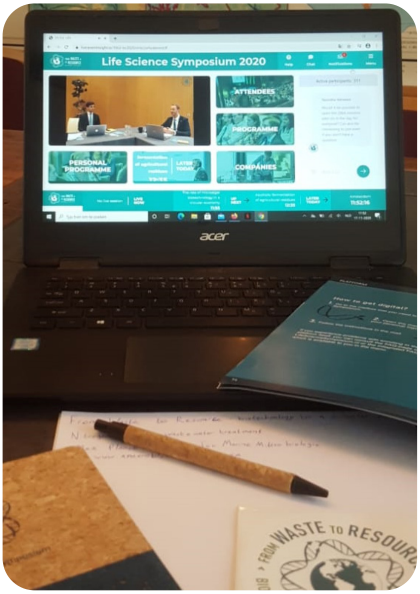
FROM WASTE › TO RESOURCE

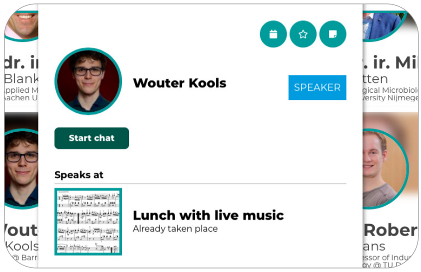
Biotechnology for a Circular Economy

Review booklet
9th Life Science Symposium

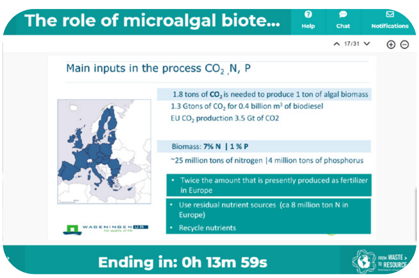
November 17th 2020
Online

PHOTOS





“Loved the event! Thanks a lot! Shout out to Martijn and Maxim for the epic banter between talks.”
~ an attending student



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CASPER VAN DER LUIJT

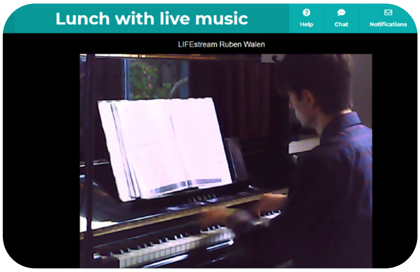
Chairman of the Symposium Committee

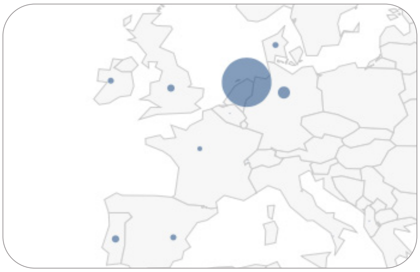
The 9th edition of the Life Science Symposium, "From Waste to Resource – Biotechnology for a Circular Economy" will be remembered as a **special edition**: due to the COVID-19 pandemic, we had to reschedule the event from June 4th to November 17th, 2020, and eventually we even had to make the switch to an online event. Although we would have liked to welcome you all in Theater de Veste and Pathé Delft, changing to an online event brought along many **new opportunities.**

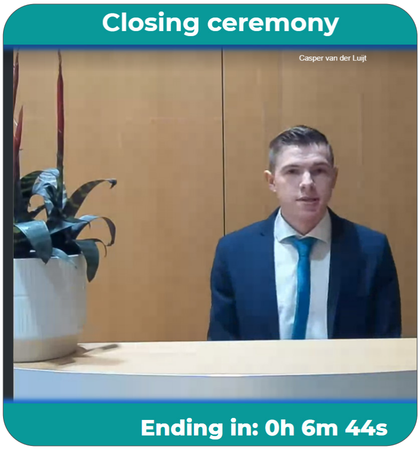
Most notably, we had a larger and much more diverse audience than usual. Next to all registrations by students and staff from Leiden University and Delft University of Technology, we saw many registrations from Wageningen University and Research, and employees and researchers at DSM, Photanol and Wetsus. However, we did not only have attendees from the Netherlands, but from **all over Europe**! Many of those abroad were from Germany, but also the UK, France, Denmark, Ireland, Portugal and Finland were represented. In total, we welcomed **365 participants** in the Let's Get Digital platform, the biggest turn-out of all editions of the Life Science Symposium: thank you all for attending! Besides that, we also had many people working behind the scenes, who I would like to thank for their efforts in making this symposium possible: our nine speakers, two chairmen, twelve Board of Recommendation members, three musicians, representatives of seven of our sponsors and finally our eight committee members, for a grand total of over 400 people involved.

Our speakers highlighted how biotechnology can contribute to moving towards a circular economy through insightful examples from biofuels to wastewater treatment and from recycling plastics to the sustainable production of biochemicals.

This review contains experiences by attendees, some behind the scenes of the symposium and summaries of the talks by our speakers. We hope it reminds you of an inspiring day and you enjoy reading it.







“We did not only have attendees from the Netherlands, but from all over Europe! Many of those abroad were from Germany, but also the UK, France, Denmark, Ireland, Portugal and Finland were represented” ~ Casper van der Luijt

ROBERT MANS

Tenure Track Assistant Professor, Delft University of Technology

Robert Mans is Tenure Track Assistant Professor at the TU Delft. His research field is the engineering of the (energy) metabolism of industrial microorganisms. The focus is on the construction of industrial strains that can be used in the production of fuels and chemicals.

Robert Mans was the opening speaker of the symposium.

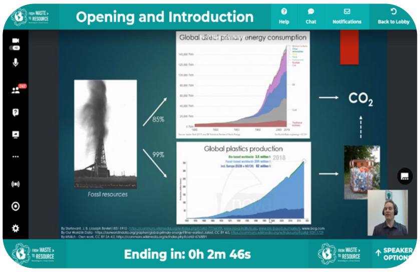
We live in a special moment in history. The world population is drastically increasing and we might be present during its peak. However, this increase in population also brings challenges along.

One of the important processes that got us so far, is the first synthetic process of nitrogen fixation. This process is developed by Fritz Haber and fixates nitrogen in the form of ammonia. Today, about half of the world population is dependent on this process. However, more ammonia than required is added to the plants. This overdosis adds up in the soil and eventually flows to the ocean. The ammonia stimulates algae to grow, resulting in a depletion of oxygen in these areas. The consequence is a so-called ‘dead zone’, where no sea animals can live.

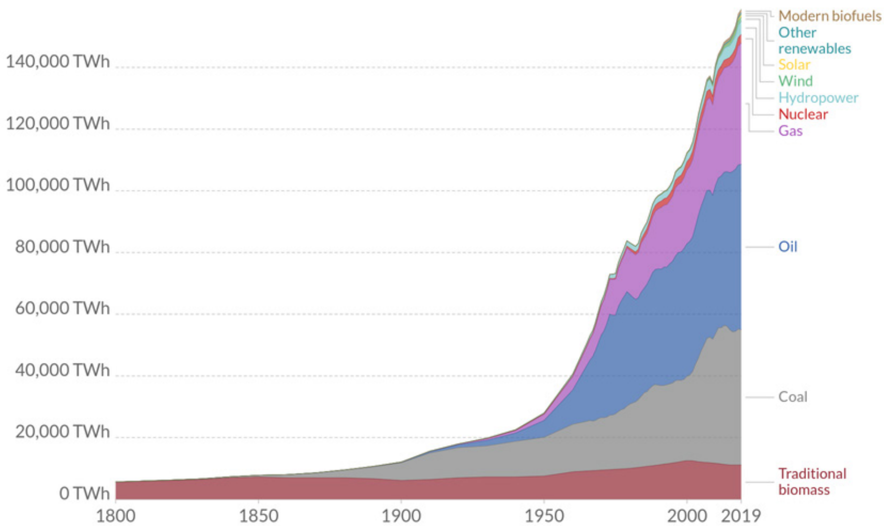
Another challenge that we face is our dependence on fossil resources. Today, we are 85% dependent on oil, gas and coal and we are beginning to face the consequences.

The third challenge addressed is plastic. Firstly, 99% of the plastic is made from fossil fuels and only 1% from biomaterial. Secondly, what is its fate once we throw it away? The last 70 years, we have been throwing it away and leaving it, resulting in an overload of plastic waste. Another option is to burn it, but this will result in more CO_2 emission.

The speakers of the 9th Life Science Symposium will discuss the above mentioned problems and address potential solutions.



“I have been thoroughly impressed by the organization of this symposium. Not only did I get to enjoy listening to a great line-up of speakers, but for an on-line event the whole day proceeded very smoothly.
The ‘lobby’, where there was constant chatter about the ongoing activities and talks gave it a very nice personal and lively, touch!” ~ Robert Mans



Global primary energy consumption. Source: Vaclav Smil (2017) and BP Statistical Review of World Energy.

MARIA BARBOSA

Professor in Microalgal Biotechnology, Wageningen University & Research

Maria Barbosa is personal professor in Microalgal Biotechnology at Wageningen University & Research. In 2008 she was asked to set up the research pilot facility AlgaePARC where she is currently the director. The goal of AlgaePARC is to fill the gap between fundamental research on algae and full-scale algae production facilities.

The role of microalgal biotechnology in a circular economy

"Why do I believe in microalgae?" Microalgae are primary producers, with the benefit that they can grow in sea water, and therefore do not demand agricultural lands. Thus, algae would serve as an interesting alternative for oils and proteins in the food industry. Currently 0.17 megatonnes a year of fish oil is produced globally, but circularity is a challenge in aquaculture, and hence new resources like algae are required. Different algae strains can produce a variety of lipids and up to 70% of the total weight of microalgae can consist of proteins, including all essential amino acids, making them an interesting food supplement. However, to obtain algae suitable for consumption purposes, accurate quality analysis is essential.

> **"Microalgae can contribute significantly to CO2 capture"**

Furthermore, microalgae can be used as a renewable for the production of bioplastics or transport fuels. To replace all transport fuels in Europe, an area equivalent to the size of Portugal would be needed to capture enough sunlight. For such upscaling, of course a lot of research is required, which is where AlgaePARC comes in. In AlgaePARC in Wageningen, the effects of dynamic light intensities are modeled to develop strategies to genetically improve algae strains, together with research to improve the understanding of algal metabolism. This all with the aim to speed up the development of large-scale algae production facilities.

MIKE JETTEN

Professor in Ecological Microbiology, Radboud University Nijmegen

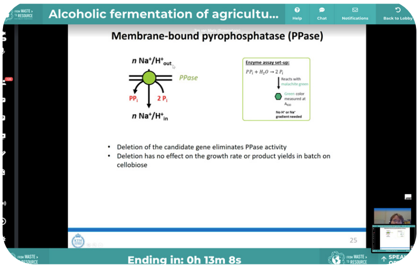
Mike Jetten is professor in Ecological Microbiology at the Radboud University in Nijmegen. In addition to this he is Extraordinary Professor in Environmental Biotechnology at Delft University of Technology. His research focuses on the ecology, physiology, biochemistry, metagenomics and applications of anaerobic microorganisms.

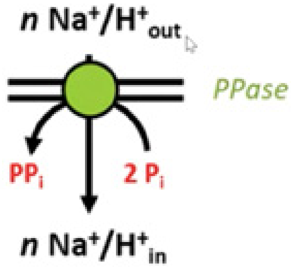
Nitrogen cycle in wastewater treatment

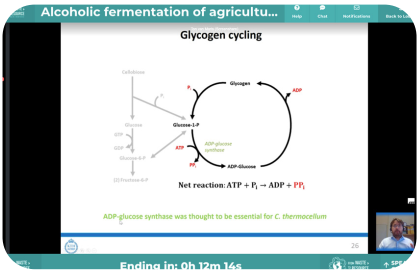
The nitrogen cycle has always played a big role in wastewater treatment but some steps in the nitrogen cycle have been unclear for a long time. Many scientists over the years have tried to find the so-called "impossible spook microbes of the nitrogen cycle" but did not succeed. However, in the recent years a lot of new genetic tools were developed which brings new options when it comes to identifying microorganisms and their genes.

To try and find these **"spook microbes"** a lot of samples were collected and taken to the lab where they were cultivated with substrate limitation. After growing these cultures the genetic toolbox was unleashed to discover all the secrets of these microorganisms. The analysis was mostly done using high-throughput screening which was followed by the design of new experiments to further unravel all secrets, but this was easier said than done and it took several years.

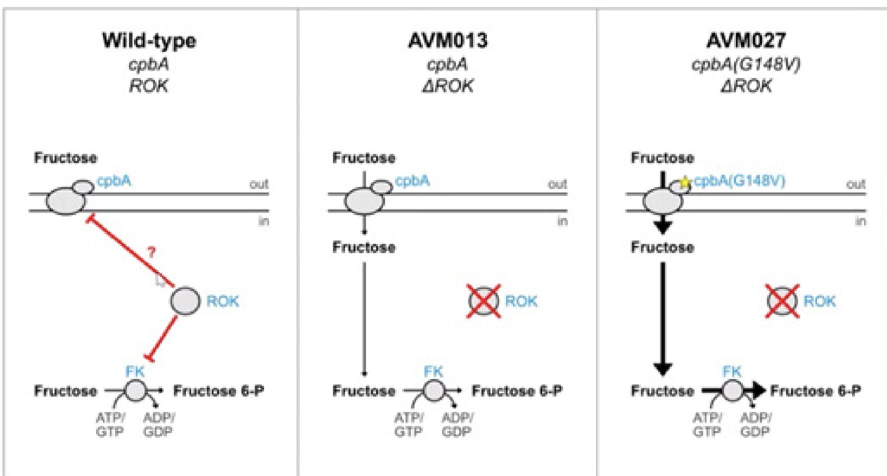
One of the bacteria species that was found in this experiment is now known as Anammox bacteria; it occurs in many wastewater treatment plants throughout Europe and there are many variants of this bacterium. The reaction this bacteria performs uses NH_4^+ and NO_2^- to produce nitrogen gas (N_2). It was also discovered that these bacteria have a lot of linked membranes to prevent protein leakage. The anammox reaction was a major surprise to the scientific community and has found many applications in wastewater treatment.







“Another fantastic symposium organized by the LST students. Great program, nice questions, many familiar faces and - even online - a great atmosphere!”
~ Ton van Maris



Proposed mechanism for fructose uptake in the cpbA mutant.

TON VAN MARIS

Professor in Biochemical Engineering, KTH Royal Institute of Technology

Antonius (Ton) van Maris is professor at the KTH Royal University of Technology, in Stockholm, where he leads the department of industrial biotechnology. He is a former professor at the TU Delft, with research interests in metabolic engineering, laboratory evolution and fermentation technology.

Engineering yeast and *Clostridium thermocellum* for alcoholic fermentation of agricultural residues: a tale of two specialists

Currently our main source of energy is fossil fuels. The problem with fossil fuels is that it takes millions of years to make it, and we use it up in a matter of years. Moreover, the released greenhouse gasses respond to global warming. To fight global warming, multiple scenarios are required. To stabilize the global warming of 1.5 degrees requires many steps and there is not just one technology that is going to fix it all. To fix it all, we need a combination of efficiency, renewables, change in behavior, carbon capture et cetera.

Here, the focus is on liquid fuels. How can we make our cars and air traffic more sustainable? One way to do this is by using biomass. Biomass can be broken down into different sugars (e.g. glucose, arabinose, fructose), which can then be converted into ethanol. At the TU Delft, the pathway for the degradation of xylose and of arabinose was successfully placed in *Saccharomyces cerevisiae*, enabling the yeast to make ethanol out of it. This resulted in collaboration with DSM, in a bioethanol factory (Project Liberty). However, there is another challenge. Yeast is really a specialist, and it does not break down cellulose itself. So, a thorough and expensive pretreatment is required to break down the cellulose into the sugars that yeast can ferment.

Here *Clostridium thermocellum* can be a solution. This is a cellulolytic (thus can break down cellulose) and can probably save 25-30% savings in OPEX and CAPEX. However, it showed a low ethanol yield and a low ethanol concentration. The metabolism of *C. thermocellum* is not fully understood yet, challenging the industrial implementation and optimization. However, the usage of laboratory evolution and metabolic engineering have already unravelled some of the questions.

RENÉ ROZENDAL

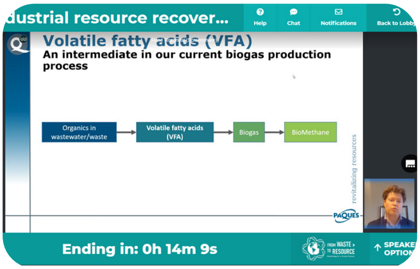
Chief Technology Officer, Paques

René Rozendal is the Chief Technology Officer at Paques Technology. Paques is a globally operating company for (biotechnological) industrial water and gas treatment. As CTO, he is in charge of technology development and leads an R&D group of around 25 people. Rozendal is specialized in bioelectrochemical wastewater treatment processes.

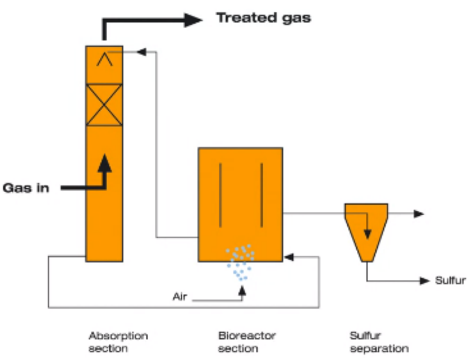
Industrial resource recovery through mixed culture biotechnology

On average, industries could recover 10% of their energy from their waste. Paques has developed the BIOPAQ reactors with which industrial off-gas can be used for methane production. Due to the risk of contamination, pure culture fermentation is not feasible for large scale wastewater treatment. That is why Paques uses mixed culture fermentation. René Rozendal emphasizes that it is vital to understand the role of microbes in nature in developing mixed culture technologies. Using “eco-engineering”, certain desirable microorganisms can be selected, such as microbes that accumulate the polymer PHBV that is produced from fatty acids that are intermediates in the biogas production process. Using substrate feed and femine periods one can select for these microbes and increase their storage capacity up to 80% of their total weight. The polymers can later be extracted and used for controlled fertilizer release, self-healing concrete and plant growth media.

Another technology developed by Paques is THIOPAQ, which is used to recover hydrogen sulfide from wastewater streams originating from for example the mining industries. Hydrogen sulfide is foul-smelling and toxic, and must be cleared from wastewater streams. Originally this was done chemically resulting in large amounts of gypsum and subsequent loss of both the metals and the sulfide. Instead of the chemical treatment Paques uses anaerobic thiobacteria that store the sulfur in little spheres. Later these spheres can be easily separated from the sludge to recycle the sulfur.



“It was a great pleasure to be part of this symposium. The program was top-class and the symposium as a whole was professionally organized with eye for detail. I was impressed by the online platform used by the Symposium Committee and particularly by how it was implemented by the team. I have attended several symposia during the corona period and this was definitely the symposium that came closest (by far!) to a real live experience. I loved everything about it: a warm welcome at entry, the continuously chatting guys at the front desk, the Q&A rooms, etc. Well done!!!” ~ René Rozendal



Absorber

$H_2S + \mathbf{OH^-} \rightarrow HS^- + H_2O$

Bioreactor

$HS^- + \frac{1}{2} O_2 \rightarrow S^0 + \mathbf{OH^-}$

THIOPAQ technology: Regeneration of alkaline scrubber solution.

YUEMEI LIN

Associate Professor, Delft University of Technology

Yuemei Lin is associate professor at Delft University of Technology. Her research focuses on extraction and characterization of extracellular polymers in microbial aggregates, such as granular sludge and biofilm. It also focuses on the conversion of the polymers into useful materials.

Extracellular biomaterials from waste sludge: recovery and application

Human waste is produced at any time and therefore wastewater is always present too. To reobtain the cleanest water possible the wastewater is cleaned thoroughly in wastewater treatment plants. Active sludge removal systems remove biological nutrients with aerobic granular sludge. The microorganisms used in this technique form a very dense and compact structure. Aerobic granular sludge has emerged in a new and very promising technique. However, it is difficult to do this and much research is done to increase the solubility of this waste. Nowadays, Nereda biomass is already used in commercial wastewater treatments. With this technology the energy and land use is significantly lowered.

“If we can recover extracellular polymeric substances from sludge we can use it as a resource"

Extracellular polymeric substances (EPS) in aerobic granular sludge have a weblike structure, this is the extracellular polymer that forms a gel around the bacteria. This sludge has always been considered a waste, however, we can recover the EPS and use it as a resource. At this moment we know that EPS contains carbohydrates and proteins, but this is difficult to characterize since the composition of sludge can be quite different. It is known that EPS has a flame retardant property and therefore it could be used as environmentally friendly replacement of other flame retardant substances.

HANS AERTS

Professor in Medical Biochemistry, Leiden University

Hans Aerts is full professor in medical biochemistry at the Leiden Institute of Chemistry of Leiden University. Through the years Hans Aerts has received many grants and awards, the most recent being the 2016 NWO Building Blocks of Life grant. His current interest lies in studying lysosomal storage diseases.

Recycling in the human cell

When you hear the word recycling, the environment directly comes to mind. However, the cell also relies on recycling for life. Cellular rejuvenation is needed in the human life cycle and this is done by the so-called 'bodies of cleavage', or in other terms the lysosomes. Lysosomes contain cleaving enzymes called hydrolases to recycle molecules and yield new building blocks. To take up these molecules the processes of endocytosis and autophagy play a key role.

"In the tiny world of cells lysosomal recycling is essential for health"

This cellular recycling is essential for human health and therefore inherited lysosomal storage diseases are very severe for human health.
These diseases are caused by an accumulation of glycogen in the lysosomes and are often recessive.

To date several methods to counter lysosomal storage diseases have been applied. In enzyme replacement therapy the patient is infused with recombinant enzyme every two weeks. This treatment has a high efficiency, unfortunately the costs are very high. In substrate reduction therapy the formation of the accumulated substrate is inhibited, countering the accumulation of glycogen. Gene therapy can also be a good treatment option for lysosomal storage diseases, in this treatment the inborn DNA mutations are repaired.

LARS BLANK

Professor in Applied Microbiology, RWTH Aachen University

Lars Blank is professor at the university of Aachen. He studied chemical engineering at the University of Dortmund and Biology at the Ruhr-University of Bochum. In his research he focuses on the applied aspects of microbial metabolism. He believes that a sound knowledge base in the Life Sciences is key for creativity and success in this field.

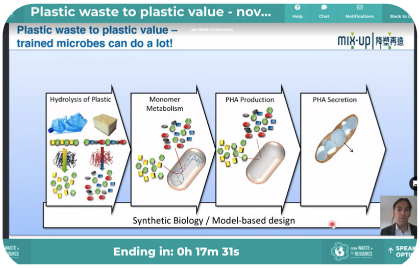
Plastic waste to plastic value – novel polymer recycling

The plastic crisis is real. Ideally we would use plastic, collect it, select it and easily recycle it. Unfortunately, today less than 10% of the plastic is recycled and less than 10% is burnt. The challenge lies not only in resolving the plastic waste, but also in the production process. The main source of the plastic production is fossil fuels.

Fortunately, many companies are investing heavily in plastic recycling. It is impossible to abolish plastic from our lives in the future, therefore biodegradation of plastics and a sustainable source are essential. This leads to three major challenges; **1**) switch of carbon source, **2**) mix-plastic upcycling and **3**) creating polymers with emergency bio-degradation utility.

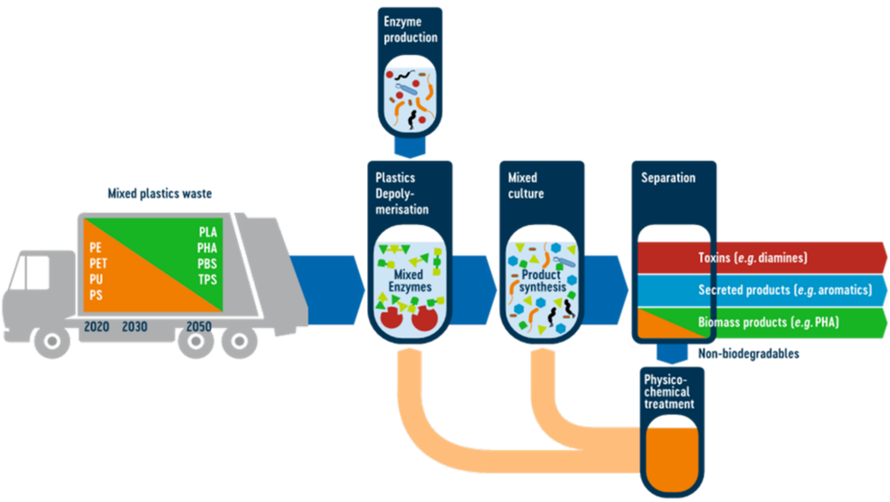
For example, plastic polymers can be made by microorganisms, microbes can use hydrogen (H_2) and carbon dioxide (CO_2) to do so. This process is sustainable if the hydrogen comes from a sustainable source. Another potential solution is to use PET degrading microorganisms. *Ideonella sakaiensis* can degrade PET, but is quite slow at it. Wing-Jin Li found that *Pseudonomas putida* with an ethylene glycol metabolism can be used as well. This strain is modified in order to study how to increase its growth rate.

Furthermore, a goal is to produce bioplastics, by using plastic monomers to make polyhydroxyalkanoate (PHA), a biobased and biodegradable polyester. The ultimate goal is to eventually break down PET and PU using PET and PU hydrolases and to use these hydrolase products as building blocks for new plastics/polymers, fuels, detergents and fine chemicals.

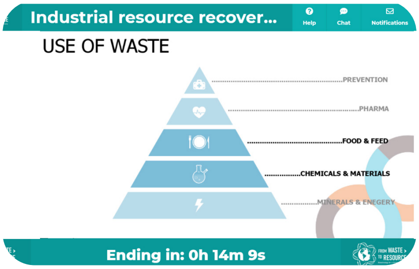


“The organizers did a fabulous job in arranging such a homogenous line-up showcasing the many different contributions microbes can make on our road to a sustainable (bio)economy. The symposium was highly educating and just pure fun!”

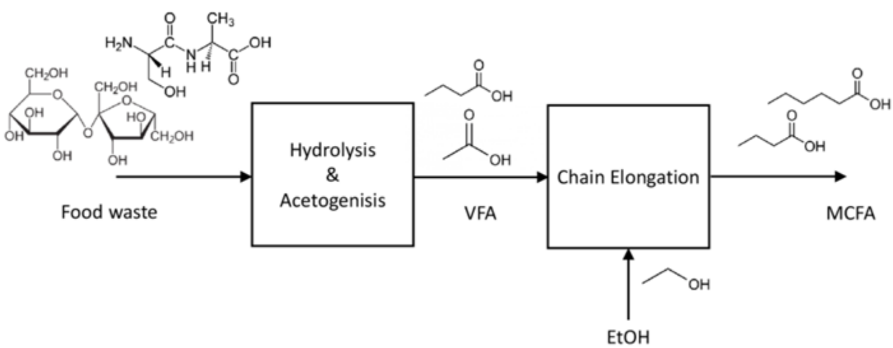
~ Lars Blank



The eu horizon 2020 project MIX-UP: Strategy for recycling of plastic waste.



“The 9th Life Science Symposium ‘From Waste to Resource’ was an inspiring and motivating event which gave a glimpse of what the future of waste recovery may look like. Various speakers from both industry and the scientific community made for a well-balanced schedule and the online environment had the feeling as if it were a real-life event.” ~ Robbert Binneveld



MCFA produced by mixed culture fermentation

ROBBERT BINNEVELD

Process Engineer, ChainCraft

Robbert Binneveld is a process engineer at ChainCraft. He is a LST alumnus and obtained his masters degree in Biochemical Engineering at Delft University of Technology. After finishing his masters degree he started working at ChainCraft, a Dutch biotechnology company located in Amsterdam that specialises in converting organic waste to new chemicals using fermentation processes.

Open mixed culture fermentations for industrial production of biochemicals from organic waste and residues

ChainCraft uses open mixed culture fermentations, a type of biotechnology that was historically applied in wastewater treatment and anaerobic digestion. Having an open mixed culture fermentation means that the bioreactor is open to different microorganisms that can enter the reactor; therefore, it is not a sterile fermentation and you are working with an (engineered) ecosystem instead of a single microorganism. This type of fermentation is known to be very capable of dealing with waste and that is exactly what it is used for.

Currently this process is used for production of two products: a blend Medium Chain Fatty Acids (MCFAs) and Kaumera. The MCFAs are used as a feed additive for animals, reducing the need for antibiotics and making the animal healthier in general. The MCFAs are produced through hydrolysis and acetogenesis of food waste, generating Volatile Fatty Acids (VFAs) which are elongated using ethanol. The second product, Kaumera, is a crosslinked polymer mainly consisting of glycoprotein and water which can be used as a biostimulant, fertilizer coating and much more. The benefit of using Kaumera for these purposes is that this offers a biobased and less energy-intensive alternative to many daily products.

JENNIFER HOLMGREN

Chief Executive Officer, LanzaTech

Jennifer Holmgren is the CEO of LanzaTech, a carbon recycling company that is working towards developing a variety of platform chemicals and fuels from industrial waste gasses. She obtained her bachelor degree at Harvey Mudd College and her PhD at the University of Illinois, followed by an MBA at the University of Chicago.

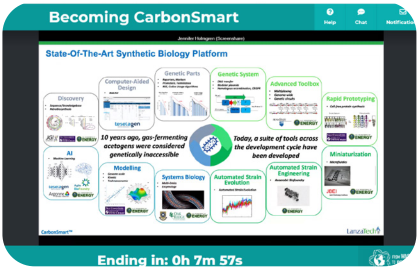
Becoming CarbonSmart - How innovation and ancient biology enables us to convert waste carbon emissions from a liability into an opportunity.

The vision for the future of Dr. Holmgren and LanzaTech's, is a world where all carbon waste is reused. A lot of the energy that is currently used comes from fossil fuels, but that does not have to be the case. Energy can be carbon free and if we want to handle climate change carbon should only be used when absolutely necessary.

For the past years a lot of work has been done to reach this goal, and biotechnology has played a big role therein. The big advantage of using biology has always been that it has the ability to do things that seem impossible on other platforms.

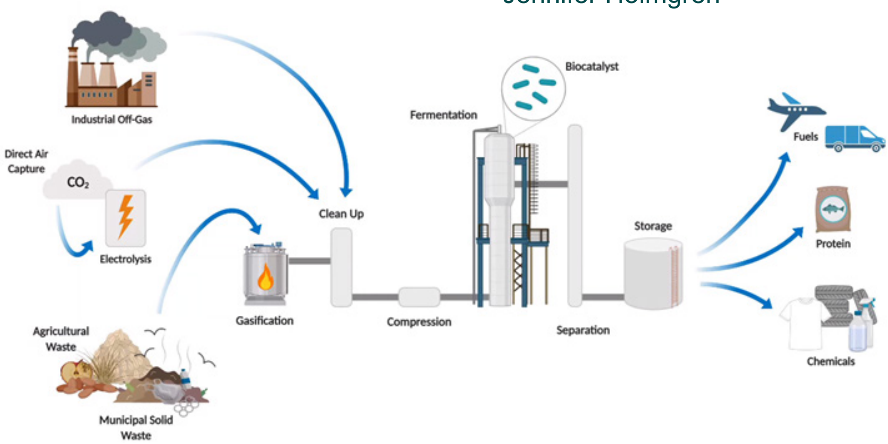
"Biology can do things no other human-made technology can do"

With biotechnology we have the tools to modify organisms to give desired products, which opens a whole new world of possibilities. LanzaTech has developed a process where (industrial) off gasses can be fermented to produce fuels, proteins and other chemicals. In addition this, gasified solid waste can also be used. The microorganism used in this process is a very versatile one as it has the ability to shift metabolic pathways depending on the composition of the available gas steam. So it can ferment gas from different sources. In 2018, a plant using this process was opened which has since produced 20 million gallons of ethanol.



“It was a great honor to take part in this exceptionally well-run symposium on Biotechnology and looking at wastes as the resources of a sustainable tomorrow. This symposium comes at a time where science and data are playing a key role in how we look towards the future wellbeing of our planet. The bioeconomy can play a role in creating new healthier and more resilient ways of living and the speakers and energetic panel discussions in this symposium showed a snapshot of what is possible today. My only regret is that we were unable to meet in person!”

~ Jennifer Holmgren



Utilizing all waste carbon.

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BEHIND THE SCENES

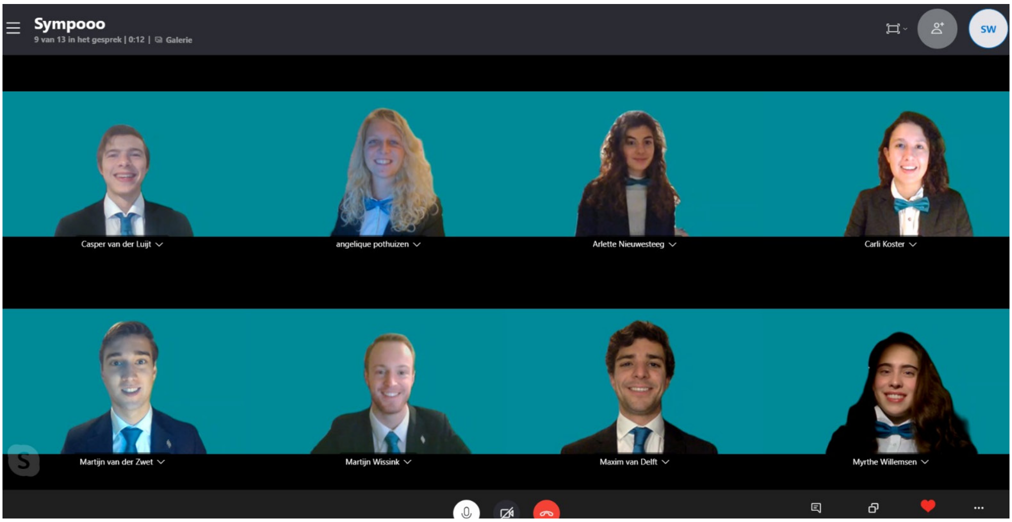
By now it has been over **two and a half years** since the committee for the 9th Life Science Symposium was formed. Since then it has been quite a journey and as with many things, it took longer than expected. Initially, the idea was to find a theme that would be applicable for both Leiden and Delft topics and befit a **lustrum year** as 2019-2020 would be. It was ultimately after about half a year that we settled on the theme ‘From Waste to Resource - Biotechnology for a Circular Economy’. It took another year to find and invite fitting top of the field speakers and sufficient funding. Both Theater de Veste and Pathé Delft were booked for the 4^{th} of June and the programme was complete. Then **COVID-19 intervened**. We decided to postpone the symposium to November 17^{th}, in the hope that COVID-19 would be sufficiently under control to have physical events again. Unfortunately, a hybrid symposium was also not meant to be and in October the decision was made to convert the entire symposium to an online event.

So on November 17^{th} all eight committee members gathered at 8h in the morning at the Applied Sciences building in Delft. We split the committee in two groups of four in two different rooms. In one room the event moderators and the committee chairman had their set-up. Although we tested all the camera equipment the day before, getting it operational was **problematic** and we only managed to get it operating less than 45 min. before the start of the symposium. In the other room the rest of the committee guided the speakers and the Q&A sessions. In the end, everything went super smooth and we are incredibly **happy with the result**. We ended the day with a glass of champagne in celebration.

The symposium committee at Applied Sciences in Delft on November 17^{th}, during the symposium.

SYMPOSIUM COMMITTEE

Casper van der Luijt	Chairman
Arlette Nieuwesteeg	Secretary
Carli Koster	Treasurer
Angelique Pothuizen	External Affairs
Martijn van der Zwet	External Affairs
Myrthe Willemsen	Promotion
Maxim van Delft	General Affairs and Support
Martijn Wissink	General Affairs and Support



From left to right and top to bottom: Casper van der Luijt, Angelique Pothuizen, Arlette Nieuwesteeg, Carli Koster, Martijn van der Zwet, Martijn Wissink, Maxim van Delft and Myrthe Willemsen. The photo was taken during one of our Skype meetings.

ACKNOWLEDGEMENTS

The Symposium Committee would like to thank the following persons, companies, funds and other partners for their contributions to the 9th Life Science Symposium:

SPEAKERS

Dr. ir. Robert Mans
Prof. dr. ir. Mike Jetten
Prof. dr. ir. Lars Blank
Prof. dr. Maria Barbosa
Dr. ir. René Rozendal
Dr. Yuemei Lin
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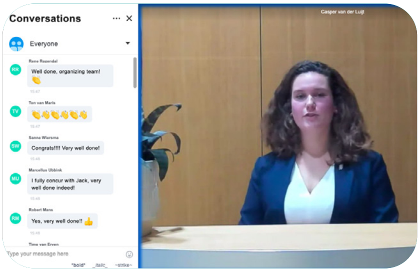

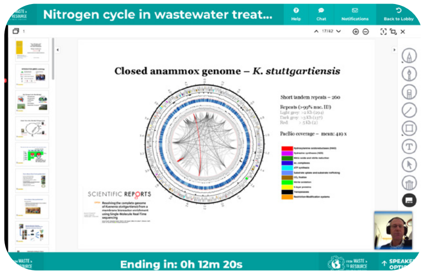

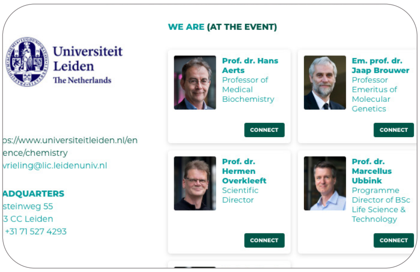

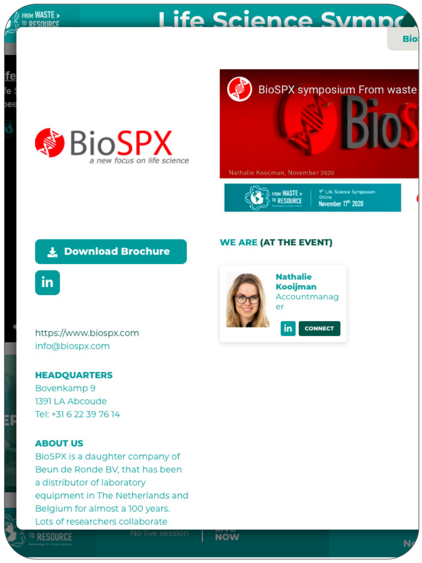

“I just want to mention how great the visuals on all the presentations were. I have seen some amazing graphs and figures!” ~ an attending student