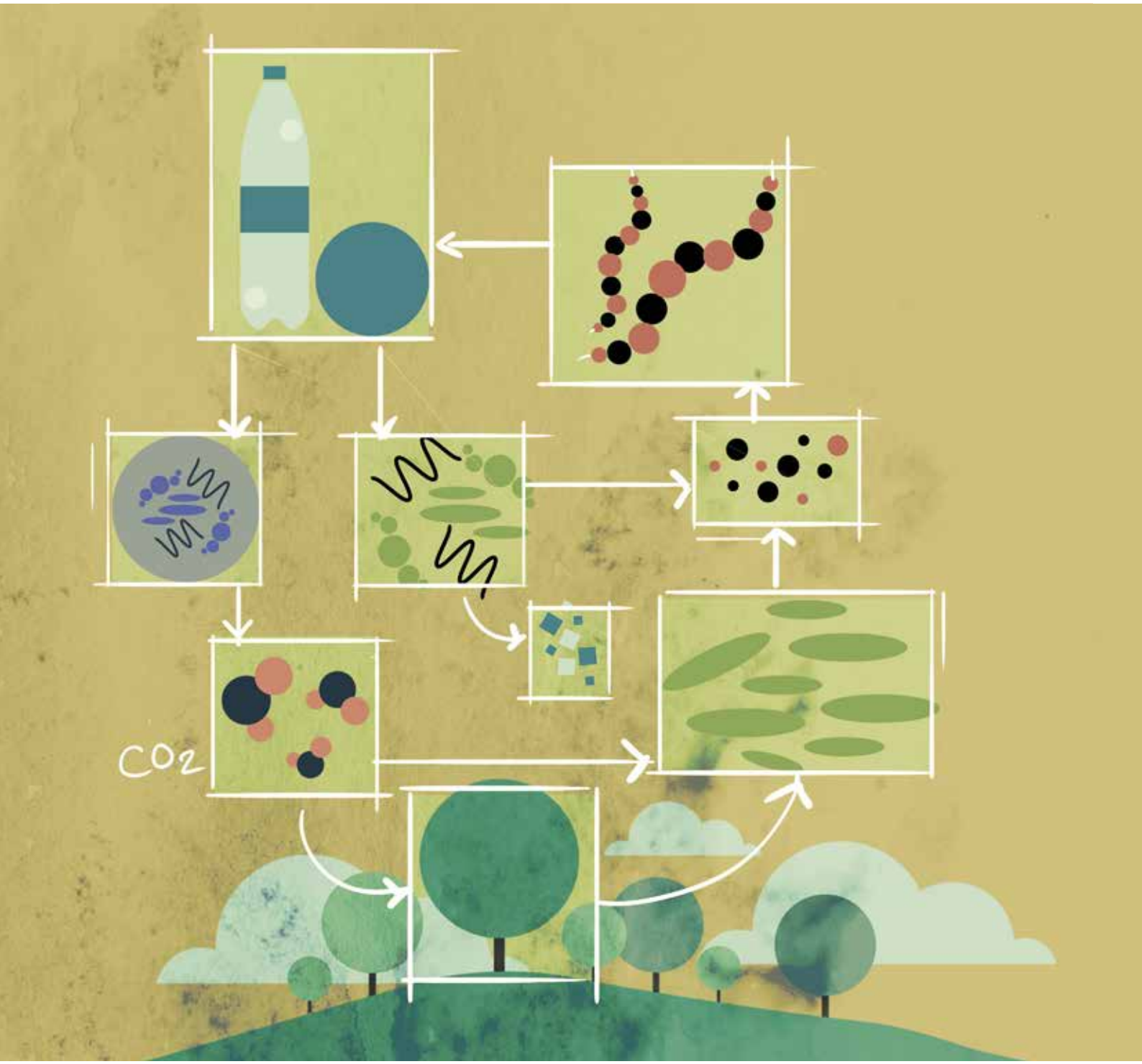
STEPS

Sustainable Plastics
and Transition Pathways

ANNUAL REPORT 2019



STEPS programme

The Mistra financed programme STEPS – Sustainable Plastics and Transition Pathways – is a research programme with a vision of a future society where plastics are sustainably produced, used and recycled. The goal is to facilitate this transition by sharing innovation, knowledge and findings between academia and stakeholders.

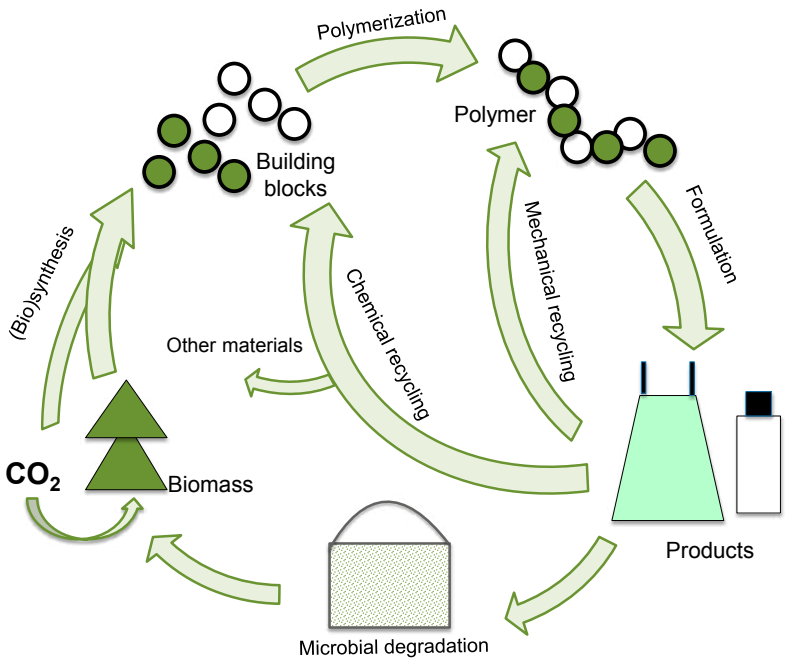
STEPS partners include Lund University, the Swedish Agricultural University, and Swerea IVF (now RISE), along with 18 industrial partners and Skåne county council – representing the entire value chain in a sustainable plastics system: renewable raw materials providers, producers of chemicals and plastic materials, users of plastics and plastic waste handlers.

STEPS is looking for sustainable solutions throughout the value chain from the choice of renewable feedstock, conversion and design of plastic products to post-consumer plastic waste handling.

The concept is to design sustainable plastics with desired materials properties and life-cycle by matching suitable carbon-neutral building blocks from agriculture and forestry side-streams, and even carbon dioxide. Transformation of feedstock to building blocks is based on green chemistry and biotechnology processes to achieve resource-efficiency and low environmental impact, and the bioplastics are designed for efficient recycling or biodegradation.

STEPS main focus is on polyesters – a plastics group with varying properties for a wide range of applications and a sizable global market. Target applications for plastics developed in STEPS are packaging, textiles, coatings and durable products.

STEPS goal is also to assess potential transition pathways to develop research-based advice on policy and industrial strategies for sustainability in the longer term. Governance and policy implications for a circular plastics economy are addressed, including social dimensions and the roles and responsibilities of key actors.



Reference: R Hatti-Kaul, L J Nilsson, B Zhang, N Rehnberg, S Lundmark (2020). Designing Biobased Recyclable Polymers for Plastics. Trends in Biotechnology 38, 50–67.

Three interlinked workpackages

Photo: Kennet Ruona

WP1 has focus on production of polyester building blocks from surplus renewable feedstocks using clean and cost-effective process technologies.

In 2019, development of a green process for the production of 5-hydroxymethylfurfural (5-HMF; used as a component in the floor coating StepOn) from fructose from Nordic Sugar was completed. A novel HMF oxidase like enzyme was developed for oxidation of HMF. Also, an integrated process for the production of different building blocks, adipic acid, 6-hydroxyhexanoic acid and caprolactone from FMF derived 1,6-hexanediol was demonstrated in lab scale.

WP2 combines suitable bio-based building blocks from WP1 to produce polyesters that will be characterised and evaluated for target applications such as fibres, coatings, packaging and films. Modified natural polymers are also evaluated as components in plastic formulations.

In 2019, we have published two important articles that combined synthetic development of new monomers and polymers together with LCA (life cycle analysis) investigations. This is very rarely seen in the literature and has received positive feedback. We have also successfully produced a first textile demonstrator, Step-In socks, which demonstrated the whole process, from molecular design, up-scaling synthesis, fiber production, and textile fabrication.

WP3 has the main task to assess potential transition pathways to develop research-based advice on policy and industrial strategies for sustainability in the longer term. Governance and policy implications for a circular plastics economy are addressed, including social dimensions and the roles and responsibilities of key actors.

Among the highlights of 2019 was the creation of a database over plastic policies in Sweden and Denmark since 2010. Moreover, an investor brief directed at financial investors with the specific aim to facilitate the financial sector to make sustainable investments, was published in collaboration with IVL Swedish Environmental Research Institute.

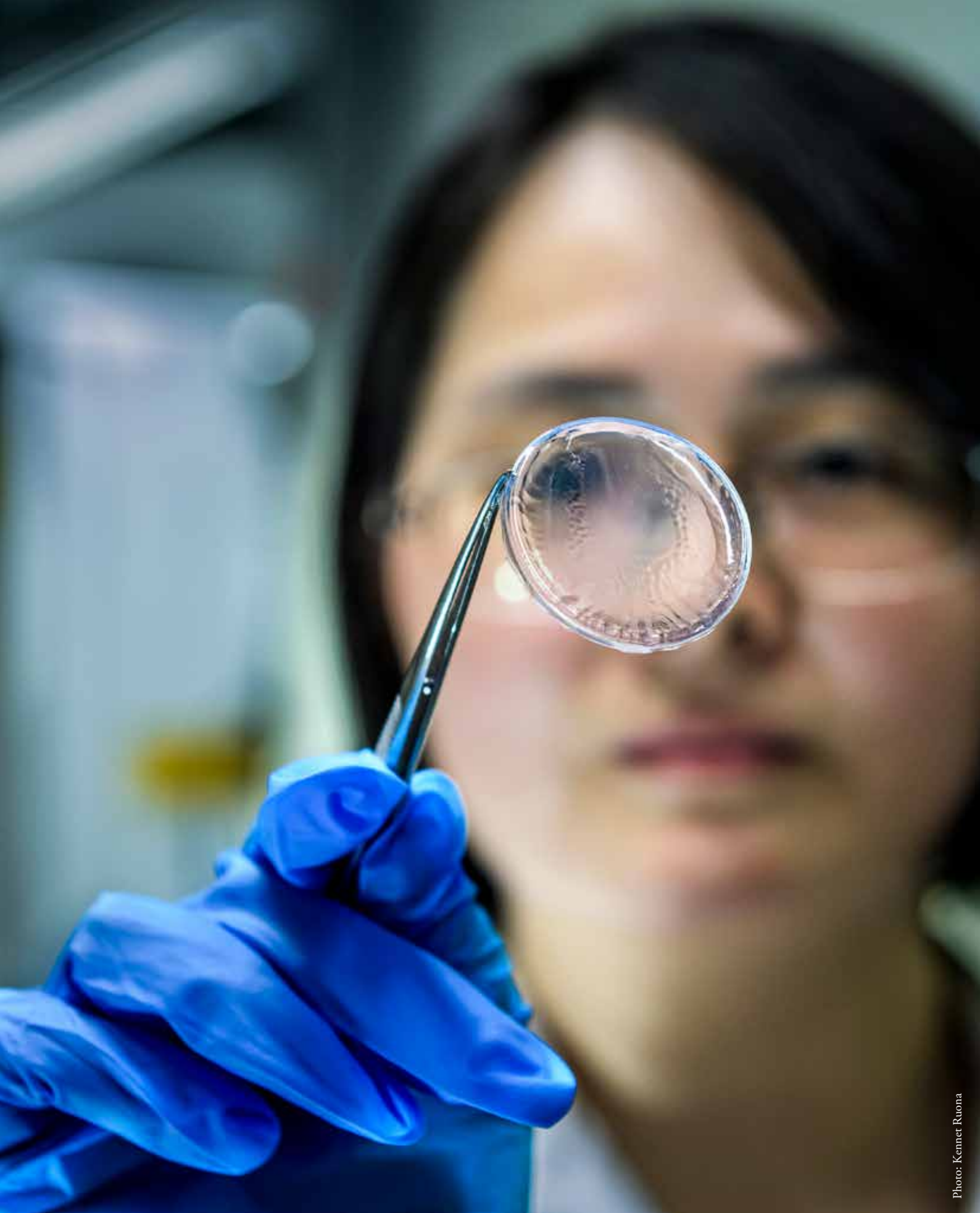


Photo: Kennet Ruona

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Cover: An artistic illustration of the new plastics economy. The carbon-neutral building blocks are produced from biomass or directly from carbon dioxide using green processes (e.g. based on biotechnology), and used for constructing polymers that are designed to produce plastics that after use can be recycled through mechanical, chemical or biological recycling. Illustration by Catrin Jakobsson, Lund University.

Message from the Board

Again, this has been a year when plastics have hit the headlines, the issues being waste, recycling, littering, taxation of plastics and a lot more. There is an obvious need for facts, sincere discussions, and evidence based decision making in society at many levels. Since its inception, STEPS has contributed by being a unique platform for science and technology, stakeholder dialogues, and communication. STEPS is recognised as a valuable and trustworthy source of information. With a proactive communication agenda, the programme has resources to meet the expectations. The prerequisite is the fruitful collaboration between different academic disciplines and industry covering the whole value chain of raw materials, plastic additives, plastic producers, plastic users, and waste management. All needed to pave the way for a circular plastics economy.

The STEPS programme has so far, besides excellent science, produced two demonstrators. One is the Step-On biobased varnish that covers the floor in a conference room at Lund University. The other very recent one, Step-In, is a sock made from knitted biobased polyester fibres. When will we see them in the shops? How to bridge and cross ”the valley of death”? The metaphor is attributed to US Congressman, Vern Ehlers, who wanted to illustrate the gap between research findings and its practical use, to go from research to innovation. Lots of great ideas get lost in the arid valley. To survive the valley of death and reach the other green side, there is a substantial need of investments for further research, development, production, marketing, etc, well known steps to a successful commercialisation. It takes money, it takes time, and it takes entrepreneurial minds. There will be more STEPS demos to provide inspiration.

There are now several more or less global networks targeting plastics. The New Plastics Economy Global Commitment consists of businesses, governments, NGOs and others, up till now more than 400 signatories. It is a collaboration between Ellen McArthur Foundation and the UNEP. They address plastic waste and pollution at its source and started with packaging and ambitious targets for year 2025. The first progress report was published in October 2019 highlighting what companies and governments have accomplished so far. The transparency is impressing.

The STEPS programme is already into its fourth year of work, which means that Phase 1 is coming to an end. STEPS Phase 2 will be launched in the second half of 2020, planned for a seamless transition. Last year was much influenced by preparing the Progress Report and the Research Application for a Phase 2, all according to Mistra´s requirements. Like the first phase, STEPS Phase 2 will be financed by Mistra and STEPS consortium partners in industry together with one county council. Most industrial partners will remain in the consortium, some are leaving, and new partners will join. Which means new constellations, new issues and ideas, and new experience. The STEPS consortium will continue delivering knowledge and guidance to the benefit of a circular plastics economy.

Britt Marie Bertilsson
Chair of STEPS Board

Message from the Management group

In 2019, plastics continued to occupy the headlines, and a number of measures have been emerging to address the problem of plastic waste in the environment. A significant example is that of the European Union and several other countries making the decision to ban or restrict several single use plastic products immediately or in the very near future. The industry has geared itself up to consider plastic recycling seriously, while concerns for climate change also resulted in increasing demand for biobased plastics. Little did we realise the momentum of the high level decisions being taken in a relatively short time span! These developments have strengthened the role of STEPS, which is also confirmed by a number of external stakeholders expressing interest to join the programme. It has further led us to rethink how best we can contribute to a sustainable transition, and increase the impact of our research in a reasonable time period. And as we near the end of the programme, we have put considerable efforts to outline our achievements in Phase 1 and submitted a research proposal to Mistra for continuation into the second phase of STEPS.

STEPS has been proactive in contributing to the discussion around the Swedish plastics enquiry, Det går om vi vill – förslag till en hållbar plastanvändning, and to the debate on the single-use plastics ban. Researchers in the programme have also been involved in close discussions with the European Environmental Agency, the European Union and organisations in Sweden.

Overall, it has been an eventful year for STEPS, marked by several outreach events, and presentations at various conferences, as well as by a number of high impact scientific publications, for example on polymer design and synthesis. We also co-produced a very well received brief for financial investors on sustainable plastic investments. An initiative, Plastic ReDesigned, was launched to engage and reach new target groups, such as designers and architects, and to explore the potential to communicate through participatory practices and art. Finally, an important highlight at the end of the year was the demonstrator Step-In – socks made from a biobased polyester fiber – a result of close collaboration between several partners. We value highly the enthusiasm and engagement of all our partners, which has played a critical role in the success of STEPS.

We have now reached a stage where we have a fairly good understanding of the plastic materials and system, of the political will and industrial interest in transition to a more sustainable system. We are pleased and inspired by the fact that all the programme partners share the same vision of a plastic sector characterised by sustainable production, use and recycling. As we look forward to the next phase of STEPS, we plan to build on this understanding and continue to work closely on specific plastic challenges, strengthening our collaborations over the coming years.

Rajni Hatti-Kaul
Programme Director

Highlights

February

Founders of Tomorrow

Lars J Nilsson presented the 1.5 °C challenge based on the recent IPCC report and decarbonisation pathways for industry including plastics and steel at the Founders of Tomorrow Impact bootcamp and idea competition in Copenhagen.

March

Science and Innovation Talk

STEPS researcher Tobias Nielsen, Political Science, Lund University, talks about Pathways to Sustainable Plastics at Tetra Pak's Science and Innovation Talk! Five pathways to more sustainable plastics are discussed: bio-based, biodegradable, recycling, fewer types and reduced use.

March

Crops or Carbon Dioxide? What is the Future of Plastics?

Researchers from Lund University and RISE explore the possibilities of using residues from agriculture, or even carbon dioxide, to produce plastics in way that avoids food insecurity and negative climate impacts in the future in a panel debate organised by STEPS as part of Lund Sustainability Week 2019.

April

Japan-Europe Dialogue 2019

STEPS researcher Tobias Nielsen talks about pathways to sustainable plastics in front of scholars and practitioners, including Japan's Vice-minister for Environment, at the *Japan-Europe Dialogue 2019, Pathway to Reducing Marine Plastic Pollution -Toward achieving Sustainable Development Goals.*

May

Plastteknik Nordic

STEPS organises a panel debate on the topic *Transition to sustainable plastics – what, who and how?* at the business fair Plastteknik Nordic in Malmö, with representatives from Perstorp, Sysav, SPIF and General Plastics Scandinavia.

May

Spring Programme Meeting

STEPS Spring Programme Meeting is attended by academic and industrial partners, board members and invited speakers, who talk about the role of packaging for food safety, about research and innovation in food packaging, how micro- and nanoplastics affect our environment and contemporary artistic visual representations of the plastic crisis.

June

Plastics ReDesigned

Designers have a key role in the transition to a sustainable plastics society, but often have limited knowledge of plastics as a material, and how to use it. STEPS and Form/Design Center in Malmö have come together to start a new collaboration to increase knowledge, highlight research, and to encourage new and creative design approaches.

June

Fully-recyclable plastics packages by 2020?

STEPS student Anna Svantesson presents her Master Thesis carried out with the coordinated supervision of Sysav and Lund University. Her study focuses on the Swedish Fast Moving Consumer Goods (FMCG) industry target of fully-recyclable plastic packaging by 2022.

June

Plastics challenges in podcasts

How can the government make plastic production sustainable? And what is the process of making plastics from sugar beets? These are some of the questions discussed in two podcasts made by Trifilon featuring STEPS researchers Tobias Nielsen and Niklas Warlin from Lund University.

August

Workshops STEPS Phase 2

Work packages 1, 2 and 3 organise workshops with academic and industrial stakeholders to discuss the continuation of STEPS research programme, STEPS Phase 2.

September

Danish Bioeconomy Conference

STEPS representatives attend the Danish Bioeconomy Conference and present STEPS latest results and demonstrators for a broad audience from both Danish industry and academia.

October

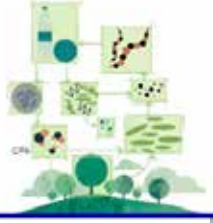
Sustainable Investments

A new report from STEPS and IVL Swedish Environmental Research Institute, directed at financial investors is published. The aim of the report is to make it easier for the financial sector to make sustainable investments.

October

What does the future of plastic look like?

A new research article is published by STEPS WP1, 2 and 3, presenting strategies on how to improve recyclability through the smarter design of polymers – and how bio-based polymers could shift to carbon neutral alternatives.



November

Collaboration for Sustainability

STEPS researcher Baozhong Zhang participates in a discussion with academic and non-academic actors on how to create good win-win relationships and collaboration across borders that enable the progress towards sustainability. Bao speaks about STEPS collaboration with industry partners Bona, Perstorp and Nordic Sugar in the development of the demoproduct StepOn, the floor coating made out of sugar.

November

Danish Bioeconomy Panel

STEPS researchers are invited to Copenhagen to present STEPS programme, vision and main achievements for the Danish Bioeconomy Panel. The panel is working on a plastic strategy report for the Danish Ministry of Environment.

December

Step-In

A bio-based polyester-like sock demonstrator is developed by STEPS!

December

Plastics & Recycling

STEPS researcher Anna Svantesson presents at Malmö University on the use of packaging in the daily trade industry in Sweden. The event is organised by students at Malmö University to highlight the complexity of plastics.

Meet some STEPS researchers

Dr Mahmoud Sayed
Biotechnology Department
Lund University

Mahmoud Sayed came from Egypt in 2014 to do his PhD at the Division of Biotechnology at Lund University. He is active in STEPS work package 1 which has focus on the sustainable production of polymer building blocks from renewable feedstocks including surplus biomass streams and carbon dioxide using biological and chemical processes separately or as integrated processes.

Mahmoud Sayed says that the possibility of achievement of a green process under mild conditions for production of a molecule at high yield and selectivity will contribute to the reduction of toxic solvent usage, energy consumption, greenhouse gas emissions, and hopefully even the production cost of plastic production. Therefore, his work in STEPS focuses not only on the production of a new building block, but also on introducing a robust catalyst (chemical or biological) as well as upstream and downstream processes for the production of plastic building block chemicals.

His research in STEPS focuses on the molecule 5-Hydroxymethylfurfural (HMF) – both its production and valorization. HMF is a derived from the most abundant sugars in biomass, but preferably from the fruit sugar, fructose.

– HMF production is very challenging due to its high instability and reactivity. Hence it can easily react with itself or the sugar used for the production. This can lead to the creation of unwanted side products.

– Currently, in STEPS we have managed to avoid all of these problems through developing a good process for the production and recovery of HMF at high yield and selectivity. Furthermore, the techno-economic analysis of this process is under investigation to take further step towards industrial scalability of our work.

– HMF is a great platform for exploring polymer chemistry. What other polymers can you create by developing new furan compounds? What can you learn by working with this molecule?

One of the furan compounds Mahmoud Sayed is currently working to develop out of HMF is 2,5-Furandicarboxylic acid (FDCA), which has recenty attracted great interest as a potential biobased substitute for terephthalic acid (TPA), which is used in large amounts in the production of PET (pol(ethylene terephthalate)), a commonly used polyester in drinking bottles and other products.

–In contrast to TPA, FDCA can provide a 100 percent biobased plastic, PEF (poly (ethylene furanoate)). PEF has a higher thermal stability, which makes it more durable and also more recyclable. PEF has even superior gas barrier properties, which is an important property for food packaging.

In the laboratory at Lund University, Mahmoud Sayed, and his colleague Rajni Hatti-Kaul, Director of the STEPS programme, have started to test different microorganisms and enzymes to convert HMF to FDCA. Since glucose is the abundant and common C6 sugar in all plants and trees, they are also looking at other routes to convert glucose to FDCA.

"5-Hydroxymethylfurfural (HMF) is one of the top ten biobased chemicals, but is highly unstable and reactive, which make its production and application quite challenging."

– I like applied science since one can test out new things. I can learn about microorganisms, but through STEPS, I also get a chance to find out more about polymer technology, and upstream and downstream plastic production and processes.

When asked why Mahmoud Sayed chose to work with biobased plastic, he replies

– There is a clear link between sustainability and plastics. We need to find other pathways to produce new materials. We also need to develop and identify a sustainable use of biomass in the future, and maybe our work with HMF and FCDA can contribute.

Photo: Kennet Ruona

Dr Meher Sanku
Chemical Engineering
Lund University

Meher Sanku, researcher at the Department of Chemical Engineering at Lund University, has just defended her PhD thesis. Her work focuses on how to capture and utilise carbon dioxide – to create new building blocks for plastics. She is a researcher in STEPS work package 1, which focuses on production of polyester building blocks from renewable feedstocks, including surplus biomass streams and carbon dioxide.

In recent years, carbon capture has started to attract an increasing interest, not only from researchers, but also from industry and policymakers. Countries need to drastically cut emissions, and capturing carbon is seen as a solution to reduce global warming. But, currently capturing carbon is both costly and energy intensive. That is why more and more researchers, including Meher Sanku, have become concerned with not only removing carbon from the atmosphere, but also to utilise it.

Yet, as a molecule, carbon dioxide is a challenge to work with, explains Meher Sanku. It is the last thing that is formed when you burn carbon-based resources such as oil and gas because it has very low chemical potential. One could draw an analogy to water flow. Water flows from higher to lower potential (or it flows with gravity). To utilise carbon dioxide is like making water flow upwards.

– I would say it is challenging but not impossible to work with carbon dioxide. The advantage of working with carbon dioxide is that it is a surplus compound, people want to get rid of it, says Meher Sanku.

"As a molecule, carbon dioxide is hard to work with"

So far, Meher Sanku and her group have succeeded in creating a system that could both capture and utilise carbon dioxide at the same time. They have used the compound amine, which contains basic nitrogen atoms, to create a reaction with the carbon dioxide. This process captures the carbon dioxide. By controlling the amount of carbon dioxide in the amine solution, the carbon dioxide can be bound either into the liquid solution or into a salt form. This liquid is then used to make building blocks to create polyester plastics.

– We came up with the idea to use the amine as a reactant for both processes. We combined the capturing process with the catalysis process for the utilisation step, to both capture and then utilise the carbon dioxide.

– If we can separate plastic production from the capture and utilisation of carbon, it is a good thing. We would then avoid having to build several plants and systems in the same place, for example, and more companies can contribute to the production and distribution of new plastic polymers.

Around the world, some companies have already started to use carbon dioxide to produce plastics, for example foams for mattresses, and shoes. This indicates that there is a growing market to use carbon dioxide as an alternative feedstock. Plastics made from carbon dioxide can attain different properties, depending on the amount of carbon dioxide incorporated. For example, a small amount of carbon dioxide makes for softer, more malleable plastic, whereas larger amount yields a plastic which is harder and more durable.

– Today, plastic production in general is not sustainable. It could be sustainable based on how the plastics are produced and the rest of their life cycle. In the context of plastic production, using carbon dioxide as a feedstock has a lot of potential.

– The big hurdle to carbon capture is to create a market which is willing to pay for it. This can be done by decreasing the cost of capture and/or combine capture with processes of economic benefit like utilisation of carbon dioxide to produce plastics.

– We are trying to do both decrease the cost of capture and give it an economic value by producing value added products from it. The size of the market for products based on carbon dioxide is very small. But if sustainable plastics are produced from carbon dioxide, that market share can be increased. If we concentrate our efforts in decreasing the emissions of carbon dioxide and simultaneously utilise the emitted carbon dioxide in sustainable plastics production, we can have a sustainable yet economically viable society, concludes Meher Sanku.

Meet some STEPS researchers

Dr William Newson
Plant Breeding
Swedish Agricultural University

William (Bill) Newson is a researcher at the Swedish University of Agricultural Sciences and part of STEPS' work package 2. It aims to produce "drop-in" as well as novel polyesters that will be characterized and evaluated for applications such as fibres, coatings, packaging and films. Bill Newson and his colleagues work primarily with natural proteins such as wheat gluten. Their ambition is to contribute to knowledge on protein behavior, and ultimately to develop new materials to replace fossil oil-based plastics.

As part of their research, they have tried to combine natural proteins with biobased building blocks made for example from sugar to create polymers with new qualities and properties.

– Polymers made of fossil oil are engineered to do specific jobs. This is what we want from environmentally friendly and natural polymers too. We want a toolbox which can cover a spectrum of applications.

– Some natural protein blends have an elastic quality, which could be combined with a more brittle plastic such as biobased PLA (polylactic acid) to create a new, more stretchable polymer. This could be one way of combining different proteins and building blocks to create new materials.

However, there are many challenges involved in mixing natural proteins and synthesized materials to create new polymers. They include problems with recycling and stability. A mixed polymer cannot be recycled easily, and natural proteins are quite unstable and not very water resistant. These challenges have led Bill Newson to focus more on developing materials made out of only plant based proteins. These materials can be used to create products and applications that can biodegrade in nature, for example plastic sheets over cropland, coatings on seeds, and degradable plant pots.

– At this stage, we are looking at how proteins behave as opposed to focusing on product development. What happens when you stretch and bend the material? We need to find out more about the actual properties of the protein.

Bill Newson focuses on plant proteins with a low environmental impact, for example proteins produced from side streams of agricultural production.

– In the future, we will still need to make physical things to meet our needs. So now, we are trying to create new materials, which can perform in the same way, or even better, than the current materials, but with less impact on our environment.

Yet, Bill Newson notes that it will take more than just production of new materials to accelerate a large scale transition to a sustainable society. Consistent legislation is also needed, as are changes in consumer behavior.

– I have worked in the industry myself, and the sheer scale of the sectors that have to make a transition is staggering. The industry needs regulations that are long-term to make changes. There are so many questions to address: a company needs to know that it will be able to get enough materials over a foreseeable future, it needs to set up industrial processes and the company needs to be sure that the new material is safe.

> *"In the future, we will still need to make physical things to meet our needs. We are trying to create new materials to produce these things"*

– Yet, while we need changes on many levels, I hope that our work can contribute to this transition. By providing new knowledge and insights on protein behavior, we hope to inspire other researchers and industry to take our work one step further and produce new materials and products, he notes.

Ellen Palm
Environmental and Energy Systems Studies
Lund University

Ellen Palm is a PhD candidate at Environmental and Energy Systems Studies at Lund University, and active in work package 3. It aims to assess potential transition pathways to develop research-based advice on policy and industrial strategies for sustainability in the longer term. Ellen Palm's research focuses on issues of sustainability pathways connected to plastic.

– As I go further in my research, I'm becoming more and more interested in different perspectives on the plastic problem. What issues are seen as barriers or hinders to accelerate change? What issues are getting the most attention?

In her latest forthcoming research article, she and her colleagues have done an interview study of perceptions of the plastic problem among stakeholders and lobbyists at the European Union level. The results show that there are four major narratives emerging in the current European plastics governance: resource inefficiency, fossil feedstock dependency, plastic pollution, and toxicity. Out of these four, resource inefficiency was the most dominant narrative, with its connection to recycling and a circular economy.

– These results are interesting since it shows that some issues get more attention than others. The dominant view becomes powerful, dictating what is considered most important to tackle with the plastic problem.

"Due to the connection between plastics and climate change, we do not want to go on producing more plastics just because we can recycle it"

Ellen Palm sees a danger in this focus on one specific issue relating to plastic production and consumption. As one of the lead authors of STEPS discussion brief about pathways to achieve a more sustainable plastic system, she is acutely aware that we as a society will need to work on many different levels to transition to a low-carbon society. For example use less plastic, recycle more, develop biobased alternatives, and explore biodegradable alternatives.

– There is no silver bullet. Currently, there is an expectation that circular economy can solve all our problems but that is not likely to be the case. Due to the connection between plastic and climate change, we do not want to go on producing more plastics just because we can recycle it.

Ellen Palm's first research studies were on carbon dioxide as a feedstock since she wanted to broaden the view of what a plastic feedstock can be. But producing plastic from carbon dioxide is an energy intensive and costly process with many uncertainties to be solved.

– I think the issue of how much plastic we should produce is becoming more and more important. Even using biobased materials, as we do in STEPS, could be a problem long-term. In what quantities should we produce new plastic, and where should we grow the biomass?

Going forward, she wants to continue to track and study emerging issues relating to plastics, and how they play out on the political and societal arena. One such is toxicity, which has drawn attention to plastic additives and how they impact human health and the environment.

– We need to highlight how the dominant views become more powerful, and try to counter these narratives with broader views on plastic. Especially since we need to make sustainable changes fast.

– As academics, we can bring the wider discussion to the table, both to the industries in STEPS, and to key actors in society, she concludes.

A chat with our industry partners

Mats Wallin is a Senior Specialist in Science Relations at Södra Skogsägarna. In this interview, he shares his views on plastics, circular economy, and the challenges of working with hybrid materials. He also highlights how Södra works with sustainability, and how they use their production side streams.

Södra Skogsägarna is an economic association owned by 52 000 members who are forest owners. Their business model is based on renewable, recyclable and biologically degradable forest raw material.

Why is Södra part of STEPS?

Our motives for being part of STEPS are three-fold. We want to learn more about the plastic value chain, we want to have access to networks and knowledge, and finally, we want to inspire and stimulate researchers to work with forest raw materials.

What are your views on plastics and plastic production today?

Different materials are suited for different needs. You can build tall houses in wood and make packaging products, tissue and textile from the cellulose. In many applications, paper and cardboard can replace plastics as a functional material. Traditional plastic will probably continue to have their uses in applications in the future, and then it is good if the plastic can be made with building blocks from a renewable source from for example agriculture or the forest. Plastic recycling is a basic condition to make the plastic value chain more circular than what it is today, but then logistics, regulations and political actions need to be in place, on both a national and a global level.

What is Södra's role in a circular economy?

Circular economy is a strong trend at the moment in society. Paper and cardboard have during a long time been recycled at public recycling facilities. Some paper industries use, or mix, recycled fiber in their paper production. The paper value chain has already made big leaps towards making its process more circular.

The textile value chain needs to raise their game and find solutions for how to create a circular flow. Södra has a concept where collected textiles, a mix of cotton and polyester, is mixed into our processes to create dissolving pulp together with regular wood fibres. Dissolving pulp is the cellulose pulp which is used as raw material in viscose or lyocell process.

Wood is used as a building material and can have a life span of several hundred years. After that, the wooden house can be reused as raw material, for example in the production of paper pulp.

We believe that our main products, timber and pulp for paper and textile, will be part of the future – maybe in a refined state. Cross laminated wood can be seen as a refined wood product, and textile pulp, partly based on recycled textiles, as a refined cellulose pulp product. In the circular world, there is no single solution, but instead there will be a network of collaborations and solutions.

How do you work with your side streams?

The largest of our side streams is bark which is produced both from the sawmills and from the pulp mills. From the sawmill we get wood chips from the production of the timber. These wood chips are sent to the pulp mills as a raw material.

Mats Wallin
Senior Specialist in Science Relations
at Södra Skogsägarna

Another side stream is found in the pulp mill where you separate lignin out of the wood. The lignin in the black liquor is incinerated in the recovery boiler. The boiler produces steam which is used internally in the pulp mill, and some of it is used to produce electricity which is delivered to the market.

We also deliver district heating to cities and societies close by.

A completely new initiative is that we now purify the methanol which is produced in our production processes. The methanol can then be used as a biochemical or biofuel.

Other examples of how we use side streams include: our sawdust is used to produce particleboards, but also for pellets which are burnt for energy production. Liquor sludge is granulated and used in forests as nutrition, and our turpentine is sold as a biochemical. Our tall oil is used as raw material for tall diesel and tall oil based chemicals.


Photo: Pixabay

Finally, we are also looking at how we can capture carbon dioxide from our factories and use it as raw materials for chemicals or biofuel.

What are some of the challenges of working with hybrid materials?

The problem with mixed hybrid materials is that they may be hard to separate into their basic components. In some cases, chemical methods can be used, in other cases mechanical methods work better. Either way, resources are spent on this process. We have to avoid designing materials which will be hard to enter into a circular system.

Another challenge is to find processes that are resource effective for the different steps needed to separate a piece of wood into building blocks and further processed into a biobased polyester – and here we hope that the researchers in STEPS can help. Resources can be raw materials, energy, and investments.

The market also needs to be prepared for slightly higher prices if the products are based on renewable materials – which do not impoverish the earth's resources.

How do you work with sustainability?

Our sustainability work leads Södra forward and contributes to the process of transforming our society to a biobased society. Sustainability is one of the key areas in Södra's business strategy, with six strategic pathways, and 15 shared goals. Three of these goals are prioritised and as important as the financial goals of Södra.

Growing forests are of major importance to mitigate climate change. The yearly forest growth for our members in year 2050 should be 20 percent higher than in 2015.

Södra's total emissions of greenhouse gases should be less than zero. Södra's production is fossil free in year 2020, and our transport is fossil free in 2030.

Efforts to improve health and our work environment is preventative and systematic. Södra has a vision of zero work related injuries, and the rate of injuries is decreasing.

Södra's aim is to integrate production, environmental concerns, and social and cultural values through consideration in our forest production and actions. Forest certification is an important measure for responsible use of our members' forests. Around two thirds of our member's land area is certified according to FSC® (Forest Stewardship Council) and/or PEFC™ (Programme for the Endorsement of Forest Certification).

A chat with our industry partners

Karl Edsjö is responsible for resource and recycling policy at Electrolux. He has worked as a liaison between STEPS and Electrolux since the research programme started in 2016. Electrolux is a world leading global appliance company, and produces refrigerators, dishwashers, washing machines, cookers, vacuum cleaners, air conditioners and small domestic appliances.

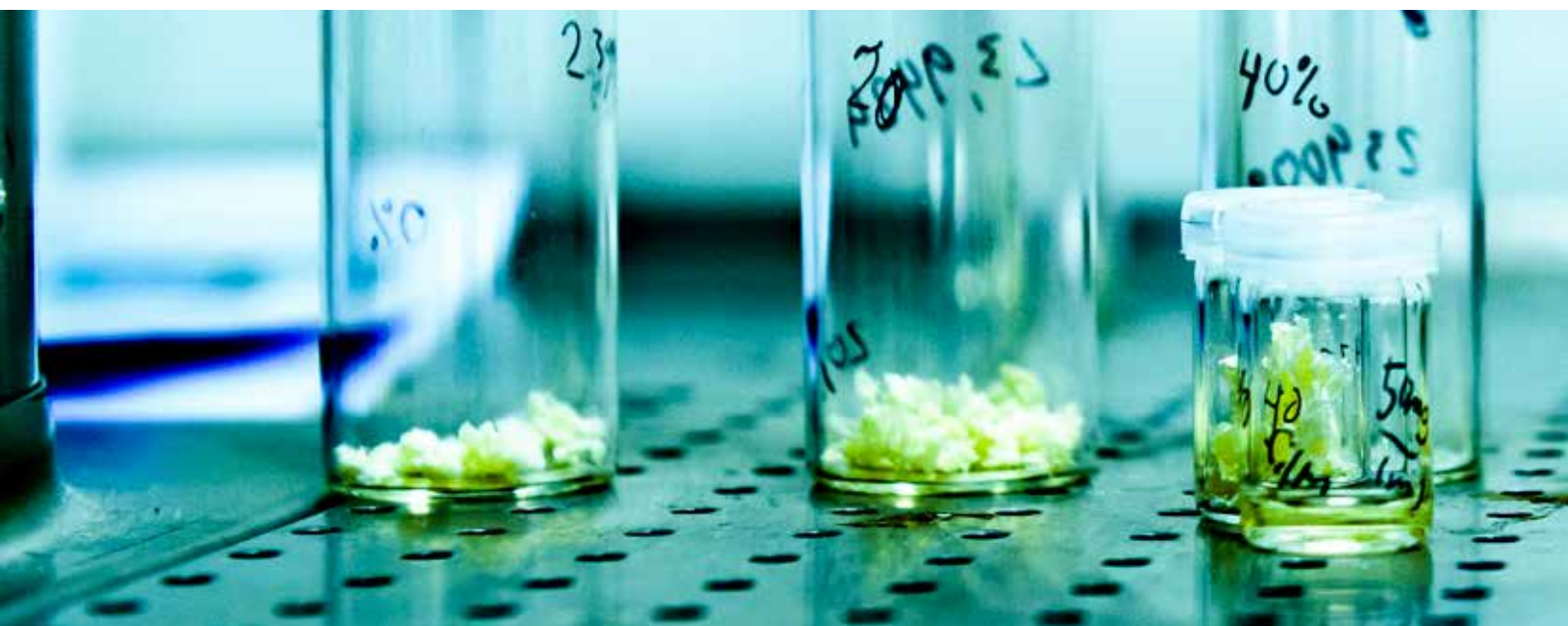
Karl Edsjö
Director of Resource efficiency policy and recycling at Electrolux

The main reason we are part of STEPS is that we as a company want to be at the forefront with our sustainability work. Taking active part in STEPS work can help us achieve that and to be prepared for the future. We are interested in driving the programme forward, and make sure that the areas we are interested in are covered. Our main contributions to the program so far have been to share with the researchers and supply partners like Perstorp our needs and requirements on materials we use today and what we would like to see in the future. When new materials emerge through STEPS we will be ready to test and characterize them in our labs and test facilities. We have also taken active part in the discussions within WP 3 on what a future sustainable plastic supply system should look like.

Plastics has been a key element driving the development of the appliance industry for many decades. The durability and availability of plastics have played a key part in making our products affordable, efficient and of value to consumers. The main challenge with plastic in the appliance industry is the recycling phase where the large variety of plastics plus the existence of legacy chemicals make separation difficult. In contrast with for example packaging materials which have lifecycles of a few months, large household appliances when collected for recycling are on average 10-15 years old with many pieces being 20-30 years old. Old equipment like that contains substances that are often banned today, and which must not end up in the recycled material.

In Electrolux, we use a substantial amount of plastic for the production of our household appliances. Our hovers for example consist of two thirds plastic material. In our freezers, half of the material is plastic. We use recycled material in some parts of our products but for many components that is quite a challenge.

For example, ten years ago, we put a lot of effort into making our vacuum cleaners more sustainable and succeeded in replacing a large part of the virgin fossil plastics with recycled plastic instead. This is the type of work we want to continue.



With products like refrigerators and freezers the challenge is more complex. There the material need to meet food safety standards since the fridge is used to store food, and the material need to have the right properties, both from a technical as well as an aesthetical point of view.

"There should be a strong link between quality and price. Long-term recycled plastic can be an opportunity"

What would increase the use of recycled plastic in your products?

I would say safety, performance and price. First of all the materials must be safe and meet our requirements on hazardous substances, which are based on legal requirements but in many aspects go further. Secondly the use of recycled material must not compromise the quality of our products so the material has to fulfill certain minimum performance requirements. Finally, considering that there are always additional efforts in using recycled versus virgin, so incurring higher costs on our side, the price of recycled has to match this.

In our sustainability strategy, Electrolux has stated that one reason for us to push the use of recycled materials is to support a strong development of the supply side. Manufacturers and suppliers need to work together to make the quality better and the supply more consistent. In the end, using recycled materials should be cost effective and give added value compared to business as usual.

If the price of virgin plastic was to increase, we might be pushed to change our production further, to use more recycled. Since plastic is substantial material in our products, even a slight change in price makes a profound difference. I expect that such price increases would, if long-term and stable, help to stimulate the supply of recycled plastic to increase both in quantity and quality.

What do you think would help accelerate a sustainable transition?

In terms of pushing forward with sustainability I believe companies in general need to take more action and be a lot braver than they are now. Carbon pricing in one way or another, where you put a cost on fossil, virgin carbon could be one way to stimulate companies to be bolder. Currently I think politicians fail to take real action and instead focus too much on certain issues relating to plastic such as littering. Littering as such is a serious problem but letting littering defining the plastic agenda misses the bigger picture. The attention is not coherent, and as such risks to make plastic into a scapegoat for a range of problems. We also see a lot of micromanaging in legislation for example in terms of how much recycled plastic different products such as washing machines or plastic bags should contain. I would like to see a tougher outer framework instead, where the industry is given a frame to work within as opposed to legislation going into very specific detail. Companies can survive a lot of things if they have to but should also be given a room of maneuver to identify and work with the most efficient ways to achieve overarching targets.

Photo: Kennet Ruona

Photo: Kennet Ruona

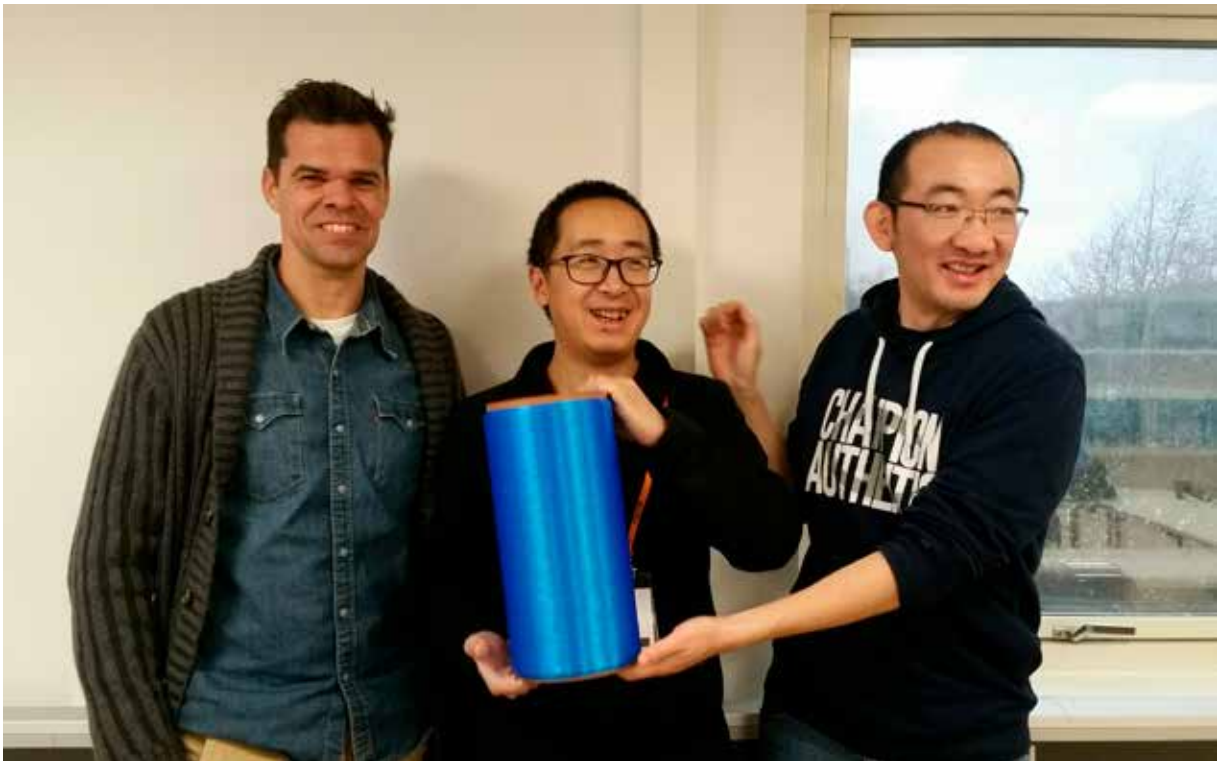
From chemical building blocks to a demonstrator: a way of upscaling

Scaling up a polymerization process from lab to pilot scale is a key step for the development of biobased plastics toward fiber applications, as well as other applications. Within the STEPS programme, a PET-like polyester called PHT, poly(hexamethylene terephthalate), has been identified as an interesting partially biobased polymer target for fiber development. In 2019, small scale synthesis and characterization of PHT was performed at Lund University and published.[1] According to small scale evaluations, PHT shows good spinnability which could be highly interesting for application as a textile fiber.

To make a textile demonstrator, the PHT synthesis was scaled up in a pilot reactor at RISE IVF. Many key parameters related to the viscosity variation, mass and heat-transfer have been investigated in order to obtain polymers with acceptable quality such as molecular weight and physical properties. Clariant contributed with their knowledge and catalysts for the polymerizations. In 2019, around 3 kg of PHT was synthesized, and the polymer was melt spun into bicomponent fibres (with core and shell structures, see the figure below) under semi-industrial conditions at RISE IVF. About 1 kg PHT yarn was produced,

"– We have learnt a lot from this process! We need to have a good polymer design and work more on the optimization stage during the scaling up process. In the meantime, we need closer collaboration at the early stages, from the very moment Lund University decides to design the polymer. Then we can discuss and adapt our optimization parameters"

Zengwei Guo
Senior researcher – RISE IVF



From left: Erik Nilsson (RISE), Baozhong Zhang (Lund University) and Zengwei Guo (RISE)

which was further produced into about 10 pairs of blue socks as a demonstrator in December 2019, based on conventional texturizing, twisting and knitting processes. This demonstrator highlights our competence within the programme, and the feasibility to develop bio-sourced textiles all the way from raw material synthesis, small scale polymerization, up-scaling production and product development.

1. N. Warlin, et al., Green Chem. 2019, 21, 6667-6684; S. Mankar, et al., ACS Sustainable Chem. & Eng. 2019, 7, 19090-19103.

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T Nielsen & F Bauer (2019) Plastics and Sustainable Investments – An information brief for investors.

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Karl Holmberg (2019). The Political Economy of Plastics: Production, Incumbency and Fossil Fuels. Master thesis, WP3.

Vanessa Srebny (2019) Biotransformation of ethylene glycol to glycolic acid and its use for lipase catalysed polycondensation. Master thesis in Biotechnology, WP1.

Stefano Sachetto (2019). Development of a biotechnological production system for aromatic building blocks from sugars. Master thesis in Biotechnology, WP1.

Sara Saleh (2019). An integrated chemo-biocatalytic process for the production of Furan-2.5-dicarboxylic acid (FDCA). Master thesis in Biotechnology, WP1.

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S Mankar. Lignin-based polyesters toward fiber or packaging applications. 14th European Bioplastics, 3-4 December 2019, Berlin

N Warlin. Sugar-based rigid monomer, polyurethanes, and polyesters for textile and coating applications. 14th European Bioplastics, 3-4 December 2019, Berlin

B Zhang. Collaboration for sustainability – how to move forward? Ekonomihögskolan, 6 November 2019, Lund

T Hansen. Transformative Innovation Policy. The Danish Ministry of Higher Education and Science. 1 October 2019, Copenhagen

F Bauer. Investor Brief för Hållbar Plast – kunskap för hållbara investeringar Presentation at SweSIF seminar, 19 September 2019, Stockholm.

F Bauer. Plasten i byggnadssektorn – klimat, teknik och politik. Presentation to Sweden Green Building Council Syd, 30 August 2019, Malmö (event for SGBC members)

L J Nilsson. Climate Change – what can we do? FA-AP seminar, 27 June 2019, Lund

R Hatti-Kaul. Sustainable transitions for plastics. CAETS 2019: Engineering a better world – the next 100 years, 26 June 2019, Stockholm. Invited presentation

L J Nilsson. Technology outlook for the low-carbon economy. EPS Low Carbon Economy Forum 2019, 18 June 2019, Brussels

T Nielsen. Pathways to sustainable plastics. Japan-Europe Dialogue 2019, 25 April 2019, Tokyo

R Hatti-Kaul. Sustainable Plastics and Transition Pathways. South Africa Sweden University Forum (SASUF) workshops, 6-10 May 2019, Pretoria, Potchefstroom and Stellensbosch, South Africa

T D Nielsen. Joint Forces for Sustainability Forum, 21 March 2019, Copenhagen

T D Nielsen. Science and Innovation Talk at Tetra Pak, 8 March 2019, Lund

F Bauer, T Hansen, S Madsen, T Nielsen, LJ Nilsson. Presentation of STEPS and research on sustainable plastics to the European Environment Agency, 26 February 2019, Copenhagen. (closed event with STEPS and EEA)

L J Nilsson. Founders of Tomorrow, 24 February 2019, Copenhagen

F Bauer, T Hansen, T Nielsen, L J Nilsson. Presentation on plastics and sustainable investments to the UN PRI International Working Group on plastics. 10 January 2019, Webinar with UN PRI

Outreach and Communication

B Zhang. Collaboration for Sustainability, 6 November 2019, Lund

B Zhang. Advanced Materials Day, 24 October 2019, Lund

R Kuktaite and W Newson. Collaboration with Lund University Design students and exposition at Dutch Design Week, October 2019, Eindhoven, The Netherlands

Z Guo. STEPS – Sustainable Plastics and Transition Pathways. 57th Global Fiber Congress, 12-14 September 2018, Dornbirn, Austria

S Madsen and B Zhang. Workshop Plastics REDesigned. Form/Design Center, 18 June 2019, Malmö

F Bauer, E Palm, P Andersson, Å Halldén Björklund and Stefan Poldrugac. Panel debate “Omställning till hållbar plast – vad, hur och vem. Plastteknik Nordic, , 8 May 2019, Malmö

E Palm. Hållbar Plast – Vad är det? (What is Sustainble Plastis?) Network event for ”Kemismart 2019”. Universeum, 2 May 2019, Gothenburg

E Palm, T D Nielsen and C Hulteberg. Panel debate: Crops or carbon dioxide, what is the future of plastics? Lund’s Sustainability week, 9 April 2019, Lund

R Hatti-Kaul and R Kuktaite. Collaboration with a designer through Form/Design Center followed by exhibition What_Matters, Spring 2019, Malmö

F Bauer. Workshop – Innovativa miljöer inom IVAs projekt Resurseffektivitet och cirkulär ekonomi, IVA, 6 March 2019, Stockholm

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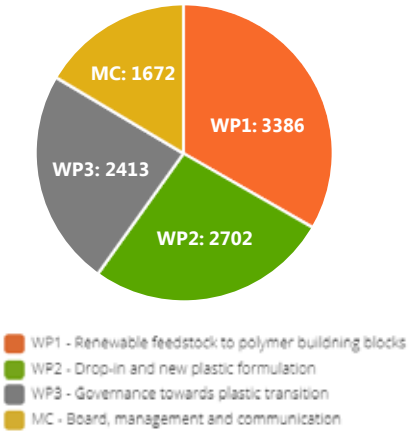
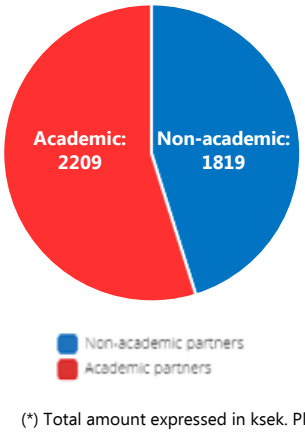
STEPS in Numbers

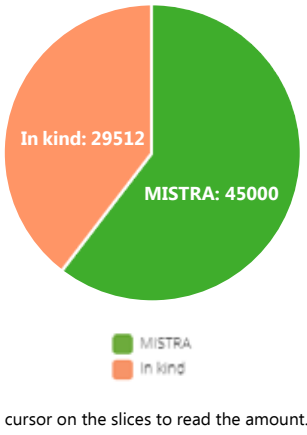
Total financial outcome(*)



Total In kind contribution(*)



Total budget 2016 – 2020(*)



(*) Total amount expressed in ksek. Place the mouse cursor on the slices to read the amount.

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