STEPS

Sustainable Plastics
and Transition Pathways

ANNUAL REPORT 2018

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.

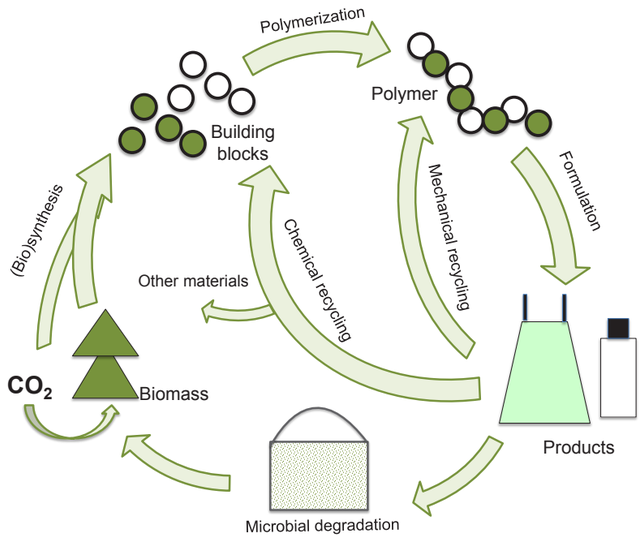
STEPS partners include Lund University, the Swedish Agricultural University, and Swerea IVF (now RISE), along with 18 industrial partners and Skåne county council – representing the entire value chain in a sustainable plastics system: renewable raw materials providers, producers of chemicals and plastic 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 (2019). Designing Biobased Recyclable Polymers for Plastics. Trends in Biotechnology. Available online 28 May 2019.

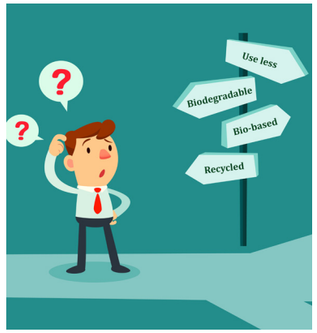
Three interlinked workpackages

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

Main achievements in 2018 were the development of processes for transformation of sugars to several furan derivatives and of sawdust to a biodegradable polyester. Systems for microbial production of adipic acid and vanillic acid from sugar is under development as is the transformation of CO2 to polymers and building blocks.

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

A major achievement in 2018 was the successful preparation of textile fibers using the bio-based polyesters derived from sugar, lignin and Perstorp's biochemicals. The fibers were spun at Swerea IVF.



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.

In 2018, different proposed pathways for sustainability have been mapped, assessed and presented in a Discussion Brief.

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Message from the Board

What is the common denominator between Neil Armstrong's 50 year old wonder suit built up of many layers of fantastic materials, Jackson Pollock´s famous paintings and Eames' iconic chair?

They are made of plastics and are exposed in museums. Artists and engineers have relied on plastics as their material for many years, while some museums have actually denied that they have plastic materials within their collections, but not any longer. Plastic art can decay and museum curators are worried. Specialists are now high in demand to determine the type and composition of the polymers in order to prescribe a remedy to deterioration. Plastic art and other objects made of plastics are part of our cultural and technological heritage.

Plastic will continue to be a very versatile and much needed material in our society, not only for art and museums. But we have to incorporate the plastics into a circular economy and eliminate waste. This is what the Mistra programme STEPS is all about – sustainable plastics and transition pathways.

This has been a year with a lot of media coverage on plastics with headlines like micro-plastics, marine pollution, plastic straws, single-use plastics and much more. Public awareness is increasing. Initiatives are many. Companies are launching road maps for fossil free and recyclable plastic packaging. New investment companies try to improve waste collection and create markets for collected materials. New organisations are formed like the recently launched New Plastics Economy Global Commitment. Negotiations within EU have led to a ban of some single-use plastics. Just to mention a few actions.

We are in a phase of reaction to the omnipresent plastic waste. Now proactivity is needed, the prerequisite being a solid base of knowledge to tackle the current situation, to provide guidance and to address solutions. The complexity of the problem must not be a deterrent against doing thorough analyses and researching possibilities. The research must go on while, in the meantime, viable improvement opportunities can be launched and implemented.

Research programmes like STEPS are very important, they provide society with facts, innovations and guidance for options. To this end, communication is of utmost importance, and STEPS is doing a lot of that. Not least by the interactions with many industrial partners, participation in national and international conferences, presence in media, and scientific publications. The STEPS programme is in its 3rd year. The work is now characterized more by interdisciplinary and transdisciplinary cooperation than before. It is argued that breakthrough knowledge and innovations are more likely to occur at the interface between different disciplines rather than within a single discipline. However, this way of working with complex issues takes time and patience. STEPS achievements so far will provide a solid base for the next phase of the program.

Britt Marie Bertilsson
Chair of STEPS Board

Plastics on your mind?

"Never before have we had so much awareness about what we are doing to the planet, and never before have we had the power to do something about it" –the words of Sir David Attenborough in the most popular BBC Series of 2017, Blue Planet II that served as a wake-up call and sparked huge interest in countering plastic pollution in oceans.

2018 followed with the "plastic waste crisis" being among the top news items in the media. Moreover, the year started with the announcement of the European Plastics Strategy and ended with the Swedish plastics review and also a provisional agreement reached by EU Parliament and Council on the single use plastic directive.

The discussion around plastic seems to evoke a lot of different opinions and emotions, and as a society we are in a dilemma – not wanting to live with it but cannot do without it! There is at least a general consensus that we cannot continue to use and dispose plastics as we have been doing so far. The proposed "fight against plastics" is more directed towards the plastic litter and microplastics in the environment; so is the banning of single-use plastics. Several multinationals are taking much-needed initiatives for cleaning up the plastic waste and even innovating systems for collection of used plastics. There are also proposals on replacing plastics with alternative materials, which in many cases pose a risk of being quick-fix solutions without a systems perspective and may miss out on the fact that plastics could indeed be a more sustainable solution if produced and used properly.

How does one then make rational choices towards a sustainable plastic system – considering the large volumes and varieties, their omnipresence in all aspects of our lives, differences in plastic recycling between countries, lack of plastic handling and recycling facilities in many parts of the world, and lack of affordable sustainable alternatives? It is here that STEPS is playing an important role as a platform for communicating a nuanced view on the pros and cons of plastics and the possibilities ahead. Most of the management group members, both from academia and industry, along with some other STEPS researchers have been participating in a number of activities organized for the general public like the Sustainability Week in Lund, panel debates during the Politicians week Almedalen in Visby and at the EIT Climate-KIC Lecture "Lowering the climate impact of plastic materials" in Lund, IVA workshops on circular economy etc., and discussing with businesses making and using plastics on their goals and strategies.

STEPS researchers have also published a discussion brief on the possible transition pathways towards a more sustainable plastic system, which highlights that a combination of pathways including biobased, recyclable and biodegradable plastics would be required in the future. In line with the European and Swedish strategies, research in STEPS has a focus on designing of plastic material considering its life cycle and also on the use of carbon-neutral building blocks for the plastics. This work has so far yielded positive results and is starting to result in scientific publications and even contributions to doctoral theses. We have attracted a number of Master students from Sweden and abroad to do their theses projects in STEPS, which we find to be a good way to interest young minds in finding solutions to global problems. Even though it indeed is a global problem, the solutions require a national if not local focus. Solutions suitable for Sweden may not be enough or suited for other parts of the world and with that in mind we need to realise that there is no single solution but with knowledge-sharing, entrepreneurship and innovations we can get far!

Rajni Hatti-Kaul
Programme Director

Highlights

February

Helsingborg City meets STEPS

Representatives from Helsingborg city´s office of environmental management and the procurement office, along with the waste management company NSR, meet STEPS to gain a better understanding of different plastic systems including biobased and biodegradable plastics, and their environmental impact.

March

LEGO and STEPS

STEPSers visit LEGO Sustainable Material Division. LEGO is a fascinating company that is putting huge efforts into developing alternatives to fossil-based bricks. Lego aims to use recycled or renewable raw materials in all its plastic products by 2030.

April

Workshop on recycling

Organised by WP3, this workshop focuses on the already known challenges of recycling plastics. Above all, the low collection of plastic waste, the lack of demand for recycled plastics, and the producer responsibility have so far failed to encourage producers to design completely recyclable products. Three different topics are discussed more in depth: plastics design, collection systems and chemical recycling.

April

Lund's Sustainability Week

STEPSers from academia and industry give a crash course on plastics and describe pathways to a more sustainable use of plastics at the seminar Tänk om plast... (Rethink plastics) during Sustainability Week in Lund.

June

Article in Framtidens Forskning

A journalist from SSF Framtidens Forskning interviews STEPS programme director and the WP2 leader from Perstorp. The article is published right before the Almedalen-week, during which it is widely distributed as a supplement of Dagens Industri.

September

Södra hosts board meeting

STEPS board meeting takes place at Södra Cell Värö. After a visit to the pulp-and-paper production site, STEPS partners from Södra present some of their innovative R&D projects, one product is Durapulp, a biodegradable material, made from new renewable resources.

November

Study visit at Perstorp

STEPS partner Perstorp hosts a study visit at their facility in Perstorp, followed by discussions about sustainable innovation, renewable sources, bioplastics and standaridsation.

December

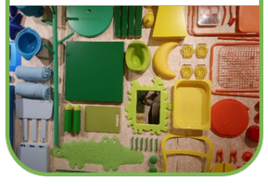
Sustainable investments

STEPS meets leading Swedish fund managers Öhman and Lannebo to discuss plastics and sustainable investments at Mistra. The aim of the meeting is to gain increased understanding about how investors work and which type of research results and information are useful for supporting sustainable investments related to plastics.

March

IKEA hosts board meeting

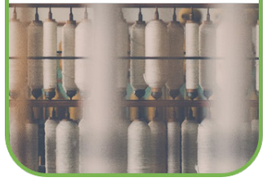
STEPS board meeting takes place at Ikea's office in Älmhult. Our host Johan Bruck presents Ikea's development work on reducing fossil based plastics and their new prototypes made using biobased plastics.



March

Study visit at SWEREA IVF

STEPS partner Swerea IVF hosts a study visit at their labs in Mölndal, followed by interesting talks about additive manufacture, surface technology, polymer processing, melt and wet spinning, and textile recycling.



April

STEPS Programme meeting

STEPS programme meeting is attended by academic and industrial partners, board members and invited speakers. After an update from the three WPs, invited speakers talk about innovation and new ways towards sustainable plastics, systemic innovation towards a circular economy for plastics, and sustainability criteria and life cycle assessment for forestry.

May

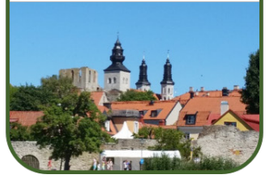
The Plastic Challenge

WP3 researchers talk about the plastic challenge for a broad audience at Ideon Science Park in Lund, pointing to the plastics system's complexity and what are the possible different pathways we can pursue to achieve a more sustainable system.

July

Almedalen

STEPS is involved in two events at Almedalen! *Life in plastic, is it fantastic? Ett hållbart system för plast till 2030,* organised by Mistra, and *Omställning till hållbar plast – vad, hur och vem,* under the umbrella of Lund University.



October

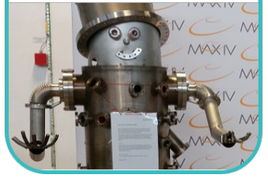
Lowering the climate impact of plastic materials

Leading researchers from EIT Climate-KIC eCircular, STEPS researchers and representatives from Perstorp, GPS and Electrolux discuss reduced consumption, recycling, bioplastics and policies to facilitate the transition towards a more sustainable plastic system.

December

Study visit at MAXIV

STEPS industrial and academic partners engage in a study visit at MAXIV. It is interesting to discover how this world-leading facility is developing, and explore what opportunities are there for STEPS stakeholders.



December

Debate article in Politiken

WP3 researchers from Lund University publish "Kampen mod plastik er kun lige begyndt" in the Danish Politiken (p. 6, 2018-12-22). They write about the new EU directive on single use plastics and the fight against plastic pollution in the oceans and on our beaches.

Meet some STEPS researchers

Baozhong Zhang develops new biopolymers

– My personal opinion as a researcher is that biodegradability is a good thing. If you can make plastics degrade to earth, you create a much larger loop than say recycling.

Baozhong Zhang, originally from China, came to Sweden in 2014, attracted by the focus on sustainable materials and the open society.

Now, he is one of the researchers working in WP2 in STEPS. His work is focused on creating different polymers by using feedstock such as lignin from the forest industry and sugar from agricultural wastes. During 2018, his group has created some very promising polymers, which was further fabricated into fibers in collaboration with Swerea IVF.

– We now have to test the polymers in terms of durability and other physical properties and see how we can use it in different plastic applications. It has been great to be able to use industry equipment since we are restricted in how much we can produce in our own lab.

Upscaling will come later in 2019 says Baozhong Zhang. There are challenges in terms of specific environmental permits and in terms of deciding what plastic product is the best one to scale up.
– Fortunately, we have recently discussed with Perstorp and Swerea IVF, and now we have a plan to prepare a few selected polyesters in kilogram scale this year.

– Working within STEPS is good, since we have a close collaboration with industry partners. Information regarding what they need, and what they think will be needed for the market are valuable information for us to develop new bioplastic material.

Baozhong Zhang and his colleagues in WP2 are also looking into making plastic that can sustain a higher temperature, up to 100 degrees. This could open up new markets for products like kettles and cups you can drink coffee and tea out of, and reuse or recycle them again and again.

– You have to start somewhere. And show society how you can use plastic in a novel way. Our industrial partners indicated that it might make industry and consumers more willing to pay the higher price for biobased plastics.

Besides developing more recyclable and durable polymers, Baozhong Zhang is also interested in exploring biodegradable plastics, plastic products that can eventually be degraded into earth or other biological material.

– If we can make plastic that degrades after a few years or even decades in nature, I think it is still valuable. It is better than never degradable products, as most of the plastics are. You create something that eventually goes back to earth.

It is essential to look at this area, he says, since there will always be leakage into oceans and nature, especially in places where there are less stringent regulation, and less developed recycling systems.

– My dream is that all plastics will be degradable, and that you can use the products many times before they degrade. Today, plastic will be the only trace left of human life on earth, even after thousands of years, it's that stable.

Baozhong Zhang on STEPS

"I feel lucky to have got to know so many intelligent people, both researchers and from industry through STEPS. This is very valuable for my work and career. Especially the contacts with industry, they are at the forefront, which is very creative and it helps build our own knowledge as researchers."

About Baozhong Zhang

Works as an associate professor at the Centre for Analysis and Synthesis at Department of Chemistry at Lund University.

Did his PhD in Canada, and spent time in Switzerland working as postdoc on developing polymers.

He is interested in: Synthesis of molecules and polymers, biopolymers, biobased antimicrobial agents, cellulose and biocomposites.

Christian Hulteberg transforms CO2 into building blocks

Christian Hulteberg, Helena Svensson, Meher Sanku and Hanna Karlsson have been busy during 2018. They have identified a completely new method for removing carbon dioxide from industrial gas streams. This development is interesting to STEPS, and to the rest of the plastics industry, because it means that clean carbon dioxide could be used as a potential feedstock for plastic.

– Using carbon dioxide is really interesting because we will always emit it to produce for example cement, steel and fertilizer. Imagine if we can turn this gas into something new instead?

There are pros and cons in using carbon dioxide as a feedstock for plastics. One very positive thing is that it will result in less carbon in the atmosphere since it will be captured instead of let out into the air, another is that it doesn't compete with food production like other feedstocks such as sugar could potentially do if production of biobased plastics would increase significantly. Challenges to use carbon dioxide include the low energy quality of carbon dioxide, and that you cannot move the production of polymers from the actual factory where you emit the carbon dioxide.

For the method to work, the factory has to build a processing plant to extract the carbon dioxide from the gas streams, as well as adding low tempered energy to the carbon dioxide to create polymers. The polymers can then be transported to a company that produces plastic materials.

– It is a big investment. But we see that it could be economically viable. We are now looking into how large the process plant would have to be, and the best ways for making our method work.

Apart from the scientific developments, dialogue between partners will play a big part in whether a method like this can take off.

– We need to get different people talking to create new value chains. Companies are not used to working together, say the forest industry and chemical companies. STEPS can be an arena for that, he concludes.

Christian Hulteberg on STEPS

"STEPS is the biggest project I have been involved in. It is a completely different exchange between partners. For me it is about getting a new understanding about what companies think of making a switch to a more sustainable production. The questions from industry are our questions too, both perspectives are needed to find a good balance between research and development."

About Christian Hulteberg

He is an associate professor, with a 20 year long connection to the Department of Chemical Engineering at Lund University,

His research focus is on understanding and advancing chemical processes and their application in society.

He has a long expertise in working closely with industry, and has started and managed several companies of his own.

Meet some STEPS researchers

Tobias Nielsen analyses pathways to sustainable plastics

– Plastics have strong connections to climate change. A debate on transition to sustainable plastics goes on. Some say it is individuals that should drive the change, other people say it's the industry or politicians.

Tobias Nielsen works in WP3, and during 2018, his group produced a discussion brief outlining five pathways to a more sustainable plastic society. They presented the brief at Almedalen in July, the democracy festival and politicians' week in Gotland. Briefly, it outlines five possible ways forward: consume less, recycle more, use biobased feedstock, develop biodegradable plastics, and use more of the same type of plastics.

– We found that people who are working with plastics will stand behind different solutions, and it can become very entrenched. We wanted to get an overview of all the options on the table and analyze them.

Because all five pathways are needed to move towards a sustainable use of plastics, and at different levels in society. Yet, there are both challenges and opportunities with each pathway, such as the low quality of the recycled plastics, or the concern that bioplastics can compete with food and feed over agriculture land, or that biodegradable plastics can complicate recycling, and are not part of a closed loop.

As a political scientist, Tobias Nielsen argues that the state has an absolutely crucial role in putting pressure on society to make changes. The recent Swedish plastic strategy (published in December 2018) is a good start but doesn't go far enough. A tax on fossil based plastic could help decarbonize the plastic system, and there is a need for shared standards and metrics for reporting what happens to the plastics produced and consumed across the European Union.

– Plastic is less divided than climate change, and there is consensus that we need to do something. Despite plastics only recently reaching the top political agenda, many countries have already started taking the first initial steps. But companies, on the other hand, don't need to wait for long drawn out political processes, and can do a lot already today.

The current public debate is focused on the negative aspects of plastics, highlighting plastic islands in the sea, and its negative impact on wildlife.

– A sustainable transformation will not happen without plastics, we are depending on it to run our society. I don't think the discussion should focus only on individual products or individuals' ability to sort their plastic waste, but rather on how we as a society can consume plastics more sustainably, and on how we need to explore all the pathways.

It is here that STEPS can come in says Tobias Nielsen. The programme is representing both academia and industry, and is reaching out to partners from different parts of society.

– We can give the broader picture, and facilitate knowledge exchange between academia, industry and policymakers. No one knows all the answers and we need to work together. In STEPS, we have built up a strong level of expertise which we can make use of in order to nuance and contextualize the debates.

Tobias Nielsen on STEPS

"I have gained a lot of academic and practical knowledge, and built my network on a personal level. It's nice to feel that you are part of a larger group, working to achieve something together."

About Tobias Nielsen

Works as post-doctoral fellow at the Department for Political Science at Lund University.

Did his PhD on discourses on deforestation in global climate politics.

His research focus is: sustainable plastics pathways, plastic governance, public policies on plastic bags, decarbonizing plastics, the role of investors in sustainable plastics.

A chat with our industry partners

Orkla Food Sweden produces some of Sweden's most popular food products: Felix meat balls, rice porridge and tomato ketchup, Abba herring, Grandiosa pizza, Frödinge cakes and Anamma vegan products.

How do you work with sustainability at Orkla?

We use a variety of packaging materials and our goal is to use 75 percent renewable and recyclable materials by 2025. For plastics that goal is 50 percent. In addition, we aim for 100% recyclable packaging by 2025. We want to develop packaging solutions that reduce impact on the climate, contribute to circularity and help reduce food waste. We are looking at the whole value chain, from production and design to recycling.

One example of how we implement our strategy is to provide clearer guidelines for Orkla's innovation projects. We want to give product developers knowledge on for example recyclability of different plastic materials, tools to calculate climate impact, and support them in making sustainable choices. It is part of ensuring that we work towards our goals in everything we do.

What are your views on biobased and biodegradable plastics?

We focus on biobased and recycled plastics, which we have already introduced in pouches and bottles. For now, we have decided not to use biodegradable plastics as there are no systems in place to take care of compostable packaging in Sweden. It is also not clear if there would be any environmental benefit in a life cycle perspective.

What is the future of plastics production?

It is a challenge to replace fossil based plastics with biobased and recycled alternatives. As a large food company we need to ensure that our food is safe to eat for our consumers, and that our packaging contributes to minimising food waste. Availability of biobased plastic needs to increase and preferably be made with feedstock from agricultural and forest by-products for example. Recycling is also an issue. Apart from designing packages to suite recycling, it will be essential to improve sorting functions and recycling technologies including possibilities for chemical recycling.

What we can do at Orkla is to set out clear demands further back in the value chain, to companies producing the polymers and packaging material. We also engage with representatives from the recycling industry to get a mutual understanding of the needs.

Lars Lundahl
Environmental Manager at Orkla Foods

It's a challenge to get any economy in using only biobased and recycled plastics. At the same time, more and more consumers are becoming aware of environmental issues, and are expecting us to take action. That's an opportunity for us to come up with smart and safe plastic solutions for our food.

What are your expectations of STEPS?

We wish to get informed and inspired about the latest research and policy developments as a partner in STEPS, and we can use insights as input to our own sustainability strategy. In the future we hope to be able to use some of the new sustainable polymers being developed in STEPS. We also get valuable contacts with the University and other industry partners, which helps us to continue our work with reaching our environmental goals.

A chat with our industry partners

Flextrus is a leader in flexible packaging, developing and manufacturing advanced materials for the food and healthcare sectors. The company has plants in Sweden and in England.

Amanda Persson
Sustainability Manager at Flextrus

How do you work with sustainability at Flextrus?

We have set out clear targets for our sustainability work, both regarding our own footprint and the performance of our products. Our overall goal is to provide 100 percent recyclable packaging by 2025 with as much renewable content as possible without compromising product safety and quality or adding risk of increased food waste. Today, 44 percent of our materials are based on renewable sources, and the majority of the plastics are fossil based.

Our strategy is in line with the recent Swedish plastic investigation and EU's plastics strategy. We are now in the process of mapping out specific guidelines and regulations regarding flexible packaging recycling in the countries we supply to. There are many differences in terms of recycling and collection systems between different regions and we need to streamline our packaging so that it can be used efficiently . It is a challenge to create packaging materials that are compatible with the recycling streams throughout Europe.

I think we are in a very interesting position in the value chain. We can collaborate easily with both raw material providers and companies that are closer to the end consumers. It is a good position to drive change but it is important to identify where you can make the most effective changes.

What are your views on biobased and biodegradable plastics?

We believe that a circular usage to new products is the most efficient way to handle packaging waste. Biodegradable plastics, if not collected and composted in the right way, can lead to more littering and microplastic emissions, just like conventional ones. There is also a risk of biodegradable plastics contaminating the recycling streams of plastics and thus lowering the quality and thereby limit the possibilities for use into new products.

At Flextrus we are using renewable, recycled and recyclable plastics in our products.

What is the future of plastics production?

We want to see guidelines around how to communicate about plastics from renewable feedstocks. Today there are no shared guidelines and that is very confusing for the whole value chain. We also would like to see more information campaigns to the end-consumer of what the different expressions mean. Ensuring that consumers can make well informed choices is as important as any financial instruments.

If we all use defined expressions for materials and recycling related matters we also avoid greenwashing.

Another important concern regarding new renewable plastics will be their design, func-tionality and recyclability. The mechanical recycling streams need virgin input at some point to maintain the quality of the recycled plastic. I believe that it is a strength to combine biobased plastics with recyclable ones, if they are designed to be compatible with the specific recycling streams.

Price is also a hot topic. Today, I'm not sure if people are willing to pay more for a packaging with renewable material than for a conventional one. You want to pay for the product, not for the packaging. However, if more companies take action, prices will eventually go down.

Finally, availability is a challenge. We need more detailed research around what feedstocks are available over a longer period of time and can be sourced in a sustainable way.

Maybe with a more diverse range of different feedstocks we will start talking about locally sourced plastics, like we do for food and other goods. It would be a unique selling point to buy locally rather than from for example Brazil as done today.

We see it as our business idea to drive change and create good business opportunities.

What are your expectations of STEPS?

For us STEPS is the bridge that we need to continue our collaboration with raw material providers, the food industry and the academia. It gives us access to knowledge and the latest research in the topic of renewable plastic and a network that we value.

Lyckeby develops, manufactures and offers starch products and potato fiber. The company is owned by 800 potato farmers.

Kalle Johansson,
Development Manager at Lyckeby Starch

How do you work with sustainability at Lyckeby?

We work towards becoming a less fossil dependent factory where we use less chemicals, pesticides and energy. I believe that sustainability will be a selling point in the future; you have to work with sustainability. We aim to create a circular loop. We use almost everything from the potato, and are looking at ways to use residues from starch processing as building blocks for plastic. It's part of our goal to not let anything go to waste.

It is also good for our farmers if we can use all part of the potato, for example some residues are used as fertilizers.

What are your views on using biobased plastics?

We are part of STEPS with the view of trying to develop processes to ferment low value nutrients, in the potato fruit juice, into building blocks for biobased polymers. However, that would involve a whole new type of process and a big investment on our part. Today, we are not there yet.

Also, my experience of working with biopolymers (e.g. starch, protein) for a long time is that you have the challenge that these materials are very sensitive to water and microorganisms. This is a good feature when it comes to biodegradability but gives the material less resistance. So you have to get around that somehow. To replace fossil based plastics you need large volumes which we don't have in our side streams today, but you have to start somewhere, and making the transition to more sustainable materials is part of our work to become more sustainable.

What is the future of plastics production?

For us that uses a lot of fossil based plastics in our company it is about being part of the development towards a more sustainable use of plastics. We do not have any specific guidelines as of yet when it comes to using biobased plastics, but they will come. As consumers become more aware, this will also reflect back on us, who are third line back in the production line. We deliver mainly to the food industry and technical industry.

Financial instruments could help to make change happen faster, but it needs to be done in a way that enables companies to make changes incrementally.

What are your views on STEPS?

STEPS as a programme is in a good place to disseminate knowledge and increase awareness of the possibilities that are there, both for us as companies and for consumers. We would like to see more demo products of real materials, not just scientific results, since they can be difficult to take on. But if you can show that you can produce plastic in a sustainable way, you can come all the way and make it easier to facilitate a change.

"The authorities are very focused on littering problems and how to prevent it, while the industry is extremely focused on sorting waste. Our general feeling is that all parties involved in a product's life cycle think that the answer to the waste problem is better sorting plants."

Peter Andersson
CEO for GPS – General Plastics Scandinavia

More focus on recycling and better sorting plants

Since GPS signed up to assist in STEPS as an industrial partner, we have also tried to attend activities in other kinds of networks to see how they look at plastics. We wanted to meet as many parts of the society as possible and see their different perspectives on the subject. Most of the events we have participated in have been held and led by the plastics industry or the recycling industry. A few have been held at local and national authorities.

The focus points of the discussions have been quite different from each other depending on whether an event was held by an authority or by the ones organised by the industry. The authorities are very focused on littering problems and how to prevent it, while the industry is extremely focused on sorting waste.

Our general feeling is that all parties involved in a product's life cycle think that the answer to the waste problem is better sorting plants. What we are hearing more and more, is that you need to address the end of life already when you make the polymer and then consider the final steps even more when you make the plastic product.

Can the plastics industry itself lead the development?

We think it can, in many ways. But a market driven society will most likely fail in limiting the number of products. It is not probable that companies will take into consideration whether their customers really need their products. Generally, they already make an effort, most of the time at least, to make their product as environmentally friendly as possible – but they don't try to limit the sales. Of course, one of the main purposes for a company is to sell as much as possible to every single customer in order to make as much money as possible for its owner.

What needs to be done to make it possible to take the next step?

A careful analysis must be carried out defining what kind of plastics are available on the market for recycled material and which of these that are valuable after they have been recycled. We also need to establish what party, or parties, should determine the necessity of a product, and we need to develop a model for determining. Finally, we need to seriously consider whether a free market is more important than limiting climate change.

GPS is a private owned company with seat in Vellinge, Sweden, providing off-grade, reprocessed and regrind plastic materials.

What happened to STEPS First Demonstrator, StepOn?

In June 2017, STEPS launched its first demo product, a plastic floor coating made out of sugar. How has the floor withstood wear and tear from students and staff at Lund University?

STEPS talks to Nicola Rehnberg from Bona as he makes a quick inspection of the floor a year and half after it was originally applied in the Berzelius room at the Chemical Center.

– When I look at the floor I can see black heel marks. But when I try to scrape it off with my fingers I can see that it is easy to remove, which is a very good quality sign.

– Another test is to try to scratch the floor coating with my nails. But when I try to do that I can't make any scratches. I can't see any scratches from chairs or shoes either.

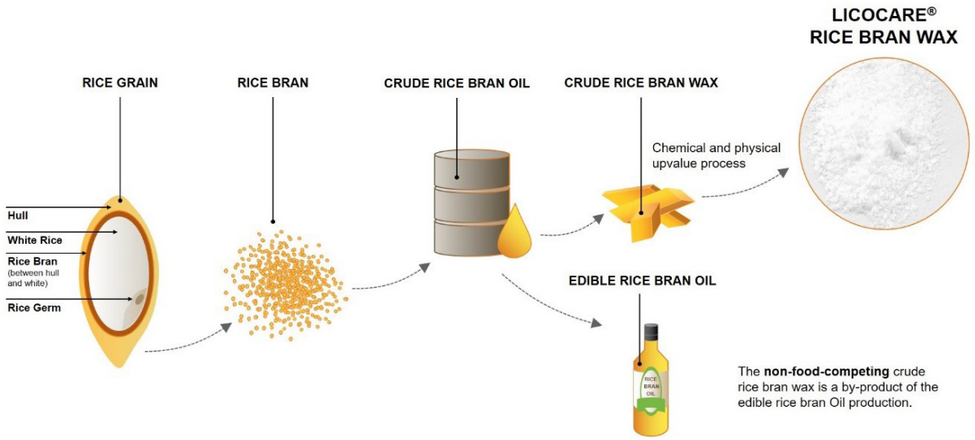
Both of these tests are signs that the quality of the coating is good.

– I'm surprised at the high quality of the floor which is rather amazing because the product development took about a week. Developing a new product with materials from the University, and then to formulate it, to make it, took one week.

– Completely astonishing. Usually it takes two to three years to develop something of this quality.

– Of course scaling up will be another issue, and a longer process. But I'm happy with what I've seen from this quick inspection, he concludes.

Renewable Raw Materials for Plastic Additives and Adhesives – in search of the right sustainable source and other benefits



In order to reduce the exploitation of finite natural resources like coal and mineral oil, as well as the environmental damage caused by it, specialty chemicals like additives for plastics could increasingly be based on renewable raw materials in the future. Moreover, additional release of carbon dioxide into the atmosphere can be prevented when changing the carbon source and thus the carbon footprint of the additives be reduced.

Additives and adhesives play an important role when modern plastics and composites/fabrics are produced for specific purposes. For instance, chemically functionalized waxes can serve as lubricants, mold release agents, and also can improve surface properties etc. Others can be used as hot melt adhesives in mattresses, carpet backings and other applications.

Lubricants for engineering plastics are often so called “montan waxes” produced by extraction of lignite followed by oxidation and further chemical modification. It is quite an energy intensive process based on a raw material that will eventually not be mined any more. Lignite is mainly used for energy generation and is under severe public scrutiny for its contribution to global warming. Lignite for wax production is a side-business that bears the risk of not being continued, once the required change in the energy industry is conducted.

Intensive research for suitable substitutes was done in recent years with the objective of achieving the same technical property profile by using a more sustainable feedstock. Evaluation of different plant based wax types finally led to crude rice bran as a renewable and non-food-competing raw material.

A new series of modified rice bran lubricants and dispersing agents was developed, being thermally stable enough and showing all the advantages of suitable processing aids for engineering plastics. In addition to the renewable source and thus a better environmental profile, following modification processes are using less energy and contributing to a more sustainable profile as well. For hot melt adhesives the starting point is different. Existing Licocene® grades of Clariant are produced by polymerization of ethylene/propylene with specific metallocene catalysts. Mineral oil or natural gas are the raw materials used in this case. Ethylene/propylene from renewable sources is far away from becoming a market standard but there are innovative companies like NESTE offering this alternative. The process uses a variety of different feedstocks with growing flexibility. It ranges from waste animal and fish fats to a number of waste or crude plant oils like used cooking oil, technical corn oil, soybean oil, rapeseed oil etc. A debatable point from today’s point of view in the environmental discussion is the remaining content of (certified) crude palm oil in the feedstock mix. However, in comparison to the traditional production of ethylene/propylene the global warming potential is clearly reduced and the content of waste and residues in the feedstock is nearly 80% with a growing tendency.

Looking at standard additives for polymers like antioxidants, changing the raw material base to renewable sources can achieve even more with regard to sustainability, when the whole product lifecycle is considered. A good example is the replacement of Tris(nonylphenyl) phosphite (TNPP). It has been used as a standard additive for years to stabilize polyethylene polymers against oxidation and color degradation. Unfortunately, liquid organic triphosphites like TNPP hydrolyze quite readily in contact with moisture to form dialkyl or diaryl hydrogen phosphites. While degrading, TNPP releases nonylphenol type molecules which migrate to the polymer surface and, from there, into the environment.

Nonylphenol persists in aquatic environments and is moderately bio-accumulative. It is not readily biodegradable, so it can take months or longer to degrade in surface waters, soils, and sediments. Non-biological degradation is negligible. Bioaccumulation is significant in water-dwelling organisms and birds, as well as in internal organs of other animals. Concentration levels were found to be 10 to 1,000 times higher than in the surrounding environment. Nonylphenol is considered as an endocrine disruptor in fish. It causes feminization of aquatic organisms, decreases male fertility, and decreases survival in young fish. Therefore, production and use of nonyl-phenol and nony-phenol ethoxylates is prohibited in the European Union. NP is on the list of priority hazardous substances for surface water in the Water Framework Directive. In 2013, nonylphenols were registered on the SVHC* candidate list by ECHA, the European Chemicals Agency.

The TNPP example demonstrates the need to develop new secondary antioxidant structures for polyolefins, creating molecules with satisfying overall performance but a better sustainability profile.

Cardanol is one of the rare naturally occurring alkyl-phenols which has recently attracted attention for the synthesis of new plasticizers. Cardanol is synthesized via a thermal decarboxylation process from anacardic acid, the main component of cashew nutshell oil. Cardanol, by its phenolic structure and the bulky alkyl side chain, has been reported to be a suitable compound for antioxidant applications. Fully developed to an industrial antioxidant for plastics, it would be produced from a renewable resource and at the same time replace an established product causing toxicological and environmental concerns.

Pascal Steffanut
Head of Product Management
BL Performance Additives
Clariant

Carina Stjernman
Sales Manager BU Additive
Plastics & Coatings (Nordic)
Clariant

Wolfgang Wanzke
Sustainability Manager
BU Additives
Clariant

Clariant is one of the world’s leading specialty chemical companies, with R&D focus on energy efficiency, renewable raw materials, emission-free mobility, and conserving finite resources.

Contributions at International Conferences

R Hatti-Kaul. *Sustainable Plastics and Transition Pathways*. Bioplastics, IDA Seminar, 23 January 2018, Copenhagen, Denmark. Invited presentation

R Hatti-Kaul. *Steps towards a Sustainable Plastics System in a Circular Economy*. Nordic Polymer Days 2018, 28-30 May, Copenhagen, Denmark. Invited keynote presentation

L Chen and **R Hatti-Kaul**. *Establishing a C3-chemicals platform through engineering of propanediol utilization pathway in Lactobacillus reuteri*. Applied Synthetic Biology in Europe. 24-26 October 2018, Toulouse, France

O Englund Örn, **L Chen** and **R Hatti-Kaul**. *Remodelling of Saccharomyces cerevisiae metabolism for succinic acid production*. Applied Synthetic Biology in Europe. 24-26 October 2018, Toulouse, France. Poster presentation

T D Nielsen and **J Stripple**. *Governing the Plastic Bag: From Total Bans to Circular Economy*. The Global Political Economy and Governance of Plastics. International Studies Association 2018 Annual Convention, 4-7 April, San Francisco, USA

T D Nielsen. *Pathways to sustainable plastics? A narrative analysis*. Petrocultures Conference 2018, 29 August-1 September, Glasgow, UK

T Hansen. *Key challenges for commercialisation of forest-based biorefineries*. Keynote at the 7th International Bioeconomy Conference, June 2018, ScienceCampus Halle, German National Academy of Sciences, Halle, Germany

L J Nilsson. In panel at LIFE Platform Meeting on Climate Change Mitigation in the Energy Intensive Industries, 26-27 September, Utrecht, The Netherlands

T D Nielsen, **J Stripple and others** organised a special session on Governing Sustainable Plastic Transitions at the 2018 Conference on Earth System Governance, 5-8 November, Utrecht, The Netherlands. Including:
– **T D Nielsen**. *Plastic and politics – A review*
– **J Hasselbalch**. *Critical analysis of the EU Plastic Strategy – A review*
– **M Cooper**. *Fossil Fabric: Decarbonisation and the Politics of Textile Transitions*

Publications

Scientific papers

R Hatti-Kaul, L Chen, T Dishisha and **H El Enshasy** (2018) Lactic acid bacteria: from starter cultures to producers of chemicals. FEMS Microbiology Letters 365, fny213.

P Wang, C R Arza, B Zhang (2018) Indole as a new sustainable aromatic unit for high quality biopolyesters. Polymer Chemistry 9, 4706.

S-H Pyo, M Sayed and **R Hatti-Kaul** (2018) Batch and continuous flow production of 5-hydroxymethylfurfural from high concentration of fructose using acidic ion exchange catalyst. *Submitted for publication*

M Sayed, S-H Pyo, N Rehnberg and **R Hatti-Kaul** (2018) Selective oxidation of 5-hydroxymethylfurfural to 5-hydroxymethyl-2-furancarboxylic acid using Gluconobacter oxydans. *Submitted for publication*

N Warlin, M Nelly Garcia Gonzalez, S Mankar, N Valsange, M Sayed, S-H Pyo, N Rehnberg, S Lundmark, L J Nilsson, R Hatti-Kaul, P Jannasch, B Zhang (2018) High performance polyesters based on a bio-sourced diol with a rigid spirocyclic structure and low greenhouse gas emission. *Submitted for publication*

F Bauer, T Hansen and **H Hellsmark** (2018) Innovation in the bioeconomy – dynamics of biorefinery innovation networks. Technology Analysis and Strategic Management, Vol. 30, No. 8, 935–947

T Nielsen, K Holmberg, J Stripple (2018) Need a bag? Mapping public policies on plastic carrier bags – where, how and to what effect? *Submitted for publication*

T Nielsen, J Hasselbalch, K Holmberg, J Stripple (2018) Locating the Politics of Plastic: flows, objects and materials. *Submitted for publication*

Discussion brief

T Nielsen, E Palm, S Madsen, L J Nilsson and **E Lindblad** (2018) Pathways to Sustainable Plastics – A Discussion Brief.

PhD Theses

L Chen. Exploring the propanediol utilization pathway in *Lactobacillus reuteri*. December 2018.

M Sayed. Microbial and enzymatic transformations of polyols and furans to polymer building blocks.December 2018.

Master Theses

L Freitas. Comparative Analysis of Plastic Packaging Recycling in Portugal and Sweden. June 2018

M Malmsjö. Sustainable materials and solutions to individual polybags used in the retail-industry. June 2018**C Lindgren**. Exploring the use of different co-solvents combined with CO2 for glycoalkaloid extraction from potato protein. June 2018.

Outreach and Communication

STEPS organised, and was part of, a number of outreach activities during the year, targeted at students, industry and politicians.

STEPS researchers also took an active part in the debate on plastics production. One highlight was the presentation at Almadalen of the discussion brief, Pathways to Sustainable Plastics, and the panel debate "Omställning till hållbar plast – vad, vem och hur".

Public Panel Discussions

Moderated by L J Nilsson:
– Omställning till hållbar plast – vad, hur och vem. 4 July, Almedalen (Visby)
– Lowering the climate impact of plastic materials. 11 October, Lund

Public Lectures

– Two introductory lectures on plastics by L Zellner and T Nielsen at the seminar Tänk om plast during Lund's Sustainability week, 26 April
(Tänk om plast is a regional platform working to reduce the amount of plastics that ends up in nature. STEPS is an active part of the platform)

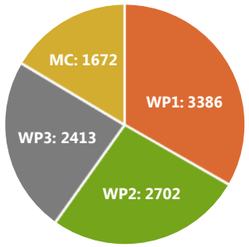
– Two seminars on pathways to sustainable plastics and closed-loop recycling by T Nielsen and E Svensson Myrin at The Plastic Challenge, Ideon, 18 May

University and School Lectures

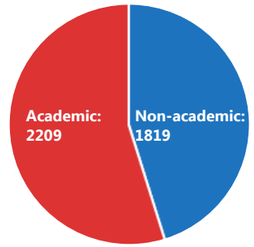
– Lectures on sustainable plastics and packaging by B Zhang and Å Halldén Björklund for the LTH course "Packaging Technology"
– Lecture on sustainable biopolymers by B Zhang for the LTH course "Polymer Chemistry"
– Lecture on bio-based plastics and sustainable use of plastics by L Zellner and N Warlin at Perstorp Gymnasium

STEPS in Numbers

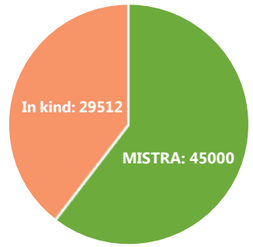
Total financial outcome(*)



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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STEPS Management group and WP leaders

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Programmes director
at Mistra

STEPS academic and industrial partners, and board members gather in programme meetings twice a year.

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