STEPS

Sustainable Plastics
and Transition Pathways

ANNUAL REPORT 2020

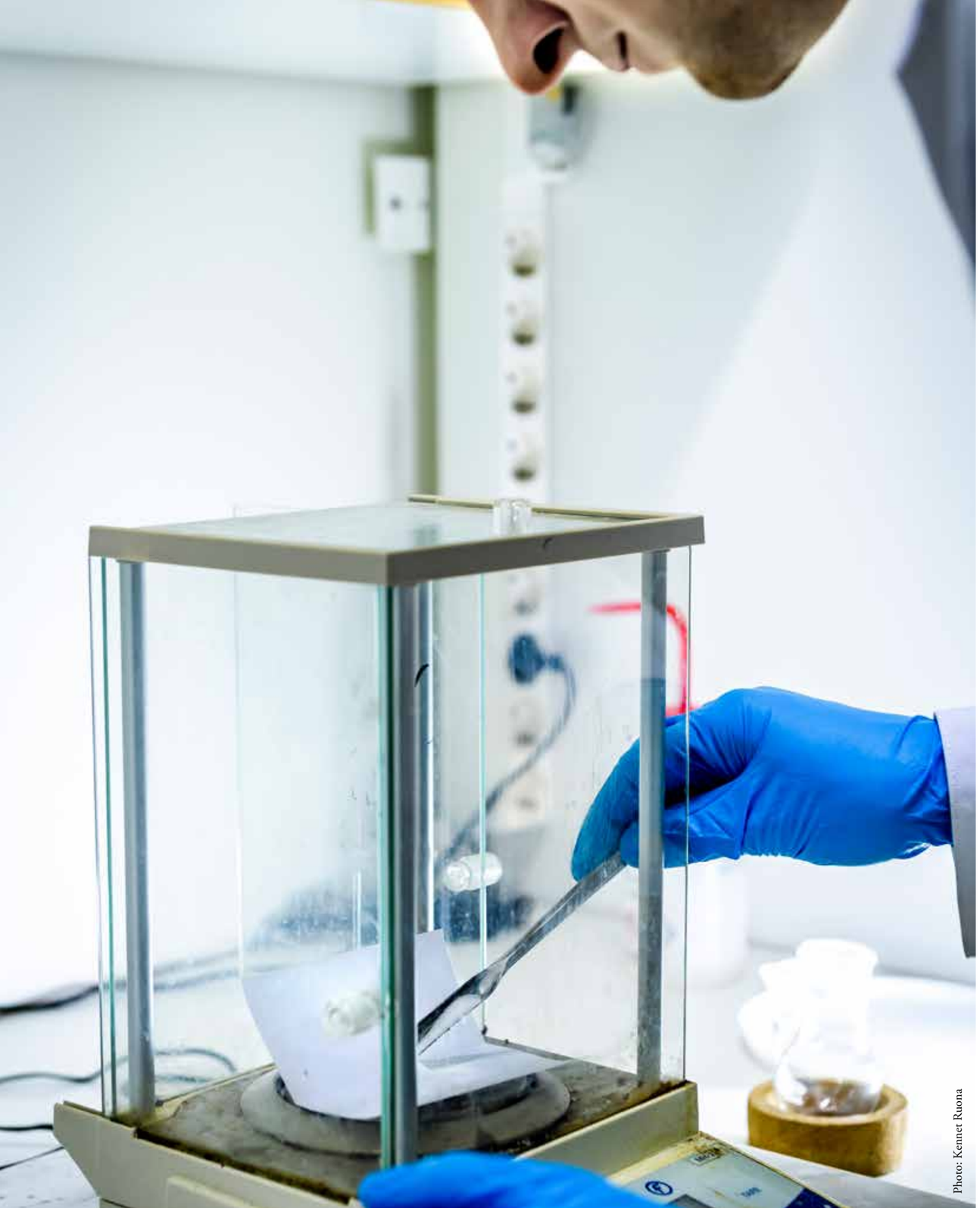

Photo: Kennet Ruona

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Cover illustration: illustration of plastic uses in our everyday life with a focus on sustainable production pathways to transition to a future plastic society where plastics are produced, used and recycled in a circular economy. Illustration: Frida Nilsson, Lund University.

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, University of Copenhagen, RISE and IVL, 21 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 sizeable 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.

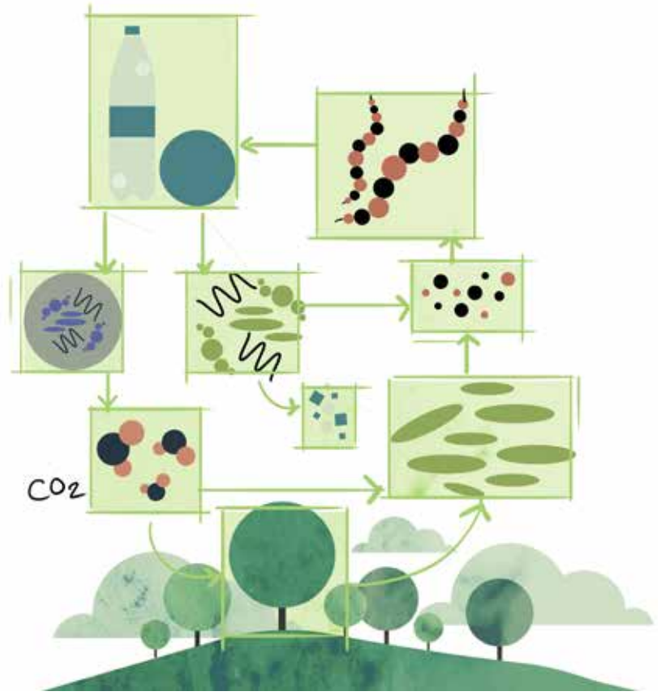


Photo: Shutterstock

Illustration: Catrin Jacobsson, Lund University

Message from the Board

Whenever you turn on the radio or look in the newspaper you will always find quotes about plastics. Often, they are negative (like fossil, waste, littering) but sometimes you also get true words saying that plastic is a fantastic material that will help mankind to solve present and future problems. We need however to put more effort into changing the chemistry from fossil oil into biobased raw materials.

2020 was the year when the coronavirus pandemic was the word on everyone's lips. To be able to handle the medical treatment you need a lot of single-use-plastics in hospitals to secure aseptic handling. Once again plastic shows to be the best material and a lot of industries suddenly changed into production of needed articles. Mankind also showed that scientists can find solutions by working with all possible ideas and tools together and within a historically short time we had several kinds of vaccines available. This is a never-ending story for creating successes.

STEPS has, during its fourth year, continued to find sustainable plastics and transition pathways. The programme has developed environmental tools and processes for making safe, nontoxic building blocks (or monomers) for the polymers from renewable feedstock. Some of them have already been proven to fit well into present available product in our daily life (coatings and cloth fibres). The programme team, which is a broad mix of different academic disciplines together with a group of professional industrial players, shows strong skills to continue to develop building blocks and ways to join them into usable material for the industry. By starting with biomass residues, which are commonly available around us, we now can see the output in the form of biobased plastics. The participants in the programme are also now even more focused on the transition into developing products for the industry. Inspite of the corona situation, STEPS has been able to share results on regular basis via available digital forums and at the same time collected input for new ideas for developments. There is a great potential for the programme to continue to build success during 2021.

Leif Nilsson
STEPS Board member

Message from the Management group

2020 has been a year of intense activity for STEPS, starting with evaluation of the programme in spring by an international committee at Mistra, and thereafter preparing for continuation into a second phase.

We are delighted to get the opportunity to build upon the research we started during the first phase on sustainable plastic systems and products. We welcome the new partners to the programme as well as the new Board member and Management group members. We also thank the members who are no longer with us, for their close collaboration during Phase 1 – we look forward to crossing paths again.

In the second phase, our ambition is to intensify academia-industry cooperation to generate knowledge and to co-develop and evaluate carbon-neutral plastic products for specific target-applications, with an inherent consideration for circular economy. A new addition to our way of working is the missions – where industrial partners and researchers work closely together on a specific challenge with an aim to develop concrete sustainable solutions.

Our continuation as a research programme comes at a time when research on plastics and its impacts on society, is more important than ever. The world is undergoing an upheaval with the ongoing coronavirus pandemic, which has overshadowed the debate on plastics. Plastics have also been prominent in the pandemic: while plastic personal protective equipment has provided protection against infection for frontline health-care workers, plastic face masks and gloves have quickly become among the most common types of plastic litter to be found.

But when the pandemic passes, we will still face the need to address the way we produce, use and dispose of plastics. And this is where STEPS can contribute: as a programme we can deliver important solutions and knowledge, and create an understanding of the different pathways needed for transition to a sustainable plastics system.

The pandemic has forced us – as so many others around the world – to adopt new ways of working and interacting. During the year, we organised three webinars to present our research from phase one – with audience and speakers from different parts of the world. Even the programme meeting had to be held online.

One of the highlights of the year has been the launching of a very well appreciated plastics exhibition Materiality & Aggregation in September at Form/Design Center in Malmö, produced by the designer Kajsa Willner. The exhibition was based on STEPS research on plastics pathways – and is part of our efforts to reach target groups such as designers who are key to designing sustainable, recyclable plastics products and applications. The exhibition is also a great example of co-creation and interaction between researchers and wider society.

As we look back on 2020, we can say affirmatively that STEPS continues to make important scientific and societal contributions providing knowledge. This knowledge will be invaluable for designing and producing more sustainable plastics as well as for developing policies for the transition to a sustainable plastics system. With our new mission oriented work in phase two, we hope to further produce demonstrators to inspire society to make the needed change. In the more near future, we hope to meet and interact with all the STEPS partners in person.

Photo: Unsplash

Three interlinked work packages


Photo: Unsplash

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

In 2020, a kilogram-scale production of 5-HMF (5-hydroxymethyl furfural) from fructose was successfully run, and also its production from molasses pretreated by membrane filtration was evaluated. Alternative routes, enzymatic and photoelectrochemical, for oxidizing 5-HMF to polymer building blocks under ambient conditions were followed. Efficient processes for other products including levulinic acid and adipic acid were reported and are being further developed. Moreover, a microbial process for improved production of an aromatic building block, 3,4-dihydroxybenzoic acid from glucose was developed.

Several products are evaluated for polymer synthesis by WP2 while life cycle of the entire process will eventually be evaluated by WP3.


Photo: Kenuer Ruona

WP2 investigates polymerisation, processing and characterisation of bio-based plastics using potentially the building blocks from WP1 and other sources toward applications such as fibers, coatings, packaging and oral hygiene products. Particular attention was paid to replace non-recyclable thermosets with potentially recyclable thermoplastics.

In 2020, vanillin (from lignin) based monomers were used to produce a series of copolyesters with enhanced thermal characteristics and oxygen barrier properties. Levulinic acid, which can be derived from cellulose and other sugars, was used for the production of aliphatic copolyesters with enhanced glass transition temperatures. Thermoplastic polyurethane fibres with sugar-based cyclic acetal units were produced, which could be potentially subjected to acid-mediated chemical recycling. Thermoplastic polyamide foams were designed and produced by 3D printing technology toward potential furniture use.


Photo: iStock

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.

STEPS WP3 researchers are studying how plastics are used and understood in different domains of society – including art and design. In 2020 they contributed to the design exhibition Materiality and Aggregation and published an analysis of how the plastic crisis is represented in contemporary art. Researchers from WP3 and insights from STEPS also contributed to a report by the European Environment Agency on the environmental impacts of plastics in Europe and pathways to a more circular economy.

Four missions

During phase 2, STEPS will intensify the collaboration between industrial, regional and research partners to co-develop and evaluate carbon-neutral plastic products for specific target applications. This work will be conducted in the form of missions, as a way not only for developing better products but also to identify challenges for transition, and to suggest potential pathways for circular economy and reduced plastics pollution.

Missions will have a lead industrial partner, and depending on the need, will involve members from the work packages to fulfil the challenges in a satisfactory manner. Each mission will have a defined time period at the end of which it will be evaluated and further recommendations provided for the industry partner(s) to take the required action either within or outside the programme. The programme starts with four missions, and based on the experience with these, other missions will be planned.

"We believe in strong collaboration between academia and industry at an early stage. By working with missions, where industry partners lead the work, we can ensure that the research corresponds to real societal needs and questions. And of course, real products and applications have more impact in terms of peaking interest and passion from the rest of the society"

– Rajni Hatti-Kaul, programme director.

	WP1	WP2	WP3
MISSION 1	Bio-based plastics for packaging applications: Level of food protection vs ease to recycle		
MISSION 2	Bio-based textile fibre		
MISSION 3	Bio-based toothpick		
MISSION 4	3D printed foam		


Photo: iStock

Highlights

MARCH

Mistra book about plastics is published

SEPTEMBER

STEPS Phase 2 starts

OCTOBER

STEPS series of webinars:
Transition Pathway to Sustainable Plastics

DECEMBER

Phase 2 kick-off meeting

JUNE

STEPS spring programme meeting

SEPTEMBER

Exhibition Materiality & Aggregation

OCTOBER

STEPS at Lunds Future Week:
Art as societal force!

Meet some of STEPS PhD students

Satabdee Dash
Product development, Lund University

Satabdee Dash recently started her PhD in work package two. A love for machines, airplanes and design brought her from India to Germany, Stockholm, and finally to Lund – where she is doing research on development of tools and methodologies for DfAM, otherwise referred to as design for additive manufacturing. Within work package two, she works with DfAM in the context of plastics.

– During my masters with Scania, I got really interested in optimisation driven design and most specifically how to design for additive manufacturing in an effective manner. The potential is huge.

She explains that the general public think of 3D-printing when they hear the word additive manufacturing, AM. But AM is a transformative approach to product design that enables the creation of lighter, stronger parts and systems – by adding layers of materials on top of each other to create a 3D part from a digital file. Hence, AM holds much more meaning to it.

– Many people think it is very easy to do 3D-printing, and do not understand the power of it. The general view is 'anything and everything can be made with AM'. The more you work with AM, the more you realise the associated challenges and limitations that come in the way of creating excellent products using AM.

– Design guidance, along with sufficient domain knowledge, as well as expertise is required to unravel the true potential of AM.

Some of the challenges for AM involve: repeatability; material availability, scalability; and standardization. Today, only a few materials are suitable to use for AM, and there are challenges in producing consistently reliable parts, as well as scaling up production. In spite of this, Satabdee Dash is convinced that AM is the future.

– With AM you can produce industrial prototypes and spare parts as well as parts with integrated functionalities. You can also produce parts with highly complex geometries, purely customised to the needs of a user, some examples are individualised products such as shoe soles, prosthetics parts, and hearing aids. In a way you can use it for anything where there is a need for complex topology to fill in a required function.

"Additive manufacturing is the future – but we have to change our mindsets"

Plastics and AM

As part of her PhD within the STEPS programme, Satabdee Dash will explore AM in relation to plastics.

– Everyone knows the impact of using plastics. If I am a designer, I have to have a sense of the environmental impacts of my designs. I want to explore the sustainability aspect of AM and strive to produce biobased sustainable alternatives.

– The inherent properties of plastics make it easy to explore with AM. As part of STEPS mission to develop 3D printed foam for upholstery applications and in collaboration with Jonas Ihreborn, I will be investigating an additively manufactured structures that can behave like foam to replace currently used oil-based polyurethane for upholstery.

During her PhD, Satabdee hopes that she can add value to the research within the field of DfAM and contribute towards enabling the shift of designers' mindset from conventional manufacturing to AM.

– AM can change society. But we need to change the way we think and this requires moving away from the mindset of traditional manufacturing. If we want to use AM in the way we could potentially do it, we have to have a willingness to shift.

– That shift includes doing more research on the type of materials we can use for AM, to develop better and more advanced machinery, to build a holistic design framework and to enable knowhow of the capabilities and challenges of AM along with the associated design rules. We also need to create a proper supply chain; how should the goods be manufactured and distributed large scale? Finally, we need standardisation and legislation to enable streamlined AM design of products, she concludes.

Meet some of STEPS PhD students

Karl Holmberg
Political science, Lund University

In autumn 2020, **Karl Holmberg** started his PhD research in STEPS, work package three. Before that he was a research assistant in the programme. He has already co-authored a number of research articles, together with STEPS researchers, focusing on the relationship between plastics and politics, and plastics in art.

In his PhD, he will investigate plastics and its wider role in society.

– I want to dig deeper into our everyday culture but also economic and political interests and how they relate to plastic use. We cannot solve the issues of plastics with technological improvements alone, but we need to also work on behavior, expectations and influences in society for us to achieve a sustainable transition of the sector.

– Many resist transitions or are afraid of change, even if solutions exist, but these solutions will likely impact our lives which can be frightening or feel like constraints. In that sense, social sciences is crucial in our efforts to make the plastic realm more sustainable, a field which is only now starting to come to the fore in plastics research.

As part of his research, Karl Holmberg has co-developed a public survey to explore people's perception of plastic. The survey includes specific questions on willingness to consume less, accept bans or pay extra for more sustainable alternatives and whether people are positive to tax increases.

– Very few studies investigate whether people are willing to accept bans, fees, or actively change their behavior when it comes to plastic use. We are interested to see how people respond to questions on tax and reduced assortment for example, to get a feel for if people are willing to walk the talk on their own usage.

Another research field that piques Karl Holmberg's interest is how the rise of the modern society has impacted plastic consumption.

– The rise of the modern industrial society brought with it an unprecedented use of new materials and technological innovations. I am interested in teasing out some of the philosophical questions that are inexorably bound up in plastic use. What has for example enabled the material to become so ubiquitous?

He reflects that the malleability of plastics is something really unique. A great material that could be hard to replace with good alternatives.

– We know that we have to decrease plastic use. A big part of this, I think, will be about changing the expectation of what plastics can give us. Or get used to the idea that one cannot use plastics for all the products that we do today. Essentially plastics and materials and objects at large need to regain their long-term value.

– However, it is important to not disregard that there are persistent ideas in our society around consumerism, disposability and a fetishism around new things and gadgets. Ideas which are largely supported by and advocated directly or indirectly by authorities and private actors which makes it difficult for people to go against this stream and see the overarching issues attached to plastics.

"I find plastics fascinating"

Karl Holmberg is hopeful that a sustainable transition can be achieved – in spite of the complexity of the plastic sector, and the need for a complete transformation of how plastics is produced, used and recycled.

– It is a huge task to tackle unsustainable plastics, especially plastics' connection to climate change. But I am still more hopeful than pessimistic! By doing research, I hope I can at least contribute to some positive change!

Meet some of STEPS PhD students

Oliver Englund Örn
Biotechnology, Lund University

Oliver Englund Örn always knew he wanted to do a PhD in biotechnology. The biggest pull was the freedom to develop his own ideas, and his own critical thinking.

Today, he is four years into his research on how to produce sustainable aromatic building blocks for plastics, in STEPS work package one.

– I like the complexity of biotechnology. You can do so much with it. That really excites me. There is a lot that needs to happen to create a monomer from a single cell!

His current work focuses on genetically modifying strains of *Escherichia coli*, a bacteria that normally lives in your intestines, to produce protocatechuic acid, PCA. This is a precursor for other compounds like vanillic acid and vanillin that can be used as building blocks for plastics. To create the molecules, he feeds the *E. coli* bacteria glucose, which makes it produce the by-product PCA – as part of its natural growth.

– I use and modify the natural metabolism of the cell to produce PCA. You can compare it to beer production, where you use glucose to produce ethanol. It is the same process as when we run and produce lactic acid in our muscles. PCA is produced when the glucose is metabolised.

Oliver Englund Örn explains that you need several steps to turn PCA molecules into monomers for plastics. For example, the PCA needs to be recovered from the bacterial culture and then purified. Alternatively, the *E. coli* can be genetically modified further to make other building blocks. In that sense, PCA production is different from producing HMF – 5-hydroxymethylfurfural, which can also be used as building blocks and is produced in a chemical process.

– I really like to work with natural cell cultures.

In the future, Oliver Englund Örn hopes to develop other types of sustainable building blocks for plastics.

– You look at plastics and there are so many types of it. It is not enough to have only one building block. We need a broad palette of biobased plastics to replace the use of fossil fuel. Biotechnology offers great potential to develop new ways to use glucose as a carbon source in plastics.

In 2022, Oliver Englund Örn will finish his research. He can see many potential uses for his work in the future. Especially since one can produce the PCA locally if glucose is sourced from Swedish sugar production or from waste products from the forest industry.

"I have freedom to develop my own ideas – in using biotechnology to create plastic monomers"

– The ideal for me is that someone can take my research further and produce a biobased plastic product. Otherwise, my ideas will end at the research level. It would be great to see a company solely focused on producing plastics from glucose. But for that to happen we need to get over the expectation that plastic should be cheap. Today, the cost of glucose is still too high, he concludes.

Photo: Kenner Kuona

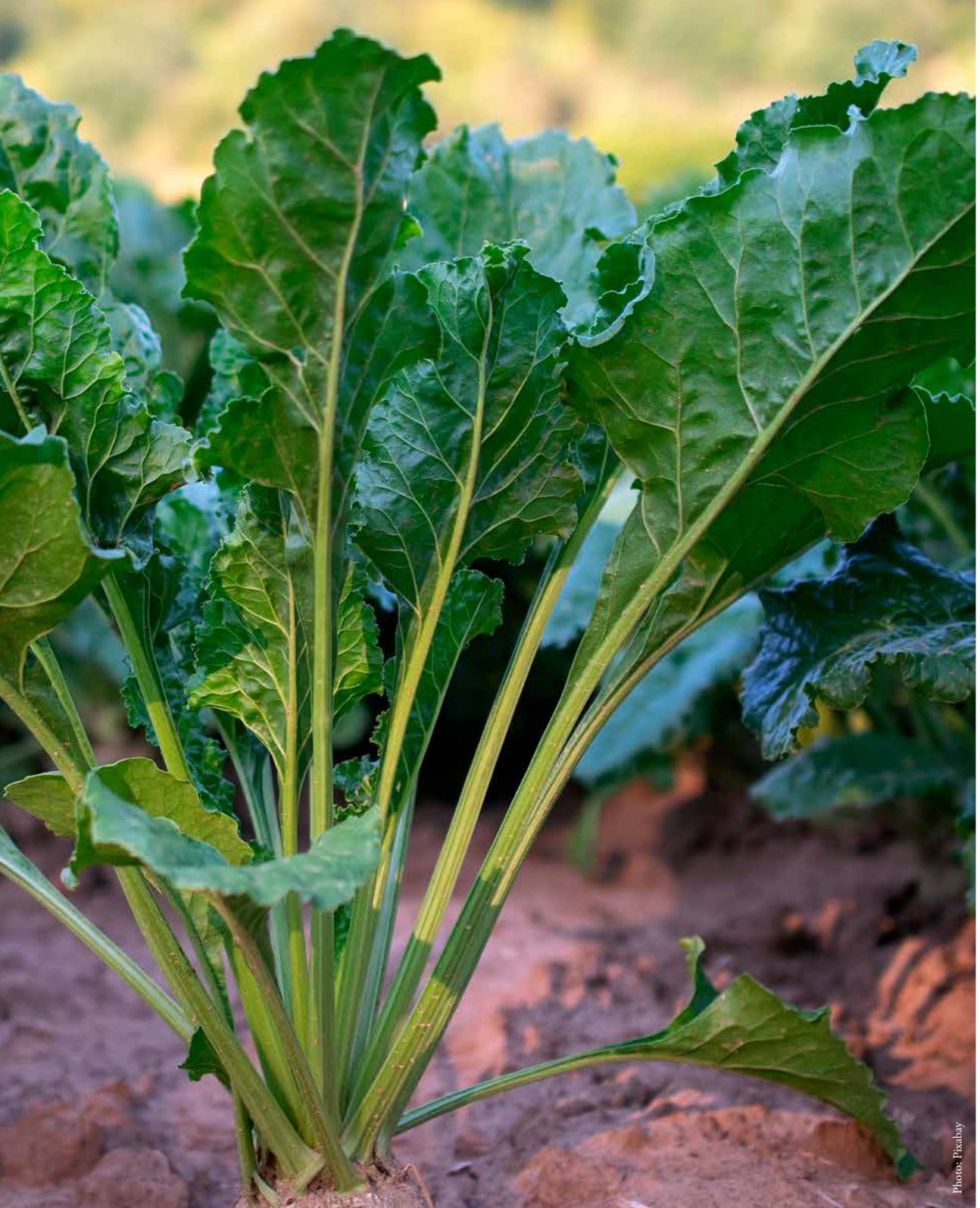


Photo: Pixabay

A chat with our industry partners

Nordic Sugar has been part of the STEPS since 2016. The company is part of Nordzucker Group – one of the world's larger producers of sugar from beet and cane.

– Sugar beet has the potential to be a very good feedstock for plastics. It has a very high yield compared to other crops and the leakage of nitrate to the environment is very low, says John P Jensen, working in QIPS (Quality, Innovation & Production Support) at Nordic Sugar.

For him, being part of STEPS, offers many benefits for the company. One of them is of course the knowledge exchange between the researchers and the partners. Another is the opportunity to monitor how sugar potentially can be utilised as a sustainable feedstock in the future.

He explains that sugar production in Europe, including in the Nordic countries, has undergone major changes in the last decade. Since 2017, internal EU market is fully liberalised – there is no guaranteed minimum price for sugar beets and sugar since the internal market is fully open within the European Union.

– Now we have to contend with variations in price. If there is a rumour that the crop will be good, the price drops. And if we cannot guarantee a good price, farmers might choose to switch crops that year.

These changes have made the case for alternative uses for sugar, beet and pulp even more urgent according to John. Already today, 10-15 percent of all the sugar produced in Europe is used to produce non-food like enzymes, medication, ethanol and furfural, used in the production of cements, adhesives, and coatings.

– There is potential to produce local sugar-based plastics from the Nordic countries. The question is of course how to do in an optimal way.

John P Jensen adds that there is no conflict in terms of land use – there is enough land in Denmark and Sweden to produce sugar for both the food industry, other sectors, and the plastics industry. Around 100 000 tons of sugar would be needed to provide the Nordic plastic sector with sugar-based building blocks. Large size production is needed for overall feasablity.

– Why should we import biobased plastics from Brazil when we can do it locally? Today companies are dependent on one supplier, and have to import the PLA, PHA, and bio-PE from far away. Imagine if we had production of biobased polymers/buildings blocks in our own backyard? You would have both a stable, local and environmentally friendly supply.

"We are part of STEPS as part of our effort to secure sugar beet production in Sweden."

STEPS can play a big part in making this happen believes John P Jensen, by providing real tangible examples of how to use sugar, beet and pulp in plastics production. One such example is the sugar-based plastic floor coating, created in 2017 by researchers and partners in the programme.

John P Jensen
Head of New Opportunities at Nordic Sugar

– The strength of STEPS is that we have the whole range. We have academics working with raw materials, and exploring ways to use sugar in different ways. Possible customers are also in the programme. I have not seen anything like STEPS elsewhere.

Another crucial factor is of course national buy-in, and some big investments.

– I hope we will see a big bioeconomy initiative in Sweden, on a government level. We need some political will to support/facilitate investment in production that can make use of the resources we have here. We have all the potential to build a booming industry in Sweden, producing sugar-based building blocks for plastics, he concludes.

A chat with our industry partners

Sysav has been part of STEPS since the programme started in 2016. Sysav stands for Sydskåne's waste company and is owned by 14 Scanian municipalities. In 2020, Sysav received and treated a total of 825,000 tonnes of waste.

– All plastic ends up with us in the end. But we are not always visible in the discussions about plastics. Being part of STEPS gives us the opportunity to be involved and influence, says Ellen Lindblad, project manager at Sysav Utveckling.

Ellen Lindblad says that Sysav handles all plastics except packaging. Most of the plastic comes in mixed with other waste and gives rise to greenhouse gas emissions. Although FTI (Förpacknings- och tidningsinsamlingen) has the responsibility to take care of packaging, many do not sort out their packaging. Instead, they are thrown directly into the waste.

– There is a great deal of ignorance about how to sort your waste. About 1/3 of all waste from households consists of packaging. I think it has to do with many people finding it inconvenient to have to deal with food packaging,

Since the waste is incinerated, this means that a large amount of plastics with the potential to be recycled instead goes to electricity production and heating.

– The incineration of plastics accounts for the single largest share of our fossil carbon dioxide emissions. At the same time, plastic has a good calorific value. Obviously, this is an issue we (and the rest of society) need to work on. Upstream work is the most important thing, but we are also looking at the possibility of being able to separate carbon dioxide from the flue gases in the future.

Sysav and other Swedish facilities differ from most other similar waste facilities in Europe and America because the incineration goes to both heating and electricity production. Sixty percent of the district heating in Malmö and Burlöv today comes from garbage. Sysav also imports and sorts a small proportion of waste from other EU countries.

The company has now started looking at solutions to be able to capture the carbon dioxide they produce in connection with the plant.

– Technology development is advancing by leaps and bounds. At the same time, our goal is that facilities like ours will not be needed in the long run. If we become better at reusing and recycling our things, we will significantly reduce the need for incineration. But it will take time, large amounts of waste are still landfilled within the EU (and in the rest of the world), which gives rise to emissions of methane – a gas that is highly harmful to the climate.

"We want to highlight the last step in the plastics chain."

– Increased material recycling can reduce landfilling; incineration takes care of the residues that arise and also the waste that is not suitable for material recycling due to unsuitable properties (eg toxic).

Ellen Lindblad also wants to see better collaboration throughout the value chain – from design and production to recycling – something that STEPS can help to promote.

Ellen Lindblad
Project Manager at Sysav Utveckling AB

– Companies and researchers who have questions can come and talk to us. We have a lot of knowledge about how to make the sorting process easier. The materials should be easy to disassemble so that you can put them in the right container.

She continues: – Do not design materials or products that cannot be recycled. Think simple! And involve us who come last in the chain!

Last but not least, Ellen Lindblad believes that in addition to society's increasing ability and knowledge to sort at source, we must also change how we as a society view plastics.

– We are so used to plastics being transparent and behaving in a certain way. But recycled plastics works just as well for many products, she concludes.

Photo: Andreas Offesson

"It is in our DNA to work with environmental issues."

Photo: Jonas Ihreborn

A chat with our industry partners

Jonas Ihreborn AB is a Swedish furniture company with its own production in Värnamo, Småland. The company is run by Jonas Ihreborn – third generation furniture manufacturer – and produces timeless furniture with a long duration for a sustainable future. Since 2020, the company is part of STEPS.

Jonas Ihreborn
CEO at Jonas Ihreborn AB

– Ever since I was young, I have been interested in environmental issues. In the 70's when I was growing up it was very dirty and polluted which made me want to contribute and make a difference. Being part of STEPS is part of this.

Jonas Ihreborn says that sustainability for him and his company is about making a change in all areas where possible.

– We use locally produced materials where possible, try to reduce our transports and work actively not to use unnecessary materials. In addition to this, we want to work to change the way we produce and utilize the world's resources in the future.

Social sustainability is also important for Jonas Ihreborn – to work to ensure that those who deliver and produce materials have good working conditions.

– Everything you do has an impact and we work to make the impact as positive as possible. For example, we create furniture with a long service life and a form that is aesthetically pleasing over time so that we can defend the use of materials and the emissions that the production gives rise to.

Jonas Ihreborn believes that we as a society must reduce mass consumption and instead focus on buying furniture or products that last longer and are produced under fair conditions.

– A sofa that costs 5000 SEK is too cheap. Furniture cannot be seen as a fashion that is replaced every year. We must change our way of thinking and become willing to pay more and also become better at demanding more from those who manufacture the furniture as it is a waste of the earth's resources to produce the large volumes that are made today.

Replace foam with bio-based alternatives

One reason why Jonas Ihreborn is part of STEPS is that he wants to investigate the possibility of replacing the plastic foam made of fossil-based polyol, which is used in the furniture with bio-based alternatives. The elasticity of the foam is important for the feeling, comfort and for the quality of the furniture.

– We do not manufacture our own material, so in this way we are dependent on what the market offers. If I can show that the issue is important to us and contribute with thoughts about what we as a furniture company need, I think it can make a difference in terms of making the use of plastic more sustainable.

Today, foam plastic is created from oil. If the surplus of raw materials does not come from oil, because we are moving away from fossil energy, it will not be a good deal to produce foam plastic in the current way. The change will create new ways of producing products, believes Jonas Ihreborn.

– Although we of course want to be able to replace the oil-based foam plastic, it is even more important to push for change. In the future, I want all the material we use, whether it is plastic or not, to be recyclable. The materials must also be more efficient so that we use smaller volumes.The major enabler for this change is the availability of green energy.

Jonas Ihreborn points out that sustainable design is about just this; to create a sustainable chain from the time you grasp the pen, how you produce the product and use materials, until the product is discarded.

– Today, many people have a skewed view of design, they confuse the concept with design. In my world, all products should be climate smart and reusable.

He talks about two of his most popular chairs; Seventy and Seventyfive. The chairs have become real classics, and consist of a metal frame that can easily be unscrewed and recycled.

– It is not always the case that you have to invent new materials. A lot is about thinking smart, long-term and resource-efficient to develop environmentally friendly products.

Photo: Kennet Ruona. Design: Kajsa Willner

Materiality & Aggregation

Materiality & Aggregation is the result of a collaboration between STEPS, designer Kajsa Willner and Form / Design Center in Malmö. Kajsa Willner was commissioned to artistically interpret STEPS' research on plastics, which identifies five ways forward to create a more sustainable plastics system: reduced use, increased recycling, fewer types, bio-based plastics and biodegradable plastics.

The collaboration is part of STEPS' effort to reach out to key target groups, such as designers and architects – who all have an important role to play in creating a more sustainable way of using plastics.

– We wanted to highlight the possibilities and complexity of today's plastics systems, where one-sided solutions such as recycling are often rewarded. At the same time, we want to create collaborations with professionals who can benefit from more knowledge about plastics as a material. Working with Kajsa was great fun. It has been especially rewarding to see how research can be shaped through art, and thus reach more people, says Fredric Bauer, researcher in STEPS and based at Environment and Energy System at Lund University.

Kajsa Willner says: Today, many people in my industry are opposed to using plastics, which is often seen as a negative material. The picture is not very nuanced. I saw the collaboration as a chance to immerse myself in a subject and learn more. It's also about how I want to run my studio – I want to work with issues that are relevant to our society.

The exhibition, Materiality & Aggregation was shown at Form/ Design Center in Malmö from 9th – 27th September 2020.

Photo: Kennet Ruona. Design: Kajsa Willner

Communication and outreach

Communication and outreach activities are key pathways for STEPS to achieve long-lasting societal, environmental and research impacts. During 2020, STEPS researchers took an active part in the policy and societal debate on plastics, in spite of the ongoing corona pandemic. Some key highlights are our researchers' comments in media on a proposed Swedish tax aimed to reduce the disposable use of mugs, cutlery and lunch boxes made of plastics, our opinion piece on the need for a new authority to achieve a circular economy in Sweden in national media, and our policy brief on the topic of strategising plastic governance. STEPS researchers also collaborated on a plastics report, to be published in 2021, by the European Environmental Agency, which will be based on STEPS' research on plastics pathways.

STEPS participated in Lund University Future Week, hosting a seminar on the portrayal of plastics in art. The seminar was based on a research paper which also received some media attention.

Our exhibition, Materiality & Aggregation, is another example of our outreach work, and presents a focused effort by our programme to explore new types of communication forms to reach both niche groups and wider society with our research.

Finally, STEPS organised three very well received research webinars to highlight research results and progress from phase one of the programme. During the webinars, issues related to STEPS' research were presented, focusing on building blocks for plastics from renewable sources, design of sustainable polymers, and plastics policy making. Researchers, companies and keynote speakers from all over the world attended – a testament to the growing reach and relevance of STEPS' research and STEPS' collaborative working model.

Selected activities, interviews and media coverage

F Bauer. Lessons learned from STEPS Investor Brief. Presentation at MISTRA programme director conference, 28 January 2020, Stockholm.

WP3. Upstream Plastic Governance: Challenges and Opportunities. Workshop at Pufendorf Institute, 4 February 2020, Lund.

F Bauer. Trögt för bioplast. Interview in Miljö & Utveckling, 26 February 2020.

F Bauer. Will Coronavirus Be the Death or Salvation of Big Plastic? Interview in TIME Magazine, 4 May 2020.

N Warlin, S Mankar. Lunds universitet forskar kring biobaserade plaster in Polymervärlden, 1 June 2020.

S Mankar. Så kan infångad koldioxid bli plast. Interview in NyTeknik, 6 July 2020.

F Bauer. Ny plastskatt på gång? Interview in Sveriges Radio P1, 11 August 2020.

F Bauer. Designer vill visa plastens plats i framtiden, Interview in Sydsvenskan, 7 September 2020.

J Stripple, LJ Nilsson. Sustainability – A rough guide to the future. Presentation at Alfa Laval Headquarters, 9 October 2020, Lund.

F Bauer. Plasten måste få nittionio liv, Interview in forskning.se, 9 October 2020.

A Nordin, N Nopparat, K Elner-Haglund. Video presentation: Hur bidrar 3D-printing till en resurssmart framtid? Framtidsveckan, 12 October 2020, Lund.

M Petersén, E Chertkovskaya, K Holmberg. Art as a societal force! Understanding and addressing the plastic crisis through photography and visual representation. Framtidsveckan, 14 October 2020, Lund.

J Generosi. Moving into Phase II of 'Sustainable Plastics and Transition Pathways'. Digital presentation at Lubirc breakfast seminar, 6 November 2020.

F Bauer. Reflektioner från forskningen om hållbar plast. Fossilfrihet och cirkularitet – vad ska vi göra med plasten? Digital panel debate organised by E.ON, SYSAV and Naturvårdsverket, 27 November 2020.

Publications

Scientific papers

Z Guo, M Eriksson, H de la Motte, E Adolfsson. 2020. Circular recycling of polyester textile waste using a sustainable catalyst. Journal of Cleaner Production 283, 124579.

M Sayed, N Warlin, C Hulteberg, I Munslow, S Lundmark, O Pajalic, P Tunå, B Zhang, S-H Pyo, R Hatti-Kaul. 2020. 5-Hydroxymethylfurfural from fructose: an efficient continuous process in a water-dimethyl carbonate biphasic system with high yield product recovery. Green Chemistry 22, 5402.

S-H Pyo, J Hoon Park, V Srebny, R Hatti-Kaul. 2020. A sustainable synthetic route for bio-based 6-hydroxyhexanoic acid, adipic acid and ε-caprolactone by integrating bio-and chemical catalysis. Green Chemistry 22, 4450

S-H Pyo, S Jonsdottir Glaser, N Rehnberg, R Hatti-Kaul. 2020. Clean production of levulinic acid from fructose and glucose in salt water by heterogeneous catalytic dehydration. ACS Omega 5, 24, 14275.

R Hatti-Kaul, LJ Nilsson, B Zhang, N Rehnberg, S Lundmark. 2020. Designing bio-based recyclable polymers for plastics. Trends in Biotechnology 38(1), 50.

E Chertkovskaya, K Holmberg, M Petersén, J Stripple, S Ullström. 2020. Making visible, rendering obscure: reading the plastic crisis through contemporary artistic visual representations. Global sustainability 3, e14.

P Wang, JA Linares-Pastén, B Zhang. 2020. Synthesis, molecular docking simulation, and enzymatic degradation of AB-type indole-based polyesters with improved thermal properties. Biomacromolecules 21, 3, 1078.

M Grillitsch, T Hansen, S Madsen. 2020. Transformative Innovation Policy Handbook of Alternative Theories of Innovation. Edward Elgar: Cheltenham.

E Palm, A Nikoleris. 2020. Conflicting expectations on carbon dioxide utilization. Technology Analysis and Strategic Management 33, 2, 217.

Other Publications

R Hatti-Kaul. 2020. Engineering a sustainable plastics system for the future. In: Engineering for the Future, The Institution of Engineers (India) Centenary Publication, P. Chaturvedi, ed. 2020, pp 415-424.

Policy Brief

F Bauer, K Holmberg, L J Nilsson, E Palm & J Stripple. 2020. Strategising Plastic Governance: Policy Brief.

Master and PhD Theses

E Friberg, E Wiktorsson, J Jarnås and M Lindblad. 2020. Feasibility study of HMF production from fructose on an industrial scale. Project report KETN25.

S Alipour. 2020. Metabolic engineering of Escherichia coli for direct production of 4-hydroxybutyrate from glucose. Master thesis in Biotechnology, KTH.

R Linssen. 2020. Bioconversion of glucose to 2,5-furan dicarboxylic acid (FDCA) using integrated biological and chemical processes. Internship Report, Wageningen University.

M Sanku. 2020. Methodologies for non-aqueous systems and precipitating systems as carbon capture technologies. PhD thesis in Chemical Engineering.

A Zejnullahu. 2020. Development of process parameters and potential applications of additive manufacturing in bio-based materials. Master thesis in Product Development.

A Karajos. 2020. Synthesis and polymerization of new bio-based building blocks. Master thesis in Polymer Chemistry.

M Pettersson. 2020. The regional technological innovation system for recycled plastics in Skåne. Master thesis in Environmental Engineering.

D Helin and K Palmér. 2020. 3D printing tools for injection moulding. Master thesis in Product Development.

Photo: Unsplash

Programme organisation

STEPS Management group and WP leaders

Rajni Hatti-Kaul
Programme Director
Leader WP1
Biotechnology
Lund University

Christian Hulteberg
Leader WP1
Biotechnology
Lund University

Nicola Rehnberg
Leader WP1
Bona and CAS,
Lund University

John P Jensen
Leader WP1
Nordic Sugar

Baozhong Zhang
Leader WP2
CAS
Lund University

Carina Stjernman
Leader WP2
Clariant

Mattias Andersson
Leader WP2
RISE IVF

Teis Hansen
Department of
Food and Resource
Economics
University of
Copenhagen

Fredric Bauer
Leader WP3
IMES
Lund University

Ellen Lindblad
Leader WP3
Sysav Utveckling AB

Peter Andersson
Leader WP3
General Plastics
Scandinavia (GPS)

Sanel Peric
Financial Officer
Biotechnology
Lund University

Noomi Egan
Communications
Manager
FSI
Lund University

Johanna Generosi
Program Coordinator
FSI
Lund University

Programme organisation

STEPS Board

Britt-Marie Bertilsson
Chair of STEPS Board
Expert

Søren Hvilsted
STEPS board member
Professor Emeritus
DTU

Maria Gustafsson
STEPS board member
Project Manager
Swedish Standards
Institute (SIS)

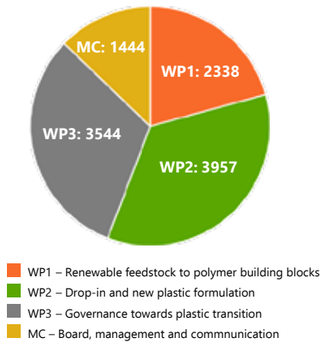
Hans Hellsmark
STEPS board member
Associate Professor at
Chalmers

Leif Nilsson
STEPS board member
Rentus AB

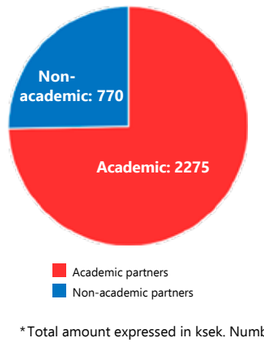
Christopher Folkeson Welch
Programmes director
at Mistra

STEPS in Numbers

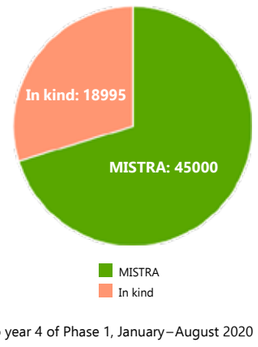
Total financial outcome*



Total In kind contribution 2020*



Total budget 2016 – 2020*



*Total amount expressed in ksek. Numbers refer to year 4 of Phase 1, January – August 2020

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