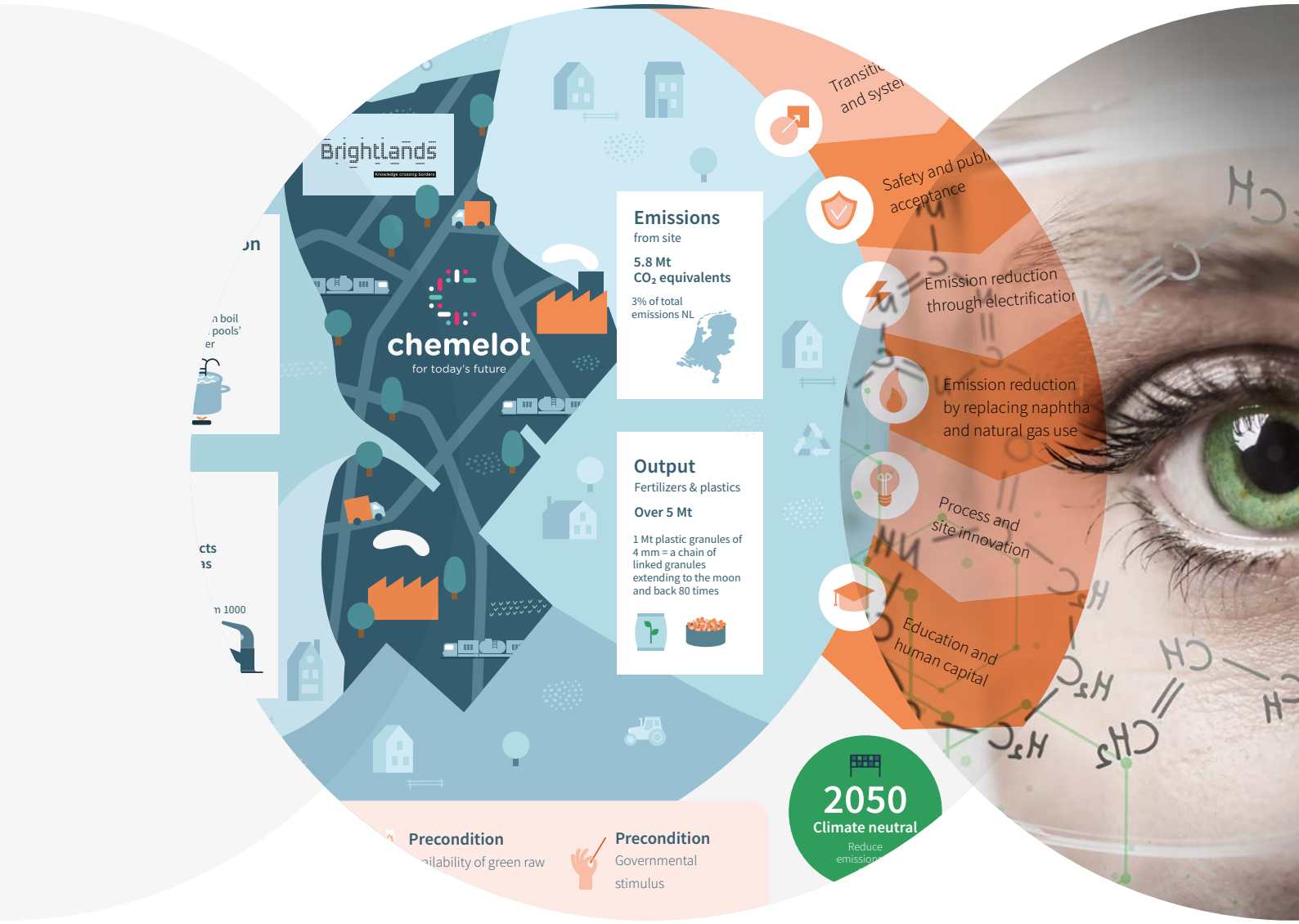
Brightsite Transition Outlook 2022



Brightsite

Transforming industry

Arnold Stokking, *Managing Director Brightsite*

"Brightsite's mission is twofold: to demonstrate that the climate targets at Chemelot can be achieved and to train a new generation of researchers and staff to help achieve them."

On the way to sustainable chemistry at Chemelot

Together, companies, knowledge institutions and government will shape the transition and achieve the climate targets at Chemelot

Transforming industry
The chemical industry, which is active on a large scale in Limburg at the Geleen Chemelot site, can make a substantial contribution to the achievement of these climate targets, given its size. In order to develop the necessary innovative technologies, the companies at Chemelot and the Brightlands Chemelot Campus encouraged the creation of Brightsite in 2019. Brightsite's mission is twofold: to demonstrate that the climate targets at Chemelot can be achieved and to train a new generation of researchers and staff to help achieve them. This Brightsite Transition Outlook presents an overview of how and when these climate targets can be achieved at Chemelot and what is required to do so. Brightsite supports the site users in their investments in the future of Chemelot. The 2030 targets are expected to be largely achievable through measures already identified. However, the zero-emissions target for 2050 still requires several new solutions.

The Brightsite Transition Outlook presents how and when the climate targets can be achieved at Chemelot and what is required to do so.

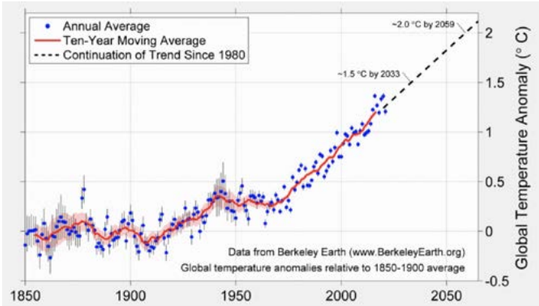
The integral approach and assessed scenarios
A future-proof Chemelot requires joint, sustainable innovation. Technologies that are needed for this have never before been applied on an industrial scale and scaling up is a significant challenge. As Brightsite, we create an overall picture and help companies at Chemelot to make the right choices for innovative technologies. It is crucial that we use processes that meet the needs of the site as a whole and that fit in with future developments in the Netherlands. We call this system integration. We will have to come up with and implement a strategy together as a site, but also as the Netherlands and Europe. Changes in processes, the advent of new technologies, products and infrastructure impact each other. By thinking in terms of systems and using well-thought-through modeling, we can better deal with uncertainties in assessed scenarios. This Brightsite Transition Outlook addresses the most important technological, social and educational solution directions. Brightsite is located on the Brightlands Chemelot Campus, a location that, surrounded by large-scale chemical industry, offers an ideal starting point for this.

Preconditions for successful transition
Currently, Chemelot is almost entirely dependent on suppliers of fossil raw materials (naphtha and natural gas) and (gray) electricity, and this will continue to be the case in the future with regard to the provision of green raw materials and sustainable CO_2-free energy. This requires improving the conditions under which new chain formation between chemistry and new supply sectors such as waste management and agriculture can be established. Much more electricity is also needed at industry sites such as Chemelot, which requires an exponential expansion of the infrastructure for generation, transport and system management. Intensive cooperation with local and regional authorities is essential for a promising transition of the chemical industry. The national government must play a stimulating and governing role, for example by setting up a 'Climate Agency NL'.

This Brightsite publication (April 2022) has been produced under the direction of Paul Brandts (Brightsite Intelligence Officer) and Dick Koster (consultant) in collaboration with the Brightsite board and the Program Managers. The publication uses facts and knowledge available in January 2022 and is expected to receive an annual update.

The challenge

International context
In 2015 and together with 195 other countries, the Netherlands signed the Paris Agreement on Climate Change. The aim of this agreement is to limit global warming to a maximum of 2 degrees and preferably 1.5 degrees Celsius. If the linear warming observed since 1970 continues, these limits will already be reached in 2033 and 2059, as shown in the figure below.



Berkeley Global Warming

The chemical industry at Chemelot uses naphtha produced from petroleum and natural gas for the manufacture of plastic products and fertilizer. This generated 5.8 megatons (Mt) of greenhouse gas emissions in 2019, contributing about 30% of Limburg's emissions and 3% of total Dutch emissions. By greening raw materials and switching to sustainable electricity for energy supply, all plants on the Chemelot site can become more sustainable.

Targets for 2030
(Chemelot Cluster Energy Strategy)
1: Reduction of emissions at Chemelot to about 3 megatons of CO_2 equivalents
- Reducing the emission of nitrous oxide
- Partial storage of CO_2 emissions under the seabed
- Implementation of various energy projects

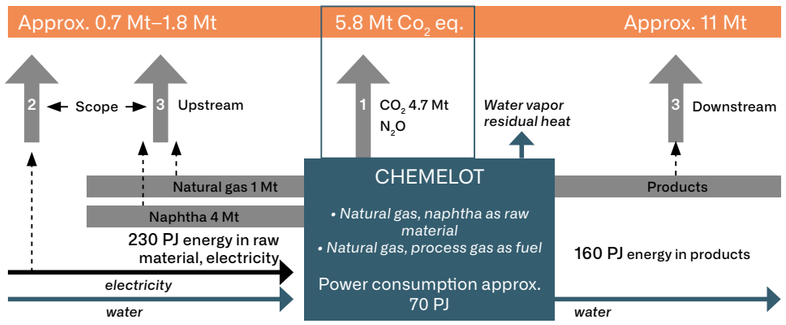
2: Replacement of fossil raw materials
- Reduce naphtha consumption by 25%
- Reduce natural gas consumption by 20%

Replacement of fossil raw materials with alternatives also reduces fossil emissions associated with end-of-life incineration of Chemelot's products.

Targets for 2050
- **Climate neutrality, the European Union's long-term strategy**

In the long term, the burning of fossil fuels must be stopped, and a switch made to (available) sustainable electricity or other energy sources without fossil emissions. With regard to the supply of raw materials, in the long term, fossil carbon in manufactured products must be replaced by alternatives and kept in circulation for as long as possible.

This transition fits in with Chemelot's policy to grow to become the most sustainable, competitive and safe chemicals and materials site in Europe. In 2018, the 'Chemelot Sustainability Team' was set up to provide a practical description of the steps to be taken to reduce CO_2 emissions.



Raw materials and energy streams and Scope 1, 2, 3 emissions at Chemelot in 2019

Sustainably connected

Cluster Energy Strategy
Chemelot 2030-2050

Adopted by Chemelot table, March 8, 2021

chemelot
for today's future

Press release
March 2021: The province of Limburg supports a circular future

With this support, Brightsite will promote the development and commercial application of the technologies and corresponding education courses that will allow the chemical industry to meet the climate targets and bring about an energy transition.

Scope 1, 2 and 3: distinction and allocation of emissions

When formulating policy and implementing regulations, a distinction is made—depending on where emissions occur—between Scope 1, Scope 2 and Scope 3 emissions.
Scope 1 concerns the emissions from processes of companies on their own premises.
Scope 2 emissions are released from external generation of electricity for on-site use.
For Scope 3, a distinction is made between upstream and downstream emissions.
Both types of emissions are released outside the company. Upstream concerns emissions that are released by supplying raw materials, and downstream emissions are released at the end of the life cycle of products, such as when plastic products are incinerated.
The essential aspect in this is the relative nature of Scopes 1, 2 and 3. The numerical values of emissions to be assigned to them depend on the point of view of the defining entity in question and are therefore not absolutely valid. For example, Scope 3 Chemelot emissions can take place both within Scope 1 and 3 of the Netherlands, depending on where the emission takes place.

Chemelot in transition

Substantial steps to achieve the targets

In South Limburg, the chemical industry at the Chemelot site is working on a clear vision to operate in a climate-neutral way by 2050, so that all the products that Chemelot makes today will also be available in the future, but in a green way. To this end, Chemelot is committed to both raw material greening and energy greening. This means not only an energy transition, but also a raw materials transition, and even a whole-chain transition with respect to using new carbon sources for chemistry.

***Loek Radix**, Executive Director Chemelot:*

"Thanks to the integration at Chemelot, our task is, in principle, manageable. So, I am confident in saying: if there is one chemical cluster that will succeed in being fully circular by 2050, it is Chemelot."

2030

Since 2005, emissions at Chemelot have already been significantly reduced, most notably by reducing N_2O emissions. To achieve the 2030 targets, various projects are being worked on to further reduce N_2O emissions:

- **Fibrant for the production of caprolactam** (investment of more than 40 million euro, now implemented)
- **AnQore for the production of acrylonitrile** (in preparation)

Together, these N_2O-emission-focused measures will result in a further reduction of over 20% in Chemelot's current Scope 1 emissions.

However, that is not enough. Another realistic option for substantially reducing Chemelot's Scope 1 emissions by 2030 is to capture, transport and store CO_2. The CO_2 released from the current production of hydrogen from natural gas for ammonia production by OCI is the most appropriate option. The CO_2 currently being released contributes nearly 20% to Chemelot's total Scope 1 greenhouse gas emissions. **OCI expects to increasingly purchase hydrogen from producers that produce fewer net CO_2 emissions. One option is an investment of hundreds of millions of euro by RWE for the construction of a gasification plant at Chemelot, which could produce around 40 kilotons of hydrogen annually from residual waste (from Limburg).** In the more distant future, connection to a national and international hydrogen network is also being considered, which would enable the transport of additional green hydrogen to Chemelot.

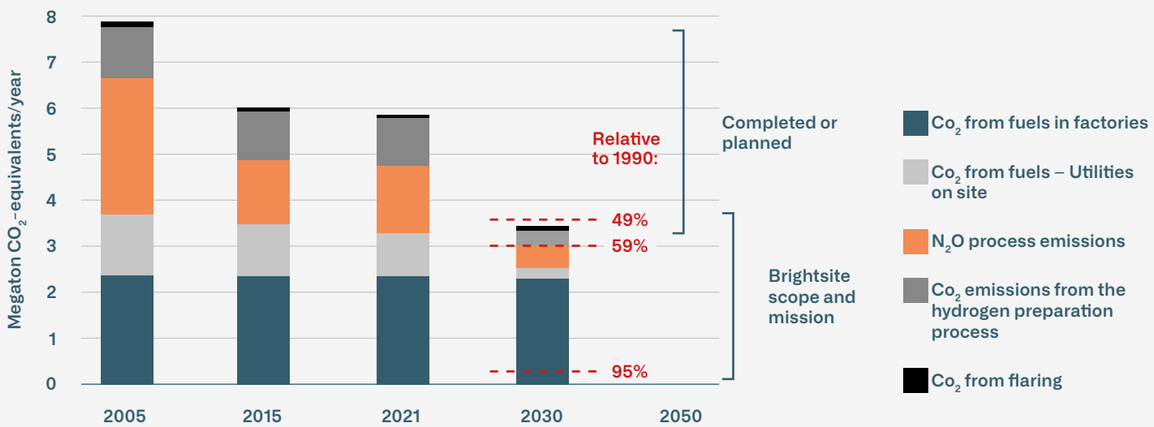
In addition to the major interventions mentioned above, there are several smaller initiatives that will help meet the 2030 targets.
However, achieving the 2050 targets still requires a significant further reduction in CO_2 emissions.

2050

The current large-scale combustion of natural gas and process methane released by steam cracking must be phased out. Technically speaking, alternative options that require timely and affordable renewable electricity are conceivable. To achieve this energy transition, Chemelot is dependent on both (timely) investments and security of supply from external electricity producers and grid operators.

Two major transitions will make the difference
In addition to this energy transition—which will mainly reduce Scope 1 and 2 emissions—a reduction of Scope 3 emissions is possible by replacing naphtha and natural gas from fossil sources. For this raw material transition, large amounts of 'green carbon' from non-fossil carbon sources must be (re)used at Chemelot as an alternative. In principle, it is possible to use household and plastic waste as a raw material for this purpose, in addition to bio-based raw materials originating from agriculture and forestry. Achieving the 2050 emissions targets requires large-scale implementation of innovations in technology and value chains, in view of the large volume of products at Chemelot (and the comparable chemical industry).

Many sub-processes will have to undergo modifications to adapt to new raw materials and (intermediate) products. In order to apply these changes in an economically and socially responsible way, new forms of cooperation will be necessary. Collectively, these transitions will lead to an entirely new way for chemical processes to be operated on an industrial scale in the second half of the 21st century.



Origin and options for reducing Scope 1 greenhouse gas emissions at Chemelot.

Brightlands Chemelot Campus

The best place for development and innovation

The joint Climate Agenda of the companies at Chemelot calls for innovation and scaling up of new technologies. This transition, unlike the transition from coal to oil and gas, will be shaped by collaboration. At Brightlands Chemelot Campus, everything revolves around innovation and growth. Whether it concerns the development of high-quality materials, sustainable processes or biomedical innovations, our dynamic community works on solutions that contribute to a more sustainable world with healthy people. A leading environment in which technology, entrepreneurship and knowledge flourish and where demo-setups can prove themselves.

The many parties involved in this transition thus form a unique and well-functioning ecosystem on the campus, an important condition for success.

Brightsite
Transforming industry

On the way to sustainable chemistry at Chemelot

The Paris Climate Convention and the Dutch National Climate Agreement have set out objectives and implemented measures to reduce greenhouse gas emissions. The Chemelot companies, supported by Brightsite, are making a significant contribution to the transition of the chemical industry required for this purpose, with the aim of making it climate-neutral while maintaining employment.

Ambition: Grow Chemelot into the most sustainable, competitive and safe chemicals and materials site in Europe.

Key projects to 2030

SABIC - Initial electrification of steam cracking
SABIC - PLASTIC ENERGY Recycling
FIBRANT, ANQORE - Nitrous oxide, emissions reduction
OCI - CO_2 emission reduction
CHEMELOT - Optimize water chain

Transition scenarios and system integration
Safety and public acceptance
Emission reduction through electrification
Emission reduction by replacing naphtha and natural gas use
Process and site innovation
Education and human capital

Brightlands
Knowledge crossing borders

chemelot
for today's future

Legend
Fossil vs green 2019
- Fossil
- Nuclear power
- Renewable + waste

Extraction NL
20 Mt

Input NL
240 Mt
>99% fossil
=1 truck per household per year

Output NL
180 Mt
>99% fossil

Consumption NL
80 Mt

240 million tons (Mt) of fossil resources per year = a 40,000 km-long, fully loaded train

Sustainable energy consumption in NL is only 9%

natural gas
naphtha

Consumption
on site
70 PJ
1 PJ energy can boil 1200 Olympic pools' worth of water

Input
on site
4 Mt oil products
1 Mt natural gas
4 PJ electricity
4 Mt oil = full flow from 1000 fully opened faucets

Emissions
from site
5.8 Mt CO_2 equivalents
3% of total emissions NL

Output
Fertilizers & plastics
Over 5 Mt
1 Mt plastic granules of 4 mm = a chain of linked granules extending to the moon and back 80 times

Legend
Energy flows
- Extraction NL
- Export/Throughput
- Consumption
- Storage
- Input

Netherlands

Chemelot

Precondition
Sustainable electricity supply

Precondition
Availability of green raw materials

Precondition
Governmental stimulus

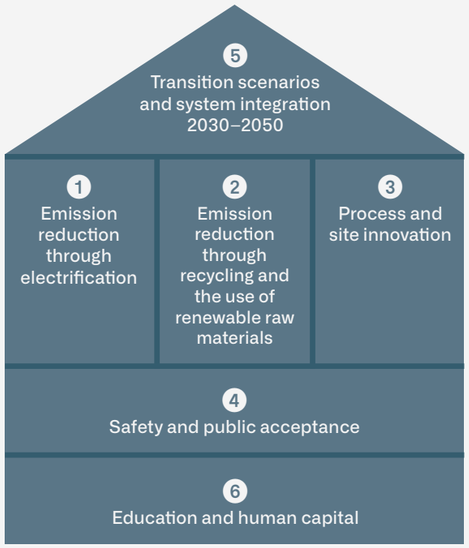
2050
Climate neutral
Reduce emissions to 0%

Brightsite is a driving force for the development and commercial application of innovative technologies

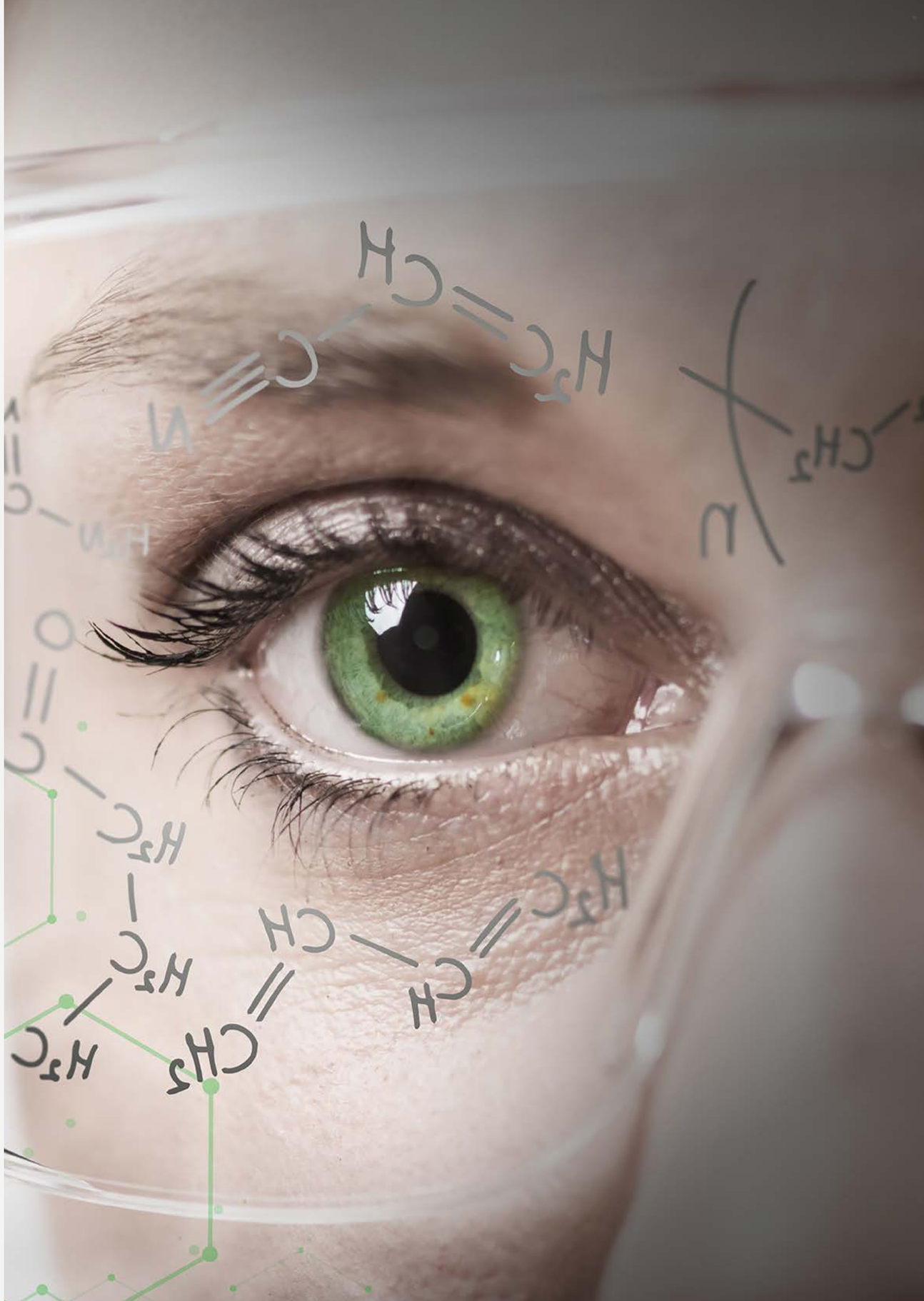
As an open-innovation platform for sustainable process technology and circularity, Brightsite brings together the knowledge of many parties, provides facilities for scaling up and commercial demonstration and support the choice and development of the right technologies to achieve the greening of the chemical industry.

The Brightsite knowledge center is a public-private partnership between Sitech Services, TNO, Maastricht University and Brightlands Chemelot Campus. A partnership characterized by openness, using a network of expertise to bring about transformation in the chemical industry. The climate goals pose hugely significant challenges for the chemical industry, but they also provide opportunities.

Sound transition management will result in economic growth and attract talent and business. As the development and application of new technology involves much more than just the technical aspects, the work also includes safety aspects, social acceptance, legal and economic feasibility, job opportunities and education. In short, Brightsite contributes to founding a broad base for future prosperity by working together with the industry partners.



Six mutually reinforcing program lines with Chemelot as a leading international testing ground.



1. Emission reduction through electrification with plasma technology as a game changer

By 2050, a large proportion of the processes and plants in the chemical industry will have to be powered by (sustainably generated) electrical energy in order to significantly reduce CO_2 emissions. **SABIC is partner in a development consortium for electrification of steam cracking.** However, large-scale implementation of electric cracking depends on the availability of sufficient (CO_2-free) energy on the site and is expected to be fully implemented only in the period after 2025. Other companies can develop their own technologies or focus on what the market will soon have to offer in terms of electric technology. We are seeing a strong increase in commercial activity in this area. Brightsite's Program Line1 'Emission Reduction through Electrification' also explores the further possibilities for electrification, for value creation at Chemelot.

***Hans Linden**, Program Manager, Brightsite:*

"Plasma technology has a great future within the chemical industry. As far as we are concerned, it is the best new process technology based on green electricity for splitting and reforming molecules."

Brightsite focus: Plasma technology
A Brightsite feasibility study shows that it is possible to convert methane into hydrogen and carbon products using electric plasma technology—without the formation of CO_2 and using much less energy than the electrolysis of water requires. At Brightsite, plasma technology is regarded as a potentially game-changing technology because it can reduce the current CO_2 emissions from the chemical industry, while also keeping carbon in the loop of the circular economy. For Chemelot, it would be interesting to produce both hydrogen for OCI and ethylene for SABIC from methane—released by electrified cracking processes.

***Marco Mensink**, Director General, Cefic:*

"I am proud to see the disruptive technologies and innovations taking place in our industry. It is this portfolio of technologies that enable the use of circular raw materials and low-emission energy such as renewable electricity, and the Plasma program is an example of this."

Through electrification of heating processes and plasma technology production of hydrogen and carbon building blocks from redundant fuel gases (e.g., process methane), Chemelot's Scope 1 emissions can be significantly reduced by 2050, relative to today. With the import of green hydrogen or additional innovations (see other program lines), zero emissions at the site are within reach.

In addition, Brightsite is investigating the use of plasma technology for CO_2-free formation of nitrogen compounds for the ammonia- and plastic-related value chains at Chemelot. This also offers potential for new business activities at Chemelot, which is being addressed in collaboration with business development at Chemelot, Brightsite's Brightlands Chemelot Campus and Program Line 2. For the further development of the plasma process and exploration of possible applications inside and outside Chemelot, the Brightsite partners have formed a joint plasma group. **With the appointment of Professor Gerard van Rooij as professor at the Faculty of Science and Engineering, a Chair of Plasma Chemistry was created at Maastricht University (UM).** For the implementation of the experimental research, the Brightsite Plasma Lab was opened at Brightlands Chemelot Campus in November 2021, hosted by UM's Department of Circular Chemical Engineering.

2. Emission reduction through recycling and use of renewable raw materials

To meet climate goals, it will be essential not only to focus on the energy transition, but also the resource transition. In a CO_2-neutral and circular economy, no new fossil raw materials should be added to the carbon cycle.
At Chemelot, the company QCP (Quality Circular Polymers) is active in the recycling of plastic household packaging waste. SABIC is also actively driving recycling through a joint venture called 'Spear': SABIC – Plastic Energy Advanced Recycling is building a pilot plant of several dozen kilotons at Chemelot.

The volumes required by the chemical industry and Chemelot are very large, and in addition to these ground-breaking first steps, there is plenty of room for further, necessary exploration and testing of potential applications. Brightsite's Program Line 2, 'Reduction of emissions by replacing naphtha and natural gas usage', examines a number of routes and technologies for the large-scale and economically most advantageous procurement of circular raw materials.

Brightsite focus: Use of biomass and recycling of plastics
In order for sustainable carbon sources to replace fossil raw materials, it is important to focus on different routes. Closing the product cycle through the use of plastic waste and biomass as feedstocks for the production of new materials are two parallel pathways that Brightsite is focusing on.

***Kim Ragaert**, Professor of Circular Plastics, Maastricht University:*

"Currently, less than 30% of plastic in the European Union is recycled. There is still a lot of progress to be made and if we intend on including plastics in the circular economy, the time to take recycling to a higher level is now."

To be used in today's production processes, alternative raw materials often must first be purified and/or chemically converted into liquid and gaseous intermediates. Given the state of the technology and outlook for application, this part of the Brightsite program line is primarily focused on the development of pretreatment methods to separate the useful and valuable components from plastic waste and bio-based raw materials. **In collaboration with Chemelot (SABIC), commercial providers and developers, the program will contribute to testing on industrially relevant scales and to developing the technical modifications required for this purpose. There is also collaboration with Brightlands Chemelot Campus on adjacent initiatives in this field, such as Chemelot Circular Hub and Brightlands Circular Space, and with the Green Chemistry – New Economy platform.**

***Bert Kip**, CEO of Brightlands Chemelot Campus:*

"Government, knowledge institutions and industry must join forces to bring together researchers, thinkers and engineers to accelerate innovation."

Chemelot's current 12.8 Mt Scope 3 greenhouse gas emissions associated with the use of fossil naphtha for the manufacture of plastics can, in principle, be fully reduced by 2050, given the abundant availability of CO_2-free energy, through the (re)use of plastic waste, bio-based raw materials and CO_2.

***Rinke Altink**, Program Manager at Brightsite, on the use of biomass:*

"Biomass usage and the recycling of plastic waste streams are two parallel trajectories that, in combination, have great potential. Collaboration is crucial in this and we need to look at the whole system in its entirety."

3. Process- and site innovation

In addition to the program lines described above focused on electrification and use of non-fossil resources, Brightsite has a third, integral innovation pillar. Program Line 3 identifies the additional process and site innovations that Chemelot needs to meet the climate objectives and to remain attractive to investors in terms of development and industrial application.

Brightsite focus: Reuse of residual gases and heat, digitalization and circular water

One of the goals of Program Line 3 is to support Chemelot site users in reducing greenhouse gases by capturing, storing or exploiting CO_2 and by eliminating N_2O emissions. **In this area, projects currently in preparation or implementation at OCI, Fibrant and AnQore, represent major steps toward the 2030 targets. Program Line 3, in collaboration with TNO and Program Lines 2 and 5, explores the possible future application of CCU and syngas for (new) value creation at Chemelot.**

The program line also focuses on efficient reuse of residual heat and residual gases. Reuse of residual gases can, in principle, bring about a significant additional reduction of CO_2 emissions at Chemelot. Moreover, a significant proportion of the residual heat released at Chemelot could be used to heat the built environment. In view of the associated costs and external dependencies, making use of these options in the short term is not yet economically feasible.
However, Brightsite will endeavor to improve this situation, in consultation with the relevant stakeholders and suppliers.
An example of this is the option of storing, transporting and releasing of heat using a heat battery based on salt hydration technology, as currently developed for smaller-scale applications by the TNO-TU/e spin-off Cellsius. Although the use of residual heat in the built environment will not lead to a reduction of the Scope 1 emissions at Chemelot, a project-based exploration has shown a saving potential of about 0.17 Mt CO_2 Scope 1 emissions.

In addition, Brightsite is looking for possibilities for further optimization of water use and purification. It should be noted that water use at Chemelot is related to the reuse of heat. Given a recent tightening of environmental requirements, a program has been set up by Chemelot—in cooperation with Brightsite, Chemelot's water organizations USG and IAZI, and regional water authorities—to meet future standards in a timely manner, and to achieve possible savings in water use.

***Lianne van Oord**, Program Manager at Brightsite on reuse as an option within the energy transition:*

"Chemelot can provide 250 MWh of >50°C of residual heat, which could potentially serve tens of thousands of homes."

In the area of digitalization, Brightsite is conducting a further exploratory study to identify the most relevant opportunities for Chemelot in the context of the energy and raw materials transition. One interesting application is the water system. In order to manage the increasing complexity and to achieve the required flexibility, more use must be made of developments in the field of digitalization and artificial intelligence.

Press release

March 2021: Circular water for Chemelot

Brightsite is about to implement its 'Circular water for Chemelot' program. Linking the two ends of the water chain together is something that requires an integrated approach and that is interlinked with the sustainability developments on the Chemelot site and in the surrounding area.

4. Safety and public acceptance

Safety is top priority

Chemelot aims not only to be the most sustainable and efficient chemical site in Europe, but also the safest and healthiest site in order to ensure that employees and local residents can enjoy a good working and living environment. Changes resulting from the energy and raw materials transition and the related process modifications can influence this. Program Line 4 'Safety and public acceptance' therefore focuses on securing the integral process safety and societal acceptance.

Brightsite focus: Predictive modeling
To identify the safety and acceptance aspects, Brightsite will undertake an analysis of the possible impact of current and future potential processes at Chemelot in this program line. This analysis will look not only at the technical and internal safety of processing plants, but also at the broader environmental effects related to the transport of energy, raw materials and products. **An example of this is the involvement in the Delta Corridor project for the construction of pipelines for, among other things, CO_2, hydrogen, propane, LPG, the creation of a multimodal corridor to the Port of Stein and the external storage of waste plastics.**

In addition, we are focusing on developing a predictive model for process safety. **In cooperation with AnQore, an 'Early Warning Safety Monitoring' system is under development, which is based on current processes and can also be used more broadly for the responsible and safe application of new technologies.** An initial version shows that modeling using artificial intelligence (AI) and machine learning (ML) provides opportunities for adding a new dimension to proactive safety policies in the chemical industry. Automated screening of available and up-to-date business information enables the software to detect early signals that may precede any later malfunctions and incidents. This technology will be able to be further improved and applied in the coming years, given the ever-increasing digital possibilities.

The use of Early Warning Safety systems will ensure that companies at Chemelot can detect and resolve possible disruptions more often and at an earlier stage, thus reducing the actual occurrence of incidents and the associated nuisance.

The methodology developed by Brightsite for early insights into hazards, risks and social aspects associated with the development of new raw materials and technologies will help Chemelot and its companies to make the transition as smooth as possible for employees and the environment.

***Esta de Goede**, Program Manager, on securing integral process safety:*

"We are convinced that predictive modeling, using Artificial Intelligence (AI) and Machine Learning (ML), offers opportunities to improve safety in the chemical industry."

5. Transition scenarios and system integration

Working together to realize the transition to sustainable chemistry

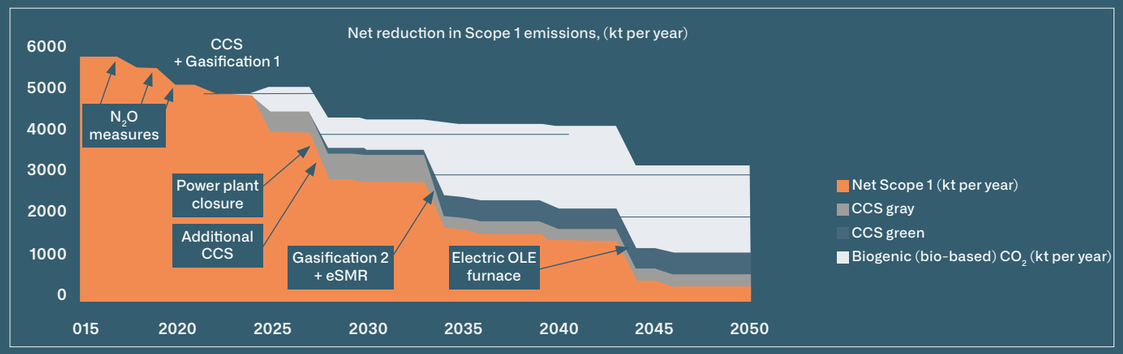
Program Lines 1, 2 and 3 address technological options that will in future enable Chemelot to meet the National Climate Agreement targets. Given the wide variety of options and the integral nature of the activities at Chemelot, an overarching and integrated approach is needed for efficient application. Program Line 5 'Transition scenarios and system integration' focuses on the dilemmas, obstacles and risks, both on site and beyond, and including social synergies and new opportunities.

Brightsite focus: working together to achieve the transition to sustainable chemistry
With Program Line 5, Brightsite is committed to achieving this transition for an entire site like Chemelot in a safe, sustainable and economically sound way. This program is primarily aimed at bringing together, acquiring and translating the available technical-economic knowledge and other relevant information and expectations. To gain control of the diversity of possible interactions, the interactions are brought together in integral software models and then, based on integral questions regarding the transition, they are translated into economic and climate effects at the system level of Chemelot in interaction with the Netherlands, the European Union and the climate. This rationale will underpin the design, testing and comparison of largely substantiated scenarios and transition paths for implementing climate-focused innovations at Chemelot. **Using this approach, Brightsite has now developed the Chemelot Integrated Model System (CIMS) model.** This model is based on the current factory installations, supplemented with a set of possible (alternative) technologies for making them more sustainability. As a next step, work is currently underway to expand the CIMS model to be able to also describe Scope 1, 2, 3 emissions and system impacts on a national and climate scale. **In addition, the more far-reaching SCIAR model is being developed, with which the current and future required and available (inter)national energy and raw material flows for manufacturing products and the associated system dynamics can be mapped out.** SCIAR stands for Source, Commodity, Intermediate, Application and Resource.

***René Slaghek**, Program Manager at Brightsite:*

"The synergies we have here at Chemelot must be preserved, exploited and revitalized with new technologies."

The figure below shows an example of a realistic transition scenario for Chemelot (CIMS model). This example describes only one combination of possible interventions and the resulting cost-optimal transition path, as calculated by the model. By inputting other future scenarios, boundary conditions, possibilities and targets, the model provides adapted transition paths. Based on these kinds of scenarios, better-informed and timely choices can be made for the actual execution of the various interventions at Chemelot.



Reduction of Scope 1 emissions through interventions in use of energy and raw materials at Chemelot.

6. Education and human capital

Educating for the future: crucial for successful transition to green chemistry

In setting up Brightsite, there was a recognition that new initiatives would be needed to attract and train researchers and collaborators to develop and apply the new technologies required for the climate transition of the chemical industry. The educational and research institutes at Chemelot can play a crucial role in this, in collaboration with each other and with the companies located at the site. For Brightsite's Program Line 6 'Education and Human Capital', the University of Maastricht is developing new educational programs within its Faculty of Science and Engineering to educate the engineer of the future.

***Professor Gerard van Rooij**, FSE Professor of Plasma Chemistry:*

"Educating a new generation of researchers and engineers who can put innovations into practice is a requirement for making the transition within the chemical industry and a circular economy a success."

Brightsite focus: Educating the engineer of the future
Facilitating the various paths leading to greenhouse gas emission reductions by 2050 requires broadly trained engineers and researchers capable of working on interdisciplinary challenges such as technology upscaling and circularity.

In the context of Brightsite, University Maastricht has taken the initiative to develop new, tailor-made courses at the bachelor's and master's level as well as the accompanying chair positions. The Circular Engineering bachelor program aims to equip engineers with a strong technological foundation. Students learn that it is only possible to reduce or even eliminate the ecological footprint of products, processes and services if the full lifecycle is considered and integrally optimized.

In addition to this bachelor's program, a master's program is in development (2024). This proposed program is an extension of the bachelor's program, as well as a mechanism for taking students educated in the bachelor's or Maastricht University's (UM's) educational ecosystem beyond its parameters and to further develop their high-level skills.

In order to further strengthen the appeal and academic positioning of the courses, Professor Gerard van Rooij has been appointed Professor of Plasma Chemistry and has employed university staff at several levels. New opportunities will also be available in the context of Chemelot Circular Hub for the training of future employees at the college and intermediate vocational levels, including in collaboration with Zuyd University of Applied Sciences and Vista College.

***Gavin Philips**, Program Manager for Education and Human Capital on the new education programs at Maastricht University:*

"The integration of education on the Brightlands Chemelot Campus is an important means of enabling the industrial relevance of our education. It allows us to use real case studies from the energy transition to provide students with industry-ready skills and knowledge."

Education with international appeal

These educational initiatives will provide a unique boost to degree programs at and around Chemelot with their international appeal. During the project and research periods of the degree programs, students will gain direct experience within their educational program and develop contacts with the companies active at Chemelot. As a result, students will be able to develop a professional awareness and broad vision regarding the challenges of the industrial energy transition.

As a result, companies active at Chemelot will have access to a new generation of top talent, equipped with integral knowledge to actualize the transition of their business operations toward climate neutrality by 2050.

What is required to reach the climate targets?

Chemelot companies have independently identified, planned or implemented measures to enable them to largely achieve the 2030 climate targets. In addition to measures already taken and further to reduce N_2O emissions, the capture, transport and storage of CO_2 (CCS) under the North Sea will also be structurally necessary and energy projects will be possible. In addition, a first step of substituting several kilotons of fossil naphtha is being taken by SPEAR, the partnership between SABIC and Plastic Energy. Brightsite supports further steps toward 2030, with the ambition to replace 20% of natural gas and 25% of naphtha. This can be achieved through the use of biomass, waste and recycling of plastics.

In order to become fully climate-neutral by 2050, further (re)use of plastic waste streams and bio-based raw materials will be required, as well as a complete transition to heating processing plants that use (renewable) electricity instead of the combustion of natural gas and process methane currently used. To achieve this, technical solutions are available or possible in the long term. However, the further development and availability of this depends largely on external suppliers and environmental factors, and where orientation toward and adoption of EU initiatives is of great importance.

***Maxine Tillij**, Director of Strategic Analysis and Policy at TNO and strategist of 'Green Chemistry, New Economy':*

"We are not so much concerned with technology as with systems thinking. This is critical because we need to move from a 'CO_2 ton hunt' to a system change if we want to achieve the Paris Accord targets. New business processes and collaborations within and between chains must be achieved."

Determining environmental factors for raw materials and energy transition at Chemelot

Chemelot is currently almost entirely dependent on suppliers of fossil raw materials—like naphtha and natural gas as well as gray electricity—and this will continue to be the case in the future with regard to the provision of green raw materials and sustainable energy. Timely availability and economic feasibility depend to a large extent on initiatives of and cooperation with suppliers and customers, for which governmental direction, regulation and support are indispensable.

The following paragraphs discuss the environmental factors crucial to Chemelot's raw materials and energy transition in more detail.

Many more green raw materials needed

Both now and in the near future, the availability of green raw materials which could be used at Chemelot as alternatives to fossil natural gas and naphtha is limited. For this large-scale industrial transition, the appropriate diversity of basic materials (plastic/household waste, bio-based raw materials and CO_2 from the atmosphere) must be converted into semi-finished products (so-called 'commodities') of sufficient quality. This requires the development of an entirely new "green raw materials industry" that will ultimately be able to compete on price and quality with the current fossil-based oil and gas sectors.

Given that 100% circularity is not feasible through recycling due to inevitable losses, additional routes must also be invested in, in order to meet the proposed climate targets. Biomass is currently the most realistic green alternative for supplementing carbon losses in the chemical industry.

To what degree this new industry will be formed by the transition of the currently established companies and to what degree the renewal will be undertaken by new players remains to be seen. It is likely that the burning of fossil material will be stopped first. However, the use of natural gas and crude oil as raw materials will continue for a longer period of time. This is partly due to the shortfall in the required, large amounts of suitable, non-fossil carbon needed to accommodate the economic growth expected before 2050. The radical innovation needed is expected to come from companies and consortia with access to the new resources and investment budgets required for this purpose. New value chains with new participants are expected to emerge as part of this transition.

Companies at Chemelot that purchase sustainable raw materials in these chains can play an initiating role for the new suppliers as "launching customers". Practical examples can be found in the roles currently being fulfilled by the previously mentioned **QCP** and **SPEAR** at Chemelot.

Sustainable electricity supply is inadequate

In order to be able to use renewable electricity instead of burning natural gas or fossil process gases (methane) in 2050, various large-scale adjustments are needed in the generation, supply and application of electricity. The development of electric cracking plants is considered technically feasible and has recently been taken up worldwide by various consortia of end-users. Before large-scale investment decisions can be taken to apply this new technology at Chemelot, structural certainty is needed regarding the availability of electrical energy. In comparison, the amount of (sustainable) electricity that must be available to Chemelot corresponds to what is currently produced by one or two modern, gas-fired power plants. Depending on the degree of electrification at Chemelot (there are alternatives), this is no less than 30–90% of all renewable electricity generated from wind and solar energy in the Netherlands in 2019.

Given the comparable electricity needs of other chemical and industrial sites and new entrants such as data centers, it is already evident that the current (renewable) electricity supply is largely insufficient. The same applies to the infrastructure of network operators to make electricity locally available for Chemelot and similar large-scale consumers.

More sustainability and limited security of supply of green electricity require flexibility of processes

Although the chemical industry and Chemelot have a more direct involvement and influence in the transition to the use of green raw materials, this does not automatically apply to the fulfillment of (sustainable) energy needs. The development of energy sources and necessary technical facilities are critical to all industrial and societal sectors. In this regard, Chemelot is largely dependent on third parties for both sufficient CO_2-free generation and the transport options for electricity to the site, which could have a negative impact on the energy transition deemed technically possible and the achievement of the associated emissions targets for 2050.

***Jan van der Lee**, responsible for the TenneT Climate Agreement Program:*

"We have to invest ahead on the basis of MIEK and, together with regional and national governments, we have to look for space."

CES & MIEK

Six Dutch industry clusters, including Chemelot, have been asked to draw up a regional vision for a sustainable industry in 2030. These Cluster Energy Strategies (CES) bring together supply and demand and together they lead to projects of national interest being placed on the agenda for the implementation of the Multi-Year Program for Infrastructure Energy and Climate (MIEK).
The MIEK is a program of energy and raw materials infrastructure projects that contribute to the climate transition and stimulate the earning capacity of the Netherlands.

Need for 'Delta Plan-type' approach on a national scale and associated governmental stimulus

In order to meet national emissions targets, there is an increasing need for renewable raw materials and electricity at Chemelot and similar industrial sites. **The main obstacles to the development of the new value chains for green raw materials required for this purpose are outlined in the 'Green Chemistry, New Economy' Action Agenda.** This agenda points to the need to improve the conditions for chain formation between the chemical industry and new supply sectors such as waste processing and agriculture, improved financing opportunities for new initiatives and designing stimulus policies.

In the area of renewable electricity, there is a better starting point, as existing companies and new consortia have taken up the development and operation of offshore wind farms with government support. After initial subsidies, it is now possible to compete with fossil fuel electricity generation at market rates.

However, in order to meet the rapidly growing needs, an exponential expansion of the infrastructure for the generation, transmission and system management of electricity is still required to make it available on the scale of industrial sites such as Chemelot. Electricity producers and network operators are aware of this issue, but are already experiencing difficulties responding in a timely manner to changes in the supply of and demand for renewable energy.

In order to achieve the ambitions of the National Climate Agreement in a timely and sustainable way, the impasses and possible failures of the market outlined above must be overcome.
This calls for a long-term 'Delta Plan-type' approach on a national scale as well as the accompanying governmental stimulus.
A national 'Climate Agency NL' could guarantee the necessary developments and consequences of choices and also coordinate cooperation with the European Environment Agency.
If this removes a sufficient number of existing uncertainties and risks on an (inter)national scale, it can be expected that new initiatives will develop on a commercial basis.

This will enable the Netherlands to create new, internationally leading business activities for the world market. In view of the nature of climate technology, there are particularly good opportunities here for the continuity of the chemical sector by establishing links with the internationally leading position of the Dutch high-tech industry, as well as with the prominent waste processing and bio-based raw materials sectors. Similar developments achieved by ASML and its suppliers within the semiconductor industry over the past 30 years are also considered possible in the field of climate technology, with the associated positive impacts for future national employment and economy."

***Manon Bloemer**, Director of the Royal Association of the Dutch Chemical Industry (VNCI):*

"Chemical companies are currently facing two major challenges: how to reduce CO_2 emissions and how to make their products more sustainable. The main focus of current policies is on reducing direct CO_2 emissions, but there is enormous potential on the product side. By using sustainable, bio-based raw materials and recyclable waste to generate chemical building blocks, it will be possible to save CO_2 and build sustainable, circular value chains that have a positive impact on the climate on a global scale."

The Brightsite way

Integral and model-based approach shows no-regret options with great potential and limited risks

In view of the external dependencies indicated above, it is not yet possible to say with certainty what will be realistically possible at Chemelot after 2030. What can be done, however, is to periodically perform and share technical and scenario analyses with increasing reliability, based on Brightsite's integrated and model-based approach. Various scenarios can be tested for their sensitivity to changes in prices, regulations and availability of sustainable raw materials, energy and effect on CO_2 emissions. In this way, 'no regret' options with high potential and limited risks can be identified, which are therefore the most eligible for development and integration at the Chemelot site of the future. Based on such analyses, it is already clear, for example, that the use of plasma technology for methane conversion and gasification technology as well as other methods for chemical recycling of plastic waste shows stable positive results in these types of "stress tests".

***Paul Brandts**, Intelligence Officer at Brightsite:*

"The SCIAR model helps us make the right choices for the next generation. It is the first roadmap from source to re-use."

***Leon Jacobs**, Director of Sustainability Europe at SABIC:*

"It's not 'one size fits all'. Brightsite looks with us at what fits our portfolio and together we work out different options."

In this way, Brightsite will continuously test the potential economic and social impact of new technologies and translate them into transition scenarios for Chemelot. Where there are positive results and high potential, Brightsite will also mobilize the necessary resources together with partners and stakeholders to scale up such technologies from the laboratory and pilot project phase to demonstration plants. As a next step, the approach and results followed for Chemelot can be translated and extended to similar industrial sites and connected to other (inter) national resource and energy-based models already developed. Examples include: Energy Transition Model (ETM), Carbon Transition Model (CTM) and Life Cycle Assessment (LCA) modeling.

Last but not least, the start of the dedicated training courses at various educational levels and the expansion of related chairships and infrastructure for experimental research and development at Chemelot will ensure that international talent is educated and settled in Limburg in order to put the opportunities and challenges outlined above into practice.

Interested in participating?

If you would like to know more about how Brightsite supports the transition of the chemical industry or if you would like to contribute to it, please contact us at info@brightsitecenter.com

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