THE CIRCULAR ECONOMY IN GRONINGEN

Building local strength and a competitive advantage with the circular economy

AUGUST 2023

CIRCLE ECONOMY

CIRCLE ECONOMY

We are a global impact organisation with an international team of passionate experts based in Amsterdam. We empower businesses, cities and nations with practical and scalable solutions to put the circular economy into action. Our vision is an economic system that ensures the planet and all people can thrive. To avoid climate breakdown, our goal is to double global circularity by 2032.

NATIONAAL PROGRAMMA GRONINGEN

The National Programme Groningen is a partnership of the national government, province of Groningen and five municipalities (Eemsdelta, Het Hogeland, Groningen, Midden-Groningen en Oldambt).

The programme allocates a seed capital of 1.15 billion for implementation plans and projects up until 2030 to strengthen the living environment, the economy, education, jobs and nature and the climate.

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CIRCULAR ECONOMY IN GRONINGEN

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CIRCLE ECONOMY

This report explores four strategic directions that can inform the National Programme Groningen's (NPG's) multi-year investment plan to jump-start the province's journey towards a circular economy. The region aims to transition from an extraction-based system to a more diversified and sustainable economy that boosts social welfare, creates new jobs and prevents further earthquake damage. A circular economy can help Groningen achieve these goals and provide a competitive advantage to the region's economic sectors, both nationally and internationally.

The region is already well-positioned to reap the rewards of a circular economy. Advanced logistics and infrastructure characterise Groningen, its farmers being some of the most advanced in Europe in terms of knowledge and equipment. A circular economy can further enhance the green chemistry sector that is also taking root in the region. The geographic location of Groningen, historically making it a pioneer in international trade, can also contribute to the province's status as a pioneer in the global circular economy. To this end, developing sustainable production practices would generate ample supply of materials and products while complying with EU environmental regulations—ensuring Groningen's long-term socio-economic success at home and abroad. Furthermore, this regional transformation can foster job creation and secure existing jobs through investment in people, their skills, and further cooperation among the active labour market stakeholders.

The Chemical Manufacturing and Agrifood sectors could play a major role in Groningen's transition. This report explores two sectors of particular interest to the region: **Chemical Manufacturing** and **Agrifood**. The two sectors are crucial for the regional economy, but they are also resource-intensive and, as such, are major contributors to the region's emissions. Linking the Chemical Manufacturing and Agrifood sectors in a symbiotic relationship will be crucial to preserving the sectors' competitive advantage nationally and internationally. By fostering collaboration and interdependence between these various stakeholders, Groningen can harness the potential of the circular economy by scaling up circular practices and creating new business opportunities.

STRATEGIC DIRECTIONS FOR FUTURE INVESTMENT

Optimised biomass valorisation

Optimised biomass valorisation for a circular bio-based economy: This presents an opportunity for Groningen to establish a synergistic connection between the Agrifood and Chemical manufacturing sectors, leveraging the province's biomass flows and simultaneously fostering the development of a new, diversified circular bioeconomy. This will not only contribute to reinforcing the two sectors but also to exploring new value-creation pathways, placing the province at the forefront of biorefining in Europe and worldwide. Impacts: Circularity will ensure that biomass valorisation limits low-value treatment of biomass (energy recovery) and does not exacerbate land competition issues, necessitating innovative circular business models, and becoming the catalyst for future-proofing the region's labour market.

CIRCULAR INDUSTRIAL PROCESSES

Optimising the use of resources by reducing dependence on fossil fuels, minimising the use of fossil-based carbon sources (plastics), prioritising the use of regenerative sources (green hydrogen) and efficiently circulating by-products (CO_2) can create a low-carbon, circular industrial ecosystem in Groningen. Impacts: Circular industrial processes not only create new economic opportunities by creating innovative, sustainable products but also reduce environmental impacts associated with virgin material extraction.

Circular agricultural practices

Shifting to circular practices in agriculture will be necessary to satisfy food demand and demand for biomass feedstock while maintaining the province's competitive advantage in international markets and contributing to the health of local ecosystems and securing the future of farmers. Impacts: Circular farming can have substantial long-term positive impacts across economic (avoid hidden costs and negative externalities), environmental (reduce nitrogen pollution and CO_2 emissions) and social indicators (a more localised and interconnected rural economy and communities).

Urban-rural-industrial symbiosis

Urban areas generate substantial amounts of waste that can be used as secondary raw materials for the chemical industry or transformed into compost or biofertilisers for the agricultural sector. Impacts: Urban-industrial symbiosis minimises the environmental impacts of low-value waste disposal practices, such as incineration. If demolition waste in Groningen, Drenthe and Friesland is reused and recycled between now and 2030, it could potentially be worth €136 million alongside a reduction of €4 million in environmental costs.[1] Moreover, reducing reliance on virgin materials can help alleviate pressures on agriculture to produce new biomass and help decarbonise the chemical sector by providing secondary inputs.

The circular economy can help Groningen achieve its social, economic and climate goals. The insights from this report recommend a tangible action plan with supporting investment strategies co-created and backed by local stakeholders. Indeed, to achieve the desired outcomes, Groningen will need a substantial investment commitment of several hundred million euros, delivered through long-term investment plans supported by the NPG and other funding partners such as the European Commission, the European Investment Bank and private sector investors. These investments will support the infrastructural and economic transformation of the two key sectors across strategic directions. It is clear that, with substantial and long-term investment, Groningen is ready to capitalise on the opportunities that the circular economy has to offer and position itself as a frontrunner in the field of circular economy—supporting residents with new jobs and promoting local activities for social welfare and prosperity along the way.

1

INTRODUCTION & OUR APPROACH

Today's world is predominantly linear: materials are extracted, processed, used and discarded at a rate and scale never seen before. Worldwide, total material extraction more than tripled since 1970, and almost doubled since the year 2000—reaching 100 billion tonnes today.[2] This take-make-waste economy has led emissions to spiral and has pushed us past the limit of several planetary boundaries: we no longer operate within Earth's safe limits. The circular economy—a system in which waste is designed out, products and materials are used longer and ecosystems are regenerated—is being championed as a solution. To this end, the circular economy can combat ecological breakdown by drastically reducing material consumption and reshaping our relationship with resources.

The Netherlands boasts ambitious goals for both climate change mitigation and resource use: it has pledged to reduce greenhouse gas (GHG) emissions by at least 49% by 2030 and by 80–95% by 2050. It also aims to be fully circular by 2050, with the intermediary target of halving resource consumption by 2030—goals governed by the Circular Economy Implementation Programme. Groningen as a region will play a crucial role in realising these targets.

In working towards a circular Dutch economy, Groningen should shift away from carbon-intensive activities, such as gas extraction that has led to damaging seismic activity. This is already underway: the National Programme Groningen (NPG) aims to find new prospects for the province in light of these adverse impacts. For example, the government has introduced stricter construction guidelines to ensure that new builds are designed to withstand earthquakes, while a buyout scheme was introduced for residents living in high-risk areas that allows them to relocate. Tackling the root cause of the issue is the ultimate aim, however: a cap on gas extraction is in place that will be progressively lowered until it can cease entirely by 2030.

THE CIRCULAR ECONOMY IN GRONINGEN: HOW THE CIRCULAR ECONOMY CAN RESHAPE THE PROVINCE

In collaboration with the national government, local stakeholders have already taken the first steps to transform the local economy, aiming to embrace a new economic system that aligns with sustainability goals while increasing the resilience and prosperity of the province's economy and citizens.

Groningen is well-poised to take on the challenges this shift will bring, thanks to a highly-innovative industrial ecosystem, well developed infrastructure and logistics systems, and a strategic location both within the Netherlands and Europe. By leveraging these strengths, the province can work towards a circular economy that:

- Encourages the development of new industries and sectors that can consolidate existing circular activities, reducing the region's dependence on gas extraction;
- Promotes the use of renewable energy sources and energy efficiency measures;
- Optimises resource use within the province; and
- Involves residents in decision-making, fosters sustainable practices among residents and supports community initiatives.

To this end, this report—an investigation led by Circle Economy and National Programme Groningen—investigates how the circular economy could become a key pillar of the province's sustainable development strategy. In particular, it aims to provide a baseline picture of circularity for two key focus areas:

- The **Chemical manufacturing sector,** which encompasses the manufacturing, processing and distribution of chemicals and chemical products.
- The **Agrifood sector**, including both agriculture and food production.

These sectors provide a national and international competitive advantage for the province. While they are the main drivers of the province's economy regarding value-added and employment, they are also significant polluters due to their intensive use of natural resources, energy consumption, waste generation and emissions. The project is, therefore, centred on identifying the most strategic interventions for these high-impact areas that would position the province at the forefront of a circular bioeconomy, which would allow it to sustain its competitiveness while remaining within environmentally and socially safe boundaries. The results of the research will be used to inform the multi-year investment programme for the National Programme Groningen to accelerate the circular transition in the province.

OUR APPROACH

Circle Economy and National Programme Groningen conducted this research to achieve the following objectives:

- Assess the province's potential to increase its competitive advantage concerning materials and the transition to a circular economy, taking the unique strengths and characteristics of the province into account.
- Identify and analyse circular interventions to ensure effective deployment of the circular economy at the provincial level and beyond.
- Define strategic directions and a high-level action plan so that the National Programme Groningen can develop an investment plan.

Two types of analysis inform the baseline assessment: PESTEL (Political, Economic, Social, Technological, Legal and Environmental) and SWOT (Strengths, Weaknesses, Opportunities and Threats). The baseline assessment results were presented during an online workshop in June 2023. Around ten representatives of academia, businesses, local authorities and policymakers worked together to prioritise interventions that could be the focus of the multi-year investment plan of the National Programme Groningen. Based on this discussion, four interventions were defined and further analysed. In July 2023, a second workshop united about 20 stakeholders in Groningen to turn theory into concrete action plans that build upon the region's competitive advantages and provide the highest innovation, economic development and welfare potential.

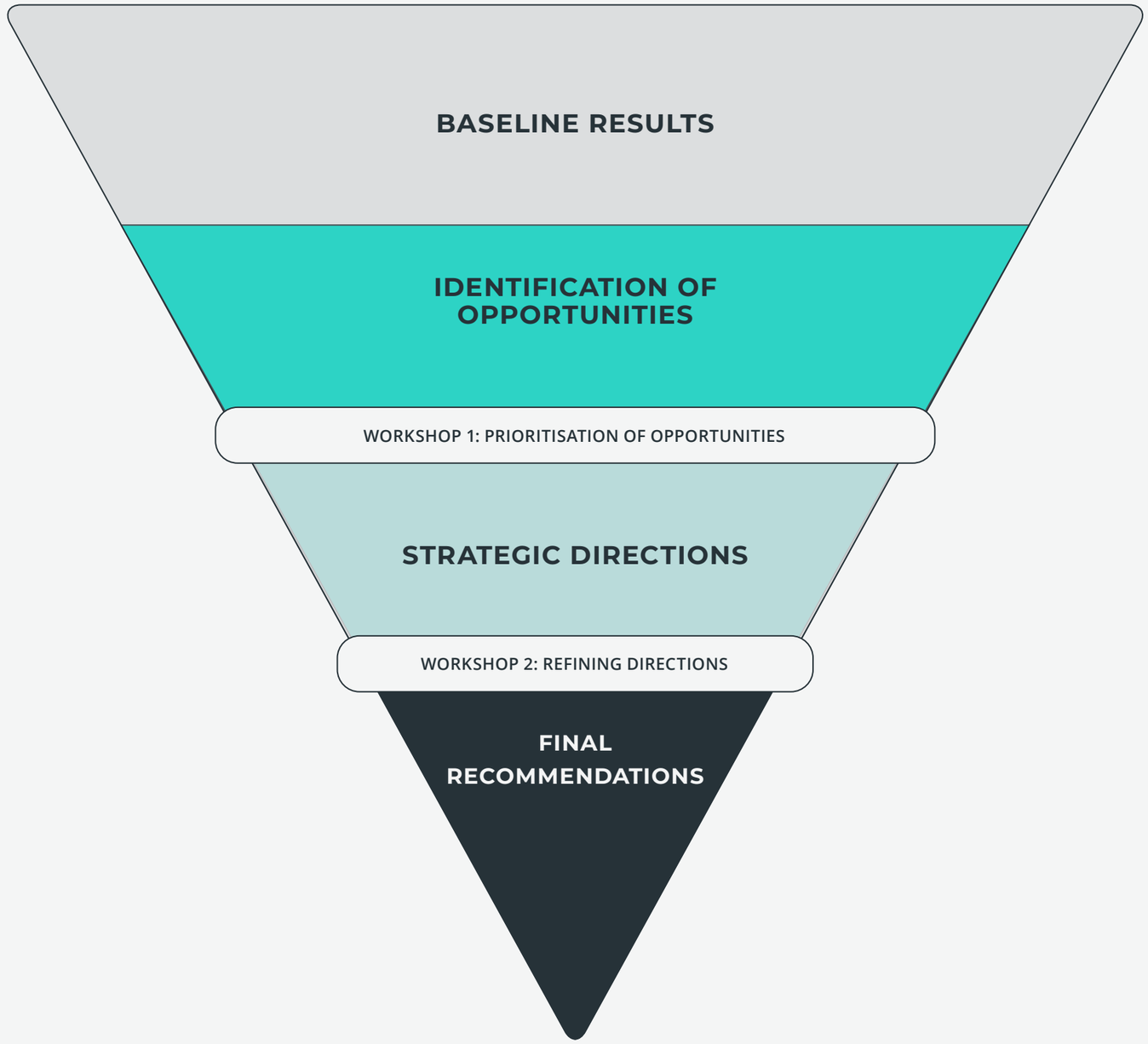


Figure one: *our approach at a glance*

2

BASELINE ASSESSMENT

PESTEL ANALYSIS

Before Groningen can develop its circular economy, it's necessary to uncover the baseline from which the province is starting. A Political, Economic, Sociological, Technological, Legal and Environmental (PESTEL) analysis can shed light on this starting point. Insights from this analysis will be used to identify challenges and opportunities for scaling circularity in the Chemical Manufacturing and Agrifood sectors.

Political

The province of Groningen,[3] the Dutch national government[4] and European institutions[5] [6] have created an enabling environment for the circular economy to thrive. Policies on the circular economy have continued to grow and gain importance as a means to transform the European economy. The Netherlands was one of the first countries to set a national Circular Economy Plan, which has now trickled down to action plans for many municipalities, including Groningen.[7] The two selected sectors—Agrifood and Chemicals—are high on the political agenda, as they both play a core role in achieving biodiversity, climate and circularity goals. In Groningen, they significantly contribute to the social welfare of residents and have featured in many programmes, strategies, support schemes and networks to facilitate the circular transition in line with the Netherlands' broader goals.[8]

Barriers facing circular Agrifood policy

Policies targeting the Agrifood sector are not new: the sector has long been a priority of policymakers in Europe and worldwide, and it has been heavily subsidised to maintain market stability and ensure food security.[9] However, more recent and stringent attempts to regulate the sector's negative environmental impact have been controversial in the Netherlands.[10] As the world's second-largest exporter of agricultural products, the country's highly productive—and intensive—farming system has driven the so-called 'nitrogen crisis': it adds more nitrogen into its agricultural system than it removes. To comply with EU regulations and protect Natura 2000 areas, nitrogen emissions must be drastically reduced by 50% before 2030.[11] However, the targeted reduction will require significant and potentially costly changes for local farmers, whose operations have contributed to nearly half of the country's nitrogen emissions.[12] Circular economy principles are widely recognised as a key solution to the Agrifood sector's environmental challenges, and this is reflected across policy: the Dutch government has expressed the aim of becoming a global leader in circular agriculture, for example.[13] This ambition is also reflected in Groningen's Sustainable Agriculture Programme, which highlights how circular interventions can help the province achieve key targets.[14]

Implementing circular Chemical policy

There is also some debate about how the Chemical sector may transition to a more circular economy. Much of the focus has so far centred on decarbonising the sector by reducing the consumption of fossil fuels and moving towards new, bio-based materials. In Groningen, for example, the province encourages the use and development of bio-based raw materials via financing, granting permits and lobbying.[15] Meanwhile, the Dutch government supports circularity goals for plastics[16] and emphasises clean hydrogen development—already picked up by the City of Groningen, including concrete actions for hydrogen in its future energy plan.[17] The European Commission also advocates for using biodegradable or compostable plastics,[18] and is providing a subsidy to turn the Northern Netherlands into a Hydrogen Valley consisting of an integrated hydrogen ecosystem.[19]

Given the plans and strategies that the Province has already conceived and the many local stakeholders and authorities already driving circular initiatives on the ground, Groningen has a solid foundation from which to progress to a more circular economy. Coordination between institutions will be crucial for efforts to be successful—aligning EU, national, provincial and municipal policies to ensure consistency, for example. The Northern Netherlands Alliance (SNN) could play a key role here. This partnership of the three northern provinces (Drenthe, Friesland and Groningen) is an important intermediate step from a political perspective as it enables collaboration among stakeholders, provides financial support and contributes to regional development, all elements that support the circular economy transition.

Economic

The Chemical Manufacturing and Agrifood sectors

The economy of Groningen has long been characterised by its chemical and manufacturing industries and the agricultural sector. As these sectors have largely shaped the province, they are the focus of this study. However, newer industries—such as the energy sector, healthcare, technology and knowledge-intensive industries—have emerged and are transforming the region's economic landscape. The position of the province as a best-in-class European data centre, a result of several universities and research institutions, has supported the growth of these industries. Overall, the province's economy is increasingly vibrant and dynamic, establishing Groningen as a leader in innovation in Europe.[20]

Key employers in the region

These elements position the province to embrace the circular economy as a means for long-term sustainable development and welfare. The Chemical Manufacturing and Agrifood sectors, which contribute significantly to the local economy and the region's international competitiveness, have the power to push for this. The Chemical sector in the Groningen area employs over 5,000 people and has a turnover of €1.5 billion (in 2019, the chemical sector turnover for the entire country was €71 billion, making it the fourth largest chemical producer in Europe).[21] [22] [23] The Agriculture, forestry and fishing sectors contribute €1.2 billion (2.6% of total output) to Groningen's economy, with agriculture's GVA at €435 million.[24] The sector is also a major employer in the area, with almost 3.3% of the labour force in Groningen involved in agricultural activities in 2022 (equivalent to 19,300 direct jobs).[25]

A competitive position internationally and nationally

The reach of these sectors extends far beyond the region, with many companies trading their commodities and products internationally, supported by the province's strategic geographical location, harbour and efficient transport and logistics systems. This has put Groningen on the map: the province's seed potatoes, the highest-yield agricultural product by mass, account for nearly one-quarter of global seed potato exports.[26] Whereas, chemical clusters such as Chemport Europe are becoming global incubators for green chemistry.[27] However, participation in a globally competitive market limits these sectors' ability to control the price of their commodities, with the consequence of sustainability often being sidelined. Moreover, extensive gas extraction over the years has caused sunken land and earthquakes. Costs of the seismic damage are piling on costs of the nitrogen crisis—estimated at around €14 billion for farms and other companies.[28] On top of fluctuating prices, farmers face rising production and maintenance costs, insurance challenges and soil degradation which hinders productivity. Dutch farmers' income is about 40% lower than in other sectors, placing them in a challenging position to face rising costs.

The circular economy

Developing sustainable production practices would enable sufficient supply while complying with EU environmental regulations[29] and ensuring the long-term socio-economic viability of the agricultural sector. While linking the Chemical and Agrifood sectors in a close, symbiotic relationship will be crucial to preserving the sector's competitive advantage nationally and internationally. The circular economy offers a holistic framework to do this. It simultaneously pushes for the high-value use of residual agricultural streams to produce more sustainable, bio-based chemicals, which could provide better resources for the Agrifood sector through biorefinery activities. By fostering collaboration and interdependence between these various stakeholders, the Province of Groningen can harness the potential of the circular economy approach and scale up (new) circular practices and create new business opportunities.[30]

Demand for non-food agricultural products to create bio-based materials for the Chemical sector (as well as the Construction sector's timber and hemp, for example) is also growing. Groningen's strong agricultural tradition, accessible seaport, innovative industrial park, sufficient energy sources and proximity to knowledge institutions make the province attractive to increase biomass feedstock production for other industries. While there is an opportunity for Groningen to scale its production of non-food agricultural products, a balance needs to be struck: meeting the increasing demand for such products while ensuring the sustainability of the Agrifood sector.

Collaboration across sectors and locales

Leveraging the strong presence of bio-based and biotech sectors in Groningen could foster collaboration in the province. The Northern Netherlands is one of the top six European regions in the bio-based economy and third in the Netherlands in the biotech sector. Companies are already producing bio-based products—from plastics to cosmetics. By applying circular thinking, they could prioritise residual over virgin agricultural inputs and engage in innovative research to meet the rapidly growing global demand for bio-based plastics. While many companies have expressed willingness to adopt green materials, high production and raw material costs hinder the financial feasibility of doing so. Key local players such as Delfzijl, representing 15% of chemical production in the Netherlands, will have a crucial role in leading this shift.[31] Similarly, public finance—through national and EU-level funding schemes—will be key to supporting circular practices in this sector.

Symbiotic relationships should also be explored between urban, rural and industrial areas. While the city and its suburbs have increasingly focused on the built environment and services, large-scale industrial production and agricultural activities have largely been concentrated in rural areas and increasingly serve global markets rather than the local economy. As a result, economic ties between these two settings have weakened.[32] This highlights the need to bridge the gaps between stakeholders in industry and agriculture and customers in both urban and rural areas.

Social

In Groningen—and the Netherlands more broadly—public awareness of and support for the circular economy is high. Following the extraction-induced earthquakes and the resulting damage to the economy and the well-being of Groningen citizens, the public recognised the need for change. People in Groningen are inclined to support an economy that organically connects with them, in which fossil fuel extraction and use are phased out, and sustainability and social welfare are valued.[33]

Unemployment

The province is relatively supportive of the innovation and development opportunities that have recently emerged. It recognises the environmental benefits and—as the unemployment rate in Groningen surpasses the rest of the Netherlands with younger residents increasingly leaving the province to search for work in bigger cities—the job creation potential.[34] This is particularly felt in the Agrifood sector which has had a sharp decline in employment: the number of farms in the province has decreased by nearly half between 2020 and 2022.[35] The launch of new circular initiatives and activities could help diversify the economy, retain highly skilled and young professionals and create new opportunities and job profiles.

Public interest in the circular economy

Changing consumer preferences also inspires support for circularity among industry and political stakeholders. For example, demand is growing for sustainable, locally-produced foods.[36] [37] [38] Groningen-based businesses can benefit from this trend by promoting and implementing circular agricultural practices and reducing the use of chemical inputs. The same holds true for circular plastics: residents' support for plastic waste initiatives has risen as they've seen the impact of plastic pollution on their own beaches.[39]

It's worth noting that some projects such as large chemical parks—as well as wind and solar farms—may not receive the same level of support from the public due to aesthetic concerns. This has adversely impacted investments in infrastructure developments and renewable energy.[40] This opposition could extend to other circular activities that involve changes to the landscape or local environment. Increasing demand will be crucial for the price development of CO_2-neutral hydrogen and inspire stakeholders' confidence to invest in the circular transition. Here, government intervention and support will be essential.[41]

A circular approach to CO_2 management

Another important issue is the ongoing Carbon Capture and Storage (CCS) debate. Critics across the Netherlands have expressed concerns regarding the potential environmental impact of CCS, mainly related to the long-term storage of CO_2 underground, which may lead to soil contamination, for example. Moreover, these technologies' high costs and energy intensity mean their large-scale commercial viability has been questioned. Further concerns are that pursuing these options could divert funds from renewable energy development or other more sustainable solutions. A more circular approach—such as Carbon Capture and Utilisation (CCU)—may be more desirable, as capturing CO_2 emissions and using them to produce useful goods may align with the public's desire to find practical climate change solutions.

Circular agriculture drives a more sustainable and inclusive sector

Finally, local, regional and national authorities have faced challenges in finding the right balance between supporting farmers who promote sustainable production and measures aimed at reducing production, notably of livestock, which may put several jobs at risk. Meanwhile, trends also show that the agricultural sector is slowly shifting away from a greater number of small- or medium-scale farms, with larger clusters becoming more predominant. This is particularly important for the circular transition, as farms typically organise themselves in cooperatives, often driven by social and environmental objectives as well as economic sustainability (for example, Avebe, Cosun, FrieslandCampina and Agrifirm). Values often favoured by cooperatives—such as social cohesion, cooperation, collective ownership and democratic decision-making—can help drive a more sustainable, inclusive and circular Agrifood sector.[42]

Increasing public engagement will be just as important as research and business development for the success of the circular transition.[43] Public support is crucial as it creates consumer demand for circular products and, thus, influences business, policy and regulation. It can also help foster collaboration and partnerships by raising awareness, facilitating knowledge sharing, and involving diverse stakeholders to work towards sustainable and resource-efficient solutions collectively. In doing so, public engagement can contribute to many ongoing debates in the Chemical Manufacturing and Agrifood sectors.

Technological

Groningen benefits from a solid foundation to shift to circularity: it is rich in knowledge and expertise, as well as the infrastructure needed to advance technological developments. The city of Groningen is home to the University of Groningen and Hanze University Groningen which contribute greatly to education and research in the field of technology and engineering. The strong presence of educational institutions, which closely collaborate with the many small-to-medium enterprises (SMEs)—representing around 95% of businesses in the province[44]—greatly enhances the region's capacity for technological advancements.[45] Moreover, due to its infrastructural advancements, logistics and digitalisation, the province enables connectivity within and beyond its borders and has fostered an environment for technological innovation. This is particularly relevant to the two key sectors—Agrifood and Chemicals.

Agricultural innovation

The province's advanced agricultural sector is highly competitive nationally and internationally. Farmers have easy access to new technical knowledge due to the many on-the-ground training programmes on offer and advanced equipment from the many significant investments made to modernise the sector.[46] A high level of innovation characterises the agricultural sector and many actors are already working towards the 'agriculture of the future'.[47] [48] Additionally, the strong agrifood cluster has already shown how they can manage logistics and knowledge to use and process large biomass flows. Local stakeholder knowledge will be crucial in shaping and guiding the transition towards a circular economy in Groningen.

Chemical innovation

Innovation and technological improvement is also strongly present in the Chemical sector, facilitated and promoted through the two integrated chemical clusters—Eemshaven and Delfzijl—and Emmen in the neighbouring province of Drenthe, as well as the Chemport Innovation Centre.[49] Within these clusters, companies are continuously developing and scaling up new green raw materials. The aim is to accelerate the industrialisation of bio-based and circular technologies. The presence of SMEs in the province, in addition to the larger chemical clusters, also provides a fertile environment to test new bio-based materials and circular production processes. Overall, Groningen's Chemical sector's technical capabilities cover practices along each step of the value chain, from manufacturing to end-of-life.

Opportunities for recycling and energy infrastructure

Despite the technical advancement of the province, there are still opportunities that can be unlocked through infrastructure and technological development. For instance, recycling capacity should advance for materials such as textiles[50] and bio-plastics, which are becoming increasingly prevalent in various industries and sectors. Without adequate recycling infrastructure, these materials often end up in incinerators or contaminate recycling streams, squandering their potential for circularity. Moreover, the energy transition will require a shift in the utility systems that power industrial and agricultural activities. For example, the electricity network is experiencing challenges, such as grid congestion, and will need significant investment to keep up with electrification efforts.

Upgrading the existing gas grid

As the province phases out gas extraction, upgrading and retrofitting the current natural gas network to transport more sustainable energy carriers such as biogas and green hydrogen is possible.[51] [52] Repurposing this infrastructure would prevent the need for extensive new construction. Plans in this area, especially to enable hydrogen transport and storage in the existing gas grid, are already underway. This could enable Groningen's Chemical sector to shift from its dominant natural gas-based hydrogen supply to green hydrogen. The production of green hydrogen will require a major shift in electricity production: wind from the North Sea must be scaled to produce electricity at the quantity needed.[53] The interconnectivity of electricity and gas networks will be a key part of this systemic energy shift. It will be necessary to establish a sustainable, affordable and balanced energy system, as emphasised by the electricity and gas network operators, TenneT and Gasunie. The NortH2 project aims to use this system-thinking approach to scale up green hydrogen production.[54]

These advancements will require initial investments, which can vary depending on the scale of the initiatives and the specific technologies implemented. However, while there may be initial investments required for infrastructure, equipment, and research and development, it is important to consider the long-term benefits and cost savings and how they could position the region as frontrunners in the circular transition.

Environmental

Non-circular waste generation and pollution of local ecosystems

In addition to earthquakes and the nitrogen crisis, several other environmental issues, from local pollution to toxic waste, affect both sectors of interest. While residual waste from the Agrifood sector can often be easily reused in high-value applications, the waste and by-product streams generated by the Chemical sector often contain pollutants or are diluted, making it economically infeasible to recover raw materials. What's more, plastic pollution from the sector is becoming an increasingly visible problem, especially in the sea bordering Groningen.[55] This is not only caused by plastic manufacturing but also by the use of plastics in agricultural practices. Overall, 3,600 tonnes of plastic are used to cover silage every year in the Northern Provinces, and these are often not sorted or recycled after use.[56]

Greenhouse gas emissions

Groningen is particularly vulnerable to greenhouse gas (GHG) emissions and climate change: impacts such as declining soil fertility and biodiversity loss are already a local reality.[57] As climate impacts worsen, it is expected that Groningen will experience more frequent and intense drought and heat events, and sea level rise poses a threat to the low-lying province.[58] For these reasons, climate change mitigation has been featured high on the agendas of national, provincial and municipal authorities, and on those of the key economic sectors, which play a role as major emitters in the province. For instance, the agricultural sector in the Northern Netherlands contributes significantly to direct and indirect GHG emissions: 2.9 million tonnes of CO_2e and 3.1 million tonnes of CO_2e, respectively.[59] This has already translated into regulations, especially on the national and EU level, that lay out GHG emission reduction targets.

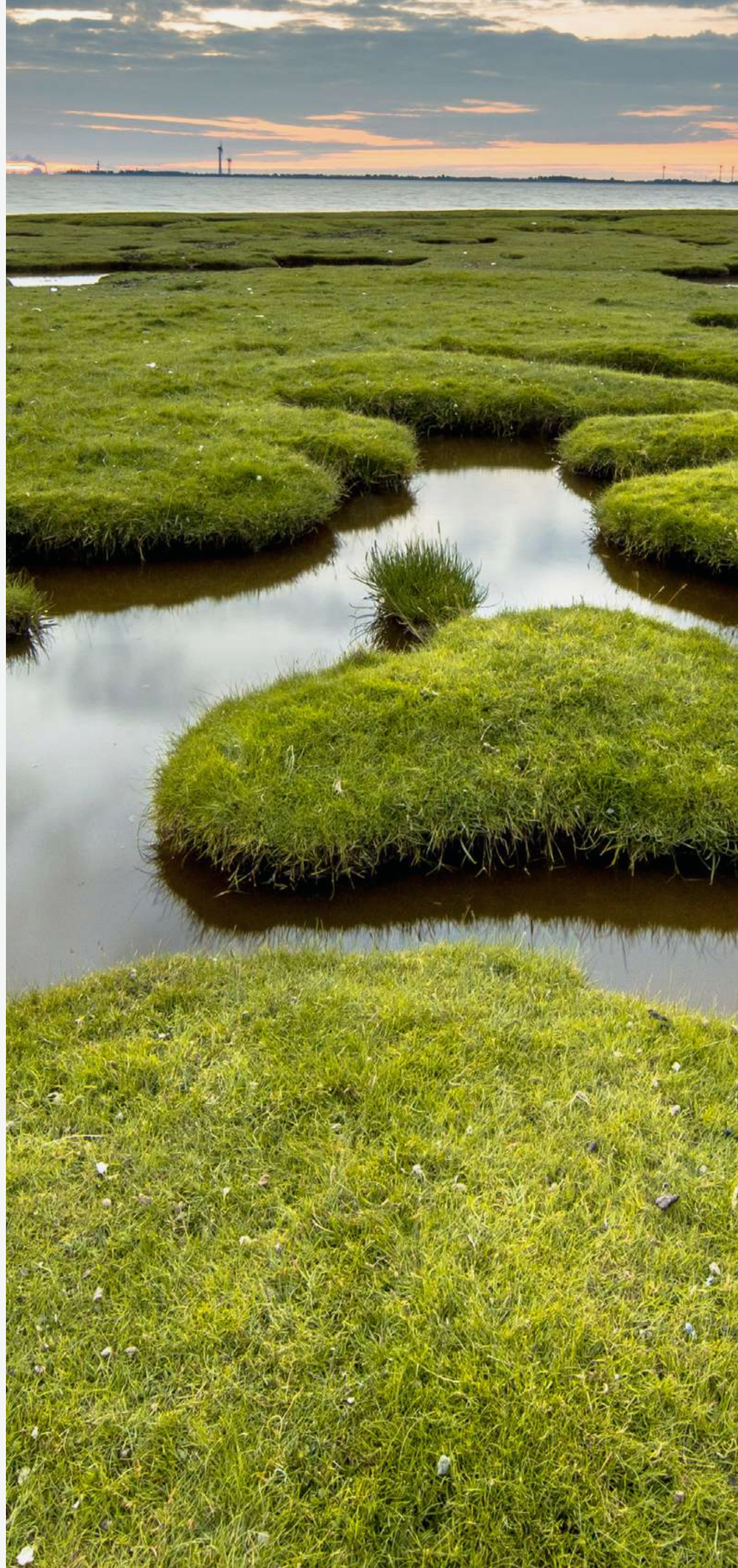
Freshwater quality and availability

Both the Agricultural and Chemical sectors consume a relatively high amount of freshwater. Both sectors are also heavy emitters of potentially polluting substances to nearby water bodies: runoff from synthetic nitrogen and phosphorus fertilisers and manure application pose major concerns. These can cause eutrophication, contributing to an overgrowth of algae and removing oxygen from water—turning water bodies into inhospitable environments for life. Moreover, fresh water is needed to produce green hydrogen, requiring around nine litres of water per kilogram of hydrogen produced.[60] To meet the province's ambitious targets for green hydrogen production—in particular for the Chemical sector—significant amounts of water will be required. This accentuates the need to strive for more circular water systems at the local scale.

Land use and availability

Both the Chemical Manufacturing and Agrifood sectors are sensitive to land-use change, with certain trade-offs arising: for example, competition between space for food crops versus bio-based feedstock crops. Balancing available land between the sectors' various needs will be a crucial component of future sustainable development.

The two sectors are deeply intertwined in this regard: ensuring a stable outlook for the Agrifood sector will be crucial to advancing circularity in the Chemical sector. Bio-based and renewable raw materials could be the most effective way for the circular economy to deliver a competitive advantage to the region, connecting the sectors further by providing new inputs for both, all while reducing waste, pollution and emissions. Groningen is characterised by strong agricultural yields, plentiful residual flows and locally abundant forms of biomass, which are already being used as sustainable inputs and also as an energy source for the Chemical sector.[61] However, there is still potential to form even greater synergies between sectors.



Legal

EU and national legislation supporting a circular economy

The legal and regulatory frameworks governing Groningen tend to be both influenced and limited by national and EU-level policies and regulations—which are outside the direct sphere of influence of the province and the municipalities. To this end, coordination with the national government is essential. Additional regulatory reforms will also be needed to address the EU's time-consuming and costly approval processes for new circular products.[62]

For the Agrifood sector, EU regulations include the Common Agricultural Policy (CAP), Natura 2000 and renewable energy plans.[63] The CAP[64] is key for the future development of the Agrifood sector through its provision of subsidies and financial support to farmers, affecting agricultural production, market stability and sustainability practices. The Netherlands submitted its CAP Strategic Plan in January 2023, which introduced subsidies, stricter regulations on agricultural and environmental conditions, and other measures designed to increase farmers' income and resilience. In addition to the CAP, Natura 2000 regulations require the province of Groningen to manage protected areas and enforce regulations to reduce nitrogen emissions.[65] There are also national-level regulations related to land use, food safety, fertiliser regulations and waste management. For instance, the National Program Rural Area (NPLG) makes €24.3 billion available to provinces, entrepreneurs and site managers working toward sustainability targets.[66]

Local initiatives advocating for better policy

The Chemical sector in the Northern Netherlands operates within a legal and regulatory framework that heavily depends on EU-level legislation. However, local initiatives concerned with regulating the hydrogen market are leading the way. Regarding green hydrogen as a new, potentially more sustainable feedstock and energy source for the sector, the government of the Netherlands is exploring how it can fit into existing energy regulations. The review includes evaluating the role of Gasunie, the gas network operator, in the future hydrogen market to ensure supply security, minimise social costs, create a flexible market environment and address safety matters.[67] Although the sector is dependent on legislation at higher levels of governance, learnings from these local experiments are key to advocating for better policy making.

Towards a circular bioeconomy

There is no current dedicated EU legislation for the bioeconomy, particularly regarding new technologies and their applications. However, various legislative acts at the EU level are relevant.[68] For example, promoting renewable energy targets and subsidies may increase bioenergy production, which can have implications for other aspects of the bioeconomy. The EU's Waste Framework Directive also influences Groningen's development of circular and bio-based solutions for its key sectors. It regulates waste management in the EU, including bio-waste streams, which can impact the implementation of circular bioeconomy practices in both sectors and require provinces and municipalities to be involved, as they are the main ones responsible for implementing these waste management directives. To this end, coordination with the national government will be essential. Additional regulatory reforms will also be needed to address the EU's time-consuming and costly approval processes for new circular products.[69]

Several other policy instruments in the agency of the province can further aid the transition. For example, Groningen has its own land use and spatial planning policies. These policies can be used to balance agricultural needs and other societal demands while preserving the agricultural character of the region, as well as its nature and biodiversity. Waste management plans at the regional and municipal level can better integrate the waste hierarchy, whereby waste avoidance through the recovery of raw materials is preferable. Through procurement, the province can also influence the uptake of standards and certifications to guarantee the performance and quality of secondary materials derived from waste and principles like Extended Producer Responsibility (EPR).

SWOT ANALYSIS

Building on the results of the PESTEL analysis, a SWOT analysis identifies the Strengths, Weaknesses, Opportunities and Threats of developing a circular economy in the province of Groningen, particularly by leveraging the opportunities that lie in and between the Agrifood and Chemical sectors. This analysis will be used to inform and frame the selection and prioritisation of concrete circular interventions that could be integrated into the investment plan.

STRENGTHS

Government support for decarbonisation and the circular transition

- The City of Groningen, the Province of Groningen and the Netherlands all boast ambitious circular economy strategies, showing a commitment to implementing supportive policies, offering incentives and actively encouraging circular practices in various sectors. At national and provincial levels, plans tackle Chemical Manufacturing and Agrifood specifically.
- Groningen cooperates closely with other provinces and municipalities via the Northern Netherlands Alliance (SNN). In doing so, the province shares best practices and resources and funds joint projects to accelerate the transition to a circular economy.[70]
- Subsidies are made available to help industrial activities decarbonise the SDE++ scheme, for example.

Strategic geographical location and advanced infrastructure

- Groningen's direct access to the North Sea provides key benefits. First, the province can easily trade with and access international markets for the products and materials it produces. Secondly, there is a high potential for further offshore wind developments to power electrolysis to produce green hydrogen, which can be used for local industrial clusters.
- Industrial activities take place in close proximity (for example, in Eemshaven and Delfzijl) and cover each step of the value chain, from manufacturing to end-of-life, which makes it easier to close material loops locally. This, coupled with excellent transport infrastructure, facilitate efficient logistics and supply chains, minimising transportation distances and enabling the smooth movement of resources.
- The province benefits from a strong and ever-growing IT sector and infrastructure, which can benefit the circular transition via digitalisation, for example, by promoting traceability of resource and materials flows.

Availability of resources and land

- Groningen is rich in natural resources, such as biomass, including crops and organic waste, which can be utilised in circular bio-based processes. Plentiful agricultural products such as sugar beets and potatoes provide a valuable raw material stream for multiple activities, such as the green chemical industry.
- Groningen benefits from significant renewable energy resources, such as wind and solar power, which can be harnessed to support sustainable energy needs in circular economy practices.
- The Province of Groningen has more available land space than many other Dutch provinces, with a higher concentration of urban areas.[71] [72]

Strong technical knowledge base and expertise

- The region boasts a thriving innovation ecosystem with research institutions, universities, and technology centres that foster collaboration, knowledge exchange and the development of circular solutions.
- Groningen's agricultural sector is characterised by a high degree of innovation and is already oriented towards the agriculture of the future.
- Best-in-class industrial know-how is present for specific materials and resource handling, such as plastic separation technology, yarn and fibre manufacturing, and other green raw materials production.
- The province's top-ranking educational institutions, such as the University of Groningen and Hanze University for Applied Sciences, provide a solid foundation for further knowledge development.
- These institutions also offer a pool of talent from which the province can benefit, boasting around 50,000 students from the Netherlands and abroad.[73]

Vibrant and dynamic business ecosystem

- The province is recognised as a European innovation leader in the Innovation Monitor and benefits from plenty of innovative and entrepreneurial SMEs.[74]
- Groningen has witnessed the emergence of various initiatives, such as Fascinating, Chemport Europe, AVEBE, Avantium, Eneco, Suikerunie and CuRe, have already rolled out circular economy strategies in the province's key sectors.
- Key sectors with evident synergies are already collaborating and forming a common vision. For instance, Chemport is helping chemical companies in Groningen and neighbouring provinces contribute to the sustainable and circular chemical industries.[75] By coordinating actors on the chemical value chain to align and complement each other, Chemport encourages industrial symbiosis and sharing principles (for example, byproducts of one facility are used as input to another process, while utility networks such as steam pipelines are shared).

WEAKNESSES

Misalignment of regulatory and policy frameworks

- Although government support for the circular economy is a strength, many plans and strategies address sustainability in silos: Groningen's Sustainable Agricultural Plan, the Delta Plan for energy and the EU Bioeconomy Strategy, for example. At times, targets and interests are also conflicting: the bio-economy agenda and the agriculture agenda might entail competition for land and biomass, resulting in certain trade-offs.
- Both sectors heavily depend on policies stipulated by the European Union and at the national level. While there is government support for the circular economy in Groningen, there may still be a need for further development and alignment of regulatory frameworks.

Financial issues

- Per capita GDP is lower compared to other regions.[76] Additionally, Groningen faces a higher unemployment rate than other provinces. Although this has gradually decreased in recent years, lacking job opportunities and a lower GDP remain a challenge.[77]
- Transitioning to circular economy practices may require significant investments in new technologies, infrastructure and processes. Currently, investments tend to favour low innovation and low-risk projects, with more guaranteed returns, rather than newer, less-tested technologies. This makes it hard to start innovation projects without public subsidies or funding. Limited access to funding and the complexity of implementing circular solutions could act as barriers, particularly for small and medium-sized enterprises (SMEs).
- Schemes such as the SDE++ have focused on subsidising renewable energy production and not on incentivising consumption of those clean energy solutions.
- Investments and subsidies largely focus on climate change rather than the circular economy. There is little national funding for circular economy projects compared to those for climate change mitigation. The challenge lies in finding enough circular economy projects to channel investment at scale.

Scalability and market demand

- Scaling up circular initiatives requires finding sufficient market demand for new, circular products and services.
- Creating robust markets for secondary materials and ensuring an economically viable circular economy are relevant considerations.
- National awareness around the circular economy is high but encouraging consumer adoption of sustainable and circular choices, which may require targeted awareness campaigns and incentives, can be challenging due to the gradual nature of behaviour change.

Land competition

- Although space is not lacking in the province, competition is high. Developing new infrastructure to support the circular transition will be challenging.
- Farmers require land; ongoing urbanisation pushes for converting this land into residential, commercial and industrial spaces, as well as for infrastructure developments (logistics and transportation).
- Renewable energy projects, such as wind farms, solar parks and biomass installations, require substantial land areas as the Netherlands aims to transition to clean energy sources. This is sometimes opposed by the local population..
- The prevalence of protected areas means that all spatial planning strategies need to account for and comply with ecosystem preservation regulations.
- The need to remedy Groingen's housing shortage—while allowing for industrial development—means that competition is fierce for space in the City of Groningen too.

Pressures on agriculture

- Groningen, like many other regions, has witnessed an increase in agricultural costs. Several factors contribute to this trend, such as rising input costs, environmental regulations and land prices. This makes it more difficult for farmers to operate profitably.
- Due to other factors, such as structural changes in agriculture, urbanisation and economic viability challenges, agriculture activity has decreased. Smaller farms have struggled to compete with larger, more cost-effective enterprises, ultimately leading to their closure.

OPPORTUNITIES

Potential for a bio-based circular economy

- With a strong agricultural sector and access to biomass resources, there is an opportunity to develop and expand the bio-based economy, utilising crops, organic waste, and residues to produce high-added value products such as biochemicals, bioplastics, in addition to biofuels. Circular approaches will be key here to ensure that biomass feedstock is optimised and comes as much as possible from secondary sources.
- All this can capitalise on existing logistics for lower-value biomass applications (such as collection and separation operations of biomass for biogas production) to provide higher-value applications (such as the production of chemical feedstocks).
- Excellent accessibility by sea, road, rail and inland shipping can also be leveraged to easily access global markets to buy and sell these new, bio-based products and ensure the province's competitive advantage nationally and internationally.

Utilities, renewables and green hydrogen

- Industrial clusters boast strong and interconnected utility infrastructure, such as electricity, steam and waste handling. Developing these further can facilitate circular activities.
- By leveraging the region's significant renewable energy resources, the province can support the transition to a circular economy by powering circular processes, reducing reliance on fossil fuels, and creating a sustainable energy infrastructure that aligns with circular principles. This is well-suited for the production of green hydrogen, which can serve as a sustainable energy carrier and facilitate the decarbonisation of various sectors, including Chemical manufacturing.

A growing market for circular plastics

- Commitment to sustainability and waste reduction goals at both municipal, provincial and national levels are all factors that contribute to this opportunity.
- Moreover, the development of innovative recycling technologies, the establishment of plastic recycling facilities, and the growth of the circular plastic market can stimulate economic growth and attract investments in the region.

Global frontrunner potential

- Groningen has strong potential to become a global frontrunner in green hydrogen production, and bio-based and renewable materials.
- The province lacks visibility internationally and, in some cases, nationally. Groningen-based businesses, initiatives and innovations are afforded less media attention compared to those operating in the Randstad area, for example.
- By leveraging the principles of the circular economy, Groningen can enhance its visibility, attract investments and reduce reliance on fluctuating global raw material costs, thereby boosting resilience.[78]

Already strong collaboration in the circular economy

- Circular initiatives are plentiful across provincial organisations—from the government to knowledge institutes and networks—and coordination will bring important benefits and set the foundation for further development.
- Circulair Groningen, a newly established association of around 30 businesses, is actively committed to accelerating and achieving a circular economy in Groningen.[79] These types of networks can play a key role, leverage all relevant expertise and increase the cooperation needed for a circular economy.
- Partnerships can help to align sectors better for mutual benefits. Cross-value-chain collaboration can improve feedstock security (biomass or secondary materials) by aligning criteria, operational procedures and processes so that resources can be exchanged between the chemical and waste management sectors, for example.
- Finally, coordination and collaboration between public institutions (national, provincial and municipal), which all share a common vision for circularity, will be key to enabling local stakeholders to overcome regulatory and legal barriers and receive financial and political support.

Circular economy can be used to achieve other goals

- Circularity will be crucial to meet other goals, such as reducing GHG emissions and protecting biodiversity.
- It can be used to break down siloed ways of looking at sustainability and be used as an umbrella term as it encompasses a holistic approach to resource management that addresses multiple dimensions of sustainability at once.
- The circular economy can help mitigate job losses resulting from the phasing out of gas extraction in Groningen by creating new employment opportunities and innovation in renewable energy, resource recovery and sustainable bio-based industries. However, this will also require reskilling workers in traditionally 'linear' sectors—such as gas extraction.

Ability to capitalise on what is already there

- Existing funding opportunities can align with making the provincial economy more circular. For instance, programmes like the National Programme Groningen and CAP support changes in circular plastics, sustainable agriculture and scaling up of sustainable practices.
- The province can take advantage of increased local and global demand for circular chemical and agri-food products. There is also growing demand for green hydrogen and bioplastics: Groningen has a unique opportunity to exercise influence on a national and international scale.
- Capitalising on the current political climate, where CO_2 emissions prices have increased in the EU Emissions Trading Scheme (ETS), can lead to investments that promote circular, emissions-reducing activities being favoured.
- Society generally encourages and supports initiatives and policies that generate employment opportunities.

THREATS

Reliance on global markets

- Companies operating in Groningen are often headquartered elsewhere, meaning that strategic decisions may be based on corporate or global agendas that don't reflect local needs and sustainability ambitions.[80]
- The Chemical Manufacturing and Agrifood sectors are particularly reliant on global markets. Competition in these markets is largely driven by commodity and product prices, so products must be price competitive. Green, bio-based products are now more expensive as environmental externalities are usually not factored into costs. It is uncertain how these markets will develop in the future.
- The environmental considerations for producing exported goods sometimes differ to locally consumed products due to variations in regulations, market demands, supply chains and resource availability across different regions.

Fossil fuel dependency and reluctance to fully cease gas extraction

- Renewables still represent a small share of the Netherlands' overall energy consumption. Despite decarbonisation efforts, the process will likely take decades.
- Moreover, disincentives exist to cease gas extraction fully. Natural gas remains cheaper than renewable electricity. Thus, there is continued domestic demand for it and the desire to be more energy self-sufficient, as the energy market is sensitive to global disruptions.

Security of material supply

- The supply of primary resources is increasingly insecure in the province, as well as globally. Climate events such as flooding and droughts impact agricultural yields and threaten the supply of virgin biomass, while global crises such as wars and pandemics can impact the supply and demand of other raw materials.
- The circular economy aims to minimise the extraction of virgin resources by promoting recycling, reusing and remanufacturing. However, the supply of recycled or secondary materials can be insufficient or unreliable.
- Moreover, certifications of secondary materials are not yet well established. Ensuring the quality and reliability of secondary materials becomes challenging without proper certification processes.

Uncertain long-term decision-making halting investments

- The Agriculture and Chemical sectors have a history of lobbying governments to continue with low-risk, short-termism strategies.
- There is significant debate as to whether the Chemical sector should focus more on producing basic bulk chemicals, higher-value specialised chemicals or a combination of both. Groningen's neighbouring industrial clusters (such as Emmen) heavily depend on producing basic bulk chemicals. Changes in industrial operations will have significant implications for these clusters and could halt new infrastructure investments.
- Nitrogen-related policies are still developing and could impact the operations of industrial clusters. Currently, there are limitations to how close these operations can be from protected areas, and changing rules in the future could force some facilities to shut down.
- Permits and administrative processes needed to develop circular economy practices and business models are very time-consuming for businesses to submit and for the government to approve.
- A shift towards electrified industrial operations often requires strengthened grid connections. Expanding or upgrading grid connections likely needs hefty investments in infrastructure and alignment with environmental standards. Moreover, implementing grid connection projects may involve overcoming regulatory challenges.[81]

Labour and skills shortage

- Sustainability is increasingly common in education programmes, but the skills needed in the labour market are lagging behind, such as technical skills.[82]
- Highly-skilled young people are increasingly leaving the province to work in larger cities—a phenomenon known as 'Brain drain'.[83]
- Limited integration of vocational institutions, higher education institutions and industry in key circular economy sectors which is essential for effective reskilling, upskilling, and the uptake of labour-intensive or technically-intensive professions.

Potential additional pressures on the local environment

- Increasing the production of bio-based and renewable resources in the two key sectors will likely pressure local natural resources. Local land use and freshwater consumption will be needed to grow bio-based feedstock, for example. This is difficult as all farmers are being asked to cut down production.
- New infrastructure may also impact the local environment: for example, pipeline installation could impact biodiversity, while increased recycling operations could cause noise pollution.

3

STRATEGIC DIRECTIONS

3 STRATEGIC DIRECTIONS

To inform the National Programme Groningen's multi-year investment in advancing the circular economy in Groningen, four strategic directions have been identified. These should become the building blocks of the multi-year investment plan.

The strategic directions target the Chemical Manufacturing and Agrifood sectors and the links between them. In particular, within these sectors, four material groups were identified as key for the circular economy:

- CIRCULAR PLASTICS
- BIO-MATERIALS
- HYDROGEN
- CO_2 AS A RAW MATERIAL (CARBON CAPTURE AND UTILISATION)

The four strategic directions have been defined based on Groningen's most competitive advantages, nationally and internationally, and validated and refined together with local stakeholders during the first and second workshop of the project. The four strategic directions below hold the highest potential to scale circularity in Groningen, complement the existing programmes and initiatives (such as FASCINATING and CHEMPORT EUROPE) and, thus, are where most investment efforts should be focused:

1 • **OPTIMISING VALORISATION OF BIOMASS FOR A CIRCULAR BIO-BASED ECONOMY** to ensure biomass is in a closed-loop system where its value is optimised.

2 • **CIRCULAR INDUSTRIAL PROCESSES** to ensure other materials that feed into chemical processes leverage new circular opportunities, for example, plastics, hydrogen and CO_2.

3 • **CIRCULAR AGRICULTURE** to produce food sustainably, but also to ensure that demand of biomass feedstock is met sustainably.

4 • **URBAN-RURAL-INDUSTRIAL SYMBIOSIS** to connect material flows and find alternative sources of secondary materials that can feed into industrial processes as well as biomass flows.

Each direction is analysed using economic, social and environmental impact indicators from relevant literature and databases, showing the benefits and trade-offs of each strategic direction. Then, drivers and barriers are considered alongside the main requirements to develop them at scale, such as enabling elements or necessary considerations for the National Programme Groningen when allocating funding.

1 •

OPTIMISED BIOMASS VALORISATION FOR A CIRCULAR BIO-BASED ECONOMY

A core element of the circular economy is ensuring that renewable, biobased resources such as biomass are utilised in the most efficient way. The province can leverage a strong Agrifood sector and a best-in-class bio-chemical industry to prioritise interventions and optimally allocate biomass resources to exploit synergies between these sectors. This will help expand and develop the bio-chemical industry of the province—placing it at the forefront of biorefining and biochemical production in Europe and worldwide—as well as diversifying the development of the bioeconomy and limiting the low-value treatment of biomass (energy valorisation). Moreover, circularity will be crucial to ensure that the valorisation of biomass does not further exacerbate land competition issues and contributes to making Groningen's economy more resilient.[84 85 86]

Optimising valorisation of biomass should include the following interventions:

(IN ORDER OF PRIORITY, FOLLOWING A VALUE-CHAIN APPROACH)

1. **Transforming agricultural residues into value-added chemical products to return nutrients to the soil.** Processing crop residues into organic fertiliser is the first step in circular farming. It sets the foundation for a closed-loop system and provides a sustainable alternative to chemical fertilisers, promoting soil health and minimising environmental impacts.

2. **Prioritising alternative or unutilised sources of primary biomass to diversify feedstock for bio-based industries, instead of relying solely on traditional feedstocks, such as food crops or dedicated energy crops.** Alternative types of biomass should be abundant, widely available and not require land that could otherwise be used for food crops. Examples include algae, hemp, lignocellulosic biomass, the non-edible parts of plants, such as crop residues (for example, corn stover and wheat straw), wood chips and dedicated energy crops (such as switchgrass and miscanthus).

3. **Support the development of innovative biomass valorisation techniques such as fermentation and biorefinery processes.** Using the alternative bio-materials mentioned above in innovative techniques such as fermentation[87] and biorefinery processes can help develop and expand the bio-based economy to produce high-value commodities, like biochemicals and bioplastics. Such techniques offer a unique opportunity for Groningen to connect multiple of its key economic sectors, finding synergies between agrifood, pharmaceutical and chemicals manufacturing, and vice versa. The presence of these sectors of activity is an excellent playground to make the most of the local knowledge and potential of such techniques.

4. **Transforming residual biomass into energy carriers, such as bio-hydrogen and bio-gas, for small-scale or local uses.** Higher-value applications for the use of biomass should be prioritised before resorting to energy recovery. However, with energy recovery from residual biomass as a renewable energy source, the region can reduce reliance on fossil fuels and contribute to decarbonisation efforts. This should be done as locally as possible, minimising the environmental impact associated with long-distance transportation while reducing greenhouse gas (GHG) emissions.

Impact assessment

Economic viability and competitiveness

- **High upfront investment costs** of key biomass conversion technologies depend on several factors such as the scale and complexity of the facility, technology employed, specific feedstocks and end products involved, as well as prices at which biomass resources can be made available and the (relative) future costs of fossil fuels (uncertain, although likely to follow an upward trend over the coming decades).[88] For example, small-scale biorefinery plants range from a few million to tens of millions of euros, while medium to large-scale facilities can cost tens of millions to several hundred million euros.[89]

- **Cost savings**. Opting for biomass coming from residual organic streams like agricultural residues, organic waste from households or food processing by-products is a way to substitute virgin materials. By leveraging the proper knowledge and techniques, EU-based projects, like GreenSolRes (based in different sites in the Netherlands, Belgium, Germany and Austria), have already demonstrated that it can be advantageous both environmentally and economically.[90] Research also shows that monomers from lignocellulosic biomass with integrated engineering to optimise conversion processes can lead to 50% cost savings, halving the market price for bio-materials.[91]

    - **Reducing the use of synthetic fertilisers.** Fertiliser prices increased by nearly 30% in 2022, representing a significant cost for farmers.[92] Circular farms can cut synthetic fertiliser use by 20 to 50%.[93]

    - **Other production cost savings**. Thanks to the small scale of the province and effective logistics, all the necessary activities to produce bio-based products in Groningen can reduce costs associated with transportation.

- **High Technological Readiness Level (TRL)**. In the Eemsmond area, at least eight types of bio-chemicals have shown high TRL, meaning that the technology has typically progressed from laboratory-scale experiments to a pilot or demonstration plant, demonstrating their potential in pre-commercial environments.[94]

- **High scaling up potential.** Current policies, local investments and local production capacities prove that this strategic direction has high scalability potential. Local investments already aim at expanding biomass production capacity locally, but could also be coupled with imports of raw materials from overseas or Germany (such as the Weser-Ems agricultural area, which contains 300,000 hectares of grassland) to fully meet the demand for biomass from the manufacturing and chemical activities.[95] Moreover, as seaweed and algae are increasingly used for higher value-added applications, such as foods or personal care products, they could leave room to increase biomass production of beet pulp, paper pulp and woody biosolids used in the northern Dutch chemical industry.[96]

- **Positive return on investment.** Depending on the investment amounts supporting a bio-based economy could turn each €1 million invested into approximately €500,000 to 2 million in additional revenue.[97] In particular, bio-based chemicals and pharmaceutical products show the highest rates of value-added per person employed in the EU (about €120,000 per worker).[98] Moreover, investing early in the time horizon on bioeconomy may come with macro-economic benefits to the Netherlands on GDP (€0.8 billion per year), value added (€0.7 billion per year) and reduce the projected decline in trade balance (by about €0.7 billion per year) or 36% compared to LowTech scenarios).[99]

- **Higher-value industries.** While the Dutch agricultural ministry prioritises applications of biomass in agriculture and food, part of the biomass could be used for application higher up the value pyramid. The highest economic value (measured in euros per kilogram for biobased products) in biobased products is found in the pharmaceutical industry, followed by meat products, processed food, materials and chemicals.[100]

Netherlands-based project, PULP2VALUE is using biorefinery systems to process low-value beetroot by-product (pulp) into 20- to 50-times higher-value products (for example, fertiliser). About 13 million tonnes of pulp are available in Europe yearly. Nine demonstration projects are taking place, with a market potential of €200 million, along with a substantial reduction of carbon footprint.

Environmental impacts

- **Emissions reduction.** For each €1 million invested in the bioeconomy, it is possible to achieve a 0.5 to 10 thousand tonne CO_2 emission reduction.[101] Nonetheless, emission reduction to 2030 is modest from investing only in bioeconomy (15% or about 30 tonnes CO_2e compared to 1990). To meet climate goals, more ambitious scenarios need to be assessed (for example, a CO_2 tax of at least $100 per tonne of CO_2). Pursuing ambitious emission mitigation goals may replace additional fossil-based capacity, thereby increasing the significance of the bioeconomy.[102]

- **Reduced virgin material consumption**. By 2030, the Dutch bioeconomy could achieve material savings of around 30 million tonnes per year compared to a business-as-usual scenario.[103] These savings are primarily attributed to the increased use of biomass resources and the substitution of fossil-based materials with bio-based alternatives and could be further increased by utilising non-food biomass feedstock, either through crop residues, processing by-products and wastes or simply alternative feedstocks (algae) to avoid using virgin or primary biomass sources (as these would be competing with other markets, and thus competing for land).

    - **Reducing the use of chemical fertilisers**. Circular farms have demonstrated reductions ranging from 20% to 50% or more in fertiliser use compared to conventional farming systems.[104] They can replace synthetic fertilisers containing finite reserves of elements like rock phosphate with recycled forms of fertilisers such as organic compost or diluted manure.[105]

- **Avoided waste generation and associated material recovery.** Either through the biorefinery of biomass residues into specific bulk chemicals or through conversion into lower value products like energy carriers or added value agricultural products (fertilisers), the processes described aimed at closing the loop or avoiding the waste of organic resources in the first place.

- **Other positive impacts on the local environment:** reduced local pollution, reduced risk of earthquakes and improved soil quality.

Social impacts

- **Job creation.** A bio-based economy in Groningen will entail new roles and occupations in biomass cultivation, logistics and bioprocessing engineering. Community engagement and organic waste management will also be crucial, with digital platforms for B2B waste collection emerging as a key area. A new biogas plant planned in the city is expected to provide at least 60 additional jobs, highlighting the sector's potential for employment creation.[107]

- **Relocating gas extraction jobs.** Comprehensive redeployment strategies can help mitigate the job decline in the gas extraction sector and ensure successful job relocation from traditional sectors to new emerging industries that will require biomass instead.[108]

- **Retaining local talents.** Groningen can capitalise on its existing strengths in innovation, sustainability and interdisciplinary collaboration in this bio-based transition. This approach can attract and retain young talents who are eager to contribute to the region's economic growth, work on cutting-edge solutions, and positively impact society and the environment.

Recovering waste from the sugar beet industry

In the Northern Netherlands in 2022, the gross agricultural proceeds of sugar beets yielded 2.23 tonnes of products. We can estimate that 156,100 tonnes of beet pulp could have been generated from processing beetroot residues. [106]

Strengths & opportunities

KEY STRENGTHS AND OPPORTUNITIES FOR THE NATIONAL PROGRAMME GRONINGEN AND LOCAL STAKEHOLDERS TO LEVERAGE

- **Demand for bio-based feedstock and sustainable products and materials is increasing.** The region has invested heavily in a well-developed biomass supply chain. Large-scale availability of different biomass feedstocks that can alleviate pressure on the local environment while meeting the demand by the chemical sector, but also construction (bio-based materials, such as hemp and timber).
- **A hub for green chemicals.** Groningen hosts renowned research institutions and universities, including the University of Groningen, with dedicated research programs focusing on green chemistry and sustainable techniques such as biomass fermentation and biorefinery processes. The province's innovation ecosystem can foster the development of circular design principles and innovative technologies that enable the creation of these new, bio-based products.
- **Dynamic network of chemical companies**, startups and technology providers that actively collaborate with research institutions to innovate and experiment with new ways of operating.
- **Strong industry collaboration in the Chemical Manufacturing and Agrifood sectors.** Existing symbiotic agreements and relationships will save costs on multiple fronts (utilities, infrastructure and by-products).
- **Small geographical scale, excellent infrastructure and logistics networks** (utilities, industrial parks, port infrastructure) and **proximity** (collection areas are close to the processing and/or storage facility) favour synergies and symbiotic relationships among industries. Also, proximity to renewable energy helps facilitate the production of green chemicals with a reduced carbon footprint.
- **Regulatory developments in the Netherlands and the EU.** Discussions in the Netherlands include requirements for balanced fertilisation and ensuring a balanced nutrient supply.[109] Moreover, bio-economy regulations are in the making, and many directives already favour alternative biomass feedstocks to virgin ones. For example, in January 2018, the European Parliament voted to limit its support for biofuels made from food crops, aiming to gradually reduce such fuels to 3.8% by 2030; ancillary measures, then, seek to incentivise the use of lignocellulosic wastes in biofuel production. This shift may impact local farmers who produce crops for biofuel production, as they might need to explore alternative feedstocks or diversify their agricultural practices.
- **Aligned political ambition** across all levels of governance and industrial associations (EU bioeconomy strategy, Dutch circular economy strategy and different agendas of the province, such as Chemport Europe, Sustainable Agricultural Plan for Groningen, Industrietafel Noord- Nederland).

Weaknesses & threaths

CRUCIAL WEAKNESSES AND THREATS THAT THE NPG AND LOCAL STAKEHOLDERS NEED TO ADDRESS

- **Logistical challenges** surrounding biomass feedstock supply at various steps of the supply chain. For example, the market is highly decentralised, meaning that feedstock comes from various sources with different qualities, unpredictable quantities and levels of contamination (such as heavy metals or foreign matter such as rocks, soil, glass, plastics and other debris). Moreover, maintaining biomass quality at high capacity and low cost can be a challenge, and there is a need for long-term storage facilities.[110]
- **R&D Gaps.** Despite the existing potential and active bioeconomy companies,[111] Groningen lags behind other Dutch provinces in terms of research and development intensity, mainly relying on public expenditures for its R&D efforts.[112] This presents a significant challenge since scalable biorefinery business cases necessitate increased R&D investment.[113]

What needs to happen

WHAT STILL NEEDS TO HAPPEN FOR THIS STRATEGIC DIRECTION TO BECOME A REALITY?

Policy and regulations

- **Future taxation** of CO_2 could increase the market potential for specific bio-based materials as, in several cases, their estimated prices are higher than fossil-based alternatives.[114] Cities and the province can harvest this benefit by advocating for a revenue-sharing mechanism that returns a portion of carbon tax revenues to local governments. The revenue from the tax, then, can be used to fund circular biomass use and help smaller farms in the transition.

- **Invest in biorefineries and bio-based chemical production facilities.** By the year 2030, the EU aims to replace 30% of oil-based chemicals with bio-based chemicals and supplant non-degradable materials with degradable materials, and provide 25% of its transportation energy via biofuels derived from cascading processes through advanced biorefineries (second-generation biorefineries).[115] Groningen could potentially attract investment and become a hub for such biorefineries, given its existing agricultural resources and expertise, as well as lead to the development of new bio-based chemical production facilities to meet those requirements, fostering the growth of industries focused on sustainable and eco-friendly materials.

Skills Development

- **Promising skills development and professional adaptation pathways**. Professionals in Groningen from the gas extraction sector can efficiently transition to the biomass sector by applying their existing skills in engineering, logistics, safety, regulations and quality control.[116]

- **Leverage existing training initiatives.** The New Energy Coalition, a collaborative effort of Groningen University and Hanze University of Applied Sciences, already focuses on energy transition research and human capital development. Such initiatives provide a solid foundation to bolster research, innovation and skills development for the biomass sector. However, creating more collaborations and networks, particularly involving vocational institutes, is vital to augment this transition and address the R&D gap.

- **Labour productivity.** Analysis shows that the Netherlands belongs to the group of member states with the highest levels of labour productivity of the bioeconomy (more than double the EU average) and with a high degree of specialisation in the manufacture of bio-based chemicals and pharmaceuticals.[117]

Others

Direct efforts to decrease logistical costs of biorefineries, achieve better economies of scale and an overall long-term commercial success and competitiveness, via several mechanisms such as:

- **Integrated logistics models** to facilitate product (and feedstock) delivery between value chain actors, in order to avoid supply chain bottlenecks.

- **Investing in adequate machinery and infrastructure** to ensure that facilities can handle large volumes of feedstock.

- **Tools to map biomass inventories**. This could be done by developing a modelling tool that would inform and optimise biomass utilisation based on real data from the province. As an example, this could be an expansion of the Agrifood nature transition model developed for the FASCINATING programme,[118] which integrates potential processes and activities from the industrial cluster (such as biorefinery and bio-based bulk chemicals) to the current parameters of the model.

- **Establishing centralised regional hubs**

2 • CIRCULAR INDUSTRIAL PROCESSES

In addition to the valorisation of renewable, bio-based materials such as biomass, the Chemical sector can leverage other materials—such as plastics, hydrogen and CO_2 (via Carbon Capture and Utilisation)—as new sources of raw materials. This can help increase the circularity of several industrial processes by minimising the use of fossil-based carbon sources, prioritising the use of regenerative sources like green hydrogen, and efficiently circulating by-products such as CO_2. Adhering to these principles enables the production of new carbon-based products (such as bulk chemicals, plastics and fuels) with reduced environmental impacts. By establishing a low-carbon, circular industrial ecosystem in Groningen, the province can position itself as a global leader in the production of high-value, sustainable products that cater to the growing demand for sustainability.

Various approaches will be necessary to create circular industrial processes, such as:

1. **Developing integrated plastic waste management facilities** These facilities encompass plastic sorting and recycling processes, ensuring effective sorting procedures to facilitate subsequent valorisation. The aim is to produce sustainable chemicals and plastics through both mechanical and chemical recycling methods. In the coming years, a big push is needed to accelerate recycling levels to meet the target set by the Dutch Transition Agenda, which aims for 40% of all plastic products to be produced from recycled plastics by 2030. Currently, this share is approximately 10%.[119]

2. **Developing infrastructure for Carbon Capture and Utilisation (CCU)** Many industrial processes still generate significant CO_2 emissions as a by-product. Instead, CCU technologies and processes can capture CO_2 and utilise it for productive purposes rather than releasing it into the atmosphere. By capturing and purifying these emissions and establishing efficient (temporary) storage and transportation systems, the captured CO_2 can serve as valuable feedstock for other processes, maintaining a balance between its supply and demand in a closed-loop approach. Most impactful applications include the production of methanol and other e-fuels.

*Note: This direction focuses on utilising CO_2 as a valuable resource rather than solely considering its storage options. Although long-term storage of CO_2 is a possibility, it is a low-value solution. However, realising the potential of utilisation will require a stimulating set of instruments, innovation and effective policy across all stages: capturing, storing, transporting and using CO_2.[120]

3. **Producing green hydrogen for use as a chemical feedstock and energy.**
Green hydrogen refers to hydrogen gas produced via electrolysis powered by renewable energy (for example, solar and wind). It can play an important role in the circular economy of the province by decarbonising industrial processes and providing a sustainable feedstock to the Chemical sector, such as methanol and ammonia—which are currently primarily produced from natural gas. It can also serve as a form of energy storage for intermittent renewable energy sources. When excess renewable energy is available, it can be used to produce green hydrogen, which can be stored and later converted back into electricity or used as a fuel when renewable energy supply is low. This helps to balance the energy grid and ensure a stable and reliable energy supply.

IMPACT ASSESSMENT

ECONOMIC VIABILITY AND COMPETITIVENESS

High investment and operational costs

CIRCULAR PLASTICS

Investments mostly concern sorting, recycling and processing facilities. The SDE++ subsidy scheme provides a reference cost of €18 million for a facility producing 18 thousand tonnes of PET per year.[121] It should be noted that both mechanical and chemical recycling technologies are expected to play a significant role in the circular economy of plastics. Both technologies have different strengths, but they should complement each other rather than compete, so investments will be needed to advance both types.

CO_2 AS A RAW MATERIAL (CARBON CAPTURE AND UTILISATION)

The SDE++ calculated the cost of capturing CO_2 at an industrial source and transporting it to a greenhouse for use at €41 to 126 per tonne of CO_2 captured, considering both investment and operating costs. This, however, depends on factors such as if the CO_2 capture installation is applied to new or existing industrial facilities and whether the CO_2 is transported by pipeline or road transport.[122] It can only be used as a cost guideline for other applications, and it is likely to be higher if a higher purity is required.

HYDROGEN

To create the latest hydrogen ecosystem in the Northern Netherlands region, necessary investments may be around €9 billion. This would span hydrogen demand applications, infrastructure and logistics, and production projects and would exclude offshore wind and grid expansions. However, in the past five years, the cost of green hydrogen production has decreased by 35%, with a further 55% drop expected by 2030. Thus, the large-scale production of green hydrogen in Groningen could become a cost-effective decarbonisation strategy for both the province itself and beyond.[123]

Scaling up potential

Despite the high initial infrastructure costs, ongoing investments in new facilities exist. This can be advantageous for several reasons. Firstly, it often indicates a commitment to cost-efficiency by incorporating modern and efficient technologies that reduce operating expenses over time. Secondly, investing in new facilities demonstrates a commitment to innovation and staying ahead of the competition. Thirdly, it facilitates scalability and future growth by preparing for increased demand and expanding operational capacity. Overall, this approach demonstrates a forward-thinking mindset, ensuring a competitive edge and adaptability in the dynamic business landscape for these materials, in particular:

CIRCULAR PLASTICS

A chemical recycling facility in Delfzijl plans to be capable of processing 350 thousand tonnes of plastic waste a year, equivalent to plastic packaging waste produced by more than 11 million Dutch residents every year.[124]

CO_2 AS A RAW MATERIAL (CARBON CAPTURE AND UTILISATION)

The Delfzijl chemical cluster is capable of utilising 1,300 thousand tonnes of CO_2 for its production processes.[125] Within the same cluster, the GasifHy project aims to produce green methanol at a large scale by utilising both green CO_2 and green hydrogen to meet their full capacity of 950,000 tonnes of methanol per year.[126]

HYDROGEN

Delfzijl and Eemshaven (alongside Emmen in Drenthe) plan to be able to develop 100 petajoules (PJ) per year of green hydrogen by 2030 to supply over a quarter of the demand in northwestern Europe.[127]

Closing the CO_2 loop

Photanol has already begun scaling up its operations of creating bio-based plastics from CO_2 and bacteria. It has progressed from its laboratory operations and is now starting production in a demonstration plant capable of producing 10 tonnes of bioplastics per year. It planned to scale up to 30 thousand tonnes by 2023 and to transition to a fully commercial plant in 2024. The technology used is highly scalable and reduces the reliance on fossil fuels for plastic production and utilises CO_2, thus contributing to direct greenhouse gas emission reduction.[128]

Environmental impacts

Greenhouse gas emissions reduction

CIRCULAR PLASTICS

The emissions associated with plastic production in the Netherlands could be reduced by 23% to 50% through mechanical recycling, chemical recycling, efficiency improvements and the use of bio-based raw materials.[129] The application of chemical recycling by itself could result in 255 to 765 thousand tonnes of CO_2 savings a year compared to the current processing of plastic waste in the Netherlands.[130] Overall, recycling plastics is found to be more environmentally beneficial than incineration across all types of plastics.[131]

CO_2 AS A RAW MATERIAL (CARBON CAPTURE AND UTILISATION)

If the northern chemical cluster fully utilises its demand capacity of 1,300 thousand tonnes of CO_2 then this would result in a direct reduction of an equivalent amount of emissions.[132]

HYDROGEN

Plans in the Netherlands to replace natural gas with green and blue hydrogen are said to have the potential to reduce emissions by 5 to 10 million tonnes, equivalent to 3 to 6% of Dutch emission levels in 1990. This potential is even greater when other end-use applications, such as shipping and heavy vehicles, are considered.[133] Moreover, replacing natural gas with green hydrogen directly contributes to ceasing gas extraction, mitigating the risk of triggering more earthquakes in the region.[134]

New infrastructure

New infrastructure requires increased virgin material consumption. Due to the significant scale of new infrastructure required to scale up technologies, such as offshore wind turbines, recycling facilities and new CO_2 capture installations, it is inevitable that much of this material demand will come from virgin sources. The extraction of materials is associated with a range of environmental impacts, from water pollution to biodiversity loss and soil erosion.

Social impacts

- **Job creation**. The transition to green hydrogen in Groningen is expected to generate a substantial number of new jobs. Just the construction of suitable infrastructure could add thousands of engineering, project management, construction, and operations jobs alone. An inter-provincial cooperation project for hydrogen production in the region is expected to create up to 6,500 new jobs (6,000 for infrastructure construction and 500 for operations).[135] Furthermore, the build-out of the Northern Netherlands hydrogen ecosystem, with a planned investment of €9 billion, is anticipated to attract over 25,000 hydrogen-related jobs by 2030.[136] Finally, despite a lack of concrete figures, for the chemical industry, the shift towards a more circular plastic industry is expected to entail new employment opportunities in supplying recycling and the bio-based plastics industry, supposing no substantive change in terms of types of work and working conditions.[137]

- **Job losses to be reallocated.** With the transition toward circular carbon and green hydrogen sectors, traditional sectors like the fossil fuel industry, traditional plastics manufacturing, and long-distance transportation and logistics could face job reductions.[138] In Groningen, it is estimated that 21,055 jobs along its gas value chain are at risk.[139] Yet some occupations, such as drivers, electricians, engineers and administrative workers, are expected to be easier to reallocate to related sectors. That said, companies like OCI (formerly BioMCN) in Delfzijl, which received a €110,000 grant from local authorities to transition toward low carbon production, illustrate the need for institutional support in retaining and retraining workers, as the firm's investment in a bio-methanol production method using green CO_2 resulted in the addition of three new jobs and retention of 14 existing positions.[140]

Strengths & opportunities

KEY STRENGTHS AND OPPORTUNITIES FOR THE NATIONAL PROGRAMME GRONINGEN AND LOCAL STAKEHOLDERS TO LEVERAGE

- **Strong industrial base focusing on plastics.** The ecosystem of actors along the plastic supply chain covers the entire plastic cycle, making it easier to close the plastic loop. With numerous companies involved in plastic production, processing and recycling, the existing infrastructure provides a solid foundation for implementing circular plastic initiatives, taking advantage of the proximity of various stakeholders in the value chain.[141] Moreover, mechanical recycling already exists in the Northern Netherlands region, but not specifically in Groningen. Chemical recycling is a newer technology being developed in several locations in the Netherlands, with a new plant in Delfzijl setting itself out to become the largest in the country with its proprietary pyrolysis technology. Given the strong chemical sector in the Netherlands, chemical recycling is a logical opportunity to close the loop in the sector.

- **Legislation pushing demand for more sustainable products.** The EU's *Circular Economy Action Plan* provides a long-term prospect of how products must be produced over the coming decades. This helps to increase demand for circular industrial processes, such as plastic recycling, where Extended Producer Responsibility (EPR) schemes are being implemented, deposit return schemes, and having a minimum recycled content target across products on the market.[142] Such policy direction helps to provide certainty for those actors making investments in the field of circularity.

- **Offshore wind developments powering green hydrogen.** Groningen is particularly well suited for the production and use of green hydrogen due to its ambitious offshore wind plans, supply of renewable electricity from Norway via the NorNed cable and presence of a developed chemical cluster both within the province as well as in neighbouring provinces.[143]

- **Presence of industrial clusters as incentive for CCU.** By capitalising on the characteristics of industrial clusters, such as concentrated emissions, economies of scale, shared infrastructure, synergistic utilisation opportunities and collaborative environments, the implementation of CCU technologies becomes more attractive and feasible.

- **Strong presence of R&D.** This can boost interventions that require advanced innovation, such as advanced plastic waste sorting facilities, chemical recycling, green hydrogen production and distribution and CO_2 CCU.

- **Grid flexibility for green hydrogen.** The country's natural gas infrastructure holds an extensive network of pipes which have the potential to be cost-effectively retrofitted to transport hydrogen.[144] This would avoid the need for extensive new infrastructure and allow Groningen's chemical sector to transition from natural gas-based hydrogen to green hydrogen. Plans in this direction are already in progress.[145] [146]

- **Financial support is available for some interventions.** The chemical recycling of plastics and the production of green hydrogen via electrolysis are both supported by the SDE++ subsidy scheme.[147] [148] Moreover, subsidies to turn the Northern Netherlands into a Hydrogen Valley are available from the EU.[149] Regional actors such as the National Programme Groningen are key to ensuring these reach the ground.

Weaknesses & threaths

CRUCIAL WEAKNESSES AND THREATS THAT THE NPG AND LOCAL STAKEHOLDERS NEED TO ADDRESS

- **Security of secondary material supply.** EPR and other policies can hinder plastic supply. While EPR is generally considered beneficial for promoting recycling and reducing the environmental impact of products, it can potentially limit access to end-of-life plastics for recyclers in certain circumstances. To mitigate these limitations and promote access to end-of-life plastics for recyclers, it is crucial to design EPR programmes that strike a balance between manufacturers' responsibilities and the broader recycling ecosystem.

- **Plastic's product quality and cost.** Recycled plastic often cannot compete in quality and cost compared to virgin alternatives.[150]

- **Reduced incentives and lock-in infrastructure.** If more investment is channelled towards plastic recycling facilities, there could be less incentive to increase plastic waste generation rather than reduce it. The same holds true for CCU infrastructure which, alongside the already proposed plans of Carbon Capture and Storage (CCS), likely reduces the incentive for industries to shift away from the use of fossil fuels. Additionally, government support for CCS is stronger due to its greater potential for CO_2 reduction; however this strategy overlooks the importance of keeping materials in use at their highest possible value for as long as possible.

- **Competition for circular products**. A wide range of products can be produced in a 'circular' way: from basic chemicals to plastic products and transport fuels. Some of these products, such as transportation fuels, are being supported by legislation, whilst others are being left behind.[151] [152] It must be carefully considered what the most optimal product routes are for Groningen.

- **Limited financial support for some other interventions.** For example, CO_2 utilisation is currently only supported in greenhouses and not in industrial applications.[153]

- **Material burden of renewable energy scale-up.** Generating sufficient quantities of green hydrogen requires massive scaling up of renewable energy technologies, which will add to the material burden. It, therefore, must be managed in a circular way (for example, through design for dismantling).

- **A low cost of electricity** is a necessary condition to produce competitive green hydrogen.

What needs to happen

WHAT STILL NEEDS TO HAPPEN FOR THIS STRATEGIC DIRECTION TO BECOME A REALITY?

Financial support for a wider scope of interventions

- **CO2**. SDE++ subsidies must be expanded beyond only CO_2 utilisation in greenhouses.
- **Green hydrogen.** By means of SDE++ subsidies or another instrument, it may be beneficial to have financial incentives for the consumption of green hydrogen rather than only the production.
- **Plastics.** A circular plastics system cannot be set up by a single actor. It needs subsidisation for the research phase (for both technological advancement and to assess different strategies) as well as to facilitate the value chain cooperation between actors.[154]

Increase information and remove legislative bottlenecks

- **There is a general lack of information on materials,** as well as the quantity currently lost as waste from industrial processes and their value potential. Having such information available could help to stimulate circular activities to utilise this material.
- **The definition of waste** is unclear and can make interpreting regulations difficult.
- **Regulations** governing the transport of waste across borders can also sometimes hamper access to the most efficient processing facilities, limiting scaling capacities.
- **Requirement**s to use specific yet outdated technologies hinder innovation. Therefore, it is important to seek for such requirements to be as updated as possible with the latest technologies.[155]

Skills Development

- **Green hydrogen skilling strategy.** Groningen's transition will require diversifying skill sets across the full value chain of green hydrogen, from production to end-use applications. This will necessitate (re)skilling in areas such as engineering, material science, renewable energy, chemical processes, safety management, system integration, and sales and marketing roles.[156] In Groningen, proactive measures are already underway through reskilling and upskilling programs. A prime example is the hydrogen degree programme offered by Brunel and the Energy Delta Institute in the region, which is specifically tailored for existing oil and gas workers. Supported by substantial investment from the European Union, this initiative aims to meet the anticipated surge in demand for hydrogen expertise in the upcoming years. Also, the RIF Gas 2.0. public-private partnership is specifically focused on ensuring that vocational education contributes to the sustainable energy transition in Groningen.[157] By establishing the 'Energy College', aimed at students and working professionals, knowledge about the energy transition was shared, including green hydrogen.
- **Strong R&D necessitates highly skilled workers.** High demand for researchers, scientists and innovators is expected to improve existing technologies and develop new ones in Groningen. A four-year project led by the University of Groningen and Hanze University of Applied Sciences, funded with around €3.8 million, is a prime example of such initiatives.[158] This project, focusing on the use of supercritical CO_2 for eco-friendly production of sustainable chemical products, is expected to provide around 50 jobs in the region's agrifood, energy and chemical sectors.

Others

- **Collaboration of actors along the entire value chain** (plastics, green hydrogen and CO_2) is key here because supply and demand must be matched alongside streamlined logistics and infrastructure.[159] [160] For example, plastic recycling depends on sufficient demand from buyers, thus agreements must be put in place to solve 'chicken and egg' issues. The same goes for green hydrogen: while potential for both producing and using green hydrogen in the region has been estimated, there must be clear definitions of who would use what and when to strengthen the investment decision of hydrogen infrastructure. In addition, quality and classification of material streams are important: what is the purity of hydrogen or CO_2 streams? What type of plastic is present, and are there contaminants?

3 · CIRCULAR AGRICULTURAL PRACTICES

The development of a biobased economy can lead to higher demands for biomass, putting pressure on agriculture to increase sustainable biomass production to satisfy the growing demand from various sectors, such as biochemicals, bioplastics and bioenergy. At the same time, however, the agricultural sector in Groningen is under pressure to shrink, specifically livestock farming, to reach the country's emission reduction goals. As recognised by the Dutch Ministry of Agriculture and the FASCINATING programme, shifting to more circular agriculture will first be necessary to sustain resident's nutrition and satisfy food demand in the province, and second to ensure the biomass feedstock needed for the bioeconomy. In turn, this could help maintain the province's competitive advantage on international markets, the health of local ecosystems and the future of the sector's workers. While the FASCINATING programme provides a vision for the sustainable future of agriculture in Groningen, this section expands on the strategic circular opportunities the local agricultural sector could leverage to achieve this vision.

Various approaches will be necessary to achieve a circular agricultural sector, such as:

1. **Integrated farming systems to optimise the balance between livestock and arable farming.**[161] As a reduction in total livestock farming is expected in the Netherlands, integrated farming practices combining livestock and arable farming can help produce both animal and plant-based protein more sustainably. Such systems seek to reduce the dependence on external inputs (chemical fertilisers, pesticides) while focusing on creating a closed-loop system in which the outputs of one system (such as manure) can be used as inputs for others (crop farming).

2. **Prioritise alternative protein sources for animal feed.** Reducing reliance on high-impact animal feed, such as imported soybean, will be key for successful circular farming in Groningen and the Netherlands. [162] Alternative protein-rich animal feed sources can be found in local crop residues and refined food processing by-products (enriched grass, beet pulp, potato peels, brewers' grains, algae and microorganisms, for example).

3. **Support energy autonomy in farms.** On-site renewable energy generation from solar panels and small-scale wind turbines, alongside efficiency and conservation measures, can contribute to greater energy autonomy of farms. Bioenergy production using on-site anaerobic digestion of animal waste (manure) and other organic streams is also an effective measure towards this goal. Recovered biogas can then be used to co-generate heat and electricity through combined heat and power systems, which are suitable for powering on-farm processes (heating, electricity consumption) but could also feed into energy exchanges and cooperative approaches with neighbouring farms or communities.[163]

IMPACT ASSESSMENT

ECONOMIC VIABILITY AND COMPETITIVENESS

- **Higher operational costs.** Based on productivity factors, circular and regenerative practices are generally seen as less economically attractive than intensive farming. Indeed, when asked about the feasibility of circular agricultural practices, farmers from Limburg note that the main drawbacks are higher costs (up to 73% higher) and less income (64% less) due to the difference in productivity and economies of scale compared to intensive agriculture.[164] [165] This is especially true in smaller-scale farms, where productivity and economies of scale are limiting factors.

- **Cost of infrastructure.** Transitioning to circular agriculture involves costly infrastructure changes, including farm layout adaptations, technology implementation and efficient waste management systems, which can be a financial barrier for farmers without sufficient resources or access to funding.

- **Long-term policies and incentives could offset higher costs**. Access to financial incentives, subsidies or support programs can help alleviate these concerns and facilitate the adoption of circular practices. The Dutch government committed to unlocking €227 million to enable farmers to transition their businesses toward sustainability and circularity by 2040.[166] An additional €25 billion was made available to reduce the cattle herd size to compensate for higher costs to farmers.[167] In addition, a variety of tax allowance schemes for renewable energy production have been introduced in the country that favour the uptake of biogas plants, such as the Opslag Duurzame Energie- en Klimaattransitie (ODE) tax, the Energy Investment Allowance (EIA scheme) and the SDE++ subsidy.[168]

Higher costs of circular agriculture could also be offset by:

- **New markets for circular and regenerative agriculture**. The market for regenerative and sustainable agriculture (for which circular practices are key enablers) is on the rise. In 2022, it reached a global market size of $975 million (roughly €897 million) and is expected to reach $4.3 trillion (roughly €3.96 trillion) by 2032. Europe makes up about 29% of this market share, and provinces like Groningen—top agricultural producers—are in a highly favourable position to take over a large market share in the future.

- **True pricing.** As Rabobank's Food and Agriculture Sector Manager mentioned in an interview: 'Farmers should not be the only ones to face the financial consequences of a circular shift, and this means that consumers and retailers must be willing to pay a fair price and appreciate food more'.[169] This will include appreciating the value of locally produced food and responsible agricultural practices. Luckily, regenerative and circular agricultural products often command a price premium, which helps offset the costs associated with these practices. In direct sales and local markets, circular products can achieve higher selling prices by effectively telling the story of their production process.

- **Potential cost savings in the long run.** Resource and material savings can be achieved through circular agricultural practices via:

    - **Avoided externalities.** Perhaps the most important 'cost savings' are those that cannot be estimated (costs that are not reflected in the market price),[170] coming from the avoided negative externalities that a circular and regenerative farming system offers, such as improved soil health, enhanced biodiversity, and reduced water and air pollution.

- **Cheaper, locally produced and more productive animal feed grain.** Alternative animal feed sources show promising performance regarding nutritional values per feed unit required. For instance, the Dairy Campus in Leeuwarden (Friesland) uses enriched grass as animal feed.[171] This often overlooked source of protein yields two and a half times more protein per hectare than its imported counterparts (such as soybeans). Additionally, research by Silvis et al. (2021),[172] suggests that an overall reduction in livestock numbers could increase the feasibility of using locally produced animal feeds (from EU and Dutch suppliers)—as total herd size decreases, using (more) locally produced animal feed becomes more feasible.[173]

- **Energy cost savings.** Utilising manure and other agricultural residues as feedstock for the on-site production of biogas also reduces the energy costs (heat and electricity) associated with running and operating a farm, making individual or collective farming systems more self-sufficient and resilient to the effects of major global shocks (the Ukraine-Russia war impact, for example) on fuel prices. This could achieve substantial long-term net benefits if done at a large scale (across multiple farms or through a rural energy cooperative).

- **Increased food production.** After overcoming initial challenges such as investments, training and policy support, circular agriculture has the potential to increase food production (up to 70%, as estimated by Wageningen University), but it's important to note that its effectiveness also depends on factors such as local conditions, implementation strategies and farmer expertise.[175]

Environmental impacts

- **Energy savings and associated GHG emission savings.** A large portion of the nitrogen management strategy for agriculture is based on the proper management of livestock manure. Surplus manure is, therefore, a pressing concern in Dutch agriculture. The good news is that manure is found on livestock and dairy farms in sufficient quantities to fulfil farms' energy needs, generating potential emission reductions of up to 173 tonnes of CO_2e per year for larger farms.[176] This is particularly relevant as the Groningen agricultural census shows that approximately 70% of cattle farms fall under the category of larger farms (100 to 200 animals and above).[177]
- **Reduced virgin material consumption.** Circular farms reduce material consumption by implementing strategies such as nutrient cycling, water conservation, waste management, energy efficiency, closed-loop systems and localised production. By utilising closed systems where waste is recycled and reused, circular farms minimise the need for external inputs and resources, such as fertilisers and water. They also focus on energy-efficient technologies, efficient water usage and local production to reduce transportation and associated material consumption.
    - **Cheaper, locally produced and more productive animal feed grain.** Circular practices in livestock farming reduce dependence on imported animal feed by incorporating locally sourced alternatives. This reduction in reliance on imported feed has important implications for reducing the environmental footprint of animal products, specifically by minimising the land use impact associated with soybean meals.[179]
- **Lower environmental pollution.** Circular agricultural practices not only benefit local ecosystems but contribute overall to improved soil and water quality by reducing emissions, runoff of pollutants and nutrient leaching. At the farm level, specific livestock feed alternatives have shown a significant positive impact on pollution reduction with higher nutritional values. For example, trials with enclosed grass at the Dairy Campus in Leeuwarden (Friesland) demonstrated emission reductions of at least 30% for nitrogen and phosphorus, as well as up to 15% reductions in methane emissions from dairy cows' enteric fermentation.[180]

On site biogas production is a reality for Dutch farmers

Five farmers from Oxe, near Deventer, recently started Oxe Geeft Gas—a local biogas network of on-farm bio-digesters connected by a ten-kilometre pipeline. The initiative was launched to shift away from using natural gas for on-site operations. The total cost of infrastructure installations was about €3 million. The cooperative received a subsidy of €500,000 to cover some of the costs of construction and, while the total investment is seen as a considerable risk, the farmers believe it is an investment in the energy transition and expect longer-term benefits for themselves and society.

Long term benefits of biogas

An assessment of the long-term benefits of biogas and biomethane production using anaerobic digestion of various Irish feedstocks shows that organic waste (food or crop waste, manure, or slurries) is the most viable and beneficial long-term option.[174] The results of this study show net benefits of €126–147 million by 2030 and up to €581–661 million by 2050, assuming a fossil fuel price increase following a rising carbon taxation. While these figures are only indicators, it shows the magnitude of the benefits that can be achieved if a large system (a country or even a province like Groningen) leverages the organic waste flows for local energy generation.

Energy generation from manure

Several dairy farms in the Netherlands have started collaborating with biogas technology specialists HoSt and the Jumpstart initiative (from FrieslandCampina) to explore on-site energy generation from manure.[178] In each of the five fairy farms taking part in the trial, an average of 14 thousand tonnes of manure is expected to be converted into 320,000 normal cubic metres of biomethane (product of anaerobic digestion), which would be sufficient to replace the gas consumption of 240 homes.

Social impacts

- **New jobs and skills.** Despite facing strong public opposition, the 2019 Dutch court ruling on nitrogen limits has motivated some farmers to explore different strategies in circular agriculture. These approaches range from utilising technology to making holistic changes in farming methods, thus potentially creating new jobs that require a mix of traditional farming knowledge, technological skills and an understanding of sustainable practices. Possible emerging roles include agricultural extension officers with circular practices expertise, waste-to-resource innovation specialists, farm shop managers, precision agriculture specialists and bio-based product developers.[181]

- **Addressing job displacement via reskilling.** The shift towards more sustainable, circular agricultural practices might displace existing occupations in conventional farming, chemical input suppliers and intensive livestock farming. This could lead to decreased demand for transportation and logistics services associated with non-sustainable supply chains, such as long-distance shipping of agricultural inputs or products. To address this, targeted reskilling programs are necessary to ensure workers throughout the agricultural value chain can transition to new occupations within a circular agricultural sector. In Groningen, existing training organisations like The Future Farmers Movement[182] or FarmHack[183] will be key, as they provide training programmes and knowledge sharing and networking opportunities for young and more experienced farmers.

- **A new rural economy.** Circular farming means that arable farmers, livestock farmers and other members of the value chain (such as food processing companies, logistics companies, market retailers) work more closely together.[184] Ultimately, this creates alternative networks, new behaviours, demands and practices. Rather than following an exponential scale-up pattern, Groningen can lead by example and establish a new way to produce, consume and do business.[185]

Strengths & opportunities

KEY STRENGTHS AND OPPORTUNITIES FOR THE NATIONAL PROGRAMME GRONINGEN AND LOCAL STAKEHOLDERS TO LEVERAGE:

- **Land availability** makes it easier to optimally reallocate space.

- **Capacity for innovation and technological adoption.** Groningen's agricultural sector is already demonstrating its ability to innovate and experiment with new ways of operating through various projects (such as FASCINATING and CHEMPORT EUROPE). Moreover, farmers often embrace precision farming techniques, such as using satellite imagery, sensors and GPS technology to optimise crop management, increase productivity and minimise environmental impact.[186]

- **Collaboration and knowledge.** Exchange Farmers in the region actively collaborate with research institutions, agricultural organisations and each other. This collaborative approach facilitates the sharing of knowledge, best practices and the adoption of new technologies, leading to novel circular farming practices.

- **A national and European sectoral front-runner.** Groningen is well-positioned to become a global leader in circular agriculture, leveraging its long history of agriculture, advanced in knowledge and expertise.

- **Enabling conditions for short and collaborative value chains**. Many of the success criteria for a circular agriculture transition lie in the overall shortening of value chains, localisation of activities and closer collaboration and development of new economic relationships among different local actors (suppliers, logistics, customers, facilitators). Fortunately, the province presents excellent baseline conditions for these to take place:
  - Highly developed and efficient logistics network
  - Geographical proximity between agricultural land, food processing facilities, cities and local end-consumers
  - Presence of all members of the value chain within Groningen and nearby provinces.

- **Funding for the transition is available.** The Netherlands' Common Agricultural Policy (CAP) Strategic Plan will make significant subsidies available to farmers.[187] Other schemes support artificial fertilisers and payment for ecosystem services, where farmers receive payments or tax exemptions for implementing circular practices.[188] Moreover, since 2017, subsidies have been available for small-scale biogas projects. Biogas projects, which have higher operational costs than options like solar power or woody biomass burning, typically struggle to secure subsidies. These projects obtained €150 million in funding, indicating their potential and the government's support for their development.[189]

Weaknesses & threaths

CRUCIAL WEAKNESSES AND THREATS THAT THE NATIONAL PROGRAMME GRONINGEN AND LOCAL STAKEHOLDERS NEED TO ADDRESS

- **Dependency on global markets.** It is difficult for individual farmers to make drastic changes, as they are very vulnerable to global trends. Farmers are susceptible to changes in crop prices, and productivity factors still drive economic viability under the current system.
- **Legislative barriers.** Policies and regulations significantly influence agricultural practices, but sometimes they fail to effectively support or encourage circular agriculture due to bureaucratic obstacles, restrictive regulations and unclear guidelines, discouraging farmers from adopting circular practices.[190] For instance, current regulation on manure processing and application makes it very difficult for manure by-products (even correctly diluted) to be used as substitutes for fertiliser.[191] Overall, stakeholders from the agri-food sector can feel overwhelmed by new regulations and by the different levels in which they may be introduced (provincial, national and EU levels), which increases the likelihood of inconsistencies, incoherence and overall lack of clarity.
- **Lack of appreciation for ecosystem services or positive externalities** that farmers could provide by adopting new practices. Circular farms often prioritise sustainable practices that minimise negative environmental impacts, such as minimising resource use, reducing waste generation and promoting ecological balance. These impacts are difficult to quantify and, generally, not recognised, leading to underinvestment or underutilisation.
- **Farmers' willingness to adapt.** Farming and agricultural practices are the first steps of the value chain, so convincing the key stakeholders in those activities is essential for any substantial change to happen. However, it is unclear whether or not the new perspective of the 'agriculture of the future' is embraced by all.
- **Scale-up potential.** Implementing circular agriculture on a large scale can be challenging, particularly if there is resistance to change or if markets are not well developed. Adapting existing farming systems to circular models may require time, experimentation and adjustments to local conditions. Moreover, the success of circular agriculture relies on market demand for sustainably produced goods and consumer willingness to pay a premium for such products, which is uncertain in the future.

What needs to happen

WHAT STILL NEEDS TO HAPPEN FOR THIS STRATEGIC DIRECTION TO BECOME A REALITY?

Policy and regulations

- **Define a clear narrative for circular agriculture.** The term 'circular' is already referred to in many governmental strategies, both at the national and provincial levels. However, a clearer definition must be developed—particularly highlighting what it means for the entire food value chain—for businesses, investors and policymakers.

- **Enforce regulations.** Stricter regulations on agricultural and environmental conditions will apply to more than 96% of the Netherlands' agricultural area in an effort to reduce emissions and protect natural resources.[192] Enforcement of these new regulations will be crucial to ensure compliance, deter harmful activities, protect public health and the environment, promote fairness, preserve natural resources and contribute to the overall sustainability of the sector.

- **Ensure that subsidies reach the right farmers**. Subsidies provide financial support, incentivise adoption, stimulate market development, foster innovation and align agricultural policies with circularity goals, thus helping farmers overcome financial barriers of a new, circular agricultural system. Many subsidy schemes already exist, and they must reach the right farmers. Further subsidies designed by the National Programme Groningen should include targeted eligibility criteria, a robust verification and documentation process, regular monitoring and evaluation and capacity building. For the latter, a good example is the sustainable agricultural plan for Groningen, which makes information available to stakeholders by summarising the different sources of public funding (from local and national levels) being made available for different purposes.

Support from private finance

Financial support to make the transition viable should not only come from the public sector—local financial market participants also have a lot of power to support circularity in the agrifood value chain. Banks are in an excellent position to do so, for example, by providing loans with favourable conditions according to sustainability and circular criteria (in terms of machinery used, practices, type of materials and resources used).

Skills Development

- **Skillset development.** Circular agriculture practices require a diverse skill set that encompasses organic farming expertise, precision agriculture skills, efficient waste management, bio-based product development, sustainable supply chain management and an understanding of agricultural laws and policies. Tailoring adult learning strategies to local conditions is crucial for successful training programs and ensuring buy-in from conventional workers.[193] The new Common Agricultural Policy (CAP) in the country provides funding of €1,750 per farmer for training, benefiting a network of 2,100 advisors.[194]

- **Research and development (R&D) needs.** Grants are being allocated for research aimed at advancing more sustainable practices in various areas of circular agriculture.[195] Further research is needed to optimise the recycling of residual flows from the food industry, advance precision agriculture technologies and develop new business models that align with circular economy principles. Experimental testing sites like 'Lighthouse Farms' can be utilised to explore and implement new technologies and practices in circular agriculture.[196] Additionally, research focusing on overcoming regulatory and financial barriers, such as utilising green (urban) spaces for local food production, is also important in promoting circular activities.

4 • URBAN-RURAL-INDUSTRIAL SYMBIOSIS

Urban areas serve as an incredible source of materials for the circular economy, offering abundant streams of recyclable materials, organic waste, and secondary resources that can be recycled and transformed into high-value products, minimising waste and fostering symbiotic relationships between urban, rural and industrial areas. For example, sourcing biomass from urban areas (such as organic and yard waste) can help meet the increasing demand for feedstock for the bio-based economy, thereby reducing the pressure on agricultural land and promoting a more sustainable and circular bioeconomy. Other materials, such as plastics and Construction and Demolition Waste (C&DW), can then be used as secondary raw materials for the chemical industry. This is crucial to close material loops and create a local, circular economy. Indeed, urban areas will be the end market and consumers of all the products produced from recovered materials. As such, they can drive the demand for higher-value products, while providing secondary materials to produce them sustainably. Together, this can greatly contribute to reducing the reliance on virgin materials, lowering energy consumption and minimising the environmental impacts of waste—contributing to ambitions such as Groningen's 2030 waste-free goal.[197]

Various approaches will be necessary to facilitate urban-industrial symbiosis, such as:

1. **Improving separation of urban waste streams to facilitate higher-value valorisation.** Carefully considering separation techniques for different material streams can enhance the quality and purity of recovered materials, making them more suitable for inputs in industrial and agricultural processes. For instance, specific separation methods can be applied to plastic and metal waste to obtain clean and high-quality materials for recycling, as well as organics. These materials can then be used as inputs in the production of chemical compounds, bio-based polymers, packaging materials, or bio-fertilisers.

2. **Harvesting biomass in cities** Various sources of biomass, including shrubs, roadside clippings, yard waste and other organic waste, can provide a valuable alternative to virgin biomass (see Strategic Direction #1) while promoting biodiversity and helping reduce the negative environmental impact of monocropping biomass at a large scale. For example, the trimmings from shrubs in urban parks and gardens, as well as garden waste, can be collected and used as feedstock for bio-based chemical production or for bio-fertilisers. Roadside clippings, such as grass and small branches, can also be collected and processed for biomass conversion.

3. **Urban mining.** Cities are considered urban mines because they generate a significant amount of C&DW that can be recovered, recycled, and reused to minimise resource extraction and promote sustainability in various sectors. C&DW often contains organic materials such as wood, sawdust and plant matter that can be used as inputs for composting. Non-recyclable C&DW, such as timber, can be used as a feedstock for biomass energy generation. Finally, specific materials such as crushed concrete and gypsum from drywall can offer valuable chemical compounds that can be used in the chemical sector or for soil stabilisation—mixed with soil, they can improve its strength and stability, making it suitable for agricultural applications like road construction, irrigation channels or retaining walls.

4. **Valorisation of wastewater streams.** Through appropriate treatment methods like nutrient recovery, nutrients such as nitrogen, phosphorus and potassium can be recovered from wastewater streams and transformed into fertilisers or soil amendments. Specialised treatment processes, such as anaerobic digestion, can also produce biogas as a byproduct or provide feedstock for bio-based chemicals via anaerobic fermentation or microbial conversion. After treatment, water can be reused for irrigation or other purposes, reducing the use of groundwater from industries.

How to choose the best separation technique

Zero Waste Europe recently investigated the winning formula for waste management in cities. It found that door-to-door collection, supplemented by Pay-As-You-Throw (PAYT) and Deposit Return Systems (DRS), can achieve separate collection rates above 90%, while mixed waste sorting (MWS) can serve as a final backstop. Waste management in Groningen, like in the rest of the Netherlands, solely relies on mixed waste sorting. This, however, makes it hard to achieve recycling rates above 60 to 70% and to achieve the Dutch goal of 100% circularity.[198]

IMPACT ASSESSMENT

Economic viability and competitiveness

Upfront investment

Upfront investment to expand processing capacity locally is key for improving waste separation in the province and ensuring that waste is available in an optimal form. In the municipality of Groningen, organic waste forms the largest share of the residual waste stream, followed by plastics.

- **Increasing organics collection.** In 2019, the average resident in the municipality of Groningen produced 150 kilogrammes of waste. Although many of these residents have access to a separate container for organic waste, only 20 to 48% of the residual waste collected contained organic waste. This translates to 30 to 73 kilogrammes of organic waste per resident per year. Clearly, the potential for better management of organic waste is high. In a bid to improve better organics recovery, the municipality of Groningen is procuring more organic waste containers for residents. They estimated that 50 new containers in public spaces would require a total investment of €137,500.[200]

- **Expanding plastic recycling capacity.** Evaluating the existing recycling infrastructure in Groningen is crucial. The availability of efficient recycling facilities, collection systems, and sorting technologies can impact the feasibility and cost-effectiveness of sourcing plastics from urban waste streams. Many municipalities in Groningen found that sorting plastic waste after collection is financially advantageous and produced better recovery yields. However, investments in plastic recycling facilities are needed to align the demand for these materials with the actual recycling capacity. Plastic generated in the province, and surrounding regions, should be circulated to avoid having to import separated plastic waste and export plastic waste not separated sufficiently for recycling.

- **Urban mining infrastructure.** Only 8% of materials in the construction sector come from secondary materials.[201] Investing in digital and physical infrastructure is crucial for efficient recovery of C&DW. Digital infrastructure, such as marketplaces, can streamline material exchange, while physical infrastructure can enable effective C&DW management. Local governments play a key role in shaping waste management infrastructure, connecting facilities and fostering a closed-loop system. Infrastructure investments include C&DW recycling facilities, reconditioning centres for building elements, and material marketplaces for redistribution.

Cost savings and incentives.

- **Organics.** The processing costs of separated organic waste are lower than when it is mixed with other waste streams. In addition, the quality is typically higher, meaning that compost can be sold at a higher price, further mitigating processing costs.

- **Savings on waste tax.** The municipal waste tax levied on residents is partly determined by the amount of residual and organic waste produced overall. Given that the tax on organic waste is lower than residual waste, there is a financial incentive for residents to both separate the waste streams and to reduce the amount of residual waste.[203]

- **Landfill savings.** Reusing and recycling C&DW for high-value purposes can result in cost savings for materials that you have to pay to dispose of in landfills or would sell at low prices to feed into low-value product production.[204]

Value creation from the urban built environment.

- **C&DW.** In the Northern Netherlands provinces of Groningen, Drenthe and Friesland, more than two million tonnes of secondary materials could become available during the demolition of buildings until 2030.[205] If these materials are reused and recycled, they are valued to be worth €136 million alongside a reduction of €4 million in environmental costs.[206]

  An existing C&DW sorting facility in Groningen, operated by PreZero, could harvest some of these benefits as it will soon be replaced by a new, more advanced installation. This new installation will use innovative technology to separate C&DW more efficiently to allow for better reuse and recycling applications and subsequently reducing the low-value disposal applications. The new facility will have the capacity to process 160 thousand tonnes of mixed C&DW annually. Examples of higher value applications that this facility promotes are the use of wood to be reused as chipboard and rubble that can act as feedstock into new concrete production, as opposed to road foundation.[207]

- **Revenue from urban biomass.** Grass verges alongside motorways and roads can yield 31,000 tonnes per year of harvested grass in the province. There could be potential to use the verges more optimally by planting faster-growing shrubs that allow for a higher yield of biomass that can subsequently be valorised, creating additional value. This intervention could also increase road safety by acting as an impact barrier whilst promoting biodiversity.[208]

Environmental impacts

GHG emissions savings

- **Organic waste** that is not separated is typically incinerated in the Netherlands. Incineration of organic waste is found to emit 50 kilogrammes of CO_2e per tonne of organic waste. This is still a favourable alternative to incinerating fossil fuels which has a higher emissions contribution.[209] However, incineration does not enable nutrients to be recycled and is thus not a strong contributor towards circularity. Indeed, it is not included in the EU Taxonomy for the Circular Economy. [210]

- **Plastics:** GHG emissions would fall sharply in the Netherlands if the plastics were recycled instead of being incinerated.[211] About 38% (89.8 thousand tonnes) of household plastic waste is currently incinerated in the Northern Netherlands. By instead recycling the plastic waste that is currently incinerated, 149 thousand tonnes of CO_2 emissions could be saved.[212]

- **Circular built environment practices** have the potential to cut GHG emissions by 49% by 2030 and decrease nitrogen emissions by 60% by 2030.[213]

Water savings from wastewater treatment

Wastewater treatment plays a crucial role in the Northern Netherlands as it provides an alternative source of water for irrigation and chemical processes, reducing reliance on groundwater extraction. [214]

Reduced virgin material consumption

Better recovery of waste for high-value products ultimately reduces the consumption of fossil fuel inputs for synthetic materials.

- **Circular built environment practices** can halve resource consumption by 2030. Meanwhile, using more bio-based materials could cut the mass of primary inputs by 81%.[216]

- **Recovery of cellulose from wastewater** can reduce the need for primary inputs for many industrial and rural activities. Wastewater contains a solid fraction consisting primarily of cellulose, coming from the use of toilet paper. An R&D project based in Groningen looked at separation of the solid fraction containing cellulose in the sewage water as a means to facilitate sewage sludge dewatering.[217] This method was found to significantly reduce the use of chemicals in the wastewater treatment plant, consume less energy and lower sludge processing costs. Additionally, the energy yield from the fermentation of the resulting sludge was found to be higher.[218] Recovered cellulose can then be used to feed into key sectors:

    - **Animal feed**: Purified cellulose from wastewater can be processed into feed additives for livestock, such as ruminants and poultry. Cellulose acts as a dietary fibre source, improving digestive health and nutrient absorption in animals.

    - **Food ingredients**: Cellulose derivatives, such as microcrystalline cellulose (MCC), can serve as food additives, providing textural enhancements, stability and fibre content to food products. MCC is commonly used as a thickener, stabiliser or bulking agent in various processed foods.

    - **Plant protection:** Cellulose-based materials can be used in agricultural applications, such as biodegradable mulch films or biostimulant coatings. These materials help conserve moisture, control weed growth and protect plants while degrading naturally over time.

    - **Bio-Based materials:** Cellulose from wastewater can be processed into bio-based materials, such as cellulose nanocrystals or cellulose acetate. These materials can be utilised in various applications, including biodegradable packaging, coatings, films and textiles, offering sustainable alternatives to petroleum-based products.

    - **Bioenergy:** Cellulosic biomass, including cellulose from wastewater, can be converted into biofuels through processes like enzymatic hydrolysis and fermentation. Cellulosic ethanol and other biofuels derived from cellulose can be used as renewable alternatives to fossil fuels in the transportation sector.

Avoided waste generation through material recovery

Increasing urban waste recycling, whether it's organics, plastics or C&DW, leads to the benefit of reducing overall waste. By diverting these materials from disposal and reintegrating them into the production cycle, the environmental impact and resource consumption associated with waste generation can be minimised.

Social impacts

- **Cities as centres of human capital and consumption.** Urban areas serve as hubs of human capital, attracting a skilled workforce and providing the necessary labour for urban-rural-industrial symbiosis to thrive. Moreover, they are centres of economic activity and the concentration of people in urban areas creates a large and diverse consumer base. High-value products made from secondary materials coming from cities can find in cities an attractive market to see new products.
- **Jobs opportunities in advanced waste separation.** By establishing sophisticated waste separation and processing facilities in Groningen, roles for technicians, operators, and supervisors can be amplified. The development of industrial symbiosis also requires a range of professionals adept in circular economy strategies, such as supply chain management, industrial ecology, environmental engineering, data analysts, urban waste researchers, policy experts, industrial symbiosis facilitators and educators, all working together to fine-tune supply chains and cultivate intra-industrial partnerships. Fostering collaborative relationships between industrial actors is pivotal in addressing the challenge of attracting more engineers to new industrial parks. The proactive approach of stakeholders at the Industrial Park Kleefse Waard is already a good example to follow.[219]
- **Job transformation is required to achieve a more advanced waste management in Groningen.** Adopting a symbiosis relationship between industry and urban areas, focusing on advanced waste management in Groningen, may result in the transformation of job roles, particularly within traditional waste management systems like incineration or landfilling and in labour-intensive low-skilled recycling jobs. As lower-value waste disposal practices, such as incineration, will be gradually phased out, it will impact these related occupations. However, the skills required in the newly emerging roles within industrial symbiosis and efficient waste management are often not drastically different from the existing capabilities of workers in these areas. Consequently, with adequate reskilling and upskilling initiatives, individuals employed in conventional waste management and recycling roles have the potential to transition and thrive within the evolving industrial symbiosis and advanced waste management framework.
- **More green in cities.** Harvesting biomass from cities will mean more urban green spaces, such as parks, gardens and trees. Urban green is found to promote healthier lifestyles, improve mental wellbeing, reduce stress levels, and enhance overall quality of life for residents in densely populated urban areas like Groningen

Strengths & opportunities

KEY STRENGTHS AND OPPORTUNITIES FOR THE NATIONAL PROGRAMME GRONINGEN AND LOCAL STAKEHOLDERS TO LEVERAGE:

- **Proximity between urban and industrial areas.** The distance between these operations and urban areas is small due to the presence of industrial clusters within the province. This can facilitate closing material loops within the province.
- **Strong innovation ecosystem.** Many of the interventions either require innovation to advance the technology (for example, plastic sorting facilities) or analysis to decide on the most optimal strategies (for example, household versus post-sorting of plastic waste).
- **Political ambition to push innovation**. Given the city's goal to become waste-free by 2030, the incentive to pursue strategies to achieve this is there.
- **Increasing demand to produce sustainable products.** Waste from urban areas faces ever-growing demand from industries in their bid to produce more sustainable products such as recycled plastic, concrete and alternative animal feed.

A threat for recycling: organics, plastics and bio-based plastics

The increasing volumes of bioplastics entering the waste stream pose a challenge for both organic processing and plastic recycling facilities.[202] Bioplastics, which are made from renewable resources, have different properties than traditional petroleum-based plastics. While bioplastics are often marketed as biodegradable or compostable, they require specific conditions to break down effectively—local facilities should be designed in a way that meets those requirements. Moreover, bioplastics can contaminate traditional plastic recycling streams when they are mistakenly mixed with petroleum-based plastics. This contamination can compromise the quality and purity of the recycled plastic material, reducing its value and usability in subsequent manufacturing processes.

To address these challenges, it is crucial to establish effective waste management systems and educate consumers and waste handlers about proper sorting and disposal practices. OMRIN, the province's main waste collector committed to circularity, is designing a new facility to increase organic treatment. The new facilities should be able to process bioplastics, and upgrade mixed sorting waste facilities in a way that bioplastics do not enter plastic recycling streams.

Weaknesses & threaths

CRUCIAL WEAKNESSES AND THREATS THAT THE NATIONAL PROGRAMME GRONINGEN AND LOCAL STAKEHOLDERS NEED TO ADDRESS

- **Balancing demand and supply.** The fluctuations in the traded volume of secondary materials across the EU and beyond indicate changes in the demand for these materials. It is important to assess the demand for secondary materials in the market and understand if there is a consistent supply for those if sourced from urban waste streams in the Groningen province.
- **Pricing Considerations.** Secondary materials are often more expensive than virgin alternatives. The business case of facilitating the urban-industrial exchange of some materials may be weaker than of virgin alternatives: virgin construction materials are, in many cases, cheaper than those that are urban mined, for example.
- **Lack of collaboration**. Waste management and industries typically work in silos. Industries need high quality materials to act as feedstocks and the waste management sector does not typically sort and characterise materials to such level of quality. Thus, advanced sorting and processing facilities can act as the key interface.
- **Lack of information.** Data describing the quantity and quality of material streams, for example C&DW, is often lacking and this makes it difficult to connect to other use applications.[220]
- **Regulatory bottlenecks.** Some materials are not permitted to be reused or recycled for high quality purposes due to quality or safety concerns: in some cases wood from C&DW that has the potential to be reused in Groningen must instead be incinerated, for example.[221]

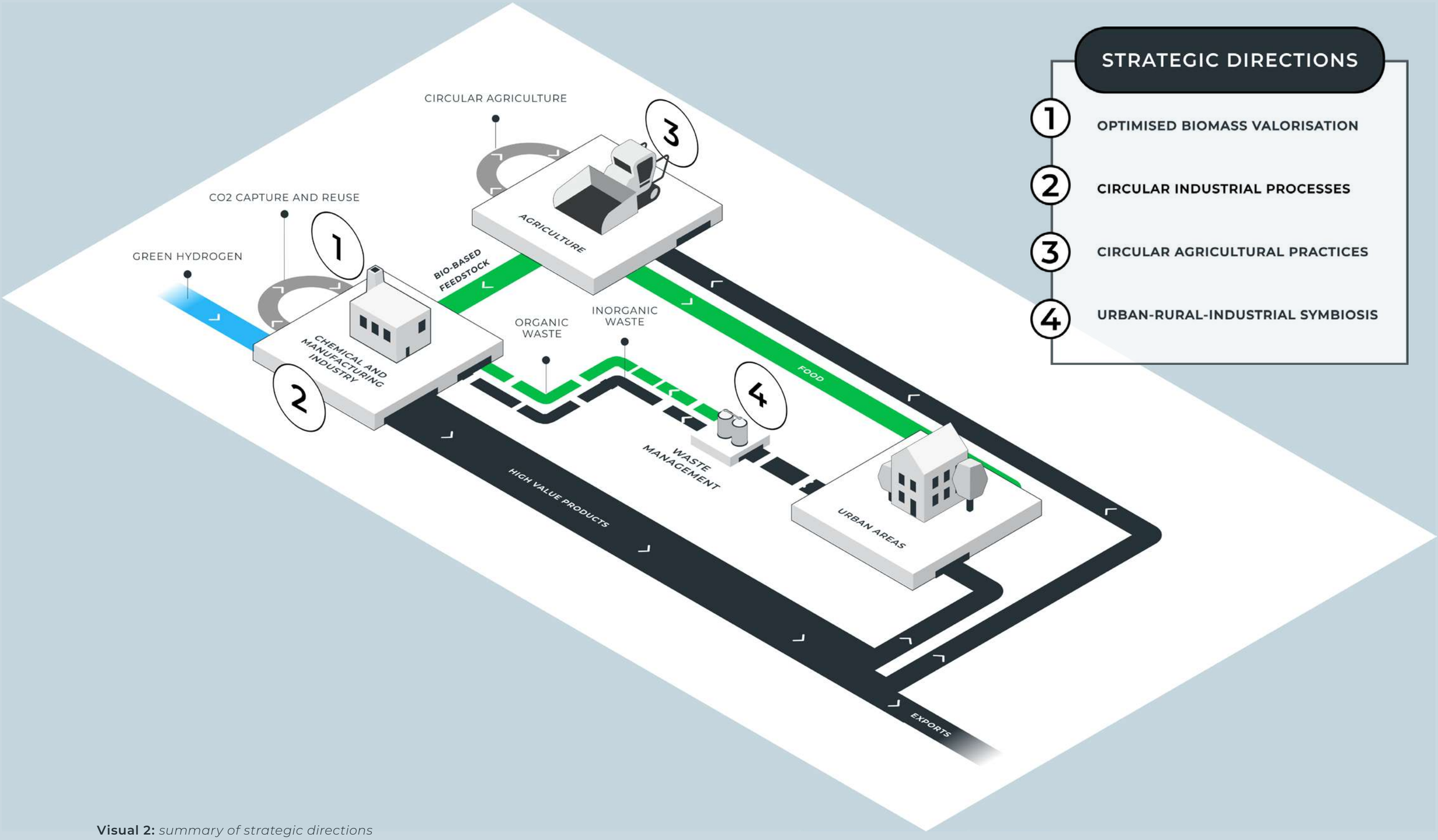
What needs to happen

WHAT STILL NEEDS TO HAPPEN FOR THIS STRATEGIC DIRECTION TO BECOME A REALITY?

- **Research should guide policymaking.** Researchers should also continue to study the most efficient and cost-optimal strategy for municipal separation, whether focussed at the household level or at centralised waste separation facilities with advanced separation technologies. A study in Northern Netherlands has already shown that post-separation (at a centralised waste separation facility) produces more separated plastics and of a higher quality than at a household level, however insights of treatment costs are still lacking.[222]
- **Coordination.** Waste management companies must coordinate with industrial parties to ensure that the waste they are handling is managed and processed in the most effective way to provide waste that can bring the highest possible value for industries. To do this, Groningen needs an entity that will take on the role of the facilitator to harmonise existing initiatives, identify synergies between them and facilitate collaboration and partnership creation (see Chapter four).
- **Public procurement.** Government can act as a key driver for products produced by industry using urban waste in order to stimulate the market. For example, newly constructed public buildings could have circular criteria in their tendering process to favour construction companies using local, secondary materials.
- **Fostering urban-industrial symbiosis through collaborative skills development initiatives.** For a successful implementation of urban-industrial symbiosis, mastery of waste management and recycling procedures, especially knowledge of advanced waste stream separation and processing technologies, is critical. Roles such as Residential Waste Management Specialist, Building Material Recycling Expert, Advanced Chemical Recycling Researcher and Circular Product Design Engineer would require this specific expertise. To foster partnerships between waste management companies and industrial sectors, skills in stakeholder facilitation and collaboration and business development are vital, creating roles like Business Developer for Waste Management, Industrial Symbiosis Facilitator and Circular Economy Project Manager. Indeed, these skills and roles are also essential in improving the synergies between knowledge institutes and companies, as it is important to align the fundamental research provided by universities with the practical solutions sought by companies.[223]

Google NL switches to surface water for its data centre cooling

In Eemshaven, North Water and Google Netherlands operate a water treatment plant based on surface water from an adjacent canal to provide cooling water for its data centre. Google invested €45 million in the project that involved the construction of the water treatment plant and a 28 kilometre pipeline. In its current configuration, the plant can produce up to 10 million cubic metres of processed water per year. The costs per cubic metre are said to be comparable to that of the local drinking water. The site was strategically located next to a wastewater treatment plant in the proximity of the city of Groningen, to allow for the future possibility to use treated wastewater as process water.[215]



Visual 2: *summary of strategic directions*

STAKEHOLDER ROLES AND RESPONSIBILITIES

Everyone will have a role to play in the circular transition. Groningen can count on a dynamic and well-aware business community, as well as societal and public sector support. Based on the research and analysis undertaken, experiences in other cities and regions, and the inputs from local stakeholders in workshop two, examples of the different stakeholders that will need to be involved in implementing the circular economy in Groningen include:

Visual 3: *stakeholder roles and responsibilities*

A key role belongs to local governments: cities and provinces

In the Netherlands, like many other countries, urban areas are responsible for the largest portion of material and carbon footprints. We must rethink how they do business and consume resources—and innovation must underpin this, as it does any disruptive transition. To spur the innovation needed, city governments in the province can:

1. **Mobilise stakeholders.** Local governments in the province and cities need a more proactive role to move towards more cross-cutting governance approaches. Value chains in the circular economy will inherently change. Local governments are well-positioned to map value chains and organise dialogue across different sectors, departments, and stakeholders to address complex and interconnected challenges. Via collaboration and partnerships, they can build new business ecosystems around new circular economies and strengthen their development locally.

2. **Educate.** Cities and provinces can increase the overall levels of awareness and build the necessary skills and knowledge around the circular economy to foster long-term change. They can use various instruments, including awareness-raising campaigns and capacity-building programs, as well as providing shared spaces like living labs or maker spaces that make resources available for co-creation and where best practices are shared. They do not have to do this alone. Initiatives such as Campus Groningen already leverage the city's innovative and young environment to provide multidisciplinary education and a space for experimentation and innovation in various fields.

3. **Leverage public procurement.** Cities and provinces can utilise their significant spending power to support developing and adopting innovative products and services, incentivising businesses to rethink their offerings, fostering a thriving ecosystem for innovation, supporting local businesses and startups, and driving competition among suppliers to catalyse new and innovative solutions.

4. **Use pilot projects to test and validate innovative ideas** and provide experimental platforms for cities to encourage creativity, mitigate risks associated with novel concepts, and assess feasibility. This will enable organisations to learn, improve and understand scalability while fostering collaboration, frequent communication, and agile adjustments based on feedback, thereby creating an environment conducive to circularity and aligning ideas with community needs. Communication will be key to share knowledge and expertise, but also to celebrate successes and results achieved through innovative projects.

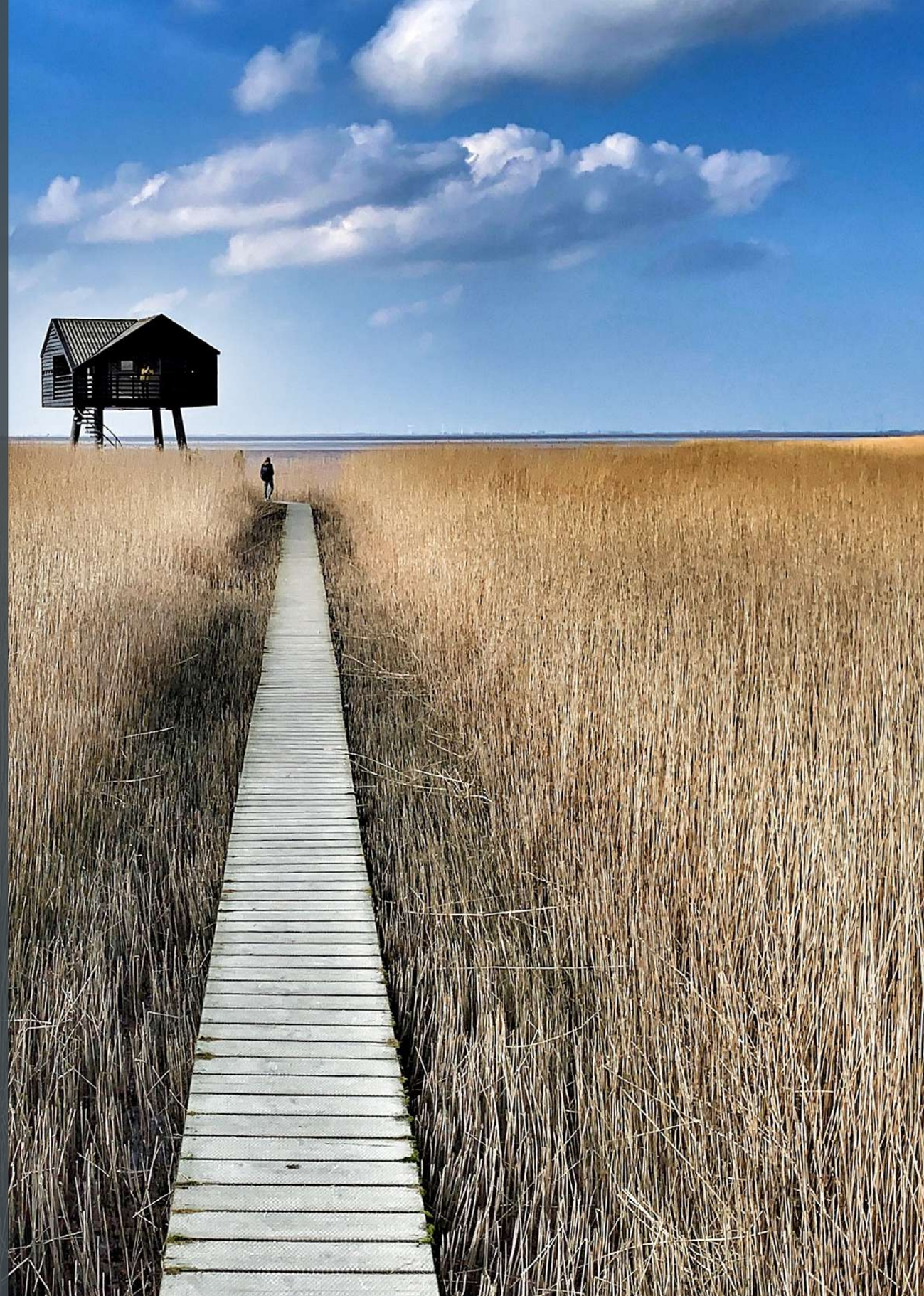
5. **Optimise spatial planning**. Cities and provinces can foster a circular economy and industrial symbiosis by designating specific zones, encouraging proximity between compatible industries, promoting mixed land use, repurposing underutilised sites, and supporting efficient infrastructure and stakeholder collaboration. This could also mean having to make room in existing eco-industrial sites and relocate companies with lower environmental performances in the future.

6. **Improve waste management.** By improving waste management practices, municipalities and provincial institutions can support the circular transition in the Agri-food and Chemical sector by collecting and sorting secondary materials for secondary inputs (such as plastic waste and organics). Secondly, they can find ways to connect waste streams with businesses that demand them and invest in recycling infrastructure and regulations that can foster waste-to-resource initiatives.

7. **Collaborate with others.** By creating a platform for dialogue between the province of Groningen and its five municipalities, the National Programme Groningen is a step in this direction. It can be leveraged to align and solve legislative bottlenecks, as well as make sure that small and big municipalities collaborate under the oversight of the province.

8. **Lead on advocacy.** Some circular practices or solutions may face regulatory barriers or restrictive regulations. To address this, Dutch provinces are jointly commissioning the National Strategic Plan within the new period of the CAP, which will require the provinces to pro-actively play a role in influencing the design of the policy framework, and making sure it aligns to the provinces' contexts, goals and ambitions as closely as possible.

4 · CONCLUSION



The transition to a circular economy in Groningen will require the region's main economic activities to undergo significant changes. The current structures and operations—in addition to their interactions across urban, rural and industrial landscapes—must be transformed. For the transformation to be successful, the region will require dedicated, long-term investment from national, international, EU (such as the EIB) and private investment partners. This investment, which should be in the range of hundreds of millions of euros, will form the foundation for necessary systemic transformation in the region.

The findings of this report aim to inform the National Programme Groningen's multi-year investment programme for using the circular economy to achieve sustainable economic transformation and improve welfare. By looking at key sectors, such as the Chemical Manufacturing and Agrifood sectors, as well as four material groups (biomass, plastics, hydrogen and CO_2 as a raw material), this report identified the local conditions and unique strengths of Groningen. In doing so, the report uncovered how the circular economy can best be implemented to limit long-term environmental impacts whilst creating a more resilient economy.

Four strategic directions have been defined based on the PESTEL and SWOT analysis: (1) optimised biomass valorisation for a circular bio-based economy; (2) circular industrial processes; (3) circular agricultural practices and (4) urban-rural-industrial symbiosis. The analysis of these strategic directions yielded several recommendations that this report aims to highlight:

1. **A value chain perspective** is essential for success across the four strategic directions. Financial resources should be invested in initiatives and projects that promote circularity across all stages of a product's lifecycle. This approach recognises the various interconnected phases of a product's lifecycle: raw material sourcing, production, distribution, consumption and disposal or recycling.

2. **Increased investment is needed** in some key activities, including biorefinery infrastructure, facilities development and maintenance, financial support to farmers changing their practices, developing advanced municipal waste sorting facilities, carbon capture and utilisation infrastructure, and upscaling projects that can use green hydrogen as a feedstock.

3. **By creating a strong ecosystem of collaboration** between different actors along and between value chains, supply and demand can be matched—resulting in high-value, innovative products that can create new job opportunities. Beyond this, strong collaboration is essential to inform education, training and R&D programmes, as well as infrastructure plans and building consumer awareness of sustainable behaviour.

4. **A focus on reskilling and upskilling** the existing workforce via vocational training programmes and life-long learning schemes will help meet the demands of these new practices and the innovations required. This cannot be achieved without a clear overview of stakeholders to involve throughout the process and their defined roles—from farmers,food processors and chemical manufacturers, to academics, the finance sector and public authorities.

The insights from this report recommend a tangible action plan with supporting investment strategies co-created and backed by local stakeholders. If the appropriate funding is made available, Groningen has all of the ingredients necessary to position itself as a circular frontrunner whilst supporting residents with new jobs and promoting local activities that foster social welfare and prosperity.

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*Authors,contributors and interviewees have contributed to the report in their individual capacities. Their affiliations are only mentioned for identification purposes.

Authors

Andrew Keys, Researcher (Circle Economy)

Claudia Alessio detto Grassi, Content Lead (Circle Economy)

Danai Louzioti, Researcher (Circle Economy)

Jordi Pascual Torner, Project lead (Circle Economy)

Otis Schwab, Project Manager (Circle Economy)

Pau Ruiz, Researcher (Circle Economy)

Design and layout

Isabel Lara Vega (Circle Economy)

Nicolas Raspail (Circle Economy)

Editorial

Ana Birliga Sutherland (Circle Economy)

Megan Murdie (Circle Economy)

Laxmi Haigh (Circle Economy)

Main contributors

Alex Berithu (NOM)

Heleen van Wijk (Groningen Seaports)

René Donkerbroek (National Programme Groningen)

Soraya Ludema (Chemport Europe)

Other contributors

Bart Volkers (Circular Groningen)

Carlo Ezinga (Rabobank)

Carolina Vogel (Gemeente Groningen)

Cor Kamminga (BioBtx)

Egbert Dommerholt (Hanze University of Applied Sciences)

Elzo de Lange (Fascinating)

Frans de Lorme van Rossem (Gemeente Groningen)

Gerwin Wiersma (Provincie Groningen)

Henk Fissering (Acantus)

Herman Prinsen (Netherlands Enterprise Agency)

Ineke Ganzeveld (Greenwise Circular Plastics, part of Chemport)

Jasper Munier (Clariter)

Marco Doorten (EEW)

Martin Tietema (Foamplant)

Niels Faber (University of Groningen)

Jeen Osinga (Avebe)

Lieve Prins (Provincie Groningen)

Robbert Bosscher (Gemeente Eemsdelta)

Suzanne Buter (Provincie Groningen)

Ton Vries (BioBtx)

Vincent Voet (NHL Stenden University of Applied Sciences)

Wanli Zheng (University of Groningen)

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