, en demonstrator tillverkad i liten "pilotskala", men innebär ett stort steg för att förverkliga visionen om nya lättviktsmaterial från skogen som en del av den framtida bioekonomin. Lättare bilar innebär lägre bränsleförbrukning eller längre räckvidd för elbilar. Idag används kolfiber främst i produkter där prestanda prioriteras före pris. Att använda lignin skulle ge väsentligt ökad tillgång på råvara och även alldagliga produkter skulle kunna tillverkas i kolfiber.

LignoCity – a centre for developing and upscaling technologies

Innventia, Paper Province and Nordic Paper have started a collaboration to develop the future forest-based bioeconomy. The first step is to establish an open test bed called LignoCity. Here, companies can develop and scale up technology that refines lignin to new climate-friendly fuels, chemicals and materials.



As the world heads towards a bio-based economy, lignin – a by-product of pulp production – is increasingly seen as a raw material with great potential. Lignin could be a green alternative for producing fuels and energy as well as chemicals and lightweight materials. Great efforts are being made to develop processes and to refine different lignin qualities for different applications.

Thanks to a broad newly established collaboration initiated by Innventia, Nordic Paper and Paper Province, several of these initiatives can now be realised. With financial support mainly from Vinnova, Innventia's demonstration plant in Bäckhammar will be further developed and made into an open test bed for companies who want to evaluate and validate new refining concepts in the lignin area. The plant is currently the only one in the world that can produce tailor-made lignin qualities in sufficient quantities for upscaling.

The purpose of LignoCity is to create a centre where ideas are brought together and opportunities for commercial development are identified and supported. Lignin from kraft pulp production and other sources, for example from ethanol and sugar production, can be processed at the plant. The project involves 18 industrial and public players, including Karlstad University, the municipality of Kristinehamn and Casco Adhesives AB.

"With LignoCity, we are bringing together business models, technological development and infrastructure for research, development and innovation. In the long term, we also hope to be able to extract other components from the black liquor and tackle other process streams," says Per Tomani, manager for the LignoCity project and the Lignin & Carbon Fibres focus area manager at Innventia.

"It is extremely valuable for the region's businesses to have access to this type of open test facility, so that we can continue the development of a forest-based bioeconomy," says Maria Hollander, CEO of Paper Province. ●

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On the 8 February the partners of LignoCity and media representatives gathered for a kick-off at LignoBoost in Bäckhammar.

Innventia, Paper Province och Nordic Paper har inlett ett samarbete för att utveckla framtidens skogsbaserade bioekonomi. I ett första skede etableras en öppen testbädd kallad LignoCity. Här kan företag utveckla och skala upp teknik som förädlar lignin till nya klimatvänliga bränslen, kemikalier och material. Anläggningen är i dag den enda i världen som kan producera skräddarsydda ligninkvaliteter i tillräckligt stora kvantiteter för uppskalning. Syftet med LignoCity är att skapa ett center där idéer förs samman och möjligheter till kommersiell utveckling identifieras och stöds. Lignin från sulfatmassaproduktion, men även från andra källor kan upparbetas i anläggningen. Projektet involverar 18 industri- och samhällsaktörer.

What do we mean when we say "lignin"? The answer depends on who you ask. A wood chemist probably regards lignin as a macromolecule with a certain chemical structure. For the pulp producer, "lignin" might be the same as the kappa number, whereas from the biorefinery perspective, we often use the term "lignin" for a preparation or a product that consists mainly of lignin (from a chemical perspective) containing more or less contaminants. What goes into the concept of "lignin" thus depends on the context and the perspective.

By Anna Jacobs and Fredrik Aldaeus

We need a common language to describe lignin

The greatest challenge to lignin trade and development is to prepare technical specifications for different lignin applications. In order to do that, we need a common language to describe lignin properties. As mentioned above, we lack a common definition of "lignin". Furthermore, we also lack analytical methods that give the same results, regardless of who performs them.

At Innventia, we have identified three groups of properties that we need to analyse in order to describe a lignin preparation: purity, molecular properties and thermal properties.

Purity includes content of lignin, moisture and various impurities (for example carbohydrates, extractives and inorganics). The main problem is that almost all standardized methods were developed for wood, pulp and paper, and may not be directly applicable to lignin samples. Lignin samples usually contain higher amounts of volatile substances compared to wood and pulp samples. These substances evaporate during drying, which makes it difficult to determine the actual dry content of the sample. You might even ask what the "sample" is. Is it the lignin including the volatiles, or is it the dried preparation? Once again, a clear definition of the term "lignin" would be very useful.

Molecular and thermal properties include molecular mass, functional groups, melting properties, etc. Many different, more or less established methods are available but no standard methods exist. In many cases these methods involve several analytical parameters that may be varied, for example type of analytical instrument or instrument parameters. The results obtained may be completely different depending on the method or method parameters of choice. Therefore it is very difficult to compare results obtained by different labs or on different occasions. To overcome these difficulties, several groups have made attempts to harmonize methods, but to our knowledge there are still no generally accepted methods. With some self-criticism, one might hazard a guess that most researchers are fond of their own particular methods and prefer to continue using them.

In conclusion, to be able to trade lignin and develop lignin-based products, we need specifications. Analytical data from the trader must be possible to reproduce in the purchaser's lab. In order to get there, we need to raise the question of analytical methods for lignin to a higher level. The players within the field need to agree on definitions and harmonize methods. That way, we can start creating the necessary common language. This is something that we at Innventia will increasingly work on during the coming years, together with our partners. ●

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Den största utmaningen för att kunna sälja lignin och utveckla nya värdefulla produkter är att ta fram kravspecifikationer för lignin med olika användningsområden. För det krävs ett gemensamt språk för att beskriva ligninets egenskaper. Det har vi inte idag. Det saknas en definition av termen "lignin", men också analysmetoder som ger samma svar oberoende av vem som utför analyserna. På Innventia har vi identifierat tre grupper av egenskaper som vi behöver kunna analysera för att beskriva ett ligninpreparat: renhet, molekylära egenskaper och termiska egenskaper. Problemet är att nästan alla standardmetoder är framtagna för ved, massa och papper, och det är inte självklart att de fungerar på ligninprover.

A new approach with Innventia TechMark Arena

The Bo Rydin Foundation presented the Best Master's Thesis of the Year 2015 award to Anna Nilsson and Hanna Skoglund. Their thesis revolves around a new bio-based material and two champagne bottle packaging demonstrators that communicate either luxury or playfulness. The project was part of Innventia's 2015 TechMark Arena.

Demonstrators produced within Innventia's 2015 TechMark Arena were showcased during Innventia Days 2015.

Innventia developed a bio-based and textile-like PLA paper having a wide range of potential applications. Anna and Hanna's Material Identity Crisis project, for which Siv Lindberg and Hjalmar Granberg were the main supervisors, dealt with the material's technical and perceived properties and the possibilities it can offer as a packaging solution. The students used various conversion techniques to create curved board demonstrator concepts with diametrically different expressions. The packaging casings for champagne bottles showed how the material can communicate a sense of either playfulness or luxury.

Anna and Hanna were recently presented with the Best Master's Thesis of the Year 2015 award by the Bo Rydin Foundation for Scientific Research.

"We're very pleased to have received this award, and that the demonstrators have won recognition," say Anna and Hanna. "Writing our thesis at Innventia was a good conclusion to our education, giving us the opportunity to apply our product development knowledge to areas that were new to us, such as papermaking and material identity. It was particularly fun working with different areas in parallel and bringing everything together in a joint end-product. It was fascinating seeing how Innventia works with product development, where demonstrators are an important tool for visualising research."

The material is part of a family of materials named by the Confederation of European Paper Industries (CEPI) as one of the most innovative products within the paper and pulp industry 2015.

Innventia's TechMark Arena represents a new approach to leading master's theses.

"Six theses were completed during 2015 around the common theme of material experience. The students were led by a supervisory team and the aim was bridging the gap between research and market. " says Marie-Claude Béland, who was one of TechMark Arena's supervisors at Innventia. "We're proud of all the students, and are delighted that Anna and Hanna have received this award." ●

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2016 TechMark Arena
Additive manufacture of cellulose-based materials, such as 3D forming of nanocellulose, will be in focus of 2016 master theses school at Innventia.

Hanna Skoglund and Anna Nilsson focus on their work. To the right, their prize-winning demonstrator.

Bo Rydins Stiftelse tilldelar priset Bästa examensarbete 2015 till Anna Nilsson och Hanna Skoglund. I centrum står två champagneflaskor i material som kommunicerar antingen lyx eller lekfullhet. Arbetet genomfördes som en del i Innventias exjobbsskola TechMark Arena 2015. Detta initiativ står för ett helt nytt sätt att leda exjobb. Med ett gemensamt tema och ett gemensamt team av handledare genomfördes sex examensarbeten med syfte att överbrygga gapet mellan forskning och marknad. Annas och Hannas projekt "Material Identity Crisis" kretsade kring ett biobaserat textilliknande PLA-pappers tekniska och upplevda egenskaper och möjligheter för en förpackningslösning.

Advanced wood-based 3D structures

The interdisciplinary project Would wood is to establish a consortium for developing integrated material and production concepts for large-scale additive manufacture of advanced wood-based 3D structures. The goal is furniture and structural elements and, in the long term, medium to large-scale construction projects for the sustainable cities of the future.

New materials cannot be developed optimally if they have to be adapted to current manufacturing processes, which is why it is important that the production of the new innovative materials is organised in close cooperation with the development of new manufacturing processes.

The Would wood project, coordinated by Mikael Lindström, Innventia, involves an innovative wood-based material for 3D printing and its manufacturing technique. The challenge is in modernising the current production technique for wood products, enabling it to be adapted for 3D printing. Would wood covers the development of materials, robotics and additive manufacturing processes, as well as design tools for developing sustainable wood-based composites that are suitable for medium/large-scale 3D printing.

"Our vision is to radically change the way we produce everything from furniture, accessories and structural elements to entire buildings. In that way, we lay the groundwork for a new chain of products and services based on 3D-printed wood," says Mikael Lindström.

Producing materials locally, to order, without large stocks, waste or middlemen and thusensuring quality and good working conditions is also an key driver inthe development of 3D-printing.

"We believe that this technology will change the way we look at allaspects of sustainability, including quality of life, environment, logistics, materials strategies, energy and transportation. It's a very exciting time and we see 3D printed wood as an innovative,sustainable and obvious material in the biobased economy of the future," says Mikael.

By working across industry boundaries in design and architecture, robotics and mechatronics, and materials engineering, the psychology of perception and the forestry industry, this project will generate interdisciplinary knowledge and interaction. The project intends to collaborate with other initiatives looking at additive manufacturing processes.●

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Would wood is one of 31 new projects being financed by Vinnova through its Challenge-Driven Innovation programme. The initiative for the application comes from three young architects: Cesilia Silvasti, Kayrokh Moattar and Lily Huang. The White architectural practice, the KTH School of Architecture and the Mechatronics group at Machine Design, KTH, as well as Innventia, are behind the application.

Det transdisciplinära projektet Would wood ska etablera ett konsortium för att utveckla integrerade material och produktionskoncept för storskalig additiv tillverkning av avancerade träbaserade 3D-konstruktioner. Målet är möbler och byggelement och i förlängningen byggnationer av mellan till stor skala för framtidens hållbara städer. Nya material kan inte utvecklas optimalt om de måste anpassas till dagens tillverkningsprocesser därför är det viktigt att framtagningen av de nya innovativa materialen sker i nära samarbete med utvecklingen av nya tillverkningsprocesser. Genom att samarbeta över branschgränser genererar projektet tvärvetenskapliga kunskaper och samverkan.

COMING EVENTS

FEBRUARY

12	Disputation by Kari Hyll: "Image-based quantitative infrared analysis and microparticle characterisation for pulp and paper applications"

MARCH

23	Innovation Pioneers Tankmeeting #1 2016

APRIL

12-14	Renserikonferens 2016, Innventia woodroom conference
20-21	Energy Storage Papers 2016
21	P3G seminar
26	WOTIM second training module
27-28	SPCI Convention and Control Systems 2016

MAY

24	Release of Innventia Global Outlook A Cellulose-Based Society
24-26	International Wood Biorefining Week

For further information on coming events, see www.innventia.com

Innventia Days
27-28 September, 2016

Innventia will host
TAPPI Advanced Coating Seminar
4-6 October, 2016

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Let us know by sending an e-mail to info@innventia.com.

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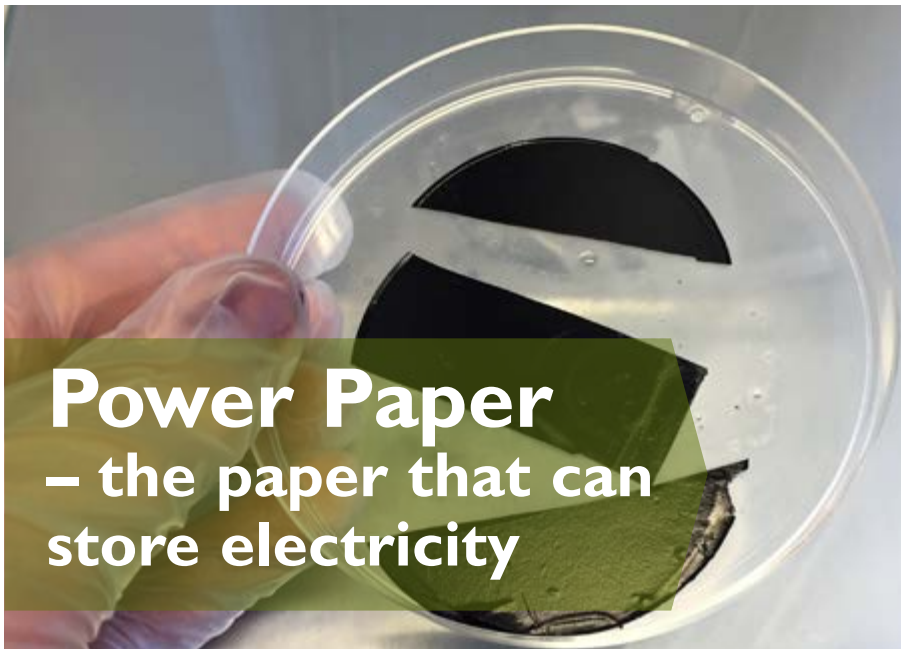
Innventia's Hjalmar Granberg has helped to develop paper with an outstanding ability to store electricity. The material consists of nanocellulose and conductive polymer, and has generated a great deal of interest.



Power Paper – the paper that can store electricity

Project manager Hjalmar Granberg at Innventia presented the findings in the journal Advanced Science, together with researchers from KTH Royal Institute of Technology, Linköping University, the Technical University of Denmark and the University of Kentucky.

The demonstrated material is a rubber-like paper based on cellulose fibres that have been refined into nanocellulose at Innventia's nanocellulose pilot facility. The nanocellulose is dispersed in water, and when an electrically conductive polymer is added the polymer forms a thin coating around the nanocellulose fibres.

The material has been used to manufacture a sheet fifteen centimetres in diameter and a few tenths of a millimetre thick that can store as much as 1 F, similar to the supercapacitors currently on the market. The material can be recharged hundreds of times, and charging only takes a couple of seconds.

Hjalmar Granberg

Hjalmar, how did you go about developing this paper?

We worked as a team and made use of each other's expertise. One of the keys to the breakthrough was working with polymers in a wet state. This makes the cellulose flexible and adaptable, enabling us to build thick layers. We also created sufficient mechanical properties to be able to handle the rubber-like paper.

What's so great about this new material?

We have beaten four world records:

- The highest charge and capacitance in organic electronics: 1.2 Coulombs and 2 Farads respectively.
- The highest measured current in an organic conductor: 1 Ampere.
- The highest capacity to conduct both ions and electrons simultaneously.
- The highest transconductance in a transistor (change in current depending on the voltage). We are the first to have measured values above 1 Siemens. The previous record was a few thousandths of a Siemens.

What are the prospects for the future?

We have a year of work left within the current Power Papers project, which is being financed by the Wallenberg foundations and RISE. In future, the Swedish Foundation for Strategic Research (SSF) will finance the production of power papers, in which we will focus on production methods. ●

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New project: Innventia is leading Production of Power Paper which is developing an industrially viable process for continuous production of the world record holding power paper.

Power Paper handlar om ett papper med enastående förmåga att lagra el. Ett gummiliknande papper som i grunden bygger på cellulosafibrer som har raffinerats till nanocellulosa i Innventias nanocellulosapilot. Nanocellulosan ligger i en vattenlösning och när en elektriskt ledande polymer tillförs, lägger sig polymeren som en tunn hinna runt nanocellulosafibrerna. Av materialet har man tillverkat en platta, femton cm i diameter och någon tiondels mm tjock som kan lagra inte mindre än 1 F, vilket är i samma storleksordning som de superkondensatorer som i dag finns på marknaden. Materialet går att ladda upp hundratals gånger och det tar bara ett par sekunder.

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