HyFINE

Green Hydrogen and Electrons for Specialty and Fine Chemicals

Project proposal 10 July 2025

Contents

Project proposal

1. General project information

Title of the project
HyFINE: Green Hydrogen and Electrons for Specialty and Fine Chemicals

Main applicant					
First name, surname, title	*Organisation*	*Appoint-ment*	*End date contract*	*Position*	*Expertise (in key words)*
[redacted]	Netherlands Organisation for Applied Scientific Research (TNO)	Tenured (indefinite)	Indefinite	Lead Scientist (TNO) and Associate Professor (TU/e)	[redacted]

Technical manager					
First name, surname, titles	*Organisation*	*Appoint-ment*	*End date contract*	*Position*	*Expertise (in key words)*
[redacted]	Delft University of Technology (TUD)	Tenured (indefinite)	Indefinite	Full professor	[redacted]

Co-applicants from research organisations					
First name, surname, title(s)	*Organisation/ host country*	*Appoint-ment*	*End date contract*	*Position*	*Expertise (in key words)*
[redacted]	Delft University of Technology (TUD)	Tenured (indefinite)	Indefinite	Full professor	[redacted]
	Avans University of Applied Sciences (AVANS)	Fixed-term	30/11/2031	Lector	
	Dutch Institute For Fundamental Energy Research (DIFFER)	Tenured (indefinite)	Indefinite	Senior scientist, Group leader	
	Fontys University of Applied Sciences (FONTYS)	Tenured (indefinite)	Indefinite	Lector	
	Hanze University of Applied Sciences (HANZE)	Tenured (indefinite)	Indefinite	Lector	

[redacted]	Leiden University (UL)	Tenured (indefinite)	Indefinite	Full professor	[redacted]
	University of Groningen (RuG)	Tenured (indefinite)	Indefinite	Full professor	
	[redacted]				
	Technical University Eindhoven (TU/e)	Tenured (indefinite)	Indefinite	Full professor	
	University of Amsterdam (UvA)	Tenured (indefinite)	Indefinite	Full professor	
	University of Twente (UT)	Tenured (indefinite)	Indefinite	Full professor	
	University of Utrecht (UU)	Tenured (indefinite)	Indefinite	Full Professor	
	Wageningen Research (WR)	Tenured (indefinite)	Indefinite	Principal Scientist	
	Wageningen University (WU)	Tenured (indefinite)	Indefinite	Full professor	

Co-applicants from enterprises and civil society organisations					
First name, surname, title(s)	*Organisation/ host country*	*Appoint-ment*	*FTE*	*Degree*	*Expertise (in key words)*
[redacted]	BTG Biomass Technology Group B.V. (BTG)	Tenure (indefinite)	1	PhD	[redacted]
	Feyecon BV (FEYECON)	Tenured (indefinite)	1	PhD	
	InCatT B.V. (INCATT)	Tenured (indefinite)	1	PhD	
	Mevaldi (MEVALDI)	Tenured (indefinite)	1	PhD	
	Paques Biomaterials (PAQUES)	Tenured (indefinite)	1	PhD	
	SCM Software for Chemistry & Materials B.V. (SCM)	Tenured (indefinite)	1	PhD	
	Signify N.V. (SIGNIFY)	Tenured (indefinite)	1	PhD	
	SULIS Polymers (SULIS)	Tenured (indefinite)	1	PhD	
	Vertoro (VERTORO)	Tenured (indefinite)	1	PhD	

Co-funders				
First name, surname, title(s)	*Organisation/host country*	*Type*	*Sector*	*Expertise (in key words)*
[redacted]	AkzoNobel	Business large	Industry	[redacted]
	Avantium Chemicals BV (AVANTIUM)	Business SME	Industry	
	BASF	Business large	Industry	
	Bronkhorst High-Tech B.V. (BRONKHORST)	Business large	Industry	
	ChainCraft B.V. (CHAINCRAFT)	Business SME	Industry	
	InnoSyn B.V. (INNOSYN)	Business SME	Industry	
	Nobian Industrial Chemicals BV (NOBIAN)	Business large	Industry	
	SCM Software for Chemistry & Materials B.V. (SCM)	Business SME	Industry	
	Shell Global Solutions International BV (SHELL)	Business large	Industry	
	Shimadzu Corporation (SHIMADZU)	Business large	Industry	
	Siemens AG (SIEMENS)	Business large	Industry	
	SULIS Polymers (SULIS)	Business SME	Industry	
	Symrise AG (SYMRISE)	Business large	Industry	

Collaborating partner				
First name, surname, title(s)	*Organisation/host country*	*Type*	*Sector*	*Expertise (in key words)*
		Other	*Other*	

Summary of the project budget	
	Amount in €
Requested from NWO	[redacted]
Funding other than provided by NWO:	
Own contribution of businesses and civil society organisations	
Contributions co-funders	
Total project budget	

Abstract

HyFINE brings together leading Dutch universities, HBOs, research institutes, SMEs, and industrial partners to accelerate the transition of the specialty and fine chemical sectors toward renewable feedstocks and the widespread use of green hydrogen and green electrons as key energy vectors. Embedded in the GroenvermogenNL program (WP6), the project fully aligns with national ambitions to develop innovative chemistries, reduce fossil dependency, and enable a climate-neutral, circular economy. The project aims at the development of innovative and scalable processes to convert biomass, waste, and CO_2-derived feedstocks into high-value chemicals using thermochemical hydrogenation, electrochemical synthesis, and photochemical transformations. To achieve this, HyFINE creates enabling technologies, including advanced catalysts, modular electrosynthesis and photochemical platforms, and digital tools for predictive design. By integrating renewable feedstocks with sustainable energy carriers, HyFINE aims to establish modular, decentralised production systems that demonstrate how green hydrogen and green electrons together can drive efficient, redox-economic sustainable transformations across the value chain. The consortium builds an innovative value chain that combines the agility of SMEs with the scale and reach of large companies. Novel scalable technologies, advanced analytics, and multiscale modelling will help deliver production platforms proven in the Netherlands and relevant worldwide. Beyond technological innovation, HyFINE invests in training the next generation of scientists and engineers and sharing knowledge with stakeholders and society. Educational initiatives and structured collaboration will embed insights into industry practice and policy. By delivering cleaner synthetic routes and demonstration-scale processes, HyFINE positions the Netherlands as a frontrunner in climate-neutral, electrified chemistry and contributes directly to GroenvermogenNL's goals of sustainable growth and global leadership.

HyFINE Key Characteristics

Total investment: [redacted]

Timeline: [redacted]

Technologies: 4 key technology domains (catalytic hydrogenation, biochemical conversions, photochemical conversions, electrocatalytic conversions)

Academic positions: 16 PhD positions + 11 PostDoc positions = 27 positions for young scientists

Target products: [redacted]

Innovation: [redacted]

Concrete results: [redacted]

Research organisations: 15 Dutch research organisations (9 universities, 3 universities of applied sciences, and 3 research institutes)

Companies: 20 private companies (9 co-applicants, and 11 co-funders)

Small companies: 11 start-ups and SME's

Large companies: 9 multinational corporations

Staff: >100 scientists, consultants, and engineers

2. Consortium and productive interactions

2.1 Consortium

2.1.1 Consortium overview

The HyFINE consortium brings together 15 leading research organisations in the Netherlands (9 universities, 3 universities of applied sciences, and 3 research institutes), 5 leading international end-users coming from the chemicals sector, and 9 clean-tech materials, and 6 engineering and analytical companies from the entire value chain. More specifically, these clean-tech companies are active in activities ranging from biofeedstocks and catalyst materials supply, to developers of new chemistries, processes, software and equipment, such as reactors, characterisation and analytical equipment. The following graphic (Figure 1) provides an overview of all the participants in the consortium (totalling 35), including the research organisations, industrial end users and partners in the clean-tech industry. In HyFINE, the Dutch clean-tech companies together with the universities and research institutes will be developing the technology base for industrial end users worldwide.

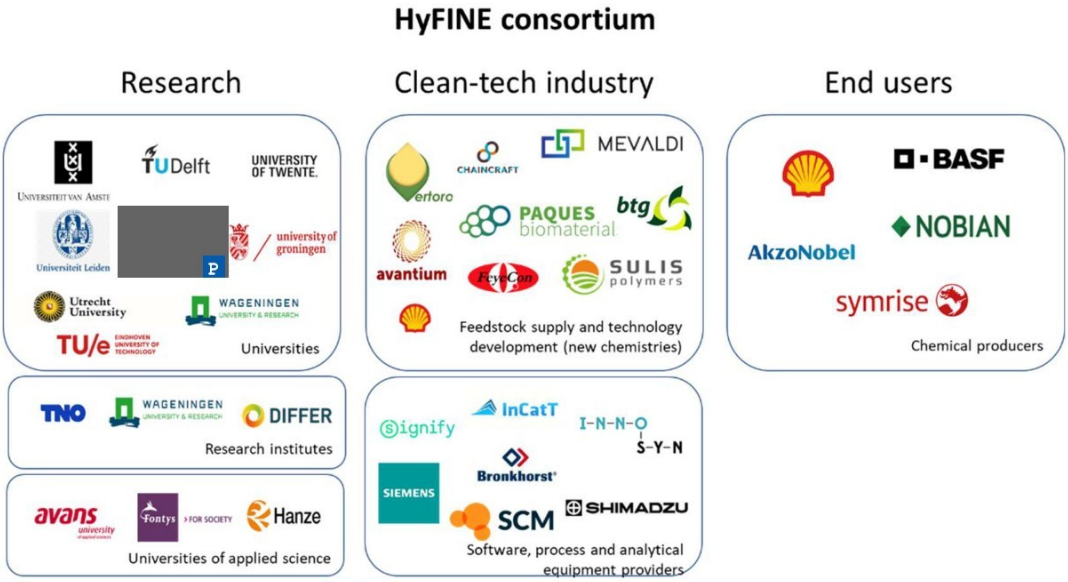


Figure 1: The HyFINE consortium and its partners, originating from different research organisations, institutions, SMEs and companies, including clean-tech industry and industrial end users.

Table 1 presents the partners divided over universities and research institutes, co-applicants and co-funders. Brief descriptions for each partner are provided in Appendix B.

Universities and research institutes	Co-applicants	Co-funders
Avans: Avans University of Applied Sciences **DIFFER:** Dutch Institute for Fundamental Energy Research **Fontys:** Fontys University of Applied Sciences **Hanze:** Hanze University of Applied Sciences **LU:** Leiden University **RUG:** Rijksuniversiteit Groningen [redacted] **TUD: Delft University of Technology** **TU/e:** Eindhoven University of Technology **TNO:** Netherlands Organisation for Applied Scientific Research **UvA:** University of Amsterdam **UT:** Universiteit Twente **UU:** Utrecht University **WR:** Wageningen Research **WU:** Wageningen University	**BTG**: Biomass Technology Group **Feyecon** **InCatT** **Mevaldi** **Paques:** Paques Biomaterials **SCM:** Software for Chemistry & Materials B.V. **Signify** **SULIS:** SULIS Polymers B.V. **Vertoro**	**AkzoNobel** **Avantium:** Avantium Chemicals **BASF** **Bronkhorst** **ChainCraft** **InnoSyn** **NOBIAN** **SCM:** Software for Chemistry & Materials B.V. **Shell:** Shell Gobal Solutions International B.V. **Shimadzu** **Siemens:** Siemens Digital Industries **SULIS:** SULIS Polymers B.V. **Symrise**

Table 1: The HyFINE consortium, including the various partnerships, thereby contributing to the different knowledge, and expertise to execute the proposed research programme. Abbreviations used in this proposal are in bold print.

2.1.2 Tasks structure and role of partners

HyFINE involves 35 partners. TNO is the main applicant for this project, represented by [redacted] as the Project Leader. The project's Technical Manager is [redacted] who will further assist in the overall project coordination with a specific focus on the technological and scientific aspects of HyFINE. The Project Leader, together with the Technical Manager, the supporting project manager (delivered by TNO) and the Task Leaders for Task A and B constitute the Management Team (MT).

Three distinct Tasks, further labelled from A to C, have been defined when preparing the HyFINE proposal. Tasks A and B follow directly from the directions given in the GroenvermogenNL WP6 call for proposals, while Task C is added for coordination, strategic analysis and dissemination activities, and support the overall direction of HyFINE. Tasks A-C can be summarised as follows:

A. Specialty and fine chemicals from biobased and waste feedstock using green H_2 or green electrons;
B. Enabling technologies and methodologies for specialty chemical synthesis using green H_2 or green electrons;
C. Coordination, strategic analysis and dissemination activities of the project.

Tasks A and B are led by a Task Leader, supported by co-chairs who together represent both industry and the knowledge institutes. The industrial and academic Task Leaders and co-chairs were selected by the full assembly of applicants for merit of their knowledge in the relevant field of expertise, their capability to deliver an innovative proposal for their respective tasks and expected leadership during the execution of the project. The Task Leaders participate in the Management Team. The Task Leaders (mentioned first) and co-chairs (mentioned second) are:

A. [redacted]
B. [redacted]
C. [redacted]

The Tasks of HyFINE are divided into Subtasks (e.g., A1, A2, and A3), and these are subdivided into activities (e.g., A1.1, A1.2, etc.). Subtask and activity leaders have also been identified in order to have clear structure and distributed responsibilities during the execution of this large, multilateral public-private project. The following Subtasks have been defined:

[redacted]

When setting up HyFINE, industrial partners have had the main say in selecting the research topics and related direction of the activities. However, the teams of representatives across the entire value as well as well as knowledge chain, including general and technical universities, universities of applied sciences, as well as research institutes have worked closely together with the small and big companies involved to create a coherent project for the respective directions. The strategic portfolio analysis Subtask C2 provide a joint basis for setting targets, doing techno-economic assessments, making portfolio decisions and coordinating the exchange of information.

The expertise of the representatives from the different knowledge institutes is listed in the table of co-applicants in Section 1 and in the detailed partner descriptions in Appendix B. The descriptions for the industrial co-applicants and co-funders include summaries of their market strategies in addition to the expertise they provide to the consortium.

2.2 Productive interactions

The HyFINE consortium will focus on the following strategic objectives:

- [redacted]

[redacted]

Project-internal interactions for knowledge exchange and synergies

- **Frequent interactions at different levels:** Partners have decided to join HyFINE in order to collaborate on joint research activities, combining their specialised knowledge, skills and resources. The main work of the project is divided into Tasks (A and B), Subtasks (e.g., A1 and A2) and Activities (e.g., B1.1 and B1.2). Interactions are organised at these levels as well as the overall project level (General Assembly, GA) and with other projects and programmes. The time plan (Gantt chart) in Section 2.3 and Appendix C shows the various interactive meetings at the different levels to ensure an efficient management and knowledge exchange structure, which is organised within a separate Task C. Here, consortium partners will exchange their information and findings as well as share their best practices. By doing so, the consortium will address research and technological challenges and develop innovative solutions more efficiently.
- **Cross-cutting themes:** In addition to the planned interactions within Tasks, Subtasks and Activities, there is the explicit aim to develop knowledge across the different tasks. The Technical Manager of the project will schedule workshops with cross-cutting themes on a regular basis to foster additional interdisciplinary cooperation. Examples include the integration of thermochemical and electrochemical routes and the use

of analytical and modelling tools, thereby strengthening the innovation potential of the overall HyFINE project.

- **Capacity development and Human Capital:** HyFINE will contribute to the human capital development within the Netherlands as many Postdocs and PhD students will be hired by the various knowledge institutes to conduct the research activities proposed. These PhD students and Postdocs will be trained and develop a wide range of skills to work together on an exciting research programme. They will be interacting with researchers with different backgrounds and originating from different knowledge institutes. Furthermore, HyFINE also involves HBO students and internships and graduation assignments at TO2 institutes, such as TNO and WR, as well as companies. Another asset is that there is the direct involvement of SMEs and large companies, thereby benefiting from their expertise and the societal context of the challenge of their specific activity. Their enrolment in educational and training programs of the local graduate schools at their respective knowledge institutes contributes to the further personal development, including presentation and communication skills, next to scientific cooperation skills. Together this provides the infrastructure to enable rapid responses to changing needs for skills and education.
- **Monitoring and evaluation:** Providing a collaborative learning environment and personal skill training do not necessarily guarantee achieving the anticipated breakthrough results in science and innovation, therefore progress needs to be monitored and evaluated. Critical questions need to be asked about the work done by informed outsiders. This will be the role of the strategic portfolio analysis In Subtask C2 and of the engagement with the Advisory Committee of GroenvermogenNL.

External interactions for communication and dissemination

- **Policy and advocacy**: The HyFINE consortium, through the strategic policy analysis in sub-task C2, will actively engage with local, national and EU policy makers, industry stakeholders, and regulatory bodies, in shaping policies and regulations related to hydrogen research, circularity, green chemistry and their deployment. The MT can engage consortium members to provide expert insights and recommendations to policy makers and when necessary to influence decision-making processes that impact the hydrogen and green chemistry sector within the Netherlands and abroad. This includes participation in standardisation and certification efforts.
- **Stakeholder engagement and education**: The knowledge institutes in HyFINE, supported by the MT, will actively reach out to their local networks of collaborating institutes, industry partners, and regional/local government by giving lecture, organising conferences, workshops and open house events and participating in educational programmes, supported by the activities in sub-task C3. The goal is to create interest in and promote the science and technologies being developed and learn about and address possible concerns among the public and stakeholders. HyFINE partners will participate in national and regional knowledge sharing events, organised by HCA GroenvermogenNL, as well as by other organisations, including the Dutch Chemistry Conference NWO Chains, the Netherlands Process Technology Symposium (NPS), the Netherlands Chemistry and Catalysis Conference (NCCC), the Electrochemical Symposium (ECNS) and the ECCM symposium. All consortium partners will contribute and share their latest developments and insights in these national events as well as other international conferences and events, including the European Catalysis Conference (Europacat), the International Catalysis Conference (ICC), the International Symposium on Homogeneous Catalysts (ISHC), as well as the Materials Research Society (MRS) and American Chemical Society (ACS) meetings.
- **Knowledge and technology transfer**: HyFINE partners will engage in technology transfer activities in order to promote the practical application of their research findings. Supported by the MT and the GroenvermogenNL secretariat, they will collaborate to identify and assess commercialisation pathways and develop strategies for technology transfer to industry partners. The conditions for the sharing of the project results, thereby respecting the existing and generated Intellectual Property (IP) portfolio of the partners, will be laid down in the Consortium Agreement (CA). Research findings will be disseminated via the usual channels, coordinated through sub-task C (e.g., peer-reviewed scientific journal publications, national and international scientific conferences, social media outlets, websites, newsletters, and the GroenvermogenNL knowledge platform).

2.3 Project governance and project management

The HyFINE consortium's vision is aligned with GroenvermogenNL's mission:

- **HyFINE vision:** To position the Netherlands as a global leader in climate-neutral hydrogen and green chemistry applications for the high-value specialty and fine chemical sector.
- **GroenvermogenNL mission:** To foster a robust innovation ecosystem where businesses, knowledge institutions, and government bodies collaborate towards advancing technologies that contribute to a sustainable, climate-neutral society.

By leveraging the HyFINE consortium, GroenvermogenNL seeks to:

- Catalyse the transition towards carbon-neutral speciality and fine chemicals manufacturing processes.
- Build a green hydrogen ecosystem to accelerate the industrial applications of these manufacturing processes.
- Inspire and train the next generation of scientific talent within the Netherlands, thereby equipping them with the latest knowledge in e.g., chemistry, chemical, mechanical and materials engineering, and analytical sciences.
- Create a competitive business climate to further strengthen the Dutch economy.

The overall **Project Leader** of HyFINE is [redacted] (TNO), together with [redacted] (TUD) as the **Technical Manager**. [redacted] will be supported within TNO by a project support team led by [redacted] of TNO who acts as **Supporting Project Manager**. [redacted] will be supported by his institute's staff to perform his tasks and assignments. Together with the **Task leaders** of Task A and B, they form the Management Team (MT) of HyFINE.

The TNO **Project Leader**, supported by the **Project Manager**, is responsible for all relevant internal and external coordination, contractual matters, contacts to NWO (both for technical and administrative matters), monitoring of progress (including initiating risk management measures if applicable) to meet submission deadlines of deliverable reports and milestones, reporting and all dissemination activities. The TNO Project Manager has the financial administrative task to take care of payments from the assigned GroenvermogenNL WP6 budget to the different participants following the approved financial budget scheme and organise administrative declarations of in-kind contributions. The team formed for this purpose at TNO is experienced in executing the applicable type of project agreement and is capable and well prepared to deal with the requirements of NWO and GroenvermogenNL and support HyFINE partners in fulfilling all obligations during execution of the proposal.

[redacted] will take on the **Technical Management** of HyFINE. They will establish and execute a review procedure for all project deliverables before submitting them and monitor the technical and scientific progress of the different research activities of the two project tasks. The Technical Management will strive for coherency of and alignment between the activities of different tasks (e.g., by organising workshops and seminars on disciplinary as well as cross-cutting research themes), foster cooperation between researchers of the different tasks and subtasks when deemed necessary or relevant, will identify options for patent applications as well as scientific publications and presentations at conferences and workshops, will handle the publication of a quarterly HyFINE internal newsletter by collecting information on scientific and technological breakthroughs, and will scout for interactions with relevant research activities taking place in other projects or programmes (including the other GroenvermogenNL work packages, e.g., HyUSE, HySUCCESS and as expected HyCARB) within or outside of the Netherlands.

HyFINE - as a new Dutch public-private partnership - consists of different "layers" of interactions at the level of the entire consortium as well as the level of the tasks and the subtasks. The proposed governance structure is shown in Figure 2. Green signifies the execution of the research in the different tasks and their subtasks, blue is for the management and coordination of the overall project, and the steering and interaction with GroenvermogenNL is in black. The Project Manager and the two Technical Managers meet at least once a month to discuss the main direction of the project as well as organise and streamline their respective activities to ensure an effective execution of HyFINE.

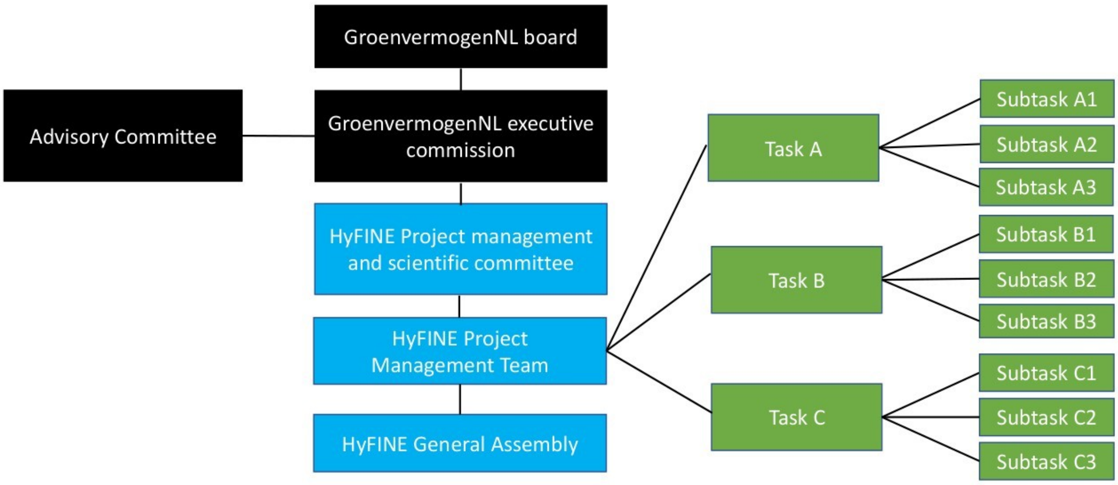


Figure 2: Governance structure for HyFINE, including the different levels of management and coordination, as visualised by the different colour schemes.

The following bodies are in place, from bottom up:

- **Subtask Leaders** are handed certain responsibilities by the Task Leaders as the subtask level is the organisation level where the project and IP aspects are 'laid down', the proper guidance of the research staff, PhD students and/or Postdocs, etc. is realised, and the entire set of activities is built up.
- **Task Leaders** are responsible for technical coordination of the Tasks and for the cross-task coordination via the MT. Each Task Leader is supported by their co-chairs, one of whom will serve as deputy task leader, and they will meet typically bi-monthly or tuned to the schedule for deliverables and milestones in the task.
- A five-person HyFINE **Management Team** (MT) consisting of the TNO Project Leader who chairs the meetings, the Technical Manager of TU Delft, the Supporting Project Manager from TNO, and the Task Leaders for Tasks A and B. This team monitors the scientific and technological progress of the project along the deliverables, milestones and budgets in the different Tasks. The Task leaders will report on a regular basis in the MT about the budget spending by each task participant as well as on the progress of the different activities. The HyFINE project MT meets at least every two months.
- The **Project Management and Scientific Coordination** (PMSC), consisting of the Project Leader and Technical Manager (from TNO and TU Delft), decides on or proposes matters that affect the entire HyFINE project, typically changes of e.g. consortium, participant roles, timing of main deliverables and milestones, and information from other GroenvermogenNL work packages. The PMSC meets twice a year and every 9 months with the Steering Committee.
- The **General Assembly** (GA) brings together one representative from each of the participants in the consortium. The GA evaluates the progress of the project, monitors the protection of the results, and identifies external and internal opportunities for the project. The GA will meet every 9 months, face-to-face if possible or otherwise by teleconference.
- The **GroenvermogenNL executive commission** (GEC) represents the full GroenvermogenNL R&D programme and its work packages such as HyFINE. The PMSC and GEC align the progress and results of the work packages. PMSC provides the GEC with detailed information about the progress and results of HyFINE. GEC and PMSC meet twice per year.
- The **Advisory Committee** (AC), installed by the GroenvermogenNL Board, consists of independent experts whose main goal is to monitor the progress and consistency of the different GroenvermogenNL work packages. The AC meets with the GroenvermogenNL executive commission (GEC) on a regular basis, and will be asked for advice specifically for HyFINE through the GEC.
- The **GroenvermogenNL Board** will safeguard the progress of the entire GroenvermogenNL programme, steering on an integral approach for all R&D programme, piloting, demonstration and HCA activities, and organises annual GroenvermogenNL meetings.

Internal communication about the project's research activities and status follows the governance structure:

- At the **Task and Subtask levels**, communication will be channelled via the Task leaders, co-chairs and Subtask Leaders. This is a two-way process with bottom-up initiative and self-organisation and regular top-down level checks (thereby avoiding the unnecessary micromanagement), starting from the Project Leader and Technical Managers via the Task leads further to the co-chairs and Subtask Leads.

- At the overall **HyFINE Project level**, exchange will take place between the Task Leaders, the Project Leader the Technical Managers and the Supporting Project Manager on MT level such as via the regular MT meetings, hosted by TNO, but also via informal meetings at the level of specific tasks and subtasks.
  - After evaluation, the MT will provide feedback on progress and status, whereas the HyFINE management, more specifically the MT, will be in direct contact with a participant on the budget reporting.
  - A yearly report will be part of an evaluation meeting that [redacted] as Technical Manager will organise to discuss and provide feedback and steering on the scientific quality and progress of the project's activities and tasks. When needed, specific progress meetings will be organised with participating parties to enhance cooperation or revise the plans of activities.
  - The MT will issue a quarterly internal newsletter to all project participants, organise and maintain a project SharePoint where all relevant documents and information is collected for the project, and organise project meetings and dedicated workshops on relevant cross-thematic topics.
  - At project level, an annual knowledge sharing symposium will be held with participation of all researchers within HyFINE.
- On the **strategic level** of the HyFINE project, all participants in the project gather in the GA to exchange views from a strategic perspective on the status and future steps of the project, including the organisation of specific workshops or seminars to foster cooperation or exchange between different tasks, subtasks or activities. When deemed necessary we will reach out to parties outside HyFINE to help or assist with missing knowledge or to get access to specific research infrastructure.
- Communication with **GroenvermogenNL** takes place via the information exchange of Project Management and Scientific Coordination (PMSC) on the side of the HyFINE project and the Executive Commission (EC) on the side of NWO / GroenvermogenNL.

To disseminate and discuss its findings, HyFINE will organise an annual conference for all participants and external interested parties. For maximum reach it seems wise to look for combination and cooperation with related organisations and networks, such as the ARC CBBC which organises the established High-Tech Chemistry conference series and the VoltaChem programme which organised a yearly business event. The same holds for e.g. the organisation of specific sessions at the annual NWO Chains and NCCC conferences, thereby maximising the interaction with the scientific and technological landscape within the Netherlands.

[redacted]

3. Research plan

3.1 Research plan

3.1.1. Towards a fossil-free, sustainable and yet competitive Dutch chemical industry

The global reliance on fossil resources undermines sustainability of the living environment (CO_2 emissions, waste), economy (finite resources), and geopolitical stability. This dependency also affects the historically competitive Dutch chemical industry. New EU and national CO_2- reduction policies challenge industries to remain competitive while transitioning to renewable feedstocks in an uneven global market. At the same time, this transition is an opportunity to leverage Dutch strengths to develop chemical industries that convert local and regional sustainable feedstocks into high-value specialty products and fine chemicals. The specific challenges are:

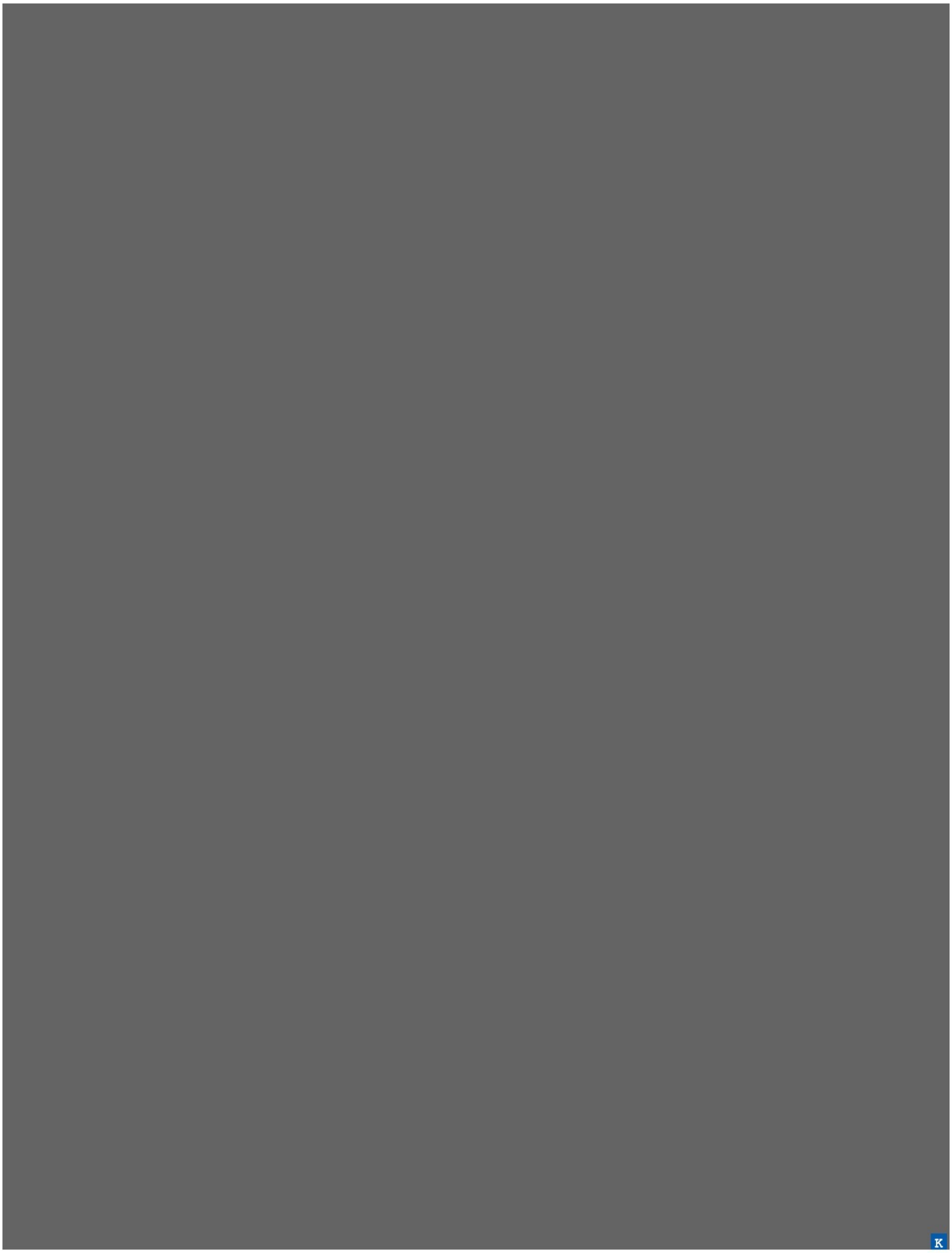
1) to increase maturity and accelerate scaleup of emerging technologies and value chains, from feedstock to intermediates to products;
2) to develop more efficient conversion methods that better exploit renewable energy, including the indirect use of green electrons via thermochemical (hydrogenation) processes as well as the direct use of electrons in electrochemical and photochemical processes;
3) to innovate methods to improve understanding of cross-cutting themes with the potential to accelerate industrial uptake of new chemistries (e.g., analytics, high throughput techniques, modelling).

[redacted]

Value chains explored in HyFINE

[redacted]

[redacted]



The following section presents the state of the art and scientific challenges to be addressed by different Subtasks.

3.1.2 State of the art and key challenges for the HyFINE technologies

3.1.2.1 Hydro-depolymerisation of technical lignin to specialty and fine chemicals (Subtask A1)

Lignin is an abundant natural biopolymer, but it is largely combusted as an undesired byproduct (in the production of pulp and paper and 2nd generation bioethanol. Lignin has a complex molecular structure, made up of aromatic sub-units connected by a variety of linkages, providing challenges to its utilisation. Nevertheless, its aromatic structure makes it an obvious renewable source for renewable platform molecules such as (substituted) aromatics, phenols, cyclohexanone and beyond. While different thermochemical conversion routes to produce chemicals and fuels from lignins are being developed at lab scale over the past decades, its efficient depolymerisation to monoaromatics remains challenging. Agglomeration of lignin fragments occurs to form condensed products and char leading to typically complex mixtures of substituted phenolics requiring further (catalytic hydro-) treatment to obtain, depending on the targeted outlet, e.g. fuel component or (fine) chemicals [3].

[redacted]

[redacted]

3.1.2.2 (Poly)saccharides & (Fatty) Acids Cluster (Subtask A2)

The sugar part of (lignocellulosic) biomass and (fatty) acids from fermentation provide chemically rich and diverse feedstock. [redacted]. [redacted]

[redacted]

Sugar/Furans valorisation towards Diols (A2.1)

Diols are crucial chemicals for producing polymers, cosmetics, and pharmaceuticals. Fossil-derived diols like ethylene glycol (EG), 1,3-propanediol (PDO), 1,4- (1,4-BDO) and 1,3-butanediol (1,3-BDO) represent a market nearing 30 billion USD in 2023. [redacted].

[redacted]

[redacted]

Sugar/furans valorisation towards (pseudo)aromatics (A2.2)

Furan-based routes to aromatic fine and specialty chemicals complement lignin-based approaches of Subtask A1. Diels-Alder (DA) aromatisation enables direct conversion of lignocellulosic sugars into substituted, oxygenated aromatics for application as additives, surfactants, etc. Alternatively, DA addition/hydrogenation yields structurally rigid, yet non-aromatic, analogues of substituted aromatics ('pseudo-aromatics'), opening new opportunities and alternatives for fine and speciality chemicals.

Traditionally, DA aromatisation has focused on highly reduced furans (e.g. 2,5-dimethylfuran) reacting with ethylene to [redacted]

[redacted]

Volatile fatty acid valorisation (A2.3)

About 90% of volatile fatty acids (VFA) are produced from petrochemical feedstock with negative environmental impact [39-41]. Fermenting wastewater streams (e.g. sludge, food waste, organic fraction of municipal solid waste) is emerging as a sustainable and cost-efficient alternative. [redacted]

[redacted]

[redacted]

Computational modelling (A2.4)

Modern computational tools, including quantum chemical modelling, molecular dynamics, and multi-scale kinetic simulations, are being transformed by integration with AI and machine learning (ML). This convergence enables systematic mining of large datasets, prediction of reaction networks, and identification of correlations between catalyst structure and performance. [redacted]

[redacted]

[redacted]

3.1.2.3 Polymer Chemistry & Upcycling Cluster (Subtask A3)

[redacted]

PHAs are produced from complex waste feedstocks (incl. municipal and industrial waste streams, biomass-processing side streams) via microbial mixed cultures to tolerate heterogeneity and impurities. [redacted]

[redacted]

H₂-based polymer synthesis (A3.1)

PHAs are an emerging class of biodegradable aliphatic polyesters with growing relevance in sustainable materials [48]. They are naturally produced within the cells of microorganisms (49). [redacted]

[redacted]

[redacted]

H_2/Electron-driven Polymer Modification (A3.2)

Modified polysaccharides (PS, link to A2) are widely used in personal and home care but currently are mostly produced via conventional chemical methods using petrochemical substituents. These modifications often reduce biodegradability. Similarly, PLA, the most used biodegradable polymer, degrades slowly in water and soil. [redacted]

[redacted]

Reductive Conversion to Fine Chemicals (A3.3)

Polyesters are expected to play a key role in transitioning a circular plastics economy due to their tuneable properties and reversible ester bonds facilitating chemical recycling [59]. [redacted]

[redacted]

3.1.2.4 Accelerated Catalyst Design and Implementation Technologies (Subtask B1)

Efficient catalytic systems are critical in fine chemical industry, where hydrogenation enables key sustainable transformations such reductions (C=C, C=O, and C=N) and selective defunctionalisations (e.g., hydrodeoxygenation, hydrodehalogenation). [redacted]

Earth-abundant transition metal catalysts for hydrogenation of biobased substrates (B1.1)

[redacted]

[redacted]

Semi-HT Experimental Kinetic and Operando Study for Catalyst Durability Control (B1.2)

A major barrier to industrial uptake of new catalytic conversions lies often not in achieving reactivity under idealised conditions, but in ensuring durability, robustness and performance in the industrial setting. Current accelerated hydrogenation catalyst discovery relies on HT categorical or numerical screening in parallel autoclaves (up to 96 wells). [redacted]

[redacted]

AI/ML-Approaches for Catalyst Durability and Selectivity Optimisation (B1.5)

[redacted]

[redacted]

3.1.2.5 Photochemical Methodologies and Reactors (Subtask B2)

Photochemistry offers powerful routes for the synthesis of fine and specialty chemicals from platform molecules [99,100] via e.g. radical-type C-C coupling, decarboxylation, isomerisation, polymer breakdown and functionalisation. [redacted]

Robotic Platform for photochemical transformations (B2.1)

The emergence of automation, AI, and self-driving laboratories (SDLs) is revolutionising synthetic chemistry by accelerating workflows, enhancing reproducibility, and enabling researchers to focus on higher-level scientific goals [104]. [redacted]

Photon-Assisted and Controlled Polymer Degradation and Modification (B2.2)

Polylactic acid (PLA) is the most widely used biodegradable polymer, valued for its biobased origin and alignment with European Green Deal objectives. However, PLA degrades slowly under ambient conditions (e.g., in soil or compost), raising concerns about microplastic accumulation. [redacted]

[redacted]

Visible light curing of paints and coatings (B2.3)

The coatings industry is a multi-billion-euro sector, employing tens of thousands of people globally. Most paints and coatings require chemical crosslinking to achieve robustness and resistance to mechanical and chemical stress. Conventional crosslinking relies on energy-intensive UV curing or heating with a high carbon footprint. [redacted]

3.1.2.6 Electrochemical Methodologies and Electrosynthesis Platforms (Subtask B3)

Electrochemical conversion of biomass-derived feedstocks is an important emerging technology. [redacted]

[redacted]

Decarboxylation of fatty acids and furan derivatives (B3.2)

Although the Kolbe reaction was discovered long time ago [124], only limited commercial applications have emerged. [redacted]

3.1.3 Tasks, subtasks and activities

Task A: Speciality and fine chemicals from bio- and waste-based feedstock

Introduction and context

A transition to a chemical industry based on renewable or circular carbon requires new chemistry and new values chains. Virgin renewable feedstocks, biomass or CO_2, and circular sources such as (municipal) waste streams differ from the fossil resources we rely on today. [redacted]

[redacted]

Task A:
Speciality and fine chemicals from bio- and waste-based feedstock using green H_2 or green electrons
(Task leaders: [redacted])

A1:	A2:	A3:
Lignin Valorisation Cluster [redacted]	**(Poly)Saccharides & (Fatty) Acids Cluster** [redacted]	**Polymer Chemistry & Polymer Upcycling** [redacted]

[redacted]

[redacted]

[redacted]

Deliverables A1

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Task B: Enabling technologies and methodologies for specialty chemical synthesis using green H_2 or green electrons

Introduction and context

Without doubt, the world needs to accelerate in transitioning toward green and sustainable production methods. Even if the scale is smaller, this also applies to chemical production of fine chemicals and specialties. [redacted]

General objectives

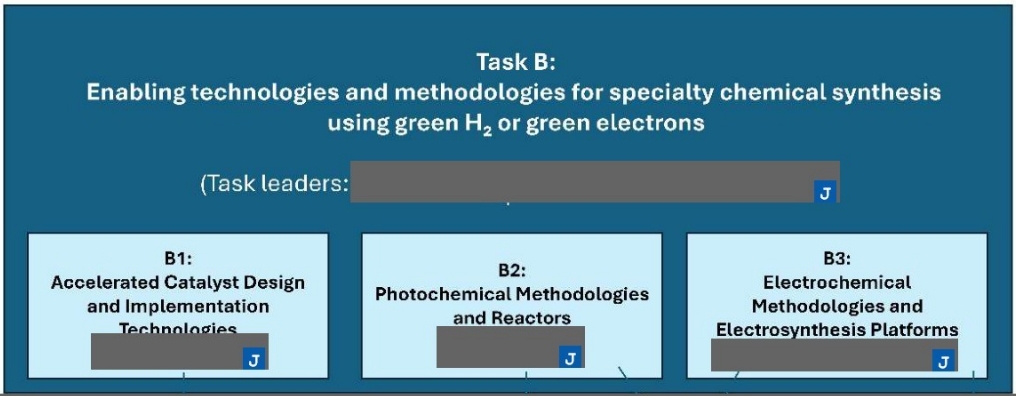
[redacted]

[redacted]

Approach and structure

The Task is subdivided into three Subtasks (Figure 20):

[redacted]



[redacted]

[redacted]

[redacted]

K

[redacted]

P

[redacted]

K

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Task C: Coordination, Strategic analysis and Dissemination

Introduction and context

HyFINE consists of two main Tasks A and B executed by 35 partners from different backgrounds (i.e., universities, universities of applied sciences, research institutions, such as TNO and WR, SMEs, and industry), all working together to reach the strategic objectives of HyFINE and of the overall GroenvermogenNL programme. [redacted]

General objectives

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.2 Tasks

Task A: Speciality and fine chemicals from bio- and waste-based feedstock **Task duration: 60 months**	
Task leader	[redacted]
Task personnel	9.5 PhD positions, 3 Postdoc positions, 4.5 Person years TO2, 4 Person years HBO
Participating consortium partners	**A1:** [redacted] **A2:** **A3:**

[redacted]

Task B: Electrochemical and photochemical synthesis of specialties and fine chemicals from platform molecules **Task duration: 60 months**	
Task leader	[redacted]
Task personnel	6.5 PhD positions, 7 Postdoc positions, 4 Person years TO2 /research institutes
Participating consortium partners	**B1** [redacted] **B2** **B3**

[redacted]

Task C: Coordination, Strategic analysis and Dissemination Task duration: 60 (72) months	
Task leader	[redacted]
Task personnel	2 Person years TO2, 0.5Person years University, 2 Postdoc position; 1.5 Person Years HBO
Participating consortium partners	**C1:** [redacted] **C2:** **C3:**

[redacted]

[redacted]

3.3 Planning

[redacted]. Note that adjustments to the GANTT chart and partners' involvement may be made due to the strong interdependence between Activities, Subtasks, and Tasks.

3.4 Risk management and contingency plan

Task	Risk	Impact	Mitigation strategy
All	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		
A1	[redacted]		
A1, A2, A3	[redacted]		
A1, A2, A3, B3	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		
All	[redacted]		

A3	[redacted]
A3	[redacted]
A3	[redacted]
B2	[redacted]
B2	[redacted]
All	[redacted]
B1	[redacted]
B1	[redacted]
B1	[redacted]

4. Route to impact

4.1 Societal impact

[redacted]

Value chain	Topic in Subtasks	Fossil-based market demand for chemicals	Production potential from biofeedstocks	% of current fossil market
[redacted]				

Therefore, the implementation of the HyFINE proposal will have substantial positive impacts in three areas.

Earning capacity

[redacted]

The research objectives link well with the comparative advantages of the Netherlands: leading chemical and technological research institutes, a strong chemical industry comprising both large international companies and SMEs, large biofeedstock availability from a highly productive agricultural sector, and growing availability green hydrogen and electrons from offshore wind parks and onshore solar fields. The Netherlands is a leader in the biobased industry, with strong connections between the agricultural and chemical sectors. The future production of biofeedstock-, waste- and captured CO_2-based specialty and fine chemicals will initially take place in the Netherlands and we can sell this technology as well, in particular to markets with structural growth potential in countries with abundant biofeedstock and cheaper sustainable energy sources than we have ourselves, such as Brazil or India.

HyFINE contributes to new earning models for the chemical industry and its customers further in the value chain, at a time when the feedstock and materials transition is urgent for structural increases in economic productivity as well as resource and energy independence. This is also crucial to address the short-term problems in this sector related to higher energy prices, increasing costs for feedstocks, availability of critical raw materials, labour, regulatory pressures and the need for costly infrastructure upgrades.

Sustainability

HyFINE contributes to sustainability and development of a circular economy as the conversion of sustainable feedstocks such as biowaste, municipal solid waste and CO_2 to specialty and fine chemicals with green hydrogen and electricity reduces the use of fossil resources and reduces CO_2 emissions and waste. HyFINE also focusses on increasing the feedstock-to-product and energy efficiency as a way to maximise resources and improve economic viability of these sustainable technologies [redacted]

To ensure that the HyFINE results are broadly applicable and thus help achieve sustainability goals as soon as possible, [redacted]

Social and societal impact

HyFINE will have a positive social impact because the new cleantech sector and production in the Netherlands need and attract sufficient and well-trained personnel and (retention of) employment. HyFINE supports the development of the Human Capital Agenda by transferring knowledge generated during the project to the training programmes of HBO and universities.

National resilience increases as a result of a broader and renewed technology base that diversifies our country's income base, and greater geopolitical independence through the use of 'home-grown' feedstocks. Elsewhere, opportunities for economic development arise in countries with abundant feedstock and cheap renewable or low-carbon energy, who can adopt the methods and technologies developed in HyFINE. When setting up new value chains in these countries, environmental and social justice issues can immediately be intertwined with new business models. By involving societal stakeholders such as consumer and environmental organisations at an early stage i identifying and assessing potential benefits, risks and impacts of the various technologies, we increase the chance of societal support for chemical production from sustainable feedstocks and the transition to a circular economy.

4.2 Outcomes

Within HyFINE, the objective is to develop and scale-up methods and technologies in order to support the Dutch industry to implement and commercialise specialty and fine chemicals production using hydrogen and green electrons. Implementation of HyFINE will lead to the following outcomes:

- **Economic Growth:** Strengthening the economy by positioning the Netherlands as a leader in the combination of green chemistry and hydrogen. Ensuring economic and environmental sustainability will drive innovation and strengthen the Dutch competitive advantage. Specifically, we foresee the following outcomes based on our results:

  [redacted]

[redacted]

- **Climate Neutrality, sustainability and environmental impact:** Contributing to the global, EU and national Climate goals by showing what is possible and making first steps in transforming the chemical industry's value chains through circular carbon. Specifically, we foresee the following outcomes based on our results:

[redacted]

- **Global Leadership:** Establishing the Netherlands as an innovation hub in Europe for chemical industries. Specifically, we foresee the following outcomes based on our results:

[redacted]

- **Societal awareness and acceptance.** Socially responsible development of chemical conversion technologies with green H_2 and green electrons is crucial to achieve societal acceptance. Specifically, we foresee the following outcomes based on our results:

[redacted]

4.3 Output

Fine and specialty chemicals are vital to everyday life, as they provide the advanced, high-purity ingredients and tailor-made solutions essential for a vast array of high-performance products like materials, pharmaceuticals, electronics, agriculture, and automotive. The demand for these chemicals is expected to grow rapidly (ca. 10% annually) as there is an i**ncrease in living standards and a demand for eco-friendly and tailored chemical solutions, and** a growing focus on sustainability and customised properties. To keep up with the demands and comply with the climate targets, we need the defossilisation of manufacturing activities, including those in the chemical industry. This requires developing and widely sharing knowledge, experience and technology development towards higher TRL. This gradual transformation process calls for cooperation between many different disciplines in a.o. chemistry, materials science, analytical sciences, and engineering, thereby bringing together people from knowledge institutes, SMEs, and large companies. This quest for intense public-private cooperation forms the basis of this HyFINE project.

[redacted]

Each of these results will be delivered in collaboration between research institutes and SME's and large companies, making sure that the research is undertaken with a clear market orientation. Some results can be of the *drop-in* kind (with the potential of being integrated in existing production processes and therefore a short lead time to market implementation), whereas other results may involve a more disruptive new way of producing and may take longer until they can be applied in the market.

[redacted]

[redacted]

In addition to these concrete results, less tangible output of HyFINE will also be:

[redacted]

5. State aid and the General Block Exemption Regulation (GBER)

5.1 Non-economic activities by research organisations

The research activities undertaken by the research organisations in HyFINE meet de requirements set in the General Block Exemption Regulation (GBER, specifically article 25 on support for research and development projects), which allow the Dutch government through NWO to provide financial support for these activities.

The independent scientific research involved in HyFINE is intended to contribute to advancing public knowledge and insights in the fields at hand, without any immediate economic objectives or commercial considerations. The research will explore fundamental principles, investigate innovative technologies, and advance theoretical frameworks in the domain of using hydrogen and green electrons for high-value specialty and fine chemistry. This involves experimental investigations, development of mathematical models, and data analysis, and culminates in the dissemination of the findings through publication in scientific journals and publicly accessible databases, and in patent applications and other ways of furthering the knowledge developed into commercial activities.

[redacted] K

Each business acting as co-applicant in HyFINE has a completed and signed declaration of General Terms and Conditions under the GBER and uploaded this in ISAAC as an annex to the application.

6. Data management

1. *Will the collected or generated data be suitable for reuse?*

HyFINE will collect and generate data that will be suitable for reuse. The types of data entail the following:

- Measured data: from developing and testing of new or improved biofeedstocks and catalysts, new chemistries and synthetic methods, processes, software and equipment, such as reactors, characterisation and analytical equipment.
- Synthetic data: data calculated, modelled and predicted in the different modelling activities.
- Industrial partner data: provided by co-funding organisations based on among others real pilot projects in the field.
- 3rd party data: data from literature or provided by third parties other than the co-funding organisations and collaborative partners.

2. *Where will the data be stored during the research?*

During the research, aforementioned data will be stored on a common HyFINE project platform for cooperation (e.g., MS SharePoint or MS Teams) that will be used exclusively by the HyFINE consortium.

In certain cases (when a dataset is under construction, too large for sharing via this common platform or when certain restrictions such as confidentiality apply that prevent availability for the entire consortium), the (lead) HyFINE consortium partner responsible for generation of the dataset will store and uphold the data. In such a case the partner will provide guidance on the common platform about the availability of the dataset (what data, how was it generated, by which (lead) partner) as to allow other partners to understand the main characteristics of the data and to discuss with the specific partner the options to get access to the data.

The sharing of data with specific or all HyFINE partners, with third parties or with the public domain will be subject to conditions of the consortium agreement. If during the project a dataset is going to be shared in the public domain via an established data repository, these data will be removed from the common platform and replaced by only meta information on the dataset.

3. *How will the data be stored for the long term and made available for use by third parties when the project has been completed? For whom will the data be accessible?*

For the long term, aforementioned data will be shared with the public domain as much as possible. Published data will be available free of charge for third parties. To achieve a wide distribution, datasets will be published in publicly accessible repositories, according to the principles: as open as possible, as closed as necessary and FAIR (findable, accessible, interoperable, reusable), in line with major funding organisations (e.g., NWO). All datasets will be accompanied by a short report that describes the metadata, methods that generated the data, and equipment and tool specifications to reproduce the data.

During the research, the HyFINE website will present an overview of the datasets that have been generated, based on the approach described for storing of data during the project. During or after the research, partners(s) involved in generation of a dataset may proceed to publish a dataset, only after consent of project management who checks on consistency with the conditions that apply from the Consortium Agreement. The partner needs to indicate which data repository they intend to use. There is preference for repositories that provide DOI numbers as identification, as datasets are easier to find when labelled in such a way. It is recommended that a dataset is published under a specific license (e.g., of the Creative Commons license type).

Another option for publishing of a dataset is to include it in a deliverable report or scientific paper, to which option the FAIR principle applies. Some datasets of the research have been marked as specific deliverables and for such cases the partners may decide together with the project management whether they should prefer to store the dataset additionally in a public repository.

The HyFINE project website, where all the deliverables will be available during and after the project, will keep track of all the datasets that have been made public via a data repository.

A review procedure will apply for project deliverables, as well as a procedure to obtain consent from the consortium for any publications on results. The partners, in particular those who contributed directly or indirectly, will thus be stimulated to review each other's datasets before or after publication.

4. *What facilities (ICT, (secure) archive, refrigerators or legal expertise) do you anticipate will be needed for the storage of data during and after the research? Are they available?*

No specific facilities and technologies for data storage are foreseen other than those available within the HyFINE consortium and its participating partners, including the different knowledge institutes. There is ample experience and expertise on data storage sharing within the consortium, as developed within many national (e.g., NWO) and international (e.g., Horizon Europe) funding schemes. The main efforts in the months before and during the start-up phase of the project will be to make sound and practical legal agreements that apply for the entire diverse consortium (comprising different types of organisations) on data sharing within and outside the consortium.

7. Ethical aspects

	Not applicable	Not yet applied for	Applied for	Received
Approval from a recognised (medical) ethics review committee	☒	☐	☐	☐
Approval from an animal experiments committee	☒	☐	☐	☐
Permission for research with the population screening Act	☒	☐	☐	☐

8. Literature references

[1] NOVA Institute and Renewable Carbon (2024). *Transition Pathway towards Bio-based Chemistry in the Netherlands.* Final report. Commissioned by Invest-NL. October 2024.

[2] Steffen, F., Zong-Ruehe, R., Douma, E. (2024), *Promoting circular carbon in the chemical industry*, Roland Berger.

[3] Joffres, B., D. Laurenti, N. Charon, A. Daudin, A. Quignard, and C. Geantet (2013). Thermochemical conversion of lignin for fuels and chemicals: a review, *Oil & Gas Science and Technology–Revue d'IFP Energies nouvelles*, **68**(4), 753–763.

[4] Mu, Y., B. Chen, H. Zhang, M. Fei, T. Liu, N. Mehta, D.Z. Wang, A.J.M. Miller, P.L. Diaconescu and D. Wang (2024). Highly Selective Electrochemical Baeyer–Villiger Oxidation through Oxygen Atom Transfer from Water, *J. Am. Chem. Soc.* **146**(19), 13438–13444.

[5] Cui, Z., H. Wang, Z. Chen, Y. Zhang, H. Tian, Z. Yin and J. Li (2022). Controllable oxidation of cyclohexanone to produce sodium adipate in an electrochemical reactor with a Pt NPs/Ti membrane electrode. *International Journal of Chemical Reactor Engineering* **20**(3), 343-355.

[6] Chacon-Huete, F., C. Messina, B. Cigana and P. Forgione (2022). Diverse Applications of Biomass-Derived 5-Hydroxymethylfurfural and Derivatives as Renewable Starting Materials. *ChemSusChem* **15**(13), e202200328. DOI: 10.1002/cssc.202200328

[7] Antonetti, C., D. Licursi, S. Fulignati, G. Valentini and A.M.R. Galletti (2016). New frontiers in the catalytic synthesis of levulinic acid: from sugars to raw and waste biomass as starting feedstock. *Catalysts* **6**(12), 196/1-196/29. DOI: 10.3390/catal6120196.

[8] Baniamerian H., M. Høj, M.J. Beier, A.D. Jensen (2023). Catalytic conversion of sugars and polysaccharides to glycols: A review. *Applied Catalysis B: Environmental* **330**, 122650. https://doi.org/10.1016/j.apcatb.2023.122650

[9] Tran, M.H., E.Y. Lee (2023). Production of polyols and polyurethane from biomass: a review. *Environ Chem Lett* **21**, 2199–2223. https://doi.org/10.1007/s10311-023-01592-4

[10] Anchan, H.N., N.S. Bhat, N. Vinod, N. P.S. Prabhakar and S. Dutta (2024). Catalytic conversion of glucose and its biopolymers into renewable compounds by inducing C–C bond scission and formation. *Biomass Conv. Bioref.* **14**, 9915–9948. https://doi.org/10.1007/s13399-022-03105-9

[11] Annuar N.H.R., Z.A. Alexzman, A.R.M.Daud, A.F.N., H.M., Alias Hairi and H.D. Setiabudi (2022). A review on hydrogenolysis of sorbitol over heterogeneous catalysts. *Journal of Environmental Chemical Engineering* **10**, 107229. https://doi.org/10.1016/j.jece.2022.107229

[12] Klis F. van der, L. Gootjes, J. van Haveren, D. S. van Es and J.H. Bitter (2015). Selective terminal C–C scission of C5-carbohydrates. *Green Chemistry* **17,** 3900-3909. https://doi.org/10.1039/C5GC01012H

[13] Zhang L., S. Huang, J. Qiu, B. Wang, B. Yan, J. Zhang, B. Zhou, J. Chen and X. Zeng (2023). Selective transformation of biomass-derived substrates to 1,2-butanediol: A comprehensive review and new insights. *Industrial Crops and Products* **202**, 116984. https://doi.org/10.1016/j.indcrop.2023.116984

[14] Zhu Y., J. Yang, F. Mei, X. Li and C. Zhao (2022). Bio-based 1,4-butanediol and tetrahydrofuran synthesis: perspective. *Green Chemistry* **24**, 6450-6466. https://doi.org/10.1039/D2GC02271K

[15] Tan J.,Y. Su, K. Gao, J. Cui, Y. Wang and Y. Zhao (2021). Recent advances in the selective hydrogenation of furfural and its derivatives to pentanediol. *Journal of Fuel Chemistry and Technology* **49**(6), 780-790. https://doi.org/10.1016/S1872-5813(21)60036-1

[16] Zhu J. and G. Yin (2021). Catalytic Transformation of the Furfural Platform into Bifunctionalized Monomers for Polymer Synthesis. *ACS Catalysis* **11**(15), 10058–10083. https://doi.org/10.1021/acscatal.1c01989

[17] Wiesfeld J.J., P. Peršolja, F.A. Rollier, A.M. Elemans-Mehring, E.J.M. Hensen (2019). Cellulose conversion to ethylene glycol by tungsten oxide-based catalysts. *Molecular Catalysis* **473**, 110400. https://doi.org/10.1016/j.mcat.2019.110400

[18] Yun Y.S., C.E. Berdugo-Díaz and D.W. Flaherty (2021). Advances in Understanding the Selective Hydrogenolysis of Biomass Derivatives. *ACS Catalysis* **11**(17), 11193–11232. https://doi.org/10.1021/acscatal.1c02866

[19] Liu X., X. Wang, S. Yao, Y. Jiang, J. Guana, X. Mu (2014). Recent advances in the production of polyols from lignocellulosic biomass and biomass-derived compounds. *RSC Advances* **4**, 49501-49520. https://doi.org/10.1039/C4RA06466F

[20] Padovan, D., K. Nakajima, and E.J.M. Hensen (2022). Metal Oxide Catalysts for the Valorization of Biomass-Derived Sugars. In: Ueda, W. (eds) Crystalline Metal Oxide Catalysts. Springer, Singapore. https://doi.org/10.1007/978-981-19-5013-1_11

[21] Patil A., M. Engelbert van Bevervoorde and M.F. Neira D'Angelo (2025). Intensifying Cyclopentanone Synthesis from Furfural Using Supported Copper Catalysts. *ChemSusChem* **18**, e202401484. https://doi.org/10.1002/cssc.202401484
[22] Patil A., C. Rosmini, A. Kumar Kodyingal, S. Simeonov and M.F. Neira D'Angelo (2025). Modulating activity and selectivity of aqueous phase furfuryl alcohol hydrogenation by tuning supported Pt on W-Zr Mixed oxides. *Applied Catalysis B: Environment and Energy* **375**, 125400. https://doi.org/10.1016/j.apcatb.2025.125400
[23] Delparish A., A. Uslu, Y. Cao, T. de Groot, J. van der Schaaf, T. Noël and M.F. Neira D'Angelo (2022). Boosting the valorization of biomass and green electrons to chemical building blocks: A study on the kinetics and mass transfer during the electrochemical conversion of HMF to FDCA in a microreactor. *Chemical Engineering Journal* **438**, 135393. https://doi.org/10.1016/j.cej.2022.135393
[24] Krzelj V., D. Perez Ferrandez and M.F. Neira D'Angelo (2021). Sulfonated foam catalysts for the continuous dehydration of xylose to furfural in biphasic media. *Catalysis Today* **365**, 274-281. https://doi.org/10.1016/j.cattod.2020.12.009
[25] Aguirre A., V. Chandra, E.A.J.F. Peters, E.A.J.F. Kuipers and M.F. Neira D'Angelo (2020). Open-cell foams as catalysts support: A systematic analysis of the mass transfer limitations. *Chemical Engineering Journal* **393**, 124656.
[26] Papaioannou M., R. J. T. Kleijwegt, J. van der Schaaf and M.F. Neira D'Angelo (2019). Furfural Production by Continuous Reactive Extraction in a Millireactor under the Taylor Flow Regime. *Industrial Engineering Chemistry Research* **58**(35), 16106–16115. https://doi.org/10.1021/acs.iecr.9b00604
[27] Krzelj V., J. van Kampen, J. van der Schaaf and M.F. Neira D'Angelo (2019). Furfural Production by Reactive Stripping: Process Optimization by a Combined Modeling and Experimental Approach. *Industrial & Engineering Chemistry Research* **58**(35), 16126–16137. https://doi.org/10.1021/acs.iecr.9b00445
[28] Dietz C.H.J.T. , M. Verra, S. Verberkt, F. Gallucci, M.C. Kroon, M.F. Neira D'Angelo, M. Papaioannou and M. van Sint Annaland (2019). Sequential and in Situ Extraction of Furfural from Reaction Mixture and Effect of Extracting Agents on Furfural Degradation. *Industrial & Engineering Chemistry Research* **58**(35), 16116–16125. https://doi.org/10.1021/acs.iecr.9b00694
[29] Coumans, F.J.A.G., Z. Overchenko, J.J. Wiesfeld, N. Kosinov, K. Nakajima and **E.**J.M. Hensen (2022). Protection Strategies for the Conversion of Biobased Furanics to Chemical Building Blocks. *ACS Sustainable Chem. Eng.* **10**(10), 3116–3130.
[30] Van der Klis, F., L. Gootjes, N.H. Verstijnen, J. van Haveren, D.S. van Es and J. H. Bitter (2022). Carbohydrate structure–activity relations of Au-catalysed base-free oxidations: gold displaying a platinum lustre. *RSC Adv.* **12**, 8918-8923.
[31] Cioc, R.C., M. Crockatt, J.C. van der Waal and P.C.A. Bruijnincx (2022). The Interplay between Kinetics and Thermodynamics in Furan Diels–Alder Chemistry for Sustainable Chemicals Production. *Angew. Chem. Int. Ed.* **61**, e202114720
[32] Scodeller, I., S. Mansouri, D. Morvan, E. Muller, K. de Oliveira Vigier, R. Wischert and F. Jérôme (2018). Synthesis of Renewable meta-Xylylenediamine from Biomass-Derived Furfural. *Angew. Chem. Int. Ed.* **57**, 10510.
[33] Lancefield, C.S., B. Fölker, R.C. Cioc, K. Stanciakova, R.E. Bulo, M. Lutz, M. Crockatt and P.C.A. Bruijnincx (2020). Dynamic Trapping as a Selective Route to Renewable Phthalide from Biomass-Derived Furfuryl Alcohol. *Angew. Chem. Int. Ed.* **59**, 23480.
[34] Cioc, R.C., E. Harsevoort, M. Lutz and P.C.A. Bruijnincx (2023). Efficient synthesis of fully renewable, furfural-derived building blocks *via* formal Diels–Alder cycloaddition of atypical addends. *Green Chem.* **25**, 9689-9694.
[35] Mariscal, R., Maireles-Torres, P., Ojeda, M., Sádaba, I. & Granados, M. L. (2016). Furfural: a renewable and versatile platform molecule for the synthesis of chemicals and fuels. *Energy Environ. Sci.* **9**, 1144–1189. DOI: 10.1039/C5EE02666K
[36] Van Putten, R.-J. et al. (2013). Hydroxymethylfurfural, A Versatile Platform Chemical Made from Renewable Resources. *Chem. Rev.* **113**, 1499–1597. DOI: 10.1021/cr300182k
[37] Mettler, M.S., D.G. Vlachos and P.J. Dauenhauer (2012). Top ten fundamental challenges of biomass pyrolysis for biofuels. *Energy Environ. Sci.* **5**, 7797-7809.
[38] Käldström, M., N. Kumar, T. Heikkilä, M. Tiitta, T. Salmi, D. Yu Murzin (2010). Formation of Furfural in Catalytic Transformation of Levoglucosan over Mesoporous Materials, *ChemCatChem* **2**(5), https://doi.org/10.1002/cctc.201000024
[39] Fufachev E.V., B.M. Weckhuysen and P.C.A. Bruijnincx (2021). Crystal Phase Effects on the Gas-Phase Ketonization of Small Carboxylic Acids over TiO2 Catalysts. *ChemSusChem* **14**(13), 2710 – 2720. DOI: 10.1002/cssc.202100721
[40] Fufachev E.V., B.M. Weckhuysen and P.C.A. Bruijnincx (2020a). Toward Catalytic Ketonization of Volatile Fatty Acids Extracted from Fermented Wastewater by Adsorption. *ACS Sustainable Chemistry and Engineering* **8**(30), 11292 – 11298. DOI: 10.1021/acssuschemeng.0c03220

[41] Fufachev E.V., B.M. Weckhuysen and P.C.A. Bruijnincx (2020b). Tandem catalytic aromatization of volatile fatty acids. *Green Chemistry* **22**(10), 3229 – 3238. DOI: 10.1039/d0gc00964d
[42] Pham T.N., T. Sooknoi, S.P. Crossley and D.E. Resasco (2013). Ketonization of carboxylic acids: Mechanisms, catalysts, and implications for biomass conversion. *ACS Catalysis* **3**(11), 2456 – 2473. DOI: 10.1021/cs400501h
[43] Goebel J. F., F. Belitz, D. S. Prendes, Y. Haver, P. Diehl, M. Muhler and L. J. Gooßen (2024), *ChemSusChem* **17**, e202400094. https://doi-org.utrechtuniversity.idm.oclc.org/10.1002/cssc.202400094
[44] Tao, F., Salmeron, M. (2024) Surface restructuring and predictive design of heterogeneous catalysts. *Science* **386**(6724), eadq0102.
[45] Nørskov, J.K., T. Bligaard, J. Rossmeisl and C.H. Christensen (2009). Towards the computational design of solid catalysts. *Nat. Chem.* **1**(1), 37-46.
[46] Toyao, T., Z. Maeno, S. Takakusagi, T. Kamachi, I. Takigawa and K.-i. Shimizu (2020). Machine Learning for Catalysis Informatics: Recent Applications and Prospects. *ACS Catal.* **10**(3), 2260-2297.
[47] Mou, T., H. S. Pillai, S. Wang, M. Wan, X. Han, N.M. Schweitzer, F. Che and H. Xin (2023). Bridging the complexity gap in computational heterogeneous catalysis with machine learning. *Nat. Catal.* **6**(2), 122-136.
[48] Tullo, A. H. (2021) Will the Biodegradable Plastic PHA Finally Deliver? (Chemical & Engineering News, 2021) https://cen.acs.org/business/biobased-chemicals/biodegradable-plastic-PHA-finally-deliver/99/i22
[49] Bolla M., M. Pettinato, P.F. Ferrari, B. Fabiano and P. Perego (2025) Polyhydroxyalkanoates production from laboratory to industrial scale: A review. *Int J Biol Macromol.* **310**(Pt3), 143255. doi: 10.1016/j.ijbiomac.2025.143255. Epub 2025 Apr 16. PMID: 40250686.
[50] Gundlapalli ,M, and S. Ganesan (2025). Polyhydroxyalkanoates (PHAs): Key Challenges in production and sustainable strategies for cost reduction within a circular economy framework, Results in Engineering, Volume 26, https://doi.org/10.1016/j.rineng.2025.105345.
[51] Yao J., X.Y. Xiao, M. Wang, Q. Zhang, Y. Chen, M. Gou, Z.Y. Xia and Y.Q. Tang (2025). A review of low-cost production of polyhydroxyalkanoates: Strategies, challenges, and perspectives. *Bioresour Technol.* **433**, 132745. doi: 10.1016/j.biortech.2025.132745. Epub 2025 May 31. PMID: 40456332.
[52] Dias, J.M.L., P.C. Lemos, L.S . Serafim, C. Oliveira, M. Eiroa, M.G.E. Albuquerque, A.M. Ramos, R. Oliveira, and M.A.M. Reis (2006), Recent Advances in Polyhydroxyalkanoate Production by Mixed Aerobic Cultures: From the Substrate to the Final Product. *Macromol. Biosci.* **6**, 885-906. https://doi.org/10.1002/mabi.200600112
[53] Torres Ruano T.M., M. Diender and D.Z. Sousa (2025). Microbial synergy between *Rhodospirillum rubrum* and *Acetobacterium woodii* enables anaerobic CO conversion to polyhydroxyalkanoates. *Green Chem.* 2025 May 28. doi: 10.1039/d5gc01092f. Epub ahead of print. PMID: 40519243; PMCID: PMC12152849
[54] Sousa, D.Z., T. M. Torres Ruano, and M. Diender (2024). Process for the production of polyhydroxyalkanoate. (Patent No. *WO2024236121*).
[55] Parera Olm I., S. Benito-Vaquerizo, C. Dubaere, V.A.P. Martins dos Santos, M. Suarez-Diez, D.Z. Sousa (2025). Synthetic microbial co-cultivation for targeted production of odd-chain carboxylates and alcohols from carbon monoxide. Submitted to Environmental Science and Technology.
[56] Peil, S., H. Gojzewski and F.R. Wurm (2023). Reversible acetalization of cellulose: A platform for bio-based materials with adjustable properties and biodegradation. *Chemical Engineering Journal* **452**(3), 139280. https://doi.org/10.1016/j.cej.2022.139280
[57] Mouhoubi R., M. Lasschuijt, S.R. Carrasco, H. Gojzewski and F.R. Wurm (2022). End-of-life biodegradation? how to assess the composting of polyesters in the lab and the field. *Waste Management* **154**(2022), 36-48, https://doi.org/10.1016/j.wasman.2022.09.025
[58] Rheinberger, T., J. Wolfs, A. Paneth, H. Gojzewski, P. Paneth and F.R. Wurm (2021). RNA-Inspired and Accelerated Degradation of Polylactide in Seawater. *J. Am. Chem. Soc.* **143**(40), 16673–16681. https://doi.org/10.1021/jacs.1c07508
[59] Aarsen, C. V., R. Mattsson, A. Liguori, M. Hakkarainen and M.H. Sipponen (2024). Designed to Degrade: Tailoring Polyesters for Circularity. *Chemical Reviews* **124**(13), 8473–8515. https://doi.org/10.1021/acs.chemrev.4c00032
[60] DeRosa, C. A., X.Q. Kua, F.S. Bates and M.A. Hillmyer (2020). Step-Growth Polyesters with Biobased (R)-1, 3-Butanediol. *Industrial & Engineering Chemistry Research* **59**(35), 15598-15613.
[61] Fernandes, A. C. (2021). Reductive depolymerization as an efficient methodology for the conversion of plastic waste into value-added compounds. *Green Chemistry* **23**(19), 7330-7360.
[62] Wang, C. and O. El-Sepelgy (2021). Reductive depolymerization of plastics catalyzed with transition metal complexes. *Current Opinion in Green and Sustainable Chemistry* **32**, 100547, https://doi.org/10.1016/j.cogsc.2021.100547
[63 Patureau, F.W., S. de Boer, M. Kuil, J. Meeuwissen, P-A. Breuil, M.A. Siegler, A.L. Spek, A.J. Sandee, B. de Bruin and J.N.H. Reek (2009). Sulfonamido-Phosphoramidite Ligands in Cooperative Dinuclear Hydrogenation Catalysis. *J. Am. Chem. Soc*. **131**, 6683-6685.

[64] Korstanje, T.J., J.I. van der Vlugt, C.J. Elsevier and B. de Bruin (2015). Hydrogenation of carboxylic acids with a homogeneous cobalt catalyst. *Science* **350**(6258), 298–302.
[65] Chakrabortty, S., B. de Bruin and J.G. de Vries (2024). Cobalt-Catalyzed Asymmetric Hydrogenation: Substrate Specificity and Mechanistic Variability. *Angew. Chem. Int. Ed.* **63**, e20231577.
[66] Chakrabortty, S., F.J. de Zwart, D. Snabilié, E. Balaraman, J.N.H. Reek, B. de Bruin and J.G. de Vries (2023). Concise Synthesis of Azilect via Cobalt-Catalyzed Enantioselective Hydrogenation in a Bio-Based Solvent. *Cat. Sci. & Techn.* **13**, 6668-6674.
[67] Chakrabortty, S. K. Konieczny, F.J. de Zwart, E.O. Bobylev, E. Baráth, S. Tin, B.H. Müller, J.N.H. Reek, B. de Bruin and J.G. de Vries (2023). Cobalt-Catalyzed Enantioselective Hydrogenation of Trisubstituted Carbocyclic Olefins: An Access to Chiral Cyclic Amides. *Angew. Chem. Int. Ed.* **62**(26), e202301329
[68] Daubignard, J., M. Lutz, R. Detz, B. de Bruin and J.N.H. Reek (2019). Origin of the Selectivity and Activity in the Rhodium-Catalyzed Asymmetric Hydrogenation Using Supramolecular Ligands. *ACS Catalysis* **9**(8), 7535-7547.
[69] Otte, M., P.F. Kuijpers, O. Troeppner, I. Ivanović-Burmazović, J.N.H. Reek and B. de Bruin (2014). Encapsulation of Metalloporphyrins in a Self-Assembled Cubic M8L6 Cage: A New Molecular Flask for Cobalt–Porphyrin-Catalysed Radical-Type Reactions. *Chem. Eur. J.*, **20**, 4880–4884.
[70] Meeuwissen, J., J.N.H. Reek (2010). Supramolecular catalysis beyond enzyme mimics. *Nature Chemistry* **2**, 615.
[71] Slagt, V.F. M. Röder, P.C.J. Kamer, P.W.N.M. Van Leeuwen and J.N.H. Reek (2004). Assembly of Encapsulated Transition Metal Catalysts. *J. Am. Chem Soc.* **126**(13), 4056-4057.
[72] Pérez, J.M., R. Postolache, M.C. Reis, E.G. Sinnema, D. Vargová, F. de Vries, E. Otten and S.R. Harutyunyan (2021), Manganese(I)-Catalyzed H-P Bond Activation via Metal-Ligand Cooperation. *J. Am. Chem. Soc.* **143**, 20071-20076.
[73] Wan, B., M. C. Reis, T. Ramspoth and S. R. Harutyunyan (2025). Manganese(I)-catalyzed enantioselective alkylation to access P-stereogenic phosphines. *J. Am. Chem. Soc.* **147**, 3740-3746.
[74] Ni, C., T.-F. Ramspoth, M. Castiñeira Reis and S.R. Harutyunyan (2024). Manganese(I)-Catalyzed Highly Enantioselective Synthesis ofAziridine Phosphines. *Angew. Chem. Int. Ed.* **64**, e20241562
[75] Sinnema, E.G., T.-F. Ramspoth, R.H. Bouma, L. Ge and S.R. Harutyunyan (2024). Enantioselective Hydrophosphination of Terminal Alkenyl Aza-Heteroarenes. *Angew. Chem. Int. Ed.* **63**, e202316785
[76] Yang, W., G. Filonenko and E.A. Pidko (2023). Performance of homogeneous catalysts viewed in dynamics. *Chem. Commun.* **59**, 1757.
[77] Van Putten, R., E.A. Uslamin and E.A. Pidko (2021). Automated high-resolution sampling and multi-mode *operando* spectroscopy of (bio-)chemical reactions for kinetic analysis, reaction characterization, and quality control. *Invention Disclosure* **1**, 100002.
[78] Jiscoot, N., E. Uslamin and E.A. Pidko (2023). Model-based evaluation and data requirements for parallel kinetic experimentation and data-driven reaction identification and optimization. *Digital Discovery* **2**, 994.
[79] Yang, W., T.Y. Kalavalapalli, A.M. Krieger, T.A. Khvorost, I.Yu. Chernyshov, M. Weber, E.A. Uslamin, E.A. Pidko and G.A. Filonenko (2022). Basic Promotors Impact Thermodynamics and Catalyst Speciation in Homogeneous Carbonyl Hydrogenation. *J. Am. Chem. Soc.* **144**, 8129.
[80] Yang, W., I.Yu. Chernyshov, R.K.A. van Schendel, M. Weber, C. Müller, G.A. Filonenko and E.A. Pidko (2021). Robust and efficient hydrogenation of carbonyl compounds catalysed by mixed donor Mn(I) pincer complexes. *Nat. Commun.* **12**, 12.
[81] Van Putten, R., N.S. Eyke, L.M. Baumgartner, V.L. Schultz, G.A. Filonenko, K.F. Jensen and E.A. Pidko (2022). Automation and Microfluidics for the Efficient, Fast, and Focused Reaction Development of Asymmetric Hydrogenation Catalysis. *ChemSusChem* **15**, e202200333.
[82] Motagamwala, A.H. and J.A. Dumesic (2021). Microkinetic modelling: a tool for rational catalyst design. *Chem. Rev.* **121**(2), 1049-1076.
[83] Yang, W., G.A. Filonenko and E.A. Pidko (2023). Performance of homogeneous catalysts viewed in dynamics. *Chem. Comm.* **59**, 1757-1768.
[84] Rama, R.J., A. Nova and M.C. Nicasio (2024). Microkinetic Model as a Crucial Tool for Understanding Homogeneous Catalysis. *ChemCatChem* **16**, e202400224
[85] Filot, I.A.W. (2022). *Introduction to Microkinetic Modelling,* Eindhoven University of Technology Library, ISBN 978-90-386-5573-4.
[86] Mehara, J., M. Anania, P. Kočovský and J. Roithová (2024). Competing Mechanisms in Palladium-Catalyzed Alkoxycarbonylation of Styrene. *ACS Catal.* **14,** 5710 – 5719.
[87] Tripodi, G. L., Max T. G. M. Derks, F. P. J. T. Rutjes and J. Roithová (2021). Tracking Reaction Pathways by a Modular Flow Reactor Coupled to Electrospray Ionization Mass Spectrometry. *Chem. Methods* **1**, 430 – 437.

[88] Bris, A., M. G. Baltussen, G. L. Tripodi, W. T. S. Huck, P. Franceschi and J. Roithova (2024). Direct Analysis of Complex Reaction Mixtures: Formose Reaction. *Angew. Chem. Int. Ed.* **63**, e202316621.
[89] Bairagi, A., A. Y. Pereverzev, P. Tinnemans, E. A. Pidko and J. Roithová (2024). Electrocatalytic CO_2 Reduction: Monitoring of Catalytically Active, Downgraded, and Upgraded Cobalt Complexes. *J. Am. Chem. Soc.* **146**, 5480 – 5492.
[90] Roithová, J., A. Gray, E. Andris, J. Jašík and D. Gerlich (2016). Helium Tagging Infrared Photodissociation Spectroscopy of Reactive Ions. *Acc. Chem. Res.* **49**, 223–230.
[91] Zelenka, J., A. Pereverzev, U. Jahn and J. Roithová (2022). Sulfonyl Nitrene and Amidyl Radical: Structure and Reactivity. *Chem.–A Eur. J.,* e202104493.
[92] Christofi, E., P. Barran (2023). Ion Mobility Mass Spectrometry (IM-MS) for Structural Biology: Insights Gained by Measuring Mass, Charge, and Collision Cross Section. *Chem. Rev.* **123**, 2902-2949.
[93] Chen, X., Q. Duez, G.L. Tripodi, P.J. Gilissen, D. Piperoudis, P. Tinnemans, J.A.A.W. Elemans, J. Roithová and R.J.M. Nolte (2022). Mechanistic Studies on the Epoxidation of Alkenes by Macrocyclic Manganese Porphyrin Catalysts. *Eur. J. Org. Chem.,* e202200280.
[94] Koovakattil Surendran, A., G.L. Tripodi, E. Pluhařová, A.Y. Pereverzev, J.P.J. Bruekers, J.A.A.W. Elemans, E.J. Meijer and J. Roithová (2023). Host-guest tuning of the CO_2 reduction activity of an iron porphyrin cage. *Nat. Sci.,* e20220019.
[95] Kalikadien, A.V., A. Mirza, A. Najl Hossaini, A. Sreenithya and E.A. Pidko (2024). Paving the road towards automated homogeneous catalyst design. *ChemPlusChem*, e202300702.
[96] Kalikadien, A.V., C. Valsecchi, R. van Putten, T. Maes, M. Muuronen, N. Dyubankova, L. Lefort and E.A. Pidko (2024). Probing machine learning models based on high throughput experimentation data for the discovery of asymmetric hydrogenation catalysts. *Chem. Sci.* **15**, 13618.
[97] Köhnke, K., N. Wessel, J. Esteban, J. Jin, A.J. Vorholt and W. Leitner (2022). *Operando* monitoring of mechanisms and deactivation of molecular catalysts. *Green Chem.* **24**, 1951.
[98] Hashemi, A., S. Bougueroua, M.-P. Gaigeot and E.A. Pidko (2023). HiREX: High-Throughput Reactivity Exploration for Extended Databases of Transition-Metal Catalysts. *J. Chem. Inf. Model.* **63**, 6081.
[99] Marzo, L., S.K. Pagire, O. Reizer and B. Koenig (2018). Visible-Light Photocatalysis: Does It Make a Difference in Organic Synthesis? *Angewandte Chemie* **57**, 10034-10072. https://onlinelibrary.wiley.com/doi/abs/10.1002/anie.201709766
[100] Noël, T. and E. Zysman-Colman (2022). The promise and pitfalls of photocatalysis for organic synthesis. *Chem Catalysis* **2**(3), 468-476. DOI: 10.1016/j.checat.2021.12.015
[101] Beil, S.B., S. Bonnet, C.C. Casadevall, R.J. Detz, F. Eisenreich, S.D. Glover, C. Kerzig, L. Næsborg, S. Pullen, G. Storch, N. Wei and C. Zeymer (2024). Challenges and Future Perspectives in Photocatalysis -Conclusions from an Interdisciplinary Workshop. *JACS AU* **4**, 2746-2766. https://pubs.acs.org/doi/10.1021/jacsau.4c00527
[102] Shaw, M. H., J. Twilton and D.W.C. MacMillan (2016). Photoredox Catalysis in Organic Chemistry**.** *J. Org. Chem.* **81**, 6898-6926.
[103] Zondag, S.D.A., D. Mazzarella and T. Noël (2023). Scale-Up of Photochemical Reactions: Transitioning from Lab Scale to Industrial Production. *Annual Review of Chemical and Biomolecular Engineering* **14**, 283-300. DOI: 10.1146/annurev-chembioeng-101121-074313
[104] Li, P., J.A. Terrett, J.R. Zbieg (2020), Visible-Light Photocatalysis as an Enabling Technology for Drug Discovery: A Paradigm Shift for Chemical Reactivity. *ACS Med Chem Lett* **11**, 2120-2130. https://pubs.acs.org/doi/10.1021/acs.joc.6b01449
[105] Corrigan, N., S. Shanmugam, J. Xu and C. Boyer (2106), Photocatalysis in organic and polymer synthesis**.** *Chem. Soc. Rev.* **45**, 6165-6212. https://pubs.rsc.org/en/content/articlelanding/2016/cs/c6cs00185h
[106] Bayley, O. E. Savino, A. Slattery, and T. Noël (2024). Autonomous chemistry: Navigating self-driving labs in chemical and material sciences. *Matter* **7**, 2382-2398, DOI: 10.1016/j.matt.2024.06.003
[107] Abolhasani, M. and E. Kumacheva (2023). The rise of self-driving labs in chemical and materials sciences. *Nature Synthesis* **2,** 483-492. DOI: 10.1038/s44160-022-00231-0
[108] Slattery, A., Z. Wen, P. Tenblad, D. Pintossi, J. Sanjose-Orduna, T. den Hartog, and T. Noël (2024). Automated self-optimization, intensification, and scale-up of photocatalysis in flow. *Science* **383**, DOI: 10.1126/science.adj1817
[109] Guillet, J.E., T. Regulski and T.B. McAneney (1974). Biodegradability of photodegraded polymers II: tracer studies of biooxidation of Ecolyte PS polystyrene. *Environmental Science and Technology* **8**, 923.
[110] Yousif E. and R. Haddad (2013). Photodegradation and photostabilization of polymers, especially polystyrene: review. *SpringerPlus* **2**, 398.
[111] Wright, D., Q. Lin, D. Berta, T. Földes, A. Wagner, J. Griffiths, C. Readman, E. Rosta, E. Reisner and J.J. Baumberg (2021). Mechanistic study of an immobilized molecular electrocatalyst by in situ gap-plasmon-assisted spectro-electrochemistry. *Nature Catalysis* **4**, 157.

[112] Peng, J. Q. Lin, T. Földes, H.-H. Jeong, Y. Xiong, C. Pitsalidis, G.G. Malliaras, E. Rosta and J.J. Baumberg (2022). *In-Situ* Spectro-Electrochemistry of Conductive Polymers Using Plasmonics to Reveal Doping Mechanisms. *ACS Nano* **16**, 21120.

[113] Zwart, F.J. de, L.A. Wolzak, K.J. van den Berg, M.J. Baran, J.E. Wulff, J. Flapper and B. de Bruin (2024). Diazirine-Functionalized Polyurethane Crosslinkers for Isocyanate-Free Curing of Polyol-Based Coatings. *ACS Appl. Polym. Mater.* **6**(6), 3517–3522.

[114] Zwart, F.J. de, L.A. Wolzak, P.C.M. Laan, S. Mathew, J. Flapper, K.J. van den Berg, J.N.H. Reek and B. de Bruin (2023). Thermal/Blue Light Induced Cross-Linking of Acrylic Coatings with Diazo Compounds. *Macromolecular Rapid Communications*, **2023**, 2300380.

[115] Bootsma, J., W.R. Browne, J. Flapper and B. de Bruin (2022). Photoactive Fe Catalyst for Light-Triggered Alkyd Paint Curing. *JACS Au* **2**, *2*, 531–540.

[116] Tolboom, J., A.K. Bauer, J. Bootsma, J. Flapper, M.L. Neidig and B. de Bruin (2025). Advancing Light-Triggered Alkyd Paint Curing: (Cp)Fe^{II}(naphthalene)](PF_6) Catalysts with Enhanced Photosensitivity and Increased Performance in Pigmented Alkyd Paints. *ChemistryEurope,* 2025. http://doi.org/10.1002/ceur.202500104 .

[117] Weiss, K.D. (1997). Paint and Coatings: A Mature Industry in Transition. *Progress in Polymer Science* **22**, 203-245. https://doi.org/10.1016/S0079-6700(96)00019-6

[118] Jiang, G, S. Wu, W. Yan, T. Tian, Y. Liao and Y. Yang (2023). Preparation of matte, abrasion-resistant and anti-fouling waterborne UV-curable coating and its application in electronic product shells. *Journal of Applied Polymer Science* **140**, 41 e54523 DOI: 10.1002/app.54523

[119] Chengmin, H. (2022). Preparation of Fast Light-curing Water-based UV Ink and Wear Resistance of Ink Film. *Journal of Photopolymer Science and Technology* **34**(6), 607-614. DOI:10.2494/photopolymer.34.607

[120] Li, Z., W. Chong, H. Yuekun, Z. Xiaojian, S. Feng, S. Zhijia, W. Jinjie, A. Zhenghua, Z. Yuda, Z. Ziping and W. Yifang (2005). Absolute light yield of the EJ-204 plastic scintillator. *Nuclear Instruments and Methods in Physics Research,* 2005, 449-455. doi:10.1016/j.polymer.2005.06.075

[121] Timounay, Y., A. Pannwitz, D.M. Klein, A.-L. Biance, M.E. Hoefnagel, I. Sen, A. Cagna, M. Le Merrer and S. Bonnet (2022), Interfacial Characterization of Ruthenium-Based Amphiphilic Photosensitizers. *Langmuir* **38**(31), 9697–9707. https://doi.org/10.1021/acs.langmuir.2c01391

[122] Lee, M.Y., J.W. Koo, J.J. Jang, Y.I. Jo, J.B. Yeo, J.E. Kim, J.S. Hong, J.H. Kim, S. Choi and K.T. Nam (2025). Electrochemical Synthesis of 2,5-furandicarboxylic acid from furfural derivative and carbon dioxide. *ACS Sus. Chem. Engin*. **13**(7), 12 Feb 2025, 2845-2852.

[123] F. Boissou, S. Baranton, M. Tarighi, K. De Oliveira Vigier and C. Coutanceau (2019). The potency of γ-valerolactone as bio-sourced polar aprotic organic medium for the electrocarboxlation of furfural by CO_2. *J. Electroanal. Chem.* **848**, 1 sept 2019, 113257.

[124] Utley, J. (1997). Trends in organic electrosynthesis. *Chem. Soc. Rev.* **26**, 157-167.

[125] Leech, M. C. and K. Lam (2020). Electrosynthesis using carboxylic acid derivatives: new tricks for old reactions. *Acc. Chem. Res.* **53**, 121–134.

[126] Hioki, Y., M. Constantini, J. Griffin, K.C. Harper and P.S. Baran (2023). Overcoming the limitations of Kolbe coupling with waveform-controlled electrosynthesis. *Science* **380**(6640), 6 Apr 2023, 81-87.

[127] Fraaije, J.G.E.M, J. van Male, P. Becherer, R.S. Gracia (2016). Coarse-Grained Models for Automated Fragmentation and Parametrization of Molecular Databases. *J. Chem. Inf. Model.*2016, **56**(12), 2361−2377.

[128] Wollensack, L., K. Budzinski and J. Backmann (2022). Defossilization of pharmaceutical manufacturing. *Current Opinion in Green and Sustainable Chemistry* **33**, 2022, 100586

[129] Elterlein, F., N. Bugdahn and P. Kraft (2024). Sniffing Out the Sustainable Future: The Renewability Revolution in Fragrance Chemistry. *Chem. Eur. J.* **30**, e202400006.

Appendix A: Overview of PhD, Postdoc and Researcher Positions

KI and PI(s)	Position	Contribution	Sub-task	Activity
[redacted]	1 PhD	[redacted]	A1	A1.1
[redacted]	1PhD	[redacted]	A1	A1.2
[redacted]	1PhD	[redacted]	A1	A1.3
[redacted]	2 PY	[redacted]	A1	A1.4
[redacted]	1PhD	[redacted]	A2	A2.1
[redacted]	1.5 PY	[redacted]	A2	A2.1
[redacted]	1PhD	[redacted]	A2	A2.2
[redacted]	2.5 PY	[redacted]	A2	A2.1; A2.2; A2.3
[redacted]	2yr PD	[redacted]	A2	A2.3
[redacted]	2yr PD	[redacted]	A2	A2.3
[redacted]	1PhD	[redacted]	A2	A2.4
[redacted]	2 PhDs	[redacted]	A3	A3.1
[redacted]	1 PhD	[redacted]	A3	A3.2
[redacted]	0.5 PhD	[redacted]	A3	A3.2
[redacted]	1.0 PY	[redacted]	A3	A3.2
[redacted]	2yr PD	[redacted]	A3	A3.3
[redacted]	2 PY	[redacted]	A3	A3.3
[redacted]	1 PhD	[redacted]	B1	B1.1; B1.3
[redacted]	1 PhD	[redacted]	B1	B1.1; B1.3;
[redacted]	1 PhD, 3yr PD	[redacted]	B1	B1.2; B1.3; B1.4
[redacted]	2yr PD	[redacted]	B1	B1.3

[redacted]	[redacted]			
[redacted]	1 PhD	[redacted]	B2	B2.1
[redacted]	0.5 PhD	[redacted]	B2	B2.2
[redacted]	1 PhD	[redacted]	B2	B2.3;
[redacted]	2yr PD	[redacted]	B2	B2.3;
[redacted]	2yr PD	[redacted]	B2	B2.3
[redacted]	2 yr PD	[redacted]	B3	B3.1
[redacted]	1 PY	[redacted]	B3	B3.1
[redacted]	1 PhD	[redacted]	B3	B3.2
[redacted]	1 PY	[redacted]	B3	B3.2
[redacted]	1 yr PD	[redacted]	B3	B3.2
[redacted]	2 PY	[redacted]	B3	B3.1; B3.2.
[redacted]	1 PY	[redacted]	C2	C2.1; C2.2
[redacted]	0.5 PY	[redacted]	C2; C3	C2.1; C3.3

Appendix B: Partner Descriptions

First the Co-applicants, then the Co-funders, and finally the different universities and research institutes, each listed in alphabetical order, contributing to HyFINE will be briefly described, including a statement why they wish to participate and actively contribute to the ambitions of HyFINE.

Co-applicants

Biomass Technology Group BV (BTG)
Biomass Technology Group (BTG) has specialised in the conversion of biomass into fuels, energy and bio-based raw materials for the past 35 years with a team of around 30 people. BTG is an independent, private company. Various spin-off companies originate from BTG. Examples are BTG-Bioliquids and BTG-neXt.

The Consultancy & Project Development Group of BTG offers services to the business community and the public sector. By advising and developing projects, BTG contributes to an increasing role of bio-based raw materials in the energy transition and the circular economy. With over 35 years of experience, BTG Consultancy has gained an extensive track record of more than a thousand successful projects with assignments in more than 80 countries. BTG RTD activities are based on thermochemical conversion of biomass and residues, while contract research can cover a much wider area. A large number of test facilities are available to perform various activities efficiently. Dedicated test facilities are also realised according to the customer's wishes, [redacted]

FeyeCon D&I BV
FeyeCon D&I BV is a technology-driven SME specialising in innovative CO_2-based solutions. Our core mission is to advance processes, equipment, and products that leverage CO_2 utilisation, expanding its applications across diverse sectors. Our expertise spans Carbon Capture and Utilisation (CCU), energy storage, and power cycle technology, enabling industrial partners to reduce their carbon footprint while unlocking new value streams. To support these advancements, FeyeCon operates a state-of-the-art infrastructure, including high-pressure CO_2 processing facilities, pilot-scale reactors, and advanced analytical laboratories, ensuring seamless transition from research to industrial-scale implementation.

We want to contribute to HyFINE in order to showcase the value of our high-pressure CO_2 technologies. Demonstrating their efficiency in converting and fixing CO_2 in combination with H_2 to produce fine and specialty chemicals will highlight the attractiveness and investment potential of o approach. Collaborating in HyFINE alongside TO2 institutions, universities, and other commercial partners will accelerate implementation and significantly expand the range of potential applications across various products. The advantages of utilising CO_2 in such processes a particularly compelling due to its natural abundance, low cost, and the unique physicochemical properties it exhibits under elevated pressures. Higher pressure relates to higher densities which induces increased solubilities and conversion rates in production.

Mevaldi B.V.
Mevaldi produces biochemicals for new bio-polymers, polyols, and recyclable polyurethanes and polyesters. Mevaldi's Bio-Based Building Blocks are used in a broad range of applications, e.g., polyesters for clothing and polyurethanes for coatings, adhesives, sealants and elastomers.

[redacted]

Paques Biomaterials (Paques)
Paques Biomaterials focuses on production of PHA biodegradable biopolymers from residual streams. A key challenge is to make PHA polymers price-competitive with common oil-based and non-biodegradable polymers. Technologies are needed that could improve the process and reduce the cost price of PHA biopolymers. In several steps of the PHA production process, the use of hydrogen or green electrons has the potential of increasing production yields, reduce chemical consumption and improve PHA quality control. All this would lead to significant steps towards making biodegradable PHA biopolymers more attractive for niche applications where biodegradation is required. Another topic of interest is the use of PHA polymers as platform for new fine

chemistry. Work with other partners, such as Hanze Hogeschool and University Twente, has already shown the potential of exploring this new platform. All these processes can also benefit from green electrons which could be further explores in this project.

Our interest in HyFINE is to implement lab infrastructure to investigate the impact of recycling or adding H_2 as green electrons carrier to the Volatile Fatty Acids (VFA) and PHA production processes in order to increase product yield of these fermentation processes. To explore these activities, Paques Biomaterials will require subsidy support to conduct lab trials with continuously operated bioreactors. Besides this, we need collaboration with universities and knowledge institutes to explore different routes of the processes described above.

Software for Chemistry & Materials B.V. (SCM)
Software for Chemistry & Materials B.V. (SCM) is a scientific software company based in Amsterdam. It employs about 30 people, most of whom have a PhD in computational / theoretical chemistry or physics. This makes SCM likely the largest employer of PhD-level computational chemists in The Netherlands. SCM's software suite, the Amsterdam Modelling Suite (AMS) is used worldwide by hundreds of companies and universities to study chemical processes in atomic scale detail. AMS has particular strengths in the study of chemical reactivity and has been used for broad energy-related applications. SCM works with approximately 50 academic partners around the world to further improve its software.

SCM has already contributed to a number of clean energy related EU and Dutch collaborations, including ReaxPro, Science4CleanEnergy (where SCM focused on carbon capture simulations), Solar2Products (a collaboration with Univ. Leiden and VU) on solar cell modelling and PREDICTOR (on battery modelling). HyFINE fits both our drive as a company and our product roadmap for our software. SCM will make its software available and extend it further in the relevant application areas. SCM will also contribute its expertise and that of its worldwide academic partner network in this area.

Signify
Signify is the world leader in connected LED lighting systems, software and services. We transform buildings, homes and retail spaces. We are interested in providing lighting solutions in the field of photochemistry, from screening up to industrial applications, and to explore new value spaces in the photo(electro)chemical area.

Participation in the HyFINE consortium gives us an opportunity to assess customer needs, and build lighting prototypes for photochemical synthesis. Getting feedback on the improvement needs based on the experimental results allows us to provide better and optimal solutions to enhance photochemical solutions for end-users.

SULIS Polymers B.V.
The profile of SULIS Polymers B.V. includes the development of new polymer formulations with a focus on sustainability and making enhanced, environmentally friendly materials, as well as polymer structure modifications. We are busy exploring new biobased polymer compositions that exhibit fast biodegradation rates assisted by light, for applications as packaging films, and in the agriculture and biomedical areas. We have already commercialised our ECOLIS biocomposting platforms, which are used to assess thermally activated aerobic biodegradation kinetics.

In HyFINE, we plan to significantly enhance and control the biodegradation rates assisted by photons for biobased polyesters (PLA), and control decomposition kinetics by introducing light-sensitive ketone constituents in the main chain. Using our photochemical approaches based on Norrish-type photochemistry, we envisage developing materials that form a generic platform for environmentally friendly plastics. The long-term interest is to scale-up the technology and transfer to mass production for a melt-blending plastics engineering company, market and sell the engineered polymers.

Vertoro
Vertoro is a spin off company from a public-private partnership between Brightlands Chemelot Campus, DSM, Chemelot InSciTe, University of Maastricht (UM) and Eindhoven University of Technology (TU/e), is a chemical start-up with a novel and protected approach to transforming woody and agricultural residues into a wide range of bio-based chemicals, materials, and fuels. We have an interest to develop (more) high value market outlets for our platform biobased (2^{nd} generation) molecules, comprising (methylated) C5 and C6 sugars, lignin oligomers, glucose, and levulinic acid.

By taking part in HyFINE, we aim to achieve 2-3 proof of concepts at lab-scale at academia that our substrates can yield fine and / or specialty chemicals. This should be followed by 2-3 bench (kg) validation of the same at one or more industrial partners, resulting in at least (conditional) offtake agreement at ton scale.

Co-funders

AkzoNobel
Sustainability is a key driver for AkzoNobel and we are keen to explore ways to reduce the carbon footprint of our coatings. One way to do this is to collaborate with knowledge institutes and other companies who can deliver more sustainable new materials which we can use in our coatings.

Our specific interest for participation in HyFINE is to have access to new ideas/sustainable materials that could eventually be used to formulate coatings with reduced carbon footprint, gain insight as to how those new materials might perform in coatings and what advantages they might bring, and make new contacts. The project may lead to new coating formulations that have an improved carbon footprint, either formulation-related or ways to reduce carbon footprint further along the value chain, such as low energy curing.

Avantium Chemicals
Avantium is a pioneer in the emerging industry of renewable and sustainable chemistry. We are at the forefront of innovative engineering solutions towards CO_2 conversion, dedicated to advancing technology and sustainability. Avantium is interested in the chemical reduction of bio (and CO_2)-based feedstocks to produce specialty polymers.

Participating in the HyFINE consortium is valuable for Avantium. [redacted]

BASF Nederland B.V. and Germany (BASF)
Chemistry for a sustainable future - that's what BASF stands for. We combine economic success with environmental protection and social responsibility. Around 112,000 employees in the BASF Group contribute to the success of our customers in nearly all sectors and almost every country in the world. Our portfolio comprises six segments: Chemicals, Materials, Industrial Solutions, Surface Technologies, Nutrition & Care and Agricultural Solutions. BASF, one of the world's leading chemical companies, has a long history of innovation and commitment to sustainability. BASF is dedicated to advancing its biobased research capabilities and expanding its portfolio of sustainable solutions. The company continues to invest heavily in biobased research, reaffirming its commitment to creating a more sustainable world. By leveraging its extensive knowledge, Verbund concept and strategic focus on biobased solutions, BASF is poised to drive significant advancements in the chemical industry, paving the way for a greener and more sustainable future.

The BASF team will provide techno-economic analysis of the lab.-results to HyFINE. Thereby their potential can be evaluated in an early phase and – if needed – the interim findings can provide impulses to improve the project trajectory towards higher technical application probability. Additionally, BASF catalyst experts will advise on technically available catalysts and – if needed – provide assistance in heterogeneous catalysts analysis.

Bronkhorst
Bronkhorst develops and manufactures systems to control flow and composition mostly in high end applications. We are developing new functionality in our flow control systems to measure medium properties like viscosity, density, heat capacity etc. that can be used a quality control or for composition analysis. We expect that by taking part in HyFINE, we can gain valuable knowledge about user cases and gain insight in how we should further develop our technology to be of added value for these cases.

In the short term we want to gain insight in the operational constraints of user cases (what temperature, pressure, flow) and gain insight in how chemical conversions can be monitored (what properties change, for instance detection limit based on viscosity or heat conductivity change during reaction). Then we aim to develop a prototype for a user case where we can offer added value, e.g., monitoring of conversion of oxalic acid to glycolic acid, and test the device under real conditions. With the insights gained we aim to develop new product lines (product versions) for fine chemistry or related markets.

Chaincraft
ChainCraft is a start-up company converting food residues (waste) into medium chain fatty acids using proprietary fermentation technology, which are or can be used in various markets ranging from animal nutrition, flavours & fragrances and food additives, agriculture, and the chemical industry to synthesise ingredients for detergents, personal care, lubricants, etc. Value chain development of Medium Chain Fatty Acids (MCFA) via derivatisation towards new applications will open up new markets for ChainCraft to offset our products. The

strategy to make chemistry circular revolves around MCFAs becoming a key platform compound for the specialty and fine chemical industry.

By participating in HyFINE, we aim to kickstart novel MCFA derivatisation projects, pick up new contacts/relations, and start collaborations that could extend beyond GroenvermogenNL scope. This will lead to verified pilots showcasing technological feasibility and positive business potential for MCFA derivatisation products, and eventually contributes to a serious manufacturing shift within the chemical industry to make specialty and fine chemicals using MCFAs as sustainable resource.

InCatT B.V.
InCatT B.V., a spin-off from University of Amsterdam, is a company specialised in catalyst screening and catalyst development, from initial catalyst-lead finding to process optimisation. Since 2009, we worked with different industries ranging from Flavour & Fragrance, Bio-based industry, Pharmaceutical and bulk chemical industry. InCatT has built a proven track record for most of the common catalytic reactions ranging from hydrogenation, hydroformylation, cross-coupling chemistry to Diels-Alder reaction and the portfolio continues to expand.

We aim to develop advanced High Throughput Reactor (HTR) platforms to significantly accelerate catalyst discovery for the fine chemical industry. The tools created in HyFINE will greatly enhance our catalyst screening and optimisation capabilities. We plan to integrate artificial intelligence (AI) and high-throughput density functional theory (DFT) calculations to combine experimental data from the HTR platform with in-silico insights. By using our already existing robotic platforms we will prepare new ligands and catalysts for HyFINE partners. Gaining deeper knowledge in the areas of green hydrogen and electro-/photocatalytic conversion technologies will be highly valuable for the future direction of InCatT.

InnoSyn B.V.
InnoSyn delivers sustainable, innovative solutions for the chemical industries. Our team of experienced problem-solvers specialises in leveraging advanced technologies such as flow chemistry, biocatalysis and chemocatalysis to drive efficiency, reduce environmental impact, and enhance competitiveness. Development of scalable chemical processes is our core activity. We aim to improve catalyst efficiencies in renewable feedstock based processes that involve a hydrogenative step up to the level that catalyst costs per kilogram product no longer prevents implementation. InnoSyn and Symrise have a new catalyst system for a specific transformation. Selectivity is good but activity is too low; the systems based on unusual additive that makes the difference.

The aim for participation in HyFINE is to gain knowledge on this system to guide further catalyst system engineering by experiments and calculations: understand catalyst activation and deactivation, also with respect to substrate impurities or side products that may act as catalyst poisons. This knowledge gaining phase may involve HTS of ligands, additives, or conditions. Further activities that are required to reach acceptable catalyst costs may involve improved synthesis of catalyst system components, purification protocols to remove catalyst poisons, or recycling protocols for catalyst system components. As a supporting activity, cost calculations will be performed to identify key cost drivers for guiding further R&D. Successful lab scale tech transfer of relevant system to industrial end user and scaleup to pilot plant scale are the next steps.

Nobian
Nobian is a European market leader in the production of salt, essential chemicals and storage caverns. We leverage our core competencies in salt production and electrochemistry to transform high purity salt into essential chemicals that contribute to society and a sustainable living environment. We optimise the use and generation of energy through flexible and safe production processes and supply chains.

Our interest in HyFINE is to change our (polymer) value chain to electrified production based on renewable carbon. Processing of both local biomass fractions as well as recycling would enable this transition. We want to study the feasibility of key reactions towards platform chemicals or based on electricity and renewable carbon, including research questions for investigating unexplored routes. This should enable first demonstration of key reactions to enable process design, and eventually implementation of electrification and renewable carbon in the production of fine chemicals. Of interest are ethylene, polyurethanes, polycarbonates, epoxies and polyester/polyamides.

Shell Global Solutions International B.V. (Shell)
Shell, a leading international energy company, has long recognised the importance of technological advancements for the energy transition. Aiming to become a ‘net-zero carbon’ company by 2050, Shell invests significantly in technology development and deployment. It currently stands as the largest industrial investor in the energy transition within the Netherlands. Globally, Shell runs active R&D programs, both internally and through open innovation collaborations with universities, start-ups, and large companies.

Shell is interested in the valorisation of lignin, originating as by-product from second generation ethanol production to aromatics rich intermediate that can be co-processed in existing facility. Participation in HyFINE will result in an assessment of viability compared to alternative options, and in an assessment of own early-phase development lignin from composition and processability point of view as compared to alternative sources. This will help evaluate the feedstock purity sensitivity of ABC-salt lignin pyrolysis, especially with respect to residual saccharides and water, and increase TRL of ABC-salt lignin pyrolysis technology to 5-6. The long-term interest is more commercially viable use of green hydrogen and electrons to upgrade lignin to economically viable products, providing more economic drive and robustness to second generation ethanol production.

Shimadzu Corporation
There is a high social need to synthesise fine chemicals that previously were made from fossil fuels using biomass and waste as raw materials. As an analytical equipment manufacturer, we have developed technology to help chemical manufacturers and pharmaceutical companies respond to the changes in this process. There are many substances that may impair quality in the process of synthesising chemicals from biomass and waste, and by advancing this analysis, we hope to promote the practical application of the technology.

By participating in HyFINE, we can quickly grasp the needs of chemical manufacturers and pharmaceutical companies and optimise our analytical technology. Our specific interest is to install ELEM-SPOT (GC-Combustion-MS) in a university or corporate laboratory and check the operation of the equipment, analyse samples generated during the process from feedstock decomposition to fine chemical synthesis, and analyse and measure quality inhibitors and useful substances. We will select analytical methods necessary to set quality standards for fine chemicals made from biomass and waste, and create proposals for quality standards, laying the foundation for their implementation in society. We aim to propose quality standards for fine chemicals made from biomass and waste to international organisations (such as ASTM) with consortium members, and develop analytical techniques that will contribute to research into increasing the variety of fine chemical substances.

Siemens
Siemens is a leading technology company focused on industry, infrastructure, mobility, and healthcare. Simcenter Culgi is a molecular modelling and simulation software that's part of Siemens' Simcenter portfolio. It specialises in soft matter and chemical applications, helping scientists and engineers predict material properties at the molecular level. The software offers comprehensive features including molecular structure building and visualisation, mesoscale modelling capabilities, and property prediction for polymers and complex fluids. It seamlessly integrates with other Simcenter tools for multiscale modelling and provides support for both quantum mechanics and molecular dynamics simulations. Simcenter Culgi proves particularly valuable across various industrial applications, serving companies working with polymers and plastics, surfactants and detergents, pharmaceutical formulations, coatings and adhesives, and battery materials. By enabling virtual testing and optimisation of materials before physical prototyping, the software helps organisations reduce experimental costs and accelerate their product development processes.

Participation to HyFINE will allow the development and testing of simulation solutions in the field of sustainable catalysis which will be validated through comparison with industrially relevant case studies. The simulation research teams involved in the work package will be provided licenses of the Simcenter Culgi software and will be supported by Siemens Simcenter.

Symrise AG
German chemicals company Symrise develops, produces and sells fragrance, flavouring and food ingredients, cosmetic active ingredients and raw materials as well as functional ingredients and solutions that enhance the sensory properties and nutrition of various products. Key pillars of our strategy are: renewable feedstocks, catalytic conversions with high atom economy and high turnover number of catalysts. Symrise and InnoSyn have a new catalyst system for a specific transformation. Selectivity is good but activity is too low; the systems based on unusual additive that makes the difference.

The aim for participation in HyFINE is to gain knowledge on this system to guide further catalyst system engineering by experiments and calculations: understand catalyst activation and deactivation, also with respect to substrate impurities or side products that may act as catalyst poisons. This knowledge gaining phase may involve HTS of ligands, additives, or conditions. Further activities that are required to reach acceptable catalyst costs may involve improved synthesis of catalyst system components, purification protocols to remove catalyst poisons, or recycling protocols for catalyst system components. As a supporting activity, cost calculations will be performed to identify key cost drivers for guiding further R&D. Successful lab scale tech transfer of relevant system to industrial end user and scaleup to pilot plant scale are the next steps.

Universities and research institutes

Avans University of Applied Sciences (Avans)
MNEXT at Avans University of Applied Sciences is a leading centre of expertise focused on advancing materials innovation and energy transition. Our mission is to drive applied research that bridges the gap between laboratory research and practical implementation of new technologies, scalable solutions in renewable energy and materials science. MNEXT's research emphasises biobased materials, biochemical processes, integration of renewable energy into power grids, materials for hydrogen production and industrial applications of hydrogen, including fine chemicals, platform chemicals and e-fuel production.

MNEXT will contribute to HyFINE by developing alternative anodes for the selective electro-synthesis of periodate, a key fine chemical used in organic synthesis and pharmaceutical applications. Focusing on electrochemical synthesis and catalyst development will enable us to investigate different electrocatalysts that can replace boron-doped diamond (BDD) anodes. Our research infrastructure includes electrochemical testing facilities and expertise in techno-economic analysis. We will assess the cost, availability, stability and environmental impact of these alternative anodes compared to BDD to determine their scale-up feasibility. Additionally, we aim to explore the electrosynthesis and photo-electrosynthesis of fine chemicals based on industry interactions and the specific needs of the WP6 consortium. Through collaborations with academic institutions and industry partners, MNEXT seeks to develop innovative, scalable electrochemical processes that support the transition to a sustainable fine chemicals sector.

Dutch Institute For Fundamental Energy Research (DIFFER)
DIFFER's mission is to conduct world-leading fundamental research on materials, processes, and systems for a sustainable global energy infrastructure, in close collaboration with academia and industry. Our research is centred on the development of materials, processes, and systems for CO_2-neutral fuels and chemicals, with a focus on electrochemical, plasma, and photochemical conversion. We also place strong emphasis on the valorisation of bio-based and waste-derived feedstocks for the synthesis of specialty and fine chemicals. Our investigations span both experimental and theoretical approaches, including electrode and reactor development, DFT calculations, and AI-driven materials discovery. DIFFER operates within an extensive collaborative network, with R&D activities positioned at Technology Readiness Levels 2 to 5 - bridging fundamental academic research and early-stage industrial and NGO engagement. With these expertises, DIFFER aims to contribute to the different activities and related Tasks and Subtasks of HyFINE.

Eindhoven University of Technology (TU/e)
Eindhoven University of Technology (TU/e) is a research university specialising in engineering science & technology. Our mission is to educate students and advance science and technology to benefit society. We intertwine education and research to develop thought leaders. Partnering with the public and private sectors, we turn basic research into applied solutions. Firmly rooted in the Brainport region of Eindhoven, TU/e supports high-tech leaders like ASML, Philips, and NXP, as well as numerous innovative SMEs in their supply chain. TU/e researchers are internationally recognised for their work on the development of stable and reusable catalyst materials, selective hydrogenation materials and processes (e.g., sorbent and membrane materials and reactors), electrocatalytic materials and electrochemical processes, plasma catalysis, thermal activation of molecules, novel electrical heating methods (e.g., induction heating and Joule heating) and photoredox catalysis.

TU/e will contribute to HyFINE in reactor engineering and new reactor design, catalyst design and development, development of membranes and green solvents, separation-enhanced conversion processes, first principles multi-scale modelling and proof of concepts and prototypes. Other contributions are electrochemical and photochemical synthesis of specialties and fine chemicals from platform molecules, development of novel synthesis routes to produce specialty & fine chemicals. Technologies to be used include electrochemistry and/or photochemistry. TU/e will contribute to direct electrochemical reduction and oxidation, development of oxidation reactions for paired electrolysis in H_2 electrolysers, process intensification, kinetic modelling, understanding electrode engineering aspects and interfacial flow dynamics and electrosynthesis induces by plasma/magnetic fields.

Fontys University of Applied Sciences (Fontys)
The Centre of Expertise (CoE) HTSM at Fontys University of Applied Sciences focuses on practice-oriented research to tackle societal challenges with enabling technologies. A key area is accelerating the energy transition through innovations in hydrogen, battery technology, and energy management. Located in Eindhoven, CoE HTSM is integral to the region’s role in this transition, contributing to sustainable and smart energy solutions. The CoE aims to hasten the shift to renewable energy by developing technologies that transform the decentralised energy infrastructure, promoting a low-carbon future. CoE HTSM explores the production of hydrogen, focusing on cost

reduction, reliability, and its application in various energy chains. The research groups Applied Natural Sciences and High Tech Embedded Software (HTES) are leading our interdisciplinary research efforts in this field. Together with the Science, Engineering and ICT programs of Fontys CoE HTSM aim to train the next generation of high-tech experts tackling todays and tomorrows sustainability challenges.

We will contribute to HyFINE by developing initial discoveries, i.e. testing and optimising potential electrocatalyst before upscaling. This includes optimising electrode fabrication, extensive electrochemical testing varying cell design and process parameters and long term stability tests. We provide a fully equipped analytical lab for offline analysis of reaction mixtures and electrolytes. The Applied Natural Science lab is equipped with facilities for the production and analysis of thin film electrodes. We will organise our research as a micro learning community involving teachers/researchers, research assistants, student interns and interdisciplinary student teams from the Fontys science, engineering and ICT programmes that interact with the consortium partners from industry and academia. The participating staff include specialists in applied electrochemistry, various printing techniques, preparative organic chemistry, chemical analytics and design of experiments. This approach will facilitate knowledge dissemination and contribute to the Human Capital Agenda (HCA) of GroenvermogenNL.

Hanze University of Applied Sciences (Hanze)
Contributing to the energy transition and circularity by practice-oriented research with a visible impact on education and society is one of the strategic aims of The Hanze University of Applied Sciences. Our institute aims to fasten the biobased/circular transition by actively collaborating with stakeholders/companies and educating "human capital" to support the (future) labour market. The Hanze has established the Expertise Center Biobased Economy (KC-BBE) to further these goals. Within the material transition we aim to replace fossil resources by renewable/sustainable alternatives. Biomass, but also waste-based feedstocks (e.g., end-of-life plastics), are utilised to prepare not only materials/plastics but also fine chemicals and/or pharmaceuticals.

The focus of the chemistry group within KC-BBE is "renewable carbon" and includes the synthesis of sustainable monomers, preparation of biopolymers, and the recycling and upcycling of both synthetic and biopolymers. Assets include scale-up facilities up to 50 Liter (multi-purpose reactor), thereby offering the ability to develop synthesis up to kg amounts (to TRL 3-4), and a unique photo-flow reactor for photochemical conversions (e.g., furfural towards 5-hydroxy-2(5H)-furanone) under flow conditions.

Leiden University (LU)
Leiden University (LU) is a renowned institution for its robust research across seven faculties encompassing multiple academic disciplines. Our recently developed strategic plan (2022-2027) prioritises cutting-edge teaching and research with a strong emphasis on societal impact. LU will bring crucial expertise in electrochemical conversion, complex modelling, and environmental impact assessment to the HyFINE consortium. Electrochemical research at LU lies at the global forefront, bringing electrocatalysis at the heart of electrochemical synthesis of specialties and fine chemicals from platform molecules and biomass conversion with green electrons. Over the past decades, we have developed a world-wide unique suite of instrumentation to test and characterise new electrocatalysts, which will play an important role in our contribution to the work package. Other researchers from LU are recognised worldwide for their expertise on photocatalysis.

In HyFINE, we aim to develop new and improved existing electrochemical and photochemical processes to convert platform molecules to specialty products, and to breakdown biomass to a set of interesting fine chemicals. We have state-of-the-art synthetic labs allowing us to prepare and characterise new catalysts and light-absorbing materials necessary for triggering the catalytic processes targeted in HyFINE. We will bring spectroscopic techniques varying from X-rays to IR, NMR, mass-spectrometry, and time-resolved spectroscopy, to identify, study, and understand the various processes occurring during photo- and electro-catalysis. Using density functional theory, we aim to further contribute to fundamental understanding of these catalytic processes, and through expertise with AI methods, we aim to contribute to the development and implementation to support catalyst and reactor design, as well as process integration.

[redacted]

[redacted]

Rijksuniversiteit Groningen (RUG)

The University of Groningen is internationally recognised for its innovative and ground-breaking research, as evidenced by high-level publications, societal recognition, and gaining of research grants, prizes and awards. We value research across the entire disciplinary spectrum of Social Science & Humanities, Science & Engineering, and Health. We use this breadth of expertise to address some of the most challenging, multi-dimensional research problems and complex societal questions, e.g. the sustainable energy transition, through inter-disciplinary collaborations. This consistent focus has led to (inter)national cooperation, in research and education with national and international academic partners, companies, NGOs and other societal parties.

The HyFINE research goals are particularly relevant to the research of several institutes of UG's Faculty of Science and Engineering (FSE), which has defined "energy" and "sustainability" as research focus. RUG will contribute to HyFINE with:

• Design and preparation of advanced/novel catalysts that are essential for the envisioned future conversion processes to fine and specialty chemicals, in particular homogeneous (transition)-metal based catalysts.
• Developing practical reactions and concepts for switching to sustainable feedstocks, such as green hydrogen, carbohydrates, green electrons and fatty acids to produce chemical building blocks suitable for the fine chemical and specialities industry.

Technical University Delft (TUD)

Technical University Delft (TUD), the Netherlands' largest and oldest technical university in the Netherlands, focuses on delivering world-class results in education, research, and innovation. Its primary goals include achieving campus carbon neutrality and a circular economy, while excelling in fields such as energy, climate, mobility, health, and digital society. The university specialises in engineering, technology, computing, design, and natural sciences, aiming to create global impact through technological solutions. TUD has established itself as a leader in the field of hydrogen and green electrons for carbon-based chemistry through its comprehensive research initiatives and collaborative approach. Collaboration with industry partners is our approach towards energy transition, fostering technology capacity and human capital development.

The ambitions of HyFINE to cost-effective produce specialty & fine chemicals from hydrogen, green electrons are highly aligned with the research goals of the TU Delft e-Refinery. Considering bio and plastic waste as potential feedstock is an established research topic at TU Delft. We will contribute to HyFINE with our existing expertise of catalyst development, multiscale modelling, biotechnology, membrane technology, process control, advanced characterisation, techno-economic analysis, recycling and system analysis, and expand our activities in this field. Available research facilities include electrochemical test systems (potentiostats, test cells, gas analysis), advanced high-pressure catalyst testing and *operando* spectroscopy systems, including high-throughput experimentation, advanced material characterisation (SEM, TEM, XPS, XRD, X-ray tomography, neutron tomography, etc.) and computational facilities for advanced simulations and ML approaches.

Netherlands Organisation for Applied Scientific Research (TNO)

The Netherlands Organisation for Applied Scientific Research (TNO) is the largest Dutch Research and Technology Organisation, with over 4.200 fte focusing on addressing societal challenges such as energy transition, healthy society and innovative industry. The unit Energy and Materials Transition (EMT) focuses on supporting industry and government in their transition towards a zero-emission energy system and circular economy whilst increasing Dutch earning power. We build public private partnerships and innovation programs to accelerate technology deployment via applied research, piloting and industrial demonstration projects. We cover the full value chain of hydrogen and green chemistry R&D, from production to transport & storage to use in various sectors, including chemical and fuels industry. TNO has various laboratories and facilities to test, develop and scale up technologies from lab to pilot scale such as the Faraday electrolysis lab (Petten), the Negative Emissions, Electrochemical and Thermo-Catalytical Technology Lab (Rijswijk), the Brightsite plasmalab (Geleen), the

Materials and Holst manufacturing lab (Eindhoven) and the HydroHub and FLIE pilot sites (Groningen and Rotterdam). Our R&D focuses predominantly on TRL 2-6, while fundamental R&D (TRL<2) is carried out in collaboration with universities and industrial piloting/demonstration (TRL>5) together with industrial partners. HyFINE fits with the strategy of our division EMT Industry, which focuses on using renewable energy to convert the feedstock of the future (biomass, waste, plastics, hydrogen and CO_2) in flexible industrial processes. TNO will contribute to HyFINE with:

• Project management: TNO has a large experience with developing public private partnerships on innovation and managing the execution of these multiyear programs in the Netherlands. Examples are, VoltaChem (10 years, 30+ partners), North Sea Energy (5 years, 30+ partners), 2 NextGen Hightech projects (6 years, 26 partners)
• New technology development: applying TNO's know-how and experience in design and delivery of novel integrated (electro)chemical reactors, integration of unit operations, e.g. capture, electrochemical/ thermocatalytic/photocatalytic conversion and downstream purification or conversion; high-tech design and manufacturing of membrane electrode assemblies for CO_2/CO electrolysis or materials for photochemical CO_2 conversion devices; design of high temperature heating technology, including heat delivery materials; plasma technologies development for use in direct electrified CO_2 conversion.
• Testing, benchmarking and validation of technologies: support by independently comparing different technology options that are developed by consortium partners and externally. We can employ technology comparison models based on prospective TEA/LCA and piloting facilities.
• Value chain integration and scale-up: support the consortium during scale up activities of selected technologies, as well as in the integration of these developments in relevant value chains (e.g., providing feed streams from upstream biorefinery processes and/or validating products in downstream applications, etc.)
• Strategy development and KPI monitoring: support the consortium in portfolio management by employing its circular carbon related market and technology datasets and models.

University of Amsterdam (UvA)
The University of Amsterdam (UvA) is committed to sustainability and innovation in green chemistry, focusing on minimising the environmental impact of chemical processes. The Van't Hoff Institute for Molecular Sciences (HIMS) is a leading research centre with expertise in photo and electrochemistry, catalysis (homogeneous, heterogeneous, bio and supramolecular), molecular chemistry, and sustainable materials. Research at HIMS is centred on the transition to a sustainable chemical industry through green hydrogen production, CO_2 utilisation, and renewable energy-driven reactions. HIMS laboratories offer state-of-the-art facilities, including multinuclear NMR, UV-vis, IR spectroscopy, GC-MS, LC-MS, various HR-MS, XRD, SEM, TEM, and catalyst screening equipment.

Positioned at the forefront of sustainable chemical research, HIMS actively contributes to the transition towards green, hydrogen-based and electricity-driven chemistries, aligning with both national and European sustainability goals. HIMS's interdisciplinary research infrastructure enables the integration of catalytic design, advanced materials, and flow systems to optimise reaction efficiency and selectivity. Within HyFINE, our specific areas of focus include method development in electrocatalysis and phot(redox) catalysis, optimising electrochemical synthesis of fine chemicals, pharmaceuticals and related compounds. Equipped with cutting-edge facilities, we will conduct electrolytic unit tests (TRL1-4), synthesise and characterise catalysts, and operate electrochemical setups focused on hydrogen production and storage, encompassing both batch and flow systems. We also aim to invest in state-of-the-art equipment for in situ spectroscopic techniques to study reaction mechanisms and catalyst stability in real time.

Universiteit of Twente (UT)
Since the founding of the University of Twente (UT) in 1961, we have committed ourselves to addressing economic and societal questions through pioneering combinations of technical and social sciences. The UT has developed into a thriving, entrepreneurial university that is known for among others its strengths in engineering capabilities to develop a resilient world, including sustainable and clean energy solutions. The energy transition is a central theme for the University of Twente in its Shaping 2030 initiative. To realise solutions for the various challenges in this domain, the UT Climate Centre focuses on Hydrogen (HyUT) and Carbon dioxide removal. The UT Molecules Centre focuses on synthesising specialty and fine chemicals, ranging from Sustainable Polymers to small molecules (e.g. formamide, t-butanol, propanol), produced from biobased feedstocks. The Polymer Center Twente includes all engineers at UT to further process or recycle sustainable materials.

The goals and focus of our centers are very much aligned to HyFINE. Our activities are aimed to cover many TRL levels, thereby significantly increasing the speed of innovation. UT is well-recognised for being active in the field of design and engineering of innovative chemical reactions, as well as utilising light, electrons and green hydrogen for sustainable processes. Examples include the direct electrochemical conversion of pyrolysis oil (a collaboration of Profs. Mul, Altomare with BTG), photochemical conversions (Mul), the use of biomass and CO_2

to synthesise sustainable polymers or polymer additives from biomass (several collaborations of [redacted] and industry partners), electrocatalysis for polymerisation and in-situ spectro-electrochemistry [redacted], and electrosynthesis of small molecules ([redacted]). The experimental facilities and dedicated process modelling/optimisation allow for studies from small scale to several kg/h operation. For example the Direct Air Capture and Biogas based pilot systems (High pressure Lab) for renewable CO_2 recovery, facilitate studying true renewable Carbon-based chemistry processes at lab to pilot scale ([redacted]).

Utrecht University (UU)
Utrecht University drives scientific advancement through four strategic research themes: Life Sciences, Pathways to Sustainability, Dynamics of Youth, and Institutions for Open Societies. These strategic themes reflect the university's commitment to addressing pressing global challenges through interdisciplinary collaboration, while its approach to open science makes research more accessible and transparent, thereby fostering knowledge exchange between academia and society. UU combines a leading technological position at the Faculty of Science in the catalysis groups with full integration in the "Pathway to Sustainability" strategic theme of UU and close collaboration with the Faculty of Geosciences, in particular with the Copernicus Institute for System and Techno-sociological Analysis. We thus offer a unique environment for training young researchers in an interdisciplinary fashion, which is crucial to addressing the challenges that our society is facing. By bringing our strong expertise and advanced infrastructure in thermal/electro-catalysis, UU will contribute to HyFINE with:

• Design and development of thermal and photochemical chemical conversion routes for the valorisation of biomass and waste streams
• Design and preparation of advanced/novel catalyst materials that are essential for the envisioned future conversion processes to fine and specialty chemicals, including homogeneous (transition)-metal based catalysts, supported metal catalysts, porous materials, including zeolites and metal-organic frameworks, and nanostructured (coated) electrodes.
• Developing advanced analytical tools and models.
• Developing practical processes and concepts for switching to sustainable feedstock, such as green hydrogen, circular carbon, and green electrons to produce chemical building blocks with a strong focus on the challenges in feed composition.

Wageningen University and Wageningen Research (WU and WR)
To explore the potential of nature to improve the quality of life. This is the mission of Wageningen University & Research (WUR). Wageningen University (WU) & Wageningen Research (WR) are two different legal entities active in the field of sustainable production of food/feed/chemicals and materials.

The Biobased Chemistry and Technology group at WU plays a key role by developing and understanding new catalysts and catalytic processes to change our society to one based on biobased and renewable feedstock. By using state-of-art and advanced quantum mechanical methodologies, the BCT research team focuses on providing detailed information about the geometries, electronic structure and properties of heterogeneous catalysts and catalytic systems, as well as the dynamic interaction and reaction mechanism of gas-solid and liquid-solid interfaces at the atomistic level. The bottom-up structure-property-performance relationships, as determined through high-throughput DFT calculations, will complement experimental research in establishing rational design principles for sustainable catalyst development. The Laboratory of Microbiology conducts research on the diversity, physiology, ecology, and evolution of microorganisms, applying this knowledge to develop novel biocatalysts. In HyFINE, we specifically focus on the conversion of wastes and waste gases, particularly C1 molecules (CO and CO_2). This includes the characterisation of metabolic fluxes, physiological responses under waste/gas-fed conditions, and microbial interactions within synthetic or enriched communities to improve the yield and selectivity of PHA and intermediate production processes.

Wageningen Food and Biobased Research (part of WR) is the most prominent research organisation in the Netherlands on biomass related research, with over 100 scientists from different scientific disciplines working on biomass pre-treatment, bio-, electro- and thermochemical conversions, (bio)catalysis, biotechnology, separation & purification, polymer chemistry, materials processing as well as recycling and biodegradation. Our mission is to sustainably convert renewable carbon sources into functional chemicals and functional materials. With over 30 years of experience on biomass conversions and green chemistry & catalysis, WFBR offers a broad, integrated and circular approach from feedstock to conversion and application, to finally end-of-life over the entire value chain of circular products. Industrial feasibility as well as economic viability are integral part of our approach. Participation in HyFINE will give WFBR the opportunity to contribute our vast expertise and experience, while also allowing to further expand our capabilities and knowledge on catalytic conversion of carbohydrates to high value intermediates and building blocks. WFBR offers knowledge, expertise and capabilities in the areas of biobased feedstock analysis and characterisation, continuous heterogeneous catalytic conversions, catalyst development and characterisation, as well as biodegradability and end-of-life analyses.

[redacted]

[redacted]

Appendix D: Technology Readiness Levels in the Chemical Industry

Table E1: Technology Readiness Levels (TRLs) in the chemical industry, specific and detailed criteria and indicators (Buchner et al. 2019), as has been used when writing HyFINE.

	TRL	1	2	3	4	5	6	7	8	9
	Title	[redacted]								
	Description									
General project criteria	Tangible work result									
	Workplace									
	Product (economic)									
Engineering criteria	Reaction engineering (including kinetics, thermodynamics, property data, conversion, selectivity, yield)									
	Process engineering (including up- & downstream and process technology of reaction steps)									
	Flow diagrams									
Capacity as fraction of full-scale / scale-up factor to full-scale	True commodities									
	Pseudocommodities									
	Fine chemicals									
	Specialty chemicals									

Toelichting grondslagen

In dit document kunt u secties vinden die onleesbaar zijn gemaakt. Deze informatie is achterwege gelaten op basis van de Wet open overheid (Woo). De letter die hierbij is vermeld correspondeert met de bijbehorende grondslag in onderstaand overzicht.

G Art. 5.1 lid 2 sub b

Het belang van de openbaarmaking van deze informatie weegt niet op tegen het belang van de economische of financiële belangen van de Staat, andere publiekrechtelijke lichamen of bestuursorganen

J Art. 5.1 lid 2 sub e

Het belang van de openbaarmaking van deze informatie weegt niet op tegen het belang van de eerbiediging van de persoonlijke levenssfeer van betrokkenen

K Art. 5.1 lid 2 sub f

Het belang van de openbaarmaking van deze informatie weegt niet op tegen het belang van de bescherming van andere dan in art. 5.1 lid 1 sub c genoemde concurrentiegevoelige bedrijfs- en fabricagegegevens

P Art. 5.1 lid 5

Het belang van de openbaarmaking van deze informatie weegt niet op tegen het belang van de onevenredige benadeling welke, in uitzonderlijke gevallen, wordt toegebracht aan een ander belang dan genoemd in art. 5.1 de leden 1 en 2, bij andere informatie dan milieu-informatie.