Valorisation of Chemical Inventions with a Sustainable Technological Character

On what role Utrecht Holdings can fulfil regarding valorisation in the chemical landscape & how the success probability for valorisation can be assessed at an early stage

Business Internship Thesis

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Content

Management Summary

Effective knowledge transfer into society can be challenging, time-consuming and complex. The science-based innovations that researchers develop can be aimed to generate impact, both societal and economic. This impact however, is often not automatically generated by merely publishing results. Effectively transferring such academic inventions into society requires (monetary) investments, but moreover a well-defined protection of the intellectual property (IP). What is the best path for commercialisation and how can inventions be converted into products? These questions are daily challenges for Knowledge Transfer Offices (KTOs). All thirteen large Dutch universities founded knowledge transfer subsidiaries or internal departments that are specialised in supporting commercial technology transfer of the generated innovations and inventions. These KTOs stimulate and support academic researchers in the process of technology transfer by organising IP protection, creating business plans or licensing agreements, and finding the right partners for investments and collaborations.

Utrecht Holdings, the KTO of both the Utrecht University and the University Medical Centre Utrecht, fulfils these tasks since 1998. Utrecht Holdings holds the mandate to manage the IP generated at these academic institutions. Although managing the IP of all inventions generated at the university, Utrecht Holdings acknowledges that specific chemical inventions -those with a sustainable technological character- are less represented in its portfolio. The relative lack of such inventions is remarkable, since chemistry is a widely practised science in Utrecht for several decades. The *Debye Institute for Nanomaterials Science* even consists of seven research groups, of which three have a focus on catalysis. These three research groups cover research focused at heterogeneous- and supported catalysts applicable for energy storage, sustainable conversions, renewable raw materials and energy carriers. So although a significant part of the research conducted at this institute is aimed at sustainable innovations, little inventions ‘flow’ to Utrecht Holdings for further valorisation. The objective of this project is to elucidate possibilities resulting in this effect. Complementary, suggestions are made how to increase the valorisation possibilities of chemical inventions with a sustainable technological character.

To elucidate such underlying possibilities, first a landscape analysis has been performed of the chemical academia and industry in the Netherlands. Via a literature study an overview was created of the chemical research conducted at the Utrecht University. A selection has been made of different companies operating in this chemical field (NL). These companies were further analysed regarding businesses (markets) in which they operate, followed by their (future) incentives regarding sustainability. By mapping these characteristics, possibilities for commercial partners have been elucidated. This study illustrates what kind of companies may be interested in academic chemical inventions that contribute to specific sustainability goals. Besides direct licensing, these companies provide collaboration opportunities for inventions that require further development. To complete the landscape analysis, interviews have been conducted to complement the literature study. A selection has been made which type of employees are suitable to interview, with the goal to gain first-hand insights from experienced employees, both in the field of chemistry as in the valorisation process. Employees of chemical companies were selected that have a managerial position or comparable functions relevant for this project. Employees that have been interviewed were positioned as for instance Technology Director, Partnership Director, Vice President Technology or even Chief Technology Officer. From academic institutions, employees from other KTOs have been interviewed with the intention the gain other’s best practises. To gain insights in the valorisation ecosystem surrounding the UU and UMCU, professors have been interviewed, as well as employees from

institutions in Utrecht that support the (commercial) valorisation of inventions generated at Utrecht's academic institutions.

The insights gathered in these two information sources used for the landscape analysis are combined and presented. In addition, two different tools were designed from the insights gathered from the analysis: a scorecard and a SWOT analysis. The scorecard is aimed to help determine the success probability for valorisation of these specific inventions at an early stage. It helps the business developers at Utrecht Holdings determine if an invention has a chance for successful commercial valorisation. The SWOT analysis was conducted for Utrecht Holdings with respect to the chemical academia in Utrecht, portraying its internal strengths and weaknesses together with the external opportunities and threats.

This thesis reveals several reasons for the relative lack of chemical inventions with a sustainable technological character that flow to Utrecht Holdings for further valorisation. In the Faculty of Beta Sciences, which the *Debye Institute* is part of, two major research topics are covered: materials and alternative energies/durability/circularity. The latter topics are mostly covered in research collaborations between academics and industrial partners. These collaborations range from pre-competitive (open science) to competitive (closed, often requested by the concerning company). The materials topics have less collaborations, but consists of very fundamental research. This fundamentality of research brings new challenges when bridging the gap between academic research and industrial implementation. The pre-competitive research collaborations are focused on gaining fundamental insights, to assess the directions certain newer topics might head to. These collaborations seldom result in patent applications: their primary function is to gain insights in (new) technologies. Competitive collaborations are more 'bricked up'. In academic-industrial research collaborations there is always a balance between the amount of financial funding the company brings in, and the amount of IP the company can draw from the research. The competitive collaborations often result in the company filing a patent. In that case, no particular roles for Utrecht Holdings play a part regarding commercial valorisation, as this process is conducted by the companies concerned.

The challenge with more fundamental research is that it is less suitable for commercial/economic valorisation. This is largely due to the nature of the chemical industry. Multiple challenges, such as the scalability of inventions to profitable scale, hamper the companies' interest. Scaling-up an invention is a very time-consuming- and costly operation that can easily take decades and cover hundreds of millions of euros. Companies often look for inventions that have a higher development stage, in order to overcome the first costs in the scaling procedure but moreover, to know that inventions can be implemented in their company. An invention that is further in its development portrays a better overview how it can be implemented in the existing operations of a company. As Utrecht performs fundamental chemical research, this gap is often larger than for instance at technical universities, where research may lead to prototypes that can already be tested. One reason for this is that often research programmes follow-up on the fundamental research, for instance by combining chemistry with chemical technology: the research focuses more on industrial conditions.

In Utrecht, researchers have limited facilities to scale their inventions themselves. Especially for the chemical industry, scaling-up inventions often requires chemical plants to be build. This process often requires phased steps ranging from a laboratory bench to mini plant, to pilot plant, all the way to an eventual full-scale plant that is economically profitable. The lack of this infrastructure also contributes to the lack of start-up creations in Utrecht. This effect is amplified by the fact that the Utrecht incubator (the institute supporting start-up creation and development) focuses on start-ups that are scalable, such as start-ups operating in IT.

It is a challenging task to develop such start-up supporting ecosystem in Utrecht, since it requires (expensive) infrastructure and a value chain consisting of other institutes and companies that can contribute. Furthermore, the fundamental nature of research conducted at the Utrecht University is difficult to change, and not desirable to change. It can be thought of to implement chemical technology studies to the curriculum, to include process technologies relevant for the industry, in order to make research more applicable and therefore more comparable and interesting for industrial companies to adopt. However, this might require change in the research nature of the Utrecht University, that is strong in its fundamental research.

The outcome that there are relatively less economic valorisation opportunities arising from the chemical academia in Utrecht must not be conceived as negative. Yes, economic valorisation contributes to societal impact and yes, especially the beta sciences like chemistry contribute to tangible sustainable solutions more than other disciplines, but the fundamental research is a very important and indispensable part of research. The fact that less tangible sustainable solutions are generated in Utrecht is not per se a negative effect of its fundament. This type of research does contribute to societal benefits when useful insights are generated and shared, but probably at a somewhat slower rate than for instance technical universities do.

In order to contribute to and increase valorisation opportunities for Utrecht Holdings in this specific field, the following actions are recommended:

- Focus on the inventions generated outside of the research collaborations. These inventions still have an opportunities regarding IP, business plan, and development. These inventions possess some challenges, so it is recommended to include a business developer to the Holdings that has the expertise and network to support valorisation.
- Cooperate more with other KTOs. As creating societal impact is the main target of the Holdings, it should not matter which party eventually contributes to the valorisation procedure. Combine the strengths with other institutes to contribute to (economic) valorisation as much as possible. It can be thought of to set up a thematic knowledge transfer institute regarding chemistry, especially since some other KTOs acknowledge the lack of such valorisation opportunities and the accompanied challenges.
- Utrecht Holdings can easily increase researchers' awareness of valorisation at the Utrecht University, by for instance developing flyers with overviews of the valorisation procedure in Utrecht. Here the information is provided regarding which institutes/parties can contribute in what ways and in which phase of invention development. By leaving these at the corresponding secretariats, valorisation awareness can easily be increased. However, this is still a passive form of increasing awareness. To actively increase the awareness, more information must be spread. By giving lectures in both the bachelor's phase as well as the master's phase regarding valorisation in Utrecht, awareness is increased. Combining these two options provide an active and passive form of awareness increasement.
- Present IP package deals to industrial companies. Although some companies responded differently, the overall sound from industry is that the companies are interested in such overviews. Present the patents generated that might be of interest for those companies. Understand what interests these companies have and selected the generated patents, before sharing with the concerning company. This might require individual packages aimed at a specific company.
- A final recommendation is to set up broader consortia. Research at universities often finishes at TRL 3 or 4. Such projects might continue at Universities of Applied Sciences. The University of Applied Science Utrecht hosts the Innovation Lab facilities where certain drop-in technologies can be tested. Try to collaborate and determine projects that can start at universities, followed by

further development at for instance the University of Applied Sciences. Contact companies that might be interested, governmental organisations (e.g. municipalities) for extra funding, and other relevant institutes that can contribute to invention development and therefore societal impact. Invention development is the important aspect, which desirably results in economic valorisation. This method does not compromise the fundamental nature of the Utrecht University, it includes the University of Applied Science while contributing to societal impact(s).

- Overall, Utrecht Holdings has limited resources to increase the valorisation opportunities in this specific field by its own. To increase valorisation opportunities, for instance an experienced business developer must be implemented. To contribute to increasing the valorisation opportunities without drastic changes, Utrecht Holdings must collaborate with the other institutes present in Utrecht. Enhance the relationships with the Research Support Network and (managerial) employees within the chemical academia, in order to expand the sustainable valorisation output. It is beneficial to determine widely supported objectives regarding the valorisation of chemical inventions with a sustainable technological character, and collectively contribute to those. Collaboration is arguably the most important factor in successful valorisation. Contributions to the valorisation ecosystem in Utrecht can be made for improvement.

Introduction

'Valorisation is the process of creating value from knowledge, by making knowledge suitable and available for societal and/or economic application and by transforming it into products, services, processes and new business.' (NWO, 2015) [(1)].

Valorisation, or effective knowledge transfer, entails an ongoing process that starts at a very early stage of innovative research. Knowledge transfer is the bridge between (academic) research and the use of the research by societal and economic stakeholders. It is one mechanism to close the gap that usually exists between researchers (often fundamental) and practitioners in any field of society [(2)].

Valorisation of research not only contributes to societal- and economic improvement, as researchers may also benefit from the process. Not only via monetary remuneration, but in the form of other assets of which some intangible. For instance collaboration lets you develop new knowledge and insights, it lets you gain access to empirical data, and you increase your chances of receiving external funding [(1)].

Multiple disciplines in the knowledge transfer process are part a part of valorisation. The valorisation definition starts with the concept of a process. It is necessary to interact with other parties to perform activities that will result in knowledge utilisation and value addition to the 'pure' research results. Sometimes, scientific knowledge is already in a state ready for valorisation, but more often it still requires several modifications in terms of form and content [(1)].

Valorisation is a wide concept with many possibilities. To actually bridge the gap between research and societal (and economic) impact, researchers may develop start-ups, collaborate for further knowledge or funding, or share their ideas and inventions in scientific papers or at conferences. Le Loux and De Haan [(1)] describe seven steps in the valorisation process. The general outline for this form of valorisation entails:

1. Identification of valorisation opportunities
2. IP management
3. Team creation
4. Value creation
5. Funding the dream
6. Starting the business
7. Networking, sales & traction

These steps accurately describe the design for start-up creation as one example knowledge transfer. However, valorisation includes other forms than those described by Le Loux and De Haan. As stated by the Dutch dictionary 'van Dale', valorisation is explained as 'to give a certain value' or 'make use of' [(3)]. This is a wide interpretation, especially when considering the wide scope that entails knowledge transfer. This definition combined with the wide scope implies that many more actions can 'add value' to scientific research or its outcomes. For instance when presenting scientific research (outcomes) at a conference; the knowledge is spread across a wider platform and others might be able to use some of it for their own benefits. It includes the funding to continue research to be able to develop prototypes or to buy new apparatuses or other resources necessary for continuation. Or when research is in an attractive development stage for a (industrial) company to 'adopt' an academic invention for further development, resulting in market implementation as a product or service. A schematic overview that underpins the broad concept of knowledge valorisation is given in the Report from the European Commission's Expert Group on Knowledge Transfer Indicators by Finne et al [4] that divides knowledge transfer in three core parts, being commercialisation, institutional research and development (R&D) cooperation and trained people. Examples of these aspects are inventing, patenting, licensing, entrepreneurship; contracts, collaboration, funding, publication; and research to business, revisit university, interaction and entrepreneurship, respectively.

It is noteworthy to underline the importance of collaboration in the valorisation process. To bridge the gap between research and eventual implementation, several phases have to be completed. Collaboration between different parties can assist the invention development in these phases, and might induce multiple opportunities. Third parties may provide resources, funding, knowledge, contracts, intellectual property, sales markets or simply other collaboration opportunities. To put it simply, the interaction between theory and practise is of significant importance. Valorisation is tailor-made and its success depends on the interactions between people [1]. One final example that underlines the importance of collaboration is the *Collaboration and Valorisation Strategy* of the SuPREME project, a project focussing on sustainable energy systems funded by the European Union's Horizon 2020 research and innovation programme. Its third mission is to 'create a multidisciplinary and collaborative environment for the delivery of clean energy solutions and European sustainability goals'. A strategic goal of the programme is 'Engagement is strategic partnerships to enhance and leverage research, development and implementation'. Finally some operational goals of the programme include 'Increase participation of business and communities in all aspects of research', 'Identify capabilities of potential partners' and 'Sustain partnerships by periodically reviewing partnership agreements to ensure effectiveness, relevance, and commitment' [5]. It can be thought of that these collaboration goals can be generalised for other valorisation projects or types of research as well.

It is necessary for companies to innovate their businesses, as technological innovation is now often the single most important competitive driver in many industries. This increasing importance is largely driven by the globalisation of markets and the advent of advanced technologies that enable more rapid product design and allow short production runs to be economically feasible. Supporting technological innovation is also important for governments, as it has a number of important effects on society, such as fostering increased GDP, enabling greater communication and mobility, or improving medical treatments. The globalisation of markets increases the importance of (technological) innovation since foreign competitors put pressure on firms to continuously innovate, in order to produce differentiated products and services. By introducing new products, firms help protect their margins and investing in process innovation helps firms lower their costs [6].

Invention Development

The often-referred-to bridge between academic research and societal impact can qualitatively and quantitatively be addressed. A scale that describes and visualises this bridge is the development phase of an invention, best referred to as 'Technology Readiness Level' (TRL). Although different definitions of these exact TRLs exist between institutes, the technology readiness levels referred to in this report are based upon the definitions stated in the Horizon 2020 programme of the European Union [7], as presented in figure 1:

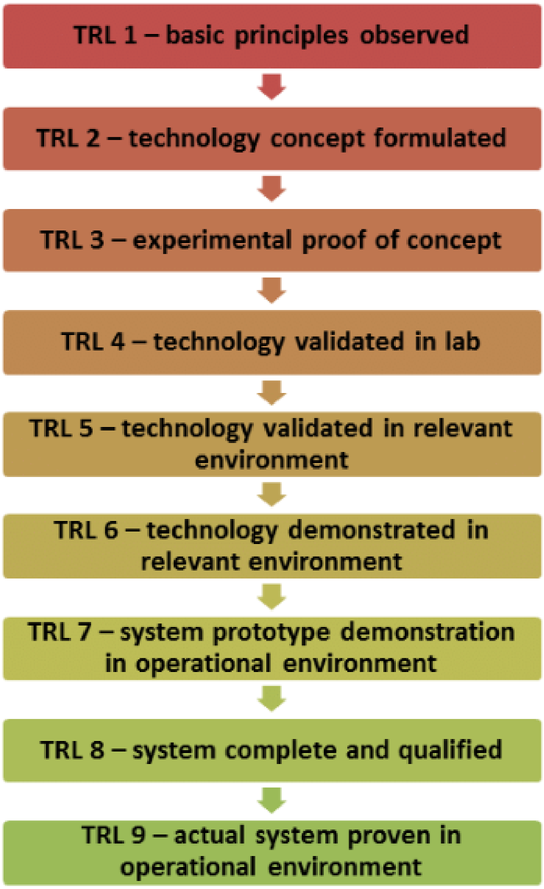

Figure 1: Technology Readiness Levels as stated by the Horizon 2020 Programme [8].

The levels range from 1 to 9, in which TRL 1 refers to the basic principles of an idea, and TRL 9 to an invention already implemented. In academia, mostly fundamental research is being conducted. It can therefore be inferred that inventions in academia ultimately possess TRL 4, where an experimental Proof of Concept has been generated and the technology is validated in a laboratory. A Proof of Concept is a proof (of the first experiments) demonstrating the invention. Technical universities such as Eindhoven, Delft or Twente, are sometimes exceptions regarding the ultimate TRL obtainable in research, since the research conducted at these universities is often more applied. This might result in prototypes that can already be tested in relevant environments; corresponding to TRL 5, 6 or even 7. It is not the core task of universities to develop products or services to a TRL so that it can be implemented market wide, nor is it to set up start-ups. Also, a university has the core task to educate, not to generate revenue or earn a lot of money.

To bridge this gap, between (academic) research and societal impact, the TRL must be raised. And since the universities do not fully support these developments, more effort from other parties and institutes is necessary before market implementation of inventions can be realised. There is a wide range of different parties, institutes, companies, volunteers etc. that can help bridge these technology readiness levels, and therefore assist in the valorisation trajectory. It often requires a lot of resources, money, dedication, time, other investments and especially collaborations before an academic idea is developed into an invention ready for market deployment.

Valorisation in the Netherlands

No other organisation produces as much new knowledge as a university. Some of that knowledge can be protected, increase in value and be traded. Governments look to the university to deliver tangible results to underpin the knowledge economy. And this is where Knowledge Transfer Offices (KTOs) enter the picture [2]. Knowledge valorisation from universities to society has become increasingly important in the past decades. In the Netherlands, all 13 large universities have founded Knowledge Transfer Offices (or Technology Transfer Offices; TTOs) to assist in the valorisation process [9] [10] [11] [12] [13]:

- *Brightlands Maastricht Health Campus*: Maastricht University (& Maastricht UMC)
- *Erasmus MC Technology Transfer Office*: Erasmus Universiteit Rotterdam (Erasmus UMC Rotterdam)
- *Impact & Innovation Centre*: Technische Universiteit Delft
- *Innovation Exchange Amsterdam (IXA)*: Universiteit van Amsterdam & Vrije Universiteit Amsterdam
- *Knowledge Transfer Office within the Corporate Value Creation (CVC)*: Wageningen University & Research.
- *Knowledge Transfer Office of Novel-T*: Universiteit Twente
- *Knowledge Transfer Office of Tilburg University*: Tilburg University
- *Luris*: Universiteit Leiden
- *Universiteit van het Noorden* – Rijksuniversiteit Groningen
- *Radboud Innovation*: Radboud Universiteit Nijmegen
- *Research Support Network*: Technische Universiteit Eindhoven
- *Utrecht Holdings*: Universiteit Utrecht

In addition to conducting research and providing education, valorisation is the third core task of universities [1] [14]. The *Universiteiten van Nederland* (former *Vereniging van Samenwerkende Nederlandse Universiteiten*), the umbrella organisation of fourteen public universities, underline the importance of both social as economic knowledge utilisation as a great value for society. Besides, valorisation and knowledge utilisation occurs in all scientific fields: from scientists that appear in public via for instance MOOCs (Massive Open Online Courses), Studium Generale (lectures and talkshows), HOVO (*Hoger Onderwijs voor Ouderen*); the countless research projects that are conducted each year at the request of various local- and regional authorities, such as the Dutch Government or the Dutch business community; the scientists and universities that are asked for advice on their expertise; to the growing number of academic start-ups, patent and patents applied for and granted [15]. As aforementioned, the wide scope of valorisation and its multiple phase process makes that a wide range of institutes and organisations, whether governmental, commercial or non-profit, can fulfil multifarious assisting roles in the valorisation process. A brief selection of such examples is presented next, to give an insight in the wide range of assisting roles that play part in the valorisation process in the Netherlands.

The Dutch Government

As early as 1974, in the *Nota Wetenschapsbeleid*, Minister of Science F. H. P. Trip questioned whether the investments in science since the Second World War had resulted in the desired consequences. This *Nota Wetenschapsbeleid* stated that it is important for the policy of future science to align research to society's priorities. This resulted in the fact that Innovation-Oriented Research programmes were introduced in 1979. Strategic research programmes were set up in 1980, and in the 1990s the Fund for the enforcement of the Economic Structure (FES) was supporting science with the aim of strengthening the position of the Dutch knowledge economy [14].

In 2004 a policy paper (*Wetenschapsbudget 2004*), issued by Minister of Science (Ministry of Education, Culture and Science 2004) M. J. A. Van der Hoeven, appointed the use of academic knowledge for societal benefits a core goal of science policy in the Netherlands. This resulted in the third goal for universities (besides education and research): transferring knowledge for the benefit of society, as stated in the Higher Education and Research Act (HWH) 1992, article 1.3 [14].

Ambitions relating knowledge transfer resulting in societal benefits are still part of the Dutch government's policy. It is facilitated with funding programmes, such as the Valorisation Programme that started in 2010. In 2010 the Dutch Government (Ministry of Economic Affairs, now Ministry of Economic Affairs and Climate) started the '*Valorisatieprogramma'* that -besides the subsidy programme Knowledge Exploitation (SKE)- functions as a second impulse to entrepreneurial education and professionalisation of valorisation in the Netherlands. This incentivises from the (global) challenges also the Netherlands faces such as the energy transition, sustainability, agriculture, water management, food, healthcare, safety and education. To tackle the forthcoming challenges, partnerships between governments, knowledge institutes, companies and societal organisations are of necessity. By these joint efforts knowledge gained from research may find an application in different walks of life.

In this way societal impact is generated, for instance in the form of new technologies for medical treatments or technologies that counteract climate change. Besides, such knowledge transfer may also contribute to economic growth and employment opportunities when companies develop or start-ups are created. It are these positive effects that the Dutch government therefore actively supports this valorisation process, especially from universities into society. In the end, the valorisation programme supported 12 regional ecosystems with a total amount of €62.7 million, which was doubled by the participants (universities, universities of applied sciences, development companies and industrial companies), and was finished successfully [16] [17].

Examples of valorisation supporting institutes

The wide scope of valorisation presents its fundament in different forms. Contribution to valorisation can present itself in a plethora of applications, of which start-up creation and support, the management of intellectual property or financing are just few. Besides the KTOs of universities, other institutes, ecosystems, and companies in the Netherlands support the valorisation concept in different manners. A selection has been made to present a brief overview what kind of institutes fulfil what kind of roles in the 'Dutch valorisation landscape'. There are many, many more: only a selection is presented.

Thematic Technology Transfer

Thematic technology transfer is an entity with a focus on a specific field. It is basically a combination of strengths of different institutes to support knowledge valorisation. In February 2014, the KNAW (*Koninklijke Nederlandse Akademie van Wetenschappen*) published several advisory remarks regarding valorisation. Titled "Exploitation of Patents on results of Scientific Research" ("*Benutting van Octrooien op resultaten van Wetenschappelijk Onderzoek*"), one advice was to set up one Technology Transfer Office focusing on oncology. It was noticed that oncology was one of the strongest research fields in the Netherlands. Also internationally, this Dutch scientific field had a strong image. Nevertheless, the translation of this strong research to diagnostic tests and therapies lacked significant behind compared to other Anglo-Saxon countries. It was thought that one national TTO/KTO for oncology would change this situation. A strong focus on a clearly defined combination of research and markets, combination of talent, and the required size are decisive elements [(18)].

Another example is "CardioLaborate", the thematic TTO for cardiology. CardioLaborate resulted from collaboration between the Amsterdam Medical Centre, Leiden University Medical Centre, University Medical Centre Utrecht and Interuniversity Cardiological Institute Netherlands, for commercialisation of research in the cardiovascular field, in particular of human biomarkers for cardiovascular diseases. This collaboration was set up with the aim to increase the visibility of the expertise of the participating parties to international customers, improving the flow of scientific knowledge to the application of this knowledge with the aim of improving care for patients with cardiovascular diseases, improving collaboration with companies in the field of cardiovascular biomarkers, and increasing the financial contribution of companies to the research activities of the participants [(18)].

Beside these aforementioned institutes, another contribution to thematic knowledge transfer is conducted by the four technical universities (4TU; Delft, Eindhoven, Twente, Wageningen), TNO and several University Medical Centres (UMCs: Erasmus Rotterdam, Radboud Nijmegen, Maastricht). This TTT supports, stimulates, and expedites the development of promising spin-offs. Three major topics are covered: Circular Technology, Smart Industry and MedTech. Although circular technology is covered by these universities, the Utrecht University is not part of this collaboration. For chemistry, there is no specific thematic collaboration: no TTT chemistry exists in the Netherlands (yet).

COCI sites

Important ecosystems for knowledge valorisation in the chemical field are the Centres for Open Chemical Innovation, or COCI sites, of which one is the Brightlands Chemelot Campus at Geleen.

The Brightlands Chemelot Campus is one of the seven Centres for Open Chemical Innovation across the Netherlands. These COCI locations provide the local required infrastructure for expanding chemical companies. They possess regional and (inter) national sources of financing, technical knowledge, entrepreneurship coaching and business advice, that are made accessible. All this with the aim to fulfil the ambition of Topteam ChemistryNL to improve innovation. The seven COCI sites in the Netherlands are:

- *Green Chemistry Campus*, Bergen op Zoom
- *Chemelot*, Geleen
- *Biotech Campus*, Delft
- *Green PAC*, Emmen
- *Pivot Park*, Oss
- *Plant One*, Botlek-Rotterdam
- *S/park*, Deventer

At these COCI sites, young companies (start-ups which already realised a turnover and tied its first customer) find all utilities and environmental permits that are necessary to scale up production. The companies can utilise the network of established chemical multinationals. Once 'matured', the company leaves the COCI sites to establish elsewhere and make room for new businesses [(19)].

The Brightlands Chemelot Campus is developing into a creative breeding ground for innovation and for new companies. This dynamic situation is partly the result of cooperation between companies, educational and knowledge institutes, as well as the government. The campus makes an active contribution, for example by facilitating the construction of pilot plants and accelerating the development of new activities [(20)]. The entire 'chain' is situated in one location: research & development centres, experimental- and demonstration plants and large-scale production industry. The participants vary from innovative start-ups and small-medium enterprises (SMEs) to strategic important investments from chemical multinationals such as SABIC, OCI Nitrogen, Arlanxeo, DSM and Sekisui. At this moment, the entire site (800 hectares) houses over 150 companies and institutions. The turnover is over €10 billion annually, in which Chemelot covers 20% of the Dutch chemical sector.

The Chemelot site started with the Dutch chemical company DSM, a former mining company (Dutch State Mines), in 1902. Its industry expanded and DSM set up chemical plants for the removal of aromatics from cokes. The industry expanded by the construction of a chemical plant for ammonia synthesis, which is still situated at the campus. Fast forward, DSM moved its facilities, but the infrastructure remained. This proved to be an attractive factor for other companies to situate themselves at the former DSM industrial park. Nowadays, companies can situate themselves at the Chemelot campus and make use of its (existing) facilities, regulatory- and networking capacities.

iLabs

Comparable to the COCI sites are the Innovation Labs, or iLabs. An iLab is a physical breeding ground in the vicinity of knowledge institution(s). At these institutes, starters can develop a promising concept to a scalable product. Start-ups associated with the iLab have access to good lab facilities to independently operate and develop itself. Next to that, the entrepreneur can go for experiments on expensive equipment at the same time, as well as for reflection of new results. When the next phase is reached and experiments on a larger scale are desired, moving to a COCI site is a logical next step [(19)]. There are currently 12 iLabs in the Netherlands:

- *iLab Nijmegen*
- *iLab Eindhoven*
- *iLab Matrix Innovation Centre Amsterdam*
- *Amsterdam Chemistry Network*
- *Zwinc*, part of Green PAC
- *iLab Delft*, part of the Biotech Campus Delft
- *iLab Wageningen*
- *iLab Utrecht*, part of the Utrecht Science Park
- *iLab Innolab Chemie Groningen*
- *iLab High Tech Factory*
- *Green Chemistry Innovation Lab*, part of the Green Chemistry Campus
- *Connectr Innovatielab*

Funding institutes

The *Valorisatieprogramma* of the Dutch government supported valorisation in different manners, with a total of €62.7 million. This is just one example of a governmental programme aimed to bridge the gap between research and societal- and economic implementation. There are multiple more institutes in the Netherlands that fulfil a funding -or funding supporting- role in the valorisation process, presented below:

ChemistryNL

ChemistryNL is the name of the Top Sector Chemistry, one of nine Top Sectors in the Netherlands. These Top Sectors are set up by the Dutch Ministry of Economic Affairs and Climate, with the goal to create opportunities from global challenges in the field of food, health, safety, climate and circularity. The Top Sector Chemistry executes the mission-driven Top Sector and Innovation policy (MTIB).

To generate the best solution for the aforementioned challenges, the business community, universities, research centres and the Dutch government cooperate on knowledge and innovation. Although not providing fundings directly, ChemistryNL offers a platform for different parties in the chemical landscape to find each other and to enter new collaborations [(21)].

ChemistryNL has a complete overview of different funding schemes, each with its own objectives regarding the mission themes. These schemes portray the possibilities for researchers to obtain funding in different stages of their technology readiness level. Figure 2 portrays a brief overview which fundings can be addressed in which development stage of an invention:

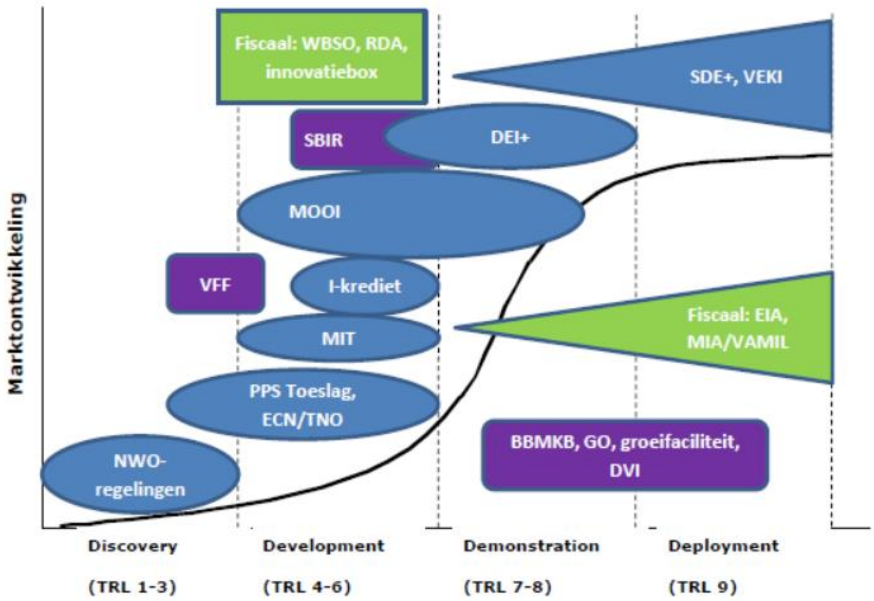

Figure 2: Overview of different types of research funding regarding invention development stage (Technology Readiness Levels) [22].

It is noteworthy to mention that most fundings are focused on the 'Development' phase: TRL 4-6. Most research at academia is conducted in the 'Discovery' phase, between TRL 1-3, and are partly funded by the institutes themselves. The scale-up to larger production, and therefore higher TRL, is a costly and time-consuming procedure, especially in the chemistry landscape. It is therefore logical that funding programmes aim to assist in overcoming these development phases aimed at the first development and scale-up, to demonstration phase.

NWO

The NWO, or *Nederlandse Organisatie voor Wetenschappelijk Onderzoek*, is a governmental organisation with the task to increase the quality of scientific research, as well as the initiation and stimulation of new developments in scientific research [23].

NWO has stated its ambitions for 2019-2022. These five ambitions are [24]:

- Nexus: connecting agendas, science and society
- People: perspective for researchers
- Research: collaboration for excellence and innovation
- Infrastructure: accessible and sustainable scientific infrastructure
- Knowledge utilisation: effective use of knowledge through co-design and co-creation

Overall, NWO invests close to €1 billion annually in curiosity-driven research, research aimed at societal challenges and in research infrastructure. NWO selects and finances research proposals based on advice from expert scientists in the Netherlands and abroad. In addition, NWO has nine of its own research institutes where internationally leading research is conducted. NWO stimulates national and international collaboration, invests in large research facilities, and promotes knowledge utilisation. It finances over 7,000 research projects at universities and other knowledge institutes (25).

Venture Capital Funds

Venture capital funds are pooled investment funds that manage monetary resources of investors who seek private equity stakes in start-ups or small-medium enterprises. These funds seek opportunities with a strong growth potential, in order to make a returning profit. These funds are generally used as seed money or venture capital by new firms seeking accelerated growth. Often investors in a venture capital fund will earn a return upon the exit of a portfolio company, either through an IPO (initial public offering), merger, or acquisition.

These funds have a commercial entity, and always require a return. However, they are attractive for entrepreneurial or other small companies since they are able to raise funding before their operations have started or revenues or profits have been earned. Since these milestones are not yet present, it is a risk to invest in such start-ups or entrepreneurial companies, hence the name venture capital.

Firms that receive venture capital often have high-growth potential, are risky, and have a long investment horizon. The venture capital funds play a more active guidance role in their investment, for instance by providing guidance or holding a board position. They therefore play an active role in the management and operations of these companies in their portfolio (26).

Seed Funds

It is only a very small number of fortunate companies that grow with little or no 'outside' help. Such companies, with a brilliant idea, steadily grow due to friends' generosities, families'- and the owner's own financial resources. However, the large majority of successful start-ups have engaged in multiple efforts to raise capital through rounds of external funding. These rounds provide external investors the opportunity to invest in a growing company, often in exchange for equity or partial ownership (27).

The very first stage of funding a new company is generally not included among the rounds of funding at all. This 'pre-seed funding' is typically aimed at the period in which a company gets its first operations off the ground. Seed funding is the first equity funding stage. It typically refers to the first money that a business raises (27).

The Dutch government support the financial investments in start-ups, as well as support via knowledge, network and experience. This so called *Seed Capital regulation* is aimed to support innovative companies on a technological and creative area raising seed funds. The regulation was active from January 1st 2022 until March 31st 2022 and totalled €32 million (with a maximum subsidy of €10 million) (28). This *Seed Capital regulation* offered several funds, each with a different investment strategy and -focus. There is a total of 40 different funds available within the investment period, and

49 other funds available outside the investment period. It is important to mention that these latter funds are only able to perform follow-up investments [29].

National Growth Fund (*Nationaal Groeifonds*)

The National Growth Fund is an incentive of the Dutch government aimed at projects that contribute to economic growth in the long term. The Growth Fund aims to invest €20 billion between 2021-2025 in such projects, to benefit all: economic growth results in a higher income. The Fund includes investments in two major topics: Knowledge Development and Research, and Development and Innovation. These are themes where most opportunities arise regarding structural and sustainable economic growth. The monetary resources reserved can be applied to specific projects, judged by an independent commission. This commission looks into the effect on the long-term growth of the Dutch economy and weighs societal benefits and drawbacks [30].

The focus on knowledge development is aimed at opportunities that exist to invest in education and the learning of skills. Investing in human capital leads to economic growth. For example, because people can make better services and products by acquiring knowledge, which generates more money. There are two themes contributing to knowledge development: Education and Lifelong Development. The focus on research, development and innovation (R&D and Innovation) portrays opportunities for economic growth, that the Growth Fund wants to realise in combination with other initiators. The themes for this section are: Energy and Sustainable Development, Agriculture and Living Environment, Health and Care, Security and Digitisation, Mobility, and Key Technologies [31].

One exemplary investment from the Growth Fund into chemistry is an investment made on April 9th 2021 of €338 million. This investment is destined for *GroenvermogenNL*, a topic of the Top Sector Energy. The Top Sector Energy is a joint collaboration of the Top Sectors Chemistry, HTSM (High Tech Systems and Materials) and Energy to reveal the potential of hydrogen [32].

Valorisation in Utrecht

It must be stated that the aforementioned institutes are just a selection of examples of institutes that are able to support parts of the valorisation process in the Netherlands. Surrounding the academia in Utrecht, several different institutes fulfil roles in the valorisation process. The institutes selected are based upon the Utrecht University or the Dutch government, meaning they do not have (strong) commercial intentions to make profit but do often ask for a fee for service. For example, Utrecht Holdings holds a 25% revenue clause regarding the profit made from for instance licensing deals, after the costs have been equalled. The other 75% consists of 50% revenue flow to the research department and 25% to the researchers themselves. It is arguable to state that Utrecht Holdings is a non-profit organisation, however it is not its incentive to make profit but to support valorisation. The costs incurred must be recovered and incentives for the licensee must be provided to continue development of the invention. Some examples of institutes that contribute to valorisation in Utrecht are presented:

Research Support Offices

Every faculty of the Utrecht University has its own Research Support Office (RSO). These RSOs support researchers in the whole process of subsidy application, such as information, examples, help with the budget, data management, ethical issues, administrative data, etc. (33).

The RSO of the Faculty Beta Sciences acknowledges the importance of a connection between science and society. The RSO utilises its expertise for the government, the industry, societal organisations and other research institutes (34). Collaboration between researcher of the Faculty Beta Sciences and other organisation can be set up in a plethora of possibilities. Some include sharing expertise and data with that of scientists from other research organisations, the development of technological innovation together with researchers from the business community, collaboration with the government on important and complex issues, or mapping out what future needs our society expects, together with civil society organisations (35).

Regional Development Company

The *Regionaal Ontwikkelingsmaatschappij* (*ROM*) of the Utrecht Region is a proactive and involved societal investor. The objective of the ROM is to increase the accessibility to capital for innovative companies in Utrecht, companies of all development stages. The ROM invests in transition sectors important for tomorrow's economy: Digital, Health, and Sustainability. One type of investments is the Proof-of-Concept Fund, aimed at product development and where the product or service is at TRL 4-6 and is created for investments between €50,000 and €250,000 (36).

One other type of funding the ROM provides is the Participation Fund (*Participatiefonds*). This fund is aimed at companies in a more developed growth phase. It provides share capital and/or (convertible) loans, with a shareholding of 5% - 49%. The investments range from €250,000 to €5,000,000 and are aimed for products or technologies in TRL 6 or higher (37).

iLabs Utrecht

The Utrecht Science Park Innovation Lab supports research in a co-creation setting. The Innovation Lab has over 25 facilities with the newest equipment to facilitate experiments in the fields of Chemistry and Life Sciences. It also houses a chemical technology/engineering facility aimed for method research and pilots. The chemical laboratory is equipped with apparatus specifically aimed to conduct elementary organic syntheses, analysis protein synthesis, analysis, polymer chemistry and analytical chemistry. The chemical technology space is designed to demonstrate and explore techniques in chemical engineering, test simple setups and conduct pilot project in the light of sustainable processes (38) (39) (40).

Utrecht Health Seed Fund (UHSF)

Utrecht Health Seed Fund is an initiative of Utrecht Holdings and the Economic Board Utrecht (EBU). The fund was made possible in part by the European Regional Development Fund (ERDF) programme by the European Union, co-financing by the Dutch government and contributions by the UMC Utrecht and Utrecht University. UHSF invests in promising (scalable) start-ups active in the fields of Life Sciences (biotech, pharma, diagnostics), Digital Health, Medical Devices and Animal Health. The potential investee is a promising start-up that produces a product or service in the Life Science & Health sector, is still in an relatively early stage (TRL 2-7) and is situated in the province of Utrecht [41] [42].

UtrechtInc

UtrechtInc is the start-up incubator for early stage tech start-ups. Founded in 2009, UtrechtInc is a top 10 university-linked incubator in the world. Researchers, first-time founders of tech start-ups, and entrepreneurial students are supported by different programmes such as the validation programmes to bring ideas or research to the market, or with the acceleration programme to grow their start-up. Next to the programmes, UtrechtInc offers facilities, including offices and office hours with lawyers, accountants etc., where the entrepreneurs are part of a community of 200+ ambitious start-ups and graduates. The incubator is aimed at researchers of the Utrecht University with entrepreneurial spirits [43] [44].

Chemical Academia in the Netherlands

The institutes presented in the chapter before, whether Utrecht-based or focussing on national scale, are just examples of different institutes that contribute to knowledge valorisation. In this section, the focus is on the chemical academia in the Netherlands. Different universities provide different chemical educational courses and research topics. They are described to provide an overview of the Dutch chemical academia.

The chemical academia in the Netherlands is widespread over multiple universities. When looking at the defined research programmes, the following universities are active in the following research topics. Note that a selection has been made where it was tried to include only academic research topics where the specific chemical inventions (with a sustainable technological character) could originate. It is therefore that some universities present more chemical research possibilities than others:

TU Delft

The Technical University Delft has one of the wider scopes regarding chemical research at Dutch universities. Often the fundamental research is combined with a practical part, resulting in more applied science. At the Faculty of Applied Sciences research is conducted covering topics such as CO_2 conversion into other compounds using electrocatalysis, exploiting the properties of copper (Cu) catalysts. Operando spectroscopy techniques are utilised to measure in real-time what happens at the surface of catalysts, to understand and improve such research. The faculty also conducts research on improving batteries and looking for alternative energy carriers, such as hydrogen. In other research groups, research is conducted on the development and improvement of luminescence molecules for biomarker applications, the fundamentals of materials and energy, and the storage of electrochemical energy. Research is conducted on for instance Sustainable Drive & Energy Systems, which concerns new, electric drive systems that run on sustainable generated energy and the implementation of this in the design of a new generation of vessels. Alloy designs and its diffusion dynamics, atomic pattern-driven structure design, impurity chemistry and compound formation in Fe (iron).

Delft focuses on gaining fundamental knowledge of local corrosion processes and promote education and best practises in corrosion control. It is focusing on the surface and interface driven solid-state reactions, to design materials for hydrogen and solar energy application, and industrial products with improved performance and lifetime. In Delft they analyses microstructure development, prediction and measurement of stress fields and associated distortion, fluid flow and flow stability of liquid metals, and hot cracking – the microstructural influences on crack initiation. It is tried to close the metals cycle. Its research focuses on the development of more efficient and sustainable technologies for metals extraction and recycling industry. The development of high-strength steel and aluminium alloys are research, as well as the substitution of potentially scarce elements, for instance rare-earth metals in magnesium alloys. Finally, research include energy topics including fuel cells, gas turbines, heat pumps, thermal storage, electrochemical conversion, and biomass. Research on processes such as process intensification, phase behaviour, membrane processes, reactor engineering, combustion, and crystallisation is conducted [(45) (46) (47) (48) (49) (50) (51) (52) (53) (54) (55) (56) (57) (58) (59)].

University of Amsterdam

The University of Amsterdam has a Faculty of Science. Of the eight institutes, the *Van 't Hoff Institute for Molecular Sciences (HIMS)* covers the chemical research where chemical inventions with a sustainable technological character might originate from. It consists of three research groups, of which the Chemistry of Complex Systems and Materials covers the elucidation, characterisation, prediction and design (and controlling) systems that contain mixture of many chemical substrates. The Chemistry for Sustainability group researchers topic regarding energy transition, such as solar fuels, efficient chemical processes and catalysts using earth-abundant, cheap, and non-toxic materials. The group also investigated the chemical recycling and how materials age and degrade [60] [61].

Wageningen University & Research

The Wageningen University has a focus on green solutions. The Wageningen Environmental Research focuses on biodiversity, green climate solutions such as climate-resilient cities and nature-based solutions for climate adaptation and -mitigation, and spatial energy research. The Wageningen Food & Biobased Research investigated possibilities regarding sustainable food packaging and biobased chemicals. Finally, the Wageningen Plant Research looks into Smart Plants & Crops and Smart Farms [62] [63] [64] [65].

TU Twente

The Technical University Twente has a Materials theme that conducts research that combines for instance computer modelling, public-private collaborations and scientists with the goal of discovering how to make materials with the right functionalities and predictable properties. This includes lighter materials for aeronautics, automotive and other industries that can decrease fuel consumption and improve environmental performance. It also includes safer batteries with better energy storage or now fluids for 3D printing [66].

Leiden University

The University of Leiden has a Faculty of Science, which includes the Leiden Institute of Chemistry (LIC). Here, topics regarding energy and sustainability are covered where the researchers employ advanced spectroscopic techniques (operando), nano-imaging, inorganic synthesis, and theoretical methods to elucidate the molecular processes that are the basis of the conversion of solar energy into chemical energy. New catalysts, materials, and molecular and supramolecular systems are developed and investigated. The research includes operando research in electrochemistry, production and storage of hydrogen, biomimetic copper complexes for energy conversion reactions, dissociative chemisorption on transition metal surfaces, electrocatalysis for sustainable energy, electrochemical, catalytic and process engineering aspects of gas-forming electrolysis, and modelling energy conversion dynamics at interfaces [67] [68].

Groningen University

The University of Groningen covers topics such as Advanced Materials, where research focuses on the design, the build and connection of nanostructured and (bio)functional materials to achieve functionality. Its research is aimed at societal themes such as energy, sustainable society and healthy ageing. In 2016, organic chemist prof. dr. Ben Feringa won the Nobel Prize for Chemistry. In 1999, prof. Feringa discovered a light-driven molecular motor, which was recognised to be a world-class breakthrough (69) (70).

Radboud University Nijmegen

The Radboud University Nijmegen researches relevant topics as sustainability, where the Environmental Science group researchers deep emission reductions in energy-intensive industry and international technology cooperation. This also includes research on the environmental impact of chemicals, products, services and technologies to provide recommendations. The group around Ultrafast Spectroscopy of Correlated Materials researcher new magnetic effects so future technologies are able to store and process information quicker and economically while requiring less processing capacity.

The Molecules and Materials focuses on Scanning Probe Microscopy, where the focus is on the electronic and magnetic properties of materials at the atom scale. It also focuses on Spectroscopy and Catalysis, where new hard disks are developed where data is stored on polymers (71) (72).

TU Eindhoven

Finally, the Technical University Eindhoven has several centres that focuses on different topics. The Centre for Wireless Technology researchers wireless systems and antennas. The Darcy Lab research uses MRI facilities to investigate properties of technological porous materials. The Equipment & Prototype Centre makes custom experimental setups and prototypes for various fields of research. The Future Fuels Lab researcher green fuels and cleaner combustions methods for engines. The High Capacity Optical Transmission Lab researchers innovative optical fibres and signal processing techniques, to enable transmission of ultra-high capacity. The Institute for Complex Molecular Systems Laboratory develops and characterises innovative materials from a molecular perspective. The Microfab/Lab develops new micromanufacturing technologies for use in life sciences applications. The Multiscale Lab research on the micro-mechanical deformation and failure behaviour of a broad class of materials. Finally, the NanoAccess entity produces, processes and analyses innovative materials such as optical chips and compound semiconductors used in for instance solar cells (73).

The chemical research conducted at the universities present in the Netherlands do have shared topics contributing to sustainability, such as catalysis and energy storage. The technical universities perform more research on the materials, making its research more applied than for instance the operando spectroscopy conducted at some universities. For instance the TU Delft utilises the knowledge gained from this operando spectroscopy to develop innovative new materials. This is also emphasised by the presence of the Equipment & Prototype Centre at the TU Eindhoven.

Chemical Academia in Utrecht

The chemical research conducted at the Utrecht University is situated in the Faculty of Science. The other faculties are Geosciences; Humanities; Law, Economics and Governance; Medicine; Social and Behavioural Sciences; and Veterinary Medicine (74), of which can be concluded that their research does not arise the chemical inventions with a sustainable technological character. Focusing on the Faculty of Science, eleven research institutes comprise this faculty (75):

- Bijvoet Centre for Biomolecular Research
- Debye Institute for Nanomaterials Science
- Freudenthal Institute for Science and Mathematics Education
- Institute of Biodynamics and Biocomplexity
- Institute of Environmental Biology
- Institute of Information and Computing Sciences
- Institute for Marine and Atmospheric Research (IMAU)
- Institute for Gravitational and Subatomic Physics
- Institute for Theoretical Physics
- Mathematical Institute
- Utrecht Institute for Pharmaceutical Sciences (UIPS)

The broad range of chemistry makes it tricky to consolidate it in one research institute. However, for simplicity, it can -arguably- be stated that chemical research is focused within the *Debye Institute for Nanomaterials Science*. Especially since this project focuses on chemical inventions with a sustainable technological character. The *Debye Institute for Nanomaterials Science* is comprised of seven different research groups and covers the following research topics (76):

- Inorganic Chemistry & Catalysis:

  The ICC group on inorganic functional materials. Specifically, the synthesis, performance and characterisation of these compounds. It has a special emphasis on well-defined heterogeneous catalysts applicable for energy storage and sustainable physicochemical conversion processes. These processes are applicable in the fields of thermal catalysis, photocatalysis, and electrocatalysis. The research group is specialised in the development of operando and *in-situ* (time-resolved) spectroscopy- and microscopy techniques (77).

- Organic Chemistry & Catalysis:

  The OCC group is involved with various catalysis aspects. It designs and synthesises new organometallic and coordination complexes to find new catalytic properties applicable in for instance catalytic conversion of biomass. Furthermore, interdisciplinary research is performed with organic and inorganic chemistry interface on the design of homogeneous, heterogeneous, and hybrid catalyst systems used for the chemical conversion of renewable feedstock (biomass, CO_2, and recycle or waste streams) [(78)].

- Physical & Colloid Chemistry:

Situated in the Van ‘t Hoff Laboratory, the PCC group focuses on the interplay between colloidal synthesis and the physical description of soft matter. Colloid particles of different sizes, shapes, interactions and materials are prepared [(79)].

- Soft Condensed Matter & Biophysics:

The SCM group develops and characterises new model colloids and the quantitative 3D real-space analysis and manipulation of their self-assembly. The application of these advanced materials can be found in photonic crystals and electronic-ink. The Molecular Biophysics group aims at developing and exploiting fluorescence spectroscopy-based techniques in microscopy [(80)].

- Condensed Matter & Interfaces:

This CMI group centres on the chemistry and physics of solids and interfaces. This comprises of the synthesis of semiconductor nanostructures with controlled dimensions and the self-assembly of such buildings blocks [(81)].

- Nanophotonics:

The Nanophotonics group researches the interaction of light and matter on the scale of a wavelength and below. Ultracold atoms can be probed and manipulated using light, to image object through scattering materials. This can be used to track and trap nanoparticles in complex flows, and to characterise and modify material surfaces [(82)].

- Materials Chemistry & Catalysis:

The MCC group focuses on the characterisation, performance, and synthesis of supported catalysts. These catalysts are essential to allow the transformation from fossil- to renewable fuels. The group elucidates structure-performance relationships and investigates large scale existing processes such as methanol synthesis and Fischer Tropsch. The group is active in energy materials, reversible hydrogen storage, and next generation battery materials [(83)].

Strategic theme: Pathways to Sustainability

The Utrecht University places sustainability at the heart of its core tasks and operational management (Strategic Plan 2021-2025 drawn up by the Executive Board) (84). Furthermore, sustainability research and education at Utrecht University are strong and cover many different fields. The communities or fields of expertise the university focuses on are Energy in Transition; Future Food Utrecht; Sustainable Cities; Sustainable Ocean; Towards a Circular Economy; Water, Climate and Future Deltas; Critical Pathways; Science for Sustainability and Sustainability Education and Engagement. The Pathways to Sustainability is one of the strategic themes of the Utrecht University. Researchers from different disciplines work together with external partners to develop a more sustainable society (85). By putting an emphasis on sustainability, the Utrecht University might contribute to these global challenges affecting our population.

Sustainable Development Goals

In the extension of the Utrecht University's 'Pathways to Sustainability' lie the Sustainable Development Goals of the United Nations. These SDG's provide a blueprint for peace and prosperity for people and the planet. The goals recognise that ending hunger, poverty and other deprivations must be aligned with strategies that improve education, health, decrease inequality, and boost economic growth. And all while tackling climate change and preserving oceans and forests. The 17 goals range from ending poverty, all the way to partnerships for the goals (86):

Figure 3: The United Nations Sustainable Development Goals.

Comparable to the fields of expertise of the Pathways to Sustainability programme of the Utrecht University, the SDG's form concrete focus areas for institutes to focus on. They are focused on (industrial) companies and a lot of companies have incorporated them in their future strategies.

Company Profile Utrecht Holdings

Utrecht Holdings is the Knowledge Transfer Office of the Utrecht University (UU) and the University Medical Centre Utrecht (UMCU). Founded in 1998, Utrecht Holdings is comprised of two subsidiaries of Utrecht University and University Medical Centre Utrecht, namely Universiteit Utrecht Holding B.V. and UMC Utrecht Holdings B.V., respectively. Utrecht Holdings has the mandate to manage the intellectual property (IP) generated by the UU and UMCU, who are both 100% shareholder of the company. When scientists of these two knowledge institutes want to valorise their invention, Utrecht Holdings steps in and assists.

Back in the 90s, the interest among researchers grew to not only publish their results in scientific papers, but also generate revenue from it. Pioneers were immunologists Logtenberg and Clevers with their biotech start-up UBiSys (later Crucell), heart surgeon Borst with Octopus, and theologian Van der Plas with his CD-ROMs about Egyptology. The Executive Board of the Utrecht University stopped this sprawl of private companies by researchers. All university's companies were gathered in a holding, who -besides a controlling role- was also given a supporting and stimulating task for starting entrepreneurs. At about the same time a similar organisation arose in the University Medical Centre Utrecht. These two organisations joined forces in the Utrecht Holdings [87].

Utrecht Holdings supports scientists in creating, building and investing in innovations with a particular expertise in biotech, MedTech, education and ICT. The activities at Utrecht Holdings include [88]:

- Screening & scouting of promising research
- Advising on knowledge utilisation, grants and consortium building
- Early-stage market, business and legal advice
- Intellectual property protection and licensing
- Controlling UU and UMCU patent applications and patents
- Leading the formation of new companies, including legal and financial structuring
- Providing investment capability

The mission of Utrecht Holdings is: "*realising economic and societal impact by science based innovation, knowledge transfer and outstanding partnerships.*" Its future vision can be described as: "*Our knowledge transfer efforts are successful when society clearly benefits from their impact.*" [89]

So Utrecht Holdings is a service provider with the researchers affiliated with the Utrecht University and University Medical Centre Utrecht as its 'customers'. These affiliates can be labelled customers, as the service provided by Utrecht Holdings focuses on these researchers. However, Utrecht Holdings supports and stimulates this group. It is better to label the companies doing business with the Holdings its customers. The Holdings bridges the gap between academic research and industrial implementation by connecting and supporting research(ers), but also in transferring IP. When companies want to set up licensing deals to obtain IP generated at Utrecht's two academic institutes, the Holdings negotiates. However, as stated, the mission of Utrecht Holdings is to realise economic and societal impact by science based innovation. It is not the goal or target of Utrecht Holdings to make as much profit as possible. Naturally, since it assists in the process of economic valorisation, a fee is asked for its services. However, this fee is aimed to earn back its expenses and employee costs. It is not intended to earn as much money as possible. Next to that, Utrecht holdings holds a unique position due to its functionality as the bridge between academic and industry. The most (societal) impact is generated when inventions are actually commercialised, whether via entrepreneurship or via licensing deals with existing companies. It would be best for Utrecht Holdings to cater to both parties, both the researchers in their business development, as the companies adopting the inventions. This unique position also translates to its position in the market. Regarding the economic valorisation functionality, with the mission to generate as much societal impact as possible, Utrecht Holdings has no real competitors. Utrecht Holdings is not ‘fighting’ to dominate a market share, this is not important. What is important is generating societal impact via economic valorisation. The more Utrecht-based inventions are valorised, the more impact is generated. Hypothetically, if Utrecht Holdings cannot assist and fulfil a supporting role in the valorisation of a specific invention, but another KTO of another university can, then still societal impact is generated and the mission of Utrecht Holdings succeeds. This also translates to other valorisation-supporting institutes in Utrecht, such as the incubator UtrechtInc. When a researcher chooses the entrepreneurial pathway, Utrecht Holdings can assist in performing a market analysis, controlling the intellectual property etc. UtrechtInc contributes to the entrepreneurial skills of the researchers; it teaches them to think like an entrepreneur, to also perform such market analysis and business related factors contributing to the start-up’s success. Is UtrechtInc therefore a competitor of Utrecht Holdings, since the valorisation is done through them? No! Just like other KTOs operating in the same field (being economic valorisation) UtrechtInc is not a competitor, but must be seen as a partner. A partner for collaboration, or to share knowledge and best practises with, just like other KTOs. These collaborative actions will support the success probability of economic valorisation and therefore, generates the maximum societal and economic impact. Which is the core of these institutes supporting valorisation.

Besides filing for patent and forming new contracts, Utrecht Holdings carried out five new investments in companies. The company has so far managed to set up two funds, which is unique for a KTO and creates great benefits for researchers in commercial technology transfer. It boosts further development of an invention and shows a level of confidence from Utrecht Holdings in the future success of the invention, which likely will attract potential other investors. In 1998, Utrecht Holdings Fund has been set up that invests in spin-offs in exchange for shares or a convertible loan. There are several preconditions: the developed technology or concept should be based on UU or UMCU research, it should be in an early stage and the concept has to be potentially scalable [(90)]. A recently set up fund is the Utrecht Health Seed Fund which is a €5.4 million fund set up by Utrecht Holdings and the Economic Board Utrecht and is financed by *Fonds voor Regionale Ontwikkeling* of the EU, the UMCU and UU. The fund is managed by Utrecht Holdings and provides the opportunity for small and medium sized enterprises that are not UMCU or UU based to also receive funding for their product development. The investments lie between €100,000 and €250,000 and provide a boost for start-ups to move to scale-ups.

Utrecht Holdings is managed by two Directors Knowledge Transfer. Five business developers with different expertise contributing to direct contact with researchers and fulfil assisting roles in the valorisation procedure. Other functions employed in Utrecht Holdings consist of a Manager Intellectual Property, an Investment Manager, two company lawyers, a financial controller, finance & PDM support, and finance administration. Including the Utrecht Health Seed Fund; a Fund Manager and an Investment Analyst. It is important to notice that this -relatively small- team manages all the inventions generated in both the Utrecht University as the University Medical Centre Utrecht.

Problem Identification

It is acknowledged by Utrecht Holdings that only few inventions with a chemical sustainable technological background flow through Utrecht Holdings for further valorisation. As Utrecht Holdings is the KTO of both UU and UMCU, supporting valorisation is the core priority. Considering the wide scope of the Beta Faculty of the UU, and in particular the seven research groups of the Debye Institute for Nanomaterials Science mentioned before, it is of high importance to understand why less valorisation opportunities pass the Holdings, compared to for instance Life Sciences. Chemistry is a very broad concept in which certain inventions from the Life Sciences academic sector (and other) can be classified as such. However, the scope of the project is regarding chemical inventions with a sustainable technological character.

The assignment of the business internship is to obtain better insights in the so called landscape/ecosystem around these particular chemical inventions generated at the Utrecht University. From the fundamental research performed in academia to the implementations in the chemical industry, Utrecht Holdings plays a fundamental role in bridging these stakeholders, ultimately resulting in societal (and economic) benefits.

To gain insight in the main stakeholders involved in the valorisation process, as well as their intentions and expectations, a landscape analysis is performed. This landscape analysis helps to elucidate and understand the role Utrecht Holdings can fulfil therein.

One deliverable resulting from this project is a structured approach on how to access the success probability of the valorisation process of an invention in this sector. The final outcome would be a scorecard that provides an indication whether an invention has a high, medium or low valorisation probability.

The final objective is to create a SWOT analysis of the position of Utrecht Holdings for the chemical academia at the Utrecht University. This SWOT analysis can function as guideline if the outcome of this project decides to chase opportunities in order to fulfil a more complete role in the valorisation process of the UU.

Internship Assignment

"*The focus of this assignment is to develop a model for Utrecht Holdings (UH) for the valorization of inventions in the chemical industry sector. The model should indicate the chance of success for the valorization of any given invention in the chemical sector. The two main envisioned outcomes of the internships are:*

1. *Landscape analysis of sustainability initiatives in the chemical industry sector. This analysis should provide an overview about the fragmentation, investment timelines, unmet innovation needs and un/successful valorization projects from KTOs. Also a classification of the different type of technologies that are licensed to external parties is to be included.*
2. *The development of a structured approach to how access the success probability of the valorization process of an invention in this sector. The final outcome would be a scorecard that provides an indication whether an invention as a high medium or low valorization probability.*

Additional outcome if time allows:

> *Map the major research lines at Utrecht University onto these industry analysis. The final outcome would be a SWOT analysis of the research fields for Utrecht Holdings.*"

Methodology

To elucidate future valorisation possibilities for Utrecht Holdings, a landscape analysis and a SWOT analysis have been made. If the outcome of the project is that Utrecht Holdings has opportunities for improved valorisation of chemical inventions with a sustainable technological character, the generated scorecard can be utilised to determine the success probability for valorisation at an early stage of such an invention. The landscape analysis is conducted by making use of a literature study followed and combined with interviews. The literature study has been conducted to gain primary insights in the chemical landscape. The interviews have been conducted to validate the primary insights gained from the literature study, but moreover to gain secondary, first-hand insights from all stakeholders selected in this project.

Scope of the Project

Before explaining the reasoning and theories for the methods used, the project's scope is determined. A selection has been made regarding the chemical research conducted at the Utrecht University, the companies operating in the (Dutch) chemical sector and therefore, consequently, the core businesses or markets they operate in and their future goals and involvements relating sustainability. This project was aimed to gain as much insights in the chemical landscape as possible. The broad interpretation of chemistry made it impossible to include all its facets within the stated timeframe of this project.

The project is defined on several levels. The inventions that Utrecht Holdings acknowledges is lacking are chemical inventions with a sustainable technological character. Chemistry is such a broad topic that not all 'chemical inventions' can be covered. Topics that heavily relate and overlap to the classical (materials) chemistry are for instance Life Sciences, Biochemistry, Analytical Chemistry and Geochemistry. When thinking of chemical inventions with a sustainable technological character, it can be thought of tangible inventions that contribute to for instance the energy transition (like solar panels), renewable materials (like certain polymers), or industry-efficiency increasements (such as catalysts that decrease resource usage or waste creation). It is therefore that at first hand the research institute *Debye Institute for Nanomaterials Science* of the Utrecht University was selected to scope these chemical inventions from. Institutes such as the "*Bijvoet Centrum voor Biomoleculair Onderzoek"* or the *Utrecht Institute for Pharmaceutical Sciences (UIPS)* were excluded from the scope of the project, although its research can arguable be classified as inventions in the chemical fields.

Literature Study

The literature study has been conducted by scouting different resources available. Books, publications, companies web pages, and other digital resources have been analysed to gain insights in the chemical landscape.

A selection has been made regarding the chemical companies operating in the field. A selection was made between large chemical multinationals and emerging chemical companies (small-medium enterprises: SMEs or start-ups) to distinguish between capital and investment possibilities and regarding the core businesses of the companies. With the focus on sustainability, it is expected that the SMEs have less (monetary) resources to invest in new technologies and new projects to comply with sustainability goals, while the chemical multinational may. When focusing on the chemical inventions with a sustainable technological character, it was therefore expected that these inventions have a higher possibility to be implemented by the multinationals compared to the SMEs. Besides the future investment possibilities, it is expected that the multinational operate in a wider scope of businesses and that some are more conservative businesses, such as the fossil fuel industry. It is thought that the SMEs focus and operate in a more narrowed range of businesses consisting of newer technologies. Hence, the SMEs may provide solutions (products or services) for the multinationals to tackle the forthcoming challenges relating sustainability.

These distinguishing factors may affect the valorisation possibilities for chemical inventions generated in Utrecht's academia. Utrecht Holdings must be aware of the industrial demands and must have, to a large extent, awareness which parties might have interest in certain inventions. That is why the literature study focuses in a selected group of companies, to map the businesses they operate in and what their incentives are relating sustainability. The goal of the literature study is to connect the demands from industry to the inventions offered by the chemical academia in Utrecht.

Interviews

Interviews have been conducted with all stakeholders mentioned in this report. The interviewees have been selected based on their functions within the institutes and companies, with one important criteria being their experience. The interviewees were scouted for managerial functions, in different fields of expertise. Some functions scouted for are comparable to 'Technology Manager', 'Partnerships Manager' or 'Licensing Manager' for companies. For other knowledge institutes the interviewees were scouted for regarding functions like 'Business Developer Chemistry', 'Business Developer Materials' or 'Director Business Development'. For interviewees working in Utrecht's academic environment, (project) managers, professors and technology transfer officers were interviewed.

Before the interviews, general questionnaires were made with questions from Utrecht Holdings that required expert's insights. These primary questionnaires are presented in Appendix 1**.** These questions were focused around the company's/institutes experience around the valorisation procedure, academic partnerships, deals around intellectual property, and what is needed before an academic invention is adopted by a company (invention requirements).

Insights gained in conducted interviews have been implemented in later interviews. One example can be the industrial trends regarding business operations or sustainability. When one interviewee mentioned that certain divisions of company A are for sale, the questionnaire for the interviewee of company A has been personalised. This agile/adaptive form of interviewing ensured accurate questioning and contributed to obtaining more specific information that might be of significance for Utrecht Holdings. For instance when one division of a company is being sold, the valorisation opportunities for Utrecht Holdings to this division may increase, fluctuate, or disappear in the future.

Combining the Literature Study and Interviews

The insights from the literature study and the interviews were selected and combined. The literature study aims to provide a first overview of the chemical landscape and the companies operating in the chemical industry, their businesses and their future goals regarding sustainability. The landscape analysis also aims to create a market overview by elucidating the different types of chemical research conducted in different research groups in Utrecht, and linking those potentials to the industrial businesses and incentives. Hereby, it becomes carefully clear which types of inventions are generated and which companies might have an interest in those: the market opportunities in the form of sales market is determined.

In order to complement the landscape analysis and market overview, interviews are conducted. The insights from the interview validate the outcomes of the literature study and provide more first-hand insight knowledge of experienced employees in the field. Combining the insights obtained from both techniques, the resulted landscape analysis portrays business opportunities for Utrecht Holdings. The insights are combined to provide two deliverables that Utrecht Holdings may utilise to assist in the valorisation process towards the specific chemical inventions.

The first deliverable is to generate a SWOT analysis for Utrecht Holdings regarding the chemical academia in Utrecht. The SWOT analysis portrays the Strengths, Weaknesses, Opportunities and Threats in this field. John Fahy and David Jobber describe three major guidelines for a SWOT analysis (91):

- Focus on relative rather than absolute strengths and weaknesses
- Strengths need to be looked at objectively, as they can turn into weaknesses
- Only those strengths that are valued by the customer should be included

The second deliverable of this project is to generate a scorecard. The scorecard can be utilised to determine the success probability of chemical inventions at an early development stage. The scorecard is based on already existing scorecards used by Utrecht Holdings, specific for other academic fields. General characteristics applicable in multiple academic fields have been revised and improved where necessary. Other characteristics specific for this chemical academic field have been incorporated.

Method

In this section, the obtained insights are presented. During the literature study a selection of companies was made. It was elucidated in which businesses these companies operate and what their (future) incentives regarding sustainability are. As described, connecting these insights to the research conducted in Utrecht might reveal market- and valorisation potential.

Literature Study

The literature study is based upon knowledge gathered during my bachelor's degree at the University of Applied Sciences in Utrecht, and my pre-master's and master's education at the Utrecht University. This formed the base for the selection of companies in the chemical landscape. Besides that, multiple resources like books, articles and internet sources have been analysed and information was gathered and bundled.

Selected Chemical Companies

The companies selected were chosen to portray the broadest possible scope of the chemical landscape regarding the chemical inventions with a sustainable technological character. Ten multinationals were selected, as well as ten younger/smaller start-up companies:

- BASF
- DuPont
- DSM
- Dow Chemical
- Unilever
- Shell
- Total Energies
- Nouryon
- Akzonobel
- Albemarle

- Avantium
- Photanol
- BioMCN
- Ioniqa
- Ceradis
- CarbonX
- Polyscope
- Paramelt
- Innosyn
- Symeres

Operating Businesses

The consecutive step after the selection of companies is determining in which markets or business they operate. The selected companies operate in the following businesses:

Multinationals

- BASF [92]:
    - Agriculture
    - Transport & Automotive sector
    - Chemicals
    - Construction
    - Electronics & Electronic Equipment
    - Energy & Resources
    - Furniture & Wood
    - Household, Industrial & Institutional Cleaning
    - Nutrition
    - Printing & Packaging
    - Personal Care & Hygiene
    - Pharmaceuticals
    - Plastic & Rubber
    - Pulp & Paper
    - Leather & Footwear

- DuPont [93]:
    - Adhesives
    - Advanced Printing Solutions
    - Clean Technologies
    - Construction Materials
    - Consumer Products
    - Electronic Solutions
    - Fabrics, Fibers & Nonwovens
    - Home Garden & Car Care
    - Industrial Films
    - Medical Devices & Materials
    - Packaging Materials & Solutions
    - Personal Protective Equipment
    - Resins
    - Solar / Photovoltaic Solutions
    - Water Solutions

- Dow Chemical [94]:
    - Agriculture, Feed and Animal Care
    - Beauty and Personal Care
    - Building, Construction and Infrastructure
    - Chemical Manufacturing and Industrial
    - Consumer Goods and Appliances
    - Electronics
    - Films, Tapes and Release Liners
    - Food and Beverages
    - Healthcare and Hygiene
    - Home Care, Industrial and Institutional Cleaning
    - Mobility
    - Oil, Gas and Mining
    - Packaging
    - Paints, Inks and Coatings, Power, Water and Telecommunications
    - Pulp and Paper
    - Textiles, Leather and Nonwovens

- DSM [95]:
    - Animal Nutrition & Health
    - Human Nutrition
    - Care & Health
    - Food & Beverage
    - Materials

- Unilever [96]:
    - Beauty & Wellbeing
    - Personal Care
    - Foods & Refreshment
    - Home Care
    - Vitamins, Minerals & Supplements

- Shell [97]:
    - Natural Gas
    - Catalysts & Technologies
    - Industrial Lubricants and Oils for Business
    - Aviation
    - Shell Chemicals
    - Bitumen
    - Commercial Fuels
    - Marine
    - Shell Liquefied Petroleum Gas (LPG)
    - Shell Sulphur Solutions
    - Shell Trading and Supply

- Total Energies [98]:
    - Oil & Gas
    - Renewable Energies
    - Bio-energies
    - Electricity
    - Refining & Petrochemical
    - Polymers
    - Specialty Chemicals
    - Aviation
    - Additives and Special Fuels
    - Batteries
    - Bitumen
    - Fuels
    - Heating
    - Specialty Chemicals
    - Energy Efficiency
    - Special Fluids
    - Natural Gas and Power
    - Gas Mobility
    - Mobility
    - Lubricants
    - Marine
    - Polymers
    - Solar Energy

- Akzonobel [99]:
    - Decorative Paints
    - Automotive and Specialty Coatings
    - Industrial Coatings
    - Marine, Protective and Yacht Coatings

- Albemarle [100]:
    - Lithium
    - Catalysts
    - Bromine Specialties

- Nouryon [101]:
    - Agriculture and food
    - Home and Personal care
    - Paints and coatings
    - Building and infrastructure
    - Polymer specialties
    - Oil, gas and mining
    - Pulp, paper and packaging
    - Transportation

- Batteries
- Catalyst production
- Chemical intermediates
- Chromatography
- Electronics
- Foundry
- Pharmaceutical industry
- Pyrotechnics and matches
- Textile
- Water treatment

Start-ups

- Avantium [102]:
  - Renewable Polymers
  - Renewable Chemistry
  - Catalysis

- Photanol [103]:
  - Renewable Chemicals by algae

- BioMCN [104]:
  - Bio-methanol
  - Grey methanol (regular)

- Ioniqa [105]:
  - Plastic (PET) recycling

- Ceradis [106]:
  - Crop Protection Purposes
  - Fertilizers for Plant Nutrition

- CarbonX [107]:
  - Carbon Nano-sized Filaments

- Innosyn [108]:
  - Bio Catalysis
  - Chemo Catalysis
  - Flow Chemistry

  - Crystallisation
  - Photochemistry
  - Biobased and Circular

- Polyscope [109]:
  - Styrene Maleic Anhydride (SMA) (co)polymers for:
    - Adhesives
    - Appliances
    - Automotives
    - Building and Construction
    - Compounding
    - Electronics
    - Leather, Detergents, and other
    - Packaging
    - Paper
    - Coatings & Inks
    - Orbiscope
    - 3D-printing

- Hucil [110]:
  - Home care
  - Personal care
  - Construction
  - Animal care
  - Automotive
  - Solvents

- Paramelt [111]:
  - Waxes, Adhesives and Coatings for:
    - Investment Casting
    - Packaging
    - Food
    - Cosmetics & Care
    - Specialty Waxes
    - Rubber & Plastics
    - Construction & Assembly

- Symeres [112]:
  - Discovery and Development Chemistry
    - Drug Discovery
    - ADME-Tox
    - Synthetic Chemistry
    - API Development

Sustainable Development Goals

In order to elucidate possible sales markets for these specific chemical inventions, the sustainability incentives of the selected companies have been elucidated. This is primarily done by looking into their incentives regarding the United Nations Sustainable Development Goals.

A selection has been made on specific SDGs that are susceptible for the selected tangible, chemical innovation (with a sustainable technological character). SDGs like 'no poverty' and 'equality' are no-brainers, but it is hard to think of chemical inventions with a sustainable technological character that counteracts these issues. When thinking of such specific inventions, measures like carbon reduction or reducing green-house-gas (GHG) emissions are highly likely to be counteracted by those inventions.

Therefore, the following eight SDGs have been selected:

It was analysed what the selected companies' incentives were for these particular SDGs. The incentives in grey are incentives specified for the SDG, but which are not directly tackled by chemical inventions with a sustainable technological character. Furthermore, not every company addresses all selected SDGs. The contributions of the selected companies to the selected SDGs are:

- **BASF** (113):

Clean water and sanitation

- Sustainable use of water
  Safe water and sanitation projects
- Starting Ventures project: "Better environment, better life"
- Water abstraction
- Maintaining quality
- Preserving conservation areas
- Ensuring improvement processes

Affordable and Clean Energy

- Solar Energy
- Energy and Climate Protection
- Product for wind power
- Energy and Resources
- CO_2 neutral growth to 2030

Industry, Innovation and Infrastructure

- Sustainable Investments
  Sustainability along the Value Chain
- Human Rights
- Cobalt Initiative
- Chemcycling™ (polymers)
- Biomass Balance
- Save fossil resources
- Reduce GHG emissions
- Drive to renewables
- Biobased products

Sustainable Cities and Communities

- Sustainable Construction
- Sustainability Resources in Construction Products
- Sustainable mobility

Responsible Consumption and Production

Sustainability in procurement
- Verbund
- Sustainable Solution Steering
- Alliance to end plastic waste
- Chemical recycling
- Energy and resources
- Member of AEPW
- ChemCyling™

Climate Action

- Climate Protection
- Our Climate Protection Goals
- Our Carbon Management
- Net zero CO_2 emissions (2050)
- Carbon Management

Life Below Water

- Water Stewardship and Water Goals
- Responsible water management
- Using water responsibly
- Reduce emissions to water
- Water Protection

Life on Land

- Biodiversity
  Palm Dialog
- Preventing plastic pellet loss
- Forest Protection
- Energy efficiency
- Resource conservation
- Climate protection
- Reduce emissions in air and water
- Avoid waste generation

- **DuPont** (114):

Leading water stewardship

- Implement holistic water strategies
- Prioritising manufacturing plants
- Leadership in advancing water technology
- Enacting strategic partnerships

Acting on climate

- Reduce greenhouse gas emissions
- Carbon neutral operations (2050)
- Reduce GHG emissions 30%
- Sourcing 60% electricity from renewables

Life Below Water

- Water Stewardship and Water Goals
- Responsible water management
- Using water responsibly
- Reduce emissions to water
- Water Protection

- **DSM** (115):

Clean Water and Sanitation

- Waste water efficiency and treatment programs

Affordable and Clean Energy

- Making affordable, renewable energy a reality with yeast and enzymes for improving biomass conversion of biofuels and biogas

Industry, Innovation and Infrastructure

- Support sustainable development agenda

Sustainable cities and Communities

Cross-sector partnerships and philanthropic initiatives

Responsible Consumption and Production

- Limiting product weight (and waste)
- Minimise waste across value chain
- Reducing weights
- Extending product shelf life
- Brighter Living Solutions

Climate Action

- Improving own carbon footprint
- Enabling a low-carbon economy
- Increasing use of renewables in energy mix
- Reducing carbon footprint in partnership with RE100

Life Below Water

- Strong fishnet fibres
- Omega-3 from algae
- Removing plastics

Life on Land

- Reduction of land use as part of the lifecycle assessment

- **Dow Chemical** (116):

Industry, Innovation and Infrastructure

- Innovating safer materials

Climate Action

- Carbon neutrality
- e-Cracker technologies
- Advancing circular economy
- Reduce carbon emissions: 15% by 2030, neutral by 2050 (scopes 1+2+3 plus product benefits)
- 750 MW from renewable sources by 2025
- Circular plastics

Life Below Water & on Land

- "Valuing nature" → USD 530 million in business value realised through project that are better for business and better for nature

- **Unilever** (117):

Water stewardship

- Reduce water usage
- Optimising operations
- Water recycling

Climate Action

- Transition to renewable energy
- Finding low-carbon ingredients
- Expand plant-based product range
- Fossil-fuel-free cleaning/laundry products
- Decarbonising the business
- Half the amount of virgin plastics
- Reduce scope 1+2 emissions by 100% (2030), interim 70% (2025)
- Net zero scope 1+2+3 by 2039
- 100% plastic are reusable, recyclable, compostable
- Use 25% recycled plastics in packaging

Zero Deforestation

- Transparency and traceability Focused sourcing
- Working with farmers and smallholders
- Regenerate forest
- Raw material origins Partnering
- Stronger monitoring and response

- **Shell** (118):

Water

- Conserve fresh water
- Reducing consumption (15% 2025 in HP areas)
- Increasing reuse and recycling (develop technologies)

Affordable and Clean Energy

- Reliable electricity supply to Africa/Asia
- Net-zero emissions energy business by 2050
- Low-carbon technologies
- Improve energy efficiency
- Reduce absolute emissions by 50% 2030 (scope 1+2)

Industry, Innovation and Infrastructure

- Support off-grid energy projects
- Upgrade/build infrastructure
- R&D investments and support open innovation
- Supporting SMEs

Sustainable Cities and Communities

- Requirements to avoid/minimise cultural impact
- Not explore/develop oil/gas sources in heritage sites
- Conduct impact assessments for new projects (nature and society)

Responsible Consumption and Production

- Ambitions and commitment for circular economy
- Reduce waste (buildings, plastics)
- Circularity for road surfaces
- 30% recycled plastics in packaging (2030)
- Reusable packaging
- 1 mln tonnes plastic a year (2025)

Climate Action

- Supporting Paris Agreement
- Net-zero emissions energy business by 2050
- Reduce absolute emissions by 50% 2030 (scope 1+2)
- Maintain methane emissions intensity below 0.2% by 2025
- Eliminate routine flaring from Upstream operations (2030 → 2025)

Life Below Water

- Avoid, minimise, restore, offset areas
- Protect people and environment

Life on Land

- Biodiversity
  Palm Dialog
- Preventing plastic pellet loss
- Forest Protection
- Energy efficiency
- Resource conservation
- Climate protection
- Reduce emissions in air and water
- Avoid waste generation

- **Total Energies** (119):

Clean Water and Sanitation

- Water management
- Risks and spills management
- Resources efficiency
- Ecosystem preservation
- Discharges <30 mg/L offshore and <15 mg/L onshore/coastal sites
- Risks management policies and measures

Affordable and Clean Energy

- Access to energy
- Renewables energies development
- Other low carbon energies
- Energy efficiency
- Education and awareness on low carbon energy
- 25 GW renewable capacity in 2025 (100 GW in 2030)
- Natural gas, biogas and hydrogen
- Biofuels
- Low carbon initiatives

Industry, Innovation and Infrastructure

- Reliable energy
- Sustainable mobility
- Carbon neutrality by 2050
- 20% of investments to renewables & electricity
- 150,000 charging points in Europe (2025)
- Fluids for electrics/hybrids

Sustainable Cities and Communities

- Providing basic needs
- Sustainable mobility
- Natural heritage
- Reduction in SO_2 emissions in air by 50% (2020)
- Limiting footprint water and air
- Promoting less carbon-intensive energy
- Biodiversity action plan (net positive effect for protected areas)

Responsible Consumption and Production

- Resources efficiency
- Energy efficiency
- Environmental policy & commitments
- Accidental pollutions preventions
- Local environment footprint
- Waste management
- Circular economy

Climate Action

- Strategy linked to climate change
- Curtailing emissions
- Carbon storage and pricing
- Act on emissions, products and customer demand
- Developing carbon sinks
- Carbon neutrality (net zero emissions) 2050 (scope 1+2)
- Carbon neutrality Europe (scope 1+2+3) 2050

Life Below Water

- Marine pollution
- Ecosystem preservation
- Global GES emissions
- From operations
- From marine transport
- From plastics

Life on Land

- Ecosystem preservation
- Sustainable biofuels sourcing
- Nature based solutions
- Biodiversity management

- **Nouryon** [120]:

Industry, Innovation and Infrastructure

- Boost plant reliability
- Bio-based/degradable ingredients for personal care and cleaning
- Digital solutions (industry 4.0)

Responsible Consumption and Production

- Improving eco-efficiency
- Starch replacing petrochemical-based products
- Reduction carbon emission (25% in 2025, neutral in 2030)
- 10% reduction of water usage and waste generation (2030)
- Net zero carbon emissions (2050)

Climate Action

- Mitigating climate change
- Improving eco-efficiency
- Meeting targets by adopting technologies, more efficient processes and sourcing low-carbon energy.

- **Akzonobel** [121]:

Sustainable Cities and Communities

- Innovation in longer lasting products for buildings and infrastructure sector
- Focus on energy efficiency
- Design net-zero buildings and sustainable infrastructure including public transport

Responsible Consumption and Production

- Zero waste programme
- Circular economy approach
- Better results with less resources
- Coatings are an enabler
- Customer solutions with improved performance, durability and long-term protection for substrates
- Coatings enable reuse and recycling

Climate Action

- Carbon neutral by 2050
- Half carbon emission by 2030
- Provide sustainable solutions to customers
- Solutions help improve energy efficiency in manufacturing processes
- Low-curing products, bio-based and water-based solutions
- Longer lasting products

- **Albemarle** [122]:

Clean Water and Sanitation

- Measure water withdrawal, especially in sensitive areas (WRI Aqueduct)
- Reviewing water consumption
- Reduce freshwater usage 25% in 2030 in areas of high/extreme high-water risk

Affordable and Clean Energy

- Catalysts solutions
- Reduce energy use (and GHG-emissions)
- Produce cleaner and more efficient transportation fuels

Industry, Innovation and Infrastructure

- Enabling electrification
- Cleaner transportation
- Improved fire safety standards

Sustainable Cities and Communities

- Positive relations with indigenous populations
- Engages with variety of stakeholders to work for sustainable solutions to global challenges

Responsible Consumption and Production

- Resource stewardship
- Preserve environment
- Efficient resource management
- Environmental friendly production
- Reducing GHG and water footprint

Climate Action

- Reducing GHG emissions
- Refining catalysts
- Cleaner, more efficient transportation fuels and reduced GHG emissions by refiners
- Bromine added to butyl rubber to extend tire life, reduce fuel consumption and minimise CO_2 emissions

Start-ups:

The literature study does not reveal any incentives of the selected start-up companies regarding the UN SDGs. Even few companies mention anything regarding sustainability initiatives. However, these companies often have their core business revolving around innovative and sustainable technologies. Where possible, their technologies and businesses have been linked to the SDGs:

- **Avantium** (123):

Avantium is a start-up company focusing on renewable polymers. As an exception to the other selected start-up companies, Avantium has developed a sustainable future initiatives programme, named Chain Reaction 2030. The actions described are:

- Achieving fossil-free chemical industry by 2050
- By 2030:
    - Technologies deliver 1.5 million tons CO_2 savings
    - Circular business
    - 100% of plant-based feedstock for Renewable Polymers and -Chemistries from sustainable sources
    - 100% advocacy focus on transforming chemical industry (circular, fossil-free)
    - Own operations are achieving net-zero carbon emissions
- By 2025: zero non-hazardous waste to incineration and landfill

Next to the Chain Reaction 2030 initiatives, Avantium performs Life Cycle Assessments (LCA). In these assessments, Avantium elucidates its GHG emissions, and the impacts on natural resources and human health. Furthermore, to achieve a better society, Avantium accelerates the transition from fossil fuels to sustainable alternatives, it manages its environmental footprint and tries to excite the new generation.

The following SDGs can be targeted by these initiatives:

- SDG 9, 11: Designing renewable polymers applicable in industry and infrastructure.
- SDG 12: Responsible consumption and production by generating products from renewable sources, that are also biodegradable.
- SDG 13, 14, 15: Climate action by developing renewable polymers that are biodegradable. Less resources are utilised (sugars as base) and less plastic waste accumulating in water/land.

- **Photanol** [124]:

Photanol is an innovative start-up that produces any carbon compound using cyanobacteria. These bacteria perform photosynthesis to convert CO_2 to carbon-containing molecules. It can be argued that Photanol may contribute directly or indirectly to the following SDGs:

- SDG 9, 11: Designing renewable compounds applicable in industry and infrastructure (e.g. monomers that can be turned into renewable bio-plastics).
- SDG 12: Responsible consumption and production by generating products from renewable sources, that might also are biodegradable.
- SDG 13, 14, 15: Reducing resources exhaustion, therefore reducing possible waste of hazardous and toxic compounds, reducing CO_2 by converting it to (renewable) compounds.

- **BioMCN** [104]:

BioMCN is a start-up company creating bio-methanol. As a widely used product, methanol is now synthesised in a renewable and durable way. This might have impact on the following SDGs:

- SDG 7, 13, 14, 15: Methanol can be used as energy source (e.g. fuel). By synthesising methanol in a durable way, less conventional resources have to be used which may have effect on waste generation that might end up in water or land.
- SDG 12: Responsible consumption and production by synthesising methanol in a durable way.

- **Ioniqa** (105):

Ioniqa is an innovative start-up focussing on the recycling of polyethylene terephthalate (PET). This plastic recycling procedure might affect the following SDGs:

- SDG 9, 11: It might contribute to sustainable infrastructure when recycled PET is used.
- SDG 12, 13, 14, 15: Recycling plastic reduces plastic waste ending up in water and land, reducing its climate impact.

- **Ceradis** (106):

Ceradis is a company involved in plant nutrition and crop protection. Its technology reduces the rate of chemical use per hectare of farmland, with lower residues in crop.

- SDG 12: Responsible production and consumption by reduced use of chemicals.
- SDG 13, 14, 15: Reduced use of chemicals reduces the amount that ‘leaks’ into land and water.

- **CarbonX** [125] [126]:

CarbonX is a young company the invented new carbon material composed of nano-sized carbon filaments. This carbon material is applied in tires and conductive plastics, for instance to increase durability and reduce waste generation. The addition of CarbonX® to tires leads to for instance fuel efficiency, durability, reduced CO_2 emissions, and reduced tyre and road wear particles. It therefore might contribute to the following SDGs:

- SDG 12: Responsible consumption and production, since the product increase durability and life-time of the products it is incorporated in.
- SDG 13, 14, 15: It contributes to these goals by e.g. reducing CO_2 emissions by improving tyre performance. It reduces the wear of tyres which contributes to less damaged life in water and on land.

The other selected start-up companies (Polyscope, Paramelt, Hucil, Innosyn and Symeres) do not develop innovative sustainable technologies. It cannot be traced how these companies might contribute to the UN SDGs. Therefore these companies are not linked to the SDGs. It can be argued that an invention that contributes to more sustainable waxes is interesting for, for instance, Paramelt, as it contributes to sustainability and their core business. However, the sustainability incentives of these companies are not mentioned and therefore these companies were not linked to the SDGs, as it cannot be stated that these companies would be interested in such academic inventions.

By grouping the companies that (might) contribute to specific SDGs, an overview is made. This overview portrays the potential sales market for new inventions, or possibilities for further development of an academic invention. These sustainability incentives make that these companies might be (first) options to contact when a specific academic inventions contributes to those SDGs or the core businesses of the selected companies. An overview has been made:

BASF, DuPont, DSM, Unilever, Shell, Albemarle

BASF, DuPont, DSM, Unilever, Shell, Total Energies, Albemarle, BioMCN

BASF, DSM, Shell, Total Energies, Akzonobel, Albemarle, Ioniqa, Photanol, Avantium

BASF, DSM, Shell, Total Energies, Akzonobel, Albemarle, Ioniqa, Photanol, Avantium

BASF, DSM, Unilever, Shell, Nouryon, Akzonobel, Albemarle, CarbonX, Ceradis, Ioniqa, BioMCN, Photanol, Avantium

BASF, DSM, DuPont, Dow Chemical, Unilever, Shell, Total Energies, Nouryon, Akzonobel, Albemarle, CarbonX, Ceradis, Ioniqa, BioMCN, Photanol, Avantium

BASF, DSM, DuPont, Dow Chemical, Shell, Total Energies, CarbonX, Ceradis, Ioniqa, BioMCN, Photanol, Avantium

BASF, DSM, Dow Chemical, Unilever, Shell, Total Energies, CarbonX, Ceradis, Ioniqa BioMCN, Photanol, Avanium

This grouping portrays the possibilities of sales markets for academic inventions that tackle these SDGs. It is important to mention that the academic inventions must suit the company's core business in order to be interesting for these companies to adopt: a new catalyst reducing CO_2, that therefore contributes in reducing climate change, is not of interest for a company like CarbonX, for instance.

Interviews

To validate the literature study and to gain first-hand insights from the industry, other KTOs and academics, interviews have been conducted with affiliates from different sectors. Unfortunately, it was not succeeded to conduct interviews with affiliates of all selected companies. Furthermore, not all interviewees provided useful insights that were relevant for this project. A selection has been made of all the relevant interviewees, presented in table 1:

Table 1: The anonymised functions of the interviewees (from industry, KTO's, Utrecht), numbered.

Number Interviewee	Anonymised Function
1	*Technology Director Chemical Multinational #1*
2	*Vice President Technology Chemical Multinational #2*
3	*Sustainable Technology Director Chemical Multinational #3*
4	*Partnership Director Chemical Multinational #4*
5	*Sr. Sustainability Manager Chemical Multinational #5*
6	*Technology Scout Chemical Multinational #5*
7	*Research Engineer Chemical Multinational #6*
8	*Chief Technology Officer Small-Medium Enterprise #1*
9	*Sr. R&D Manager – Chemical Multinational #7*
10	*Development Manager Small-Medium Enterprise #2*
11	*Technology Transfer Officer Technical University #1*
12	*Technology Transfer Officer University #2*
13	*Technology Transfer Officer University #3*
14	*Technology Transfer Officer University #4*
15	*Technology Transfer Officer University #5*
16	*Technology Transfer Officer University #6*
17	*Startup Manager COCI site*
18	*Director COCI site*
19	*Professor Beta Faculty Utrecht University #1*
20	*Professor Beta Faculty Utrecht University #2*
21	*Manager Research Consortia Utrecht University*
22	*Incubation Lead – incubator Utrecht University*

Interviewees 1-10 are employees of chemical companies. Their functions range from director of a specific technology of that company, sustainable technology director, to partnership director and technology scout.

Interviewees 11-18 are employees of other KTOs and a COCI site. The KTOs interviewed are all from KTO's linked to universities, both academic and technical.

Interviewees 19-22 are employees of different institutes in Utrecht, contributing to (commercial) valorisation.

Insights

Below presented are insights gathered during the conducted interviews. Not all questions stated in the questionnaires (Appendix 1) are portrayed, since some questions asked resulted in complementary insights. Therefore, almost all questions stated in the questionnaires have been answered and most necessary insights were given.

Industry

First, insights regarding the chemical industry are presented. The most important quotes have been processed in the following paragraph. A more complete overview is presented in Appendix 2.

Number Interviewee	Anonymised Function
1	***Technology Director Chemical Multinational #1***
2	***Vice President Technology Chemical Multinational #2***
3	***Sustainable Technology Director Chemical Multinational #3***
4	***Partnership Director Chemical Multinational #4***
5	***Sr. Sustainability Manager Chemical Multinational #5***
6	***Technology Scout Chemical Multinational #5***
7	***Research Engineer Chemical Multinational #6***
8	***Chief Technology Officer Small-Medium Enterprise #1***
9	***Sr. R&D Manager – Chemical Multinational #7***
10	***Development Manager Small-Medium Enterprise #2***
11	***Technology Transfer Officer Technical University #1***
12	*Technology Transfer Officer University #2*
13	*Technology Transfer Officer University #3*
14	*Technology Transfer Officer University #4*
15	*Technology Transfer Officer University #5*
16	*Technology Transfer Officer University #6*
17	*Startup Manager COCI site*
18	***Director COCI site***
19	***Professor Beta Faculty Utrecht University #1***
20	***Professor Beta Faculty Utrecht University #2***
21	***Manager Research Consortia Utrecht University***
22	*Incubation Lead – incubator Utrecht University*

It is important to recover reasons why industrial companies want to collaborate research with academic institutes. Several reasons form the fundament for these collaborations: primarily to combine forces and create a leverage to research new topics, in order to tackle global challenges (1,2,3,4,5,8,9,10,19,20,21). Companies do not want to discover new market opportunities by themselves, as their research & development expenditures make this expensive. By combining these forces and also sharing the costs, research on new topics is more interesting to perform for these companies. Some interviewees mentioned that by these collaborations the students are already familiar with the concerning companies, as it also forms a training of the next generation of employees (1,4,8).

One of the most important insights of this project is to elucidate what companies are looking for. What requirements must an academic invention meet before a company wants to adopt it? A uniform answer would have been desirable, as an invention fulfilling those requirements has a broad sales market. However, these specified requirements cannot be generalised, as it is very project specific (1,2,3,4,5,6,8,9). The only uniformity found in the responses was that the concerning inventions have to suit the core businesses of the companies (1,2,3,4,5,6,8,9) which, complicating the sales markets of inventions, differ significantly per company. Often companies look for inventions possessing a higher Technology Readiness Level (TRL 4 is absolute minimum), to overcome issues related to the scaling-up of inventions to industrial scale (1,2,3,4,5,6,9). Scaling up an invention is, specifically for the chemical industry, an expensive and time-consuming process that can easily takes decades and hundreds of millions of euros before an academic invention is implemented on an industrial scale.

The final important insights regard the question how academia and KTOs make an extra contribution to valorisation, from the industry’s perspective. As it was known that Utrecht Holdings considers sharing one-pagers, or overviews of the patents generated, it was asked whether companies desire receiving such overviews. Most of the interviewed companies responded positively and desire the patents to be shared with them (1,4,7,9). One company was not interested, as they have little to no time to scan through such overviews, and they fear that the patents are often mismatched with the inventions they look at that suit their strategies (5,6). As stated, most companies responded positively. It was again emphasised to focus on their core businesses (1,3,4). More insights regarding this question included to set up more research consortia for new chemistry (regarding newer topics focused on sustainability) (4) and to implement more scouts and contacts (10), in order to maintain and/or increase the network between academia and the industry.

KTOs

Continuing, insights from other Knowledge Transfer Offices are presented. These insights are listed in Appendix 2, since they often arose during the interview. There, the general key insights are presented first, followed by the listed insights given by the interviewees. A brief overview is presented here:

Number Interviewee	Anonymised Function
1	*Technology Director Chemical Multinational #1*
2	***Vice President Technology Chemical Multinational #2***
3	*Sustainable Technology Director Chemical Multinational* #3
4	*Partnership Director Chemical Multinational #4*
5	*Sr. Sustainability Manager Chemical Multinational #5*
6	*Technology Scout Chemical Multinational #5*
7	*Research Engineer Chemical Multinational #6*
8	***Chief Technology Officer Small-Medium Enterprise #1***
9	*Sr. R&D Manager – Chemical Multinational #7*
10	*Development Manager Small-Medium Enterprise #2*
11	***Technology Transfer Officer Technical University #1***
12	***Technology Transfer Officer University #2***
13	***Technology Transfer Officer University #3***
14	***Technology Transfer Officer University #4***
15	***Technology Transfer Officer University #5***
16	*Technology Transfer Officer University #6*
17	*Startup Manager COCI site*
18	*Director COCI site*
19	*Professor Beta Faculty Utrecht University #1*
20	*Professor Beta Faculty Utrecht University #2*
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22	*Incubation Lead – incubator Utrecht University*

When asking other Knowledge Transfer Institutes how the valorisation of chemical inventions proceeds at their institute, the reactions differ. The general universities (non-technical universities) acknowledge that only few of those inventions flow through their institute for further valorisation. These institutes acknowledge the accompanied challenges as well, such as scalability, determining the economics early on, or finding out the real solution the invention solves (8,11,12,14). One best practise of one KTO is to connect the researchers to a commercial partner as soon as possible, to continue the development of the invention (14).

The technical universities do it 'better', meaning more valorisation of chemical inventions occurs. Three reasons arose during the interviews: often technical universities combine the study 'chemistry' with 'chemical technology', resulting in research that is more comparable to industrial standards. The research therefore is more application oriented, often resulting in inventions with a higher TRL that is thus often easier to implement on industrial scale (11,13). The second reason is that technical universities spin-off more start-up companies compared to general universities. Often due to the more applied research conducted, but mostly because the universities operate in an ecosystem that supports academic entrepreneurship (11,13). One final reason, specific for one technical university, is that they have drawn extra professors that have affinity with valorisation, which of course contributes to the whole valorisation process around that university (13). One important insight gathered regarding chemical start-up companies, is that these are often started by ex-employees of chemical companies, instead of being university spin-offs (2).

Utrecht

The same listed overview applies for the insights gathered concerning the Utrecht University. Besides employees of the Utrecht University, other employees from Utrecht-based institutes have been interviewed. The insights presented all apply to institutes supporting (economic) valorisation of inventions generated at Utrecht University.

Number Interviewee	Anonymised Function
1	*Technology Director Chemical Multinational #1*
2	***Vice President Technology Chemical Multinational #2***
3	***Sustainable Technology Director Chemical Multinational #3***
4	***Partnership Director Chemical Multinational #4***
5	***Sr. Sustainability Manager Chemical Multinational #5***
6	***Technology Scout Chemical Multinational #5***
7	*Research Engineer Chemical Multinational #6*
8	*Chief Technology Officer Small-Medium Enterprise #1*
9	*Sr. R&D Manager – Chemical Multinational #7*
10	*Development Manager Small-Medium Enterprise #2*
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13	*Technology Transfer Officer University #3*
14	*Technology Transfer Officer University #4*
15	*Technology Transfer Officer University #5*
16	***Technology Transfer Officer University #6***
17	*Startup Manager COCI site*
18	*Director COCI site*
19	***Professor Beta Faculty Utrecht University #1***
20	***Professor Beta Faculty Utrecht University #2***
21	***Manager Research Consortia Utrecht University***
22	*Incubation Lead – incubator Utrecht University*

In Utrecht, no chemical start-up companies spin-off from the Utrecht University. The main reasons for this are that the conducted research is fundamental, so the inventions are at a relatively low TRL. Another reason contributing is that the incubator, the institute supporting academic entrepreneurship, focuses on start-up companies that are scalable. This scalability, as explained further on, is one of the biggest challenges in the chemical industry and therefore in the valorisation process. As a final reason, Utrecht does not have sufficient infrastructure for the scale-up of inventions. Yes, there are Innovation Labs, but this is not sufficient in order to scale-up to industrial scale and are focused on specific chemical themes, such as polymer extrusion (16,19,20,21).

Then, the research conducted at the Faculty of Science can be covered into two categories. The first category, focusing on 'Alternative Energies', 'Sustainability', 'Circularity', etc., is mostly covered in the collaborations between academia and industry. The other category, being 'Materials', is not consolidated in such research collaborations, but often consists of very fundamental research (resulting in low TRL inventions). Furthermore, the pre-competitive collaboration is all about generating insights, not resulting in patent applications. The Utrecht University is not a technical university or TNO, it is at the forefront of the development. These factors all contribute to less valorisation options for Utrecht Holdings (15,16).

The Scaling Problem

As stated, companies desire that inventions suit their (core) business and possess higher TRLs. This is largely due to the fact that an academic invention often cannot yet be implemented on industrial scale. The inventions must be scaled gradually in order to be implemented safe and successfully. This scaling is often a difficult process which results in a time- and resource consuming process.

An important insight regarding this issue is given:

- ***Vice President Technology Chemical Multinational #2***
    - "*The scaling-up problem relates to several factors. Toxic raw materials are often used in academic research, that cannot be implemented on industrial scale. Or compounds that contain, for example, nitrate groups, which you do not want to use on a large scale. The safety and availability of preventatives around safety makes it a challenge that is also expensive.*"

The inventions generated by academic research, especially fundamental academic research, is often not implementable on large industrial scale. The compounds that research is conducted on might contain toxic or other dangerous characteristics. When such compounds must be implemented on industrial scale, extra safety measures are necessary. Safety methods concerning for instance the plant construction and development, qualified operators, transportation and storage all accumulate to higher expenses. This all requires more significant investments in order to implement the chemical compound on a larger scale. Complementary to these technical challenges, the physical challenges also multiply. Extra safety measurements must be taken when a chemical reaction is exothermic, meaning heat is release during the reaction. On laboratory scale this exothermic effect might not be dangerous, but when tons of chemicals have to react in order to produce a sufficient amount of product this is a different cup of tea. These examples contribute to the significant costs for setting up a chemical plant, especially on a scale that it becomes profitable to conduct the operation.

To give an insight in the costs and efforts occurring during scaling up, the chemical company Avantium is exemplary. Avantium is currently building its 'FDCA flagship plant' in Delfzijl, which required about €180 million (conducted interview). Figure 4 provides insights regarding the scale, estimated costs and development level regarding the scalability in terms of chemical plant scales:

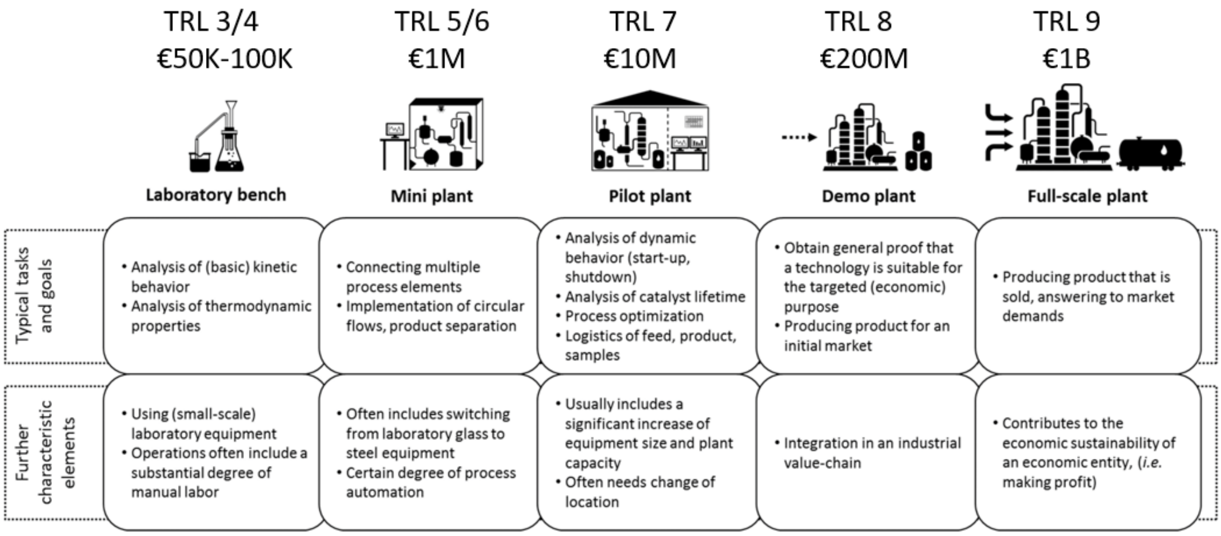

Figure 4: Examples of chemical plant sizes. The estimated costs and corresponding TRLs are included [127].

The flagship plant of Avantium corresponds to the demo plant scale in figure 4. Avantium successfully operated its pilot plant at the Chemelot Campus in Geleen (NL) and almost finishes its new plant. As stated, this flagship plant required €180 million in investments [128]. When that flagship operates, the total expenditure of the project (from research to flagship plant) sums up to €500 million (conducted interview). The TRLs illustrated are coupled based upon the definitions stated in the Horizon 2020 programme of the European Commission, portrayed in figure 1.

A final example of the high costs regarding scalability is of Dow Chemical. Conducted research in collaboration with academics resulted in a patent application. However, Dow Chemical decided not to adopt the patent since it was estimated that implementing the invention on a profitable scale would require €600 million - €700 million in investments (conducted interview).

Conclusions

Chemical Landscape

The chemical landscape is enormously diverse and the scale can certainly be called gigantic, when considering the different markets the chemical companies are active. The companies in the Dutch chemical landscape operate in a plethora of different businesses or markets, especially the multinationals. As presented, their businesses range from Personal Care to Energy, and from Nutrition to Plastics. It can also be concluded from the presented overview that most emerging SMEs operate in more sustainable technologies, such as Avantium, Photanol, BioMCN, and Ioniqa having their core businesses revolving around renewables and recycling. Yet, the businesses overview does not portray specific sales markets for inventions, as the concept is still vague. A company operating in 'Footwear' does not specify what type of inventions it might have an interest for. The sales markets for inventions, what was tried to be covered during this project, can more accurately be addressed by looking at the sustainability incentives, discussed below. Although not specifying it perfectly, and therefore still being somewhat vague, these sustainability incentives do portray a more specific goal for the companies compared to the overview of businesses, making it easier to connect specific inventions generated to these goals. This makes the determination of possible sales markets or development collaborations partners more accurate by focusing on the sustainability incentives instead of the businesses the companies operate in.

The collaboration between academia and industry is a well-founded climate in the Netherlands. Numerous collaborations between all kinds of different organisations have been taking place for decades. The range of financing options offered by the government is also well known. The industry is reasonably well aware of what kind of collaborations exist and which themes are being researched at which university. Of course, this overview can never be complete and commercial chemical companies often like to collaborate with academic institutions. In collaborations with a link between public-private partnerships (such as the ARC CBBC consortium) and bilateral collaborations (financing and supervising PhD students and other researchers), themes that are relevant to the chemical industry are investigated. The inventions that arise here, as a result of a market pull, have a greater chance of being adopted by the industrial partners involved. The role of Utrecht Holdings in this transfer of intellectual property is limited: at most it can come down to patent applications and involvement in the negotiations. In bilateral collaborations, it often happens that the industrial financier(s) carry out the applications.

The inventions generated outside this type of collaboration sometimes lack the market pull, the demand from society. The valorisation of such technology push inventions is more difficult, because the problem is not clearly known and therefore the demand from the market does not immediately arise. An invention may have an application, but if it does not solve a concrete problem, it is not easily amenable to economic valorisation. Certainly not because of the factors related to the scaling-up problem in the chemical industry. The university's inventions are generally at a (too) low TRL, making the financial risk too significant to try to scale it up to (profitable) market introduction. This scaling-up of inventions is an enormously expensive and time-consuming challenge, unlike in other fields, take the example of Avantium. The 20 years and almost €500 million total investment highlights the financial risk, even for such a disruptive developing chemical company.

This scaling-up problem results in most chemical companies not adopting inventions until they are at a higher TRL, for example by collaborating with start-ups. However, setting up (disruptive) start-ups is difficult, because in general it will only be a success if a large demand from society can be solved. Apart from the necessary financing and collaborations with third parties, this is also made more difficult by the already existing collaborations that chemical multinationals have with academic institutes. Research is already being conducted here focussing on 'questions from society/industry', making it more difficult for start-ups to define an unknown problem and find the right invention. Only a few academic start-ups are established in the Netherlands, compared to other fields. Not at all in Utrecht, which is partly due to the lack of (public) financing options, which are sometimes region specific. The ecosystem for start-up creation is also missing, which is often stronger in, for example, Eindhoven with the Brainport region. Most chemical start-ups are founded by former industry employees. They have better knowledge about the problems the industry wants to solve and possess the right network. The academic start-ups that are created often spin off from technical universities, where more applied research takes place and research more often results in inventions that can be tested in practice (prototypes). For chemistry, this is often the result of the combination of chemistry and chemical technology in the courses/research, so that research focuses more on process techniques/technologies than at academic universities. At academic universities the research is more fundamental and more focused on the (building blocks of) materials (insights into surface reactions and kinetics). This may sound like missed economic valorisation opportunities, but it is crucial for innovation within the chemical academy and industry. Fundamental chemical research does contribute to (economic) valorisation, just at a somewhat slower rate compared to more applied research conducted in the collaborations between academic and industry, and at technical universities.

Sustainability

Regarding sustainability, important information can be gathered via a literature study. Most large chemical multinationals mention their sustainability incentives regarding the UN SDGs. However, these goals are specific for the company's businesses and are often still formulated vaguely. Almost all selected companies (multinationals) try to contribute to the climate, for instance by their incentives to be carbon neutral in some decades. It is however not mentioned how these companies give substance to these incentives. Therefore, it cannot precisely be linked to the academic research conducted at the Utrecht University. It does however portray an overview which companies have which broad and general incentives regarding sustainability. It therefore portrays a first indications which companies might have an interest if an academic inventions tackles a certain sustainable challenge.

The start-up chemical companies (Small Medium Enterprises) do not mention incentives linked to the UN SDGs. Even most start-ups did not mention anything regarding sustainability at all. This can be caused by the fact that these companies are still conquering a significant position in the markets/businesses they operate in, or that their core business(es) already revolves around sustainable technologies. This can also be explained by the fact that the interviews have been mostly conducted with managerial employees of the multinationals. Only two of the ten selected start-up companies were interviewed. A reason for this might be that the start-ups are not yet ready to adopt new inventions: they are concurring their market position and need to grow, before possessing the (financial) resources to adopt academic inventions.

Nevertheless, these start-up companies more often revolve around sustainable technologies, such as Avantium and Ioniqa that are involved in bio-plastics (recycling). An effort was made to link these sustainable technologies to the UN SDGs, in order to make it comparable to the multinationals but moreover to determine the sales markets for inventions that contribute to specific SDGs. As mentioned, especially for these start-ups, the inventions must suit the core business of those companies in order to be implemented: a company focussing on bio-plastics will not adopts an invention that improves solar energy, for instance.

Conclusions regarding Utrecht Holdings

As stated, the chemical academia in Utrecht is partly based in academic-industrial collaborations. The role Utrecht Holdings can fulfil herein are limited. The most promising role will be when none of the companies wants to adopt the patent resulting from a patent application. Then, the intellectual property is -most likely, depending on type of collaboration- owned by the Utrecht University. Utrecht Holdings can then support economic valorisation, but only if the researchers or the university shares that ambition. Consequently, the companies involved in the research and patent application do not cancel the adoption for no reason. If they already do not see (economic) potential, it increases the challenges that are accompanied in the valorisation process for Utrecht Holdings. Companies are often more capable of conducting important assessments such as techno-economic evaluations early on, since they perform these assessments in multidisciplinary teams with expertise from the whole company. The researchers nor Utrecht Holdings has this ability, since it either lacks business understandings or the chemical expertise (specialism and network).

Inventions resulting from research outside these collaborations provide valorisation opportunities for Utrecht Holdings. However, more challenges are accompanied with it, since it is even more fundamental. Often researchers think their invention contributes to societal- or economic improvements, but do not understand the business around it. An invention might have an opportunity, but as it is often not known which problem(s) it solves, the changes for successful economic valorisation are limited. Besides the unknown problem definition, scalability is a huge challenge that must be overcome. Utrecht lacks important facilities to scale the invention to a scale of which the industry finds it interesting (more de-risked and easier to implement). A third reason is the lack of techno-economic evaluation capabilities, which is an important factor for companies when adopting inventions.

The chemical research at the *Debye Institute for Nanomaterials Science* includes major topics like catalysis. Catalysis is widely applicable in the chemical industry and also generate contributions to sustainability. It is therefore that this project looked into these research groups at first. Unfortunately, employees, researchers or professors of the other research groups have not been interviewed in time. Focusing on the Materials Chemistry & Catalysis group, this group might be of interest in the future since its research on energy carriers, which is expected to be an increasing market in the upcoming decades. The two research groups focusing on condensed matter also might provide valorisation opportunities since their research includes for instance semiconductor nanostructures that find application in electronics or solar panels. The Physical & Colloid Chemistry group and Nanophotonics group focus more on physical properties and optical materials. Although it must be kept track of their inventions, at first it was concluded that these inventions contribute less to sustainability compared to the Catalysis groups.

Regarding the new chemistry, which includes the topics surrounding sustainability (e.g. hydrogen, carbon-capture, etc.), a new value chain has to be set up. In the classical fields such as chemistry, the network between academics and industry is quite established. However, this is not the case for this new chemistry. Companies indicated that it would be preferential if such connections are being developed. When such a network is established, this contributes to economic valorisation as more partners are identified and more research collaborations can be established. This also relates to the awareness of industrial companies what types of research is conducted at which university. Offering overviews of patents, in the form of for instance package deals, might contribute to this awareness as well as contributing to establishing the network or value chain.

A final conclusion for Utrecht Holdings is the awareness around valorisation of the researchers. The interviewed professors all are aware of the role Utrecht Holdings can fulfil in the valorisation process. However, not all students / researchers are. Increasing this awareness in the research groups and institutes might contribute to more (economic) valorisation.

Scorecard

The scorecard developed is largely based on existing scorecards at Utrecht Holdings. The topics ‘Market Potential’, ‘Go-to-Market Conditions’, ‘Impact’, ‘Technical Feasibility’ and ‘Risks’ were already stated in the older scorecards, aimed at different academic fields. These topics have been critically reviewed and adjusted for the specific chemical field where necessary.

The topic ‘Economics’ has been developed and implemented in the revised scorecard. The insights from the interviews emphasised the importance of an early techno-economic evaluation. The following question regarding economics have been implemented in the scorecard:

Table 2: The ‘Economics’ section in the scorecard applicable for chemical inventions.

Economics				
What is a Ball Park cost indication to enter the market?	*€0-€10M €10M-€100M €100M-€500M €500M-€1B €1B+*			
What are foreseen Ball Park costs for scaling up?	*(E.g. mini plant, pilot plant, demo plant, full-scale plant)*			
Can the technology payback period be estimated?	*Until Break-even Point Cumulative Cash Flow 0-5y 5-10y 10-15y 15+y*			
Is the invention applicable for multiple purposes or processes?	*(E.g. invention that can reduce CO_2 might reduce more)*			
Does the invention require new facilities to be build, or can it be applied in existing ones?	*(E.g. drop-in)*			
To summarise: is it possible to predict a first techno-economic scenario?				
Room for explanation (max. 150 words)				

Although it might be difficult to answer these questions in advance, especially without the availability of other disciplinary teams like in the industry, it is beneficial for researchers to think about these questions. These questions aim to focus on the important business/market characteristics the chemical industry deals with, instead of solely focusing on the invention characteristics itself. Besides, the scorecard is intended to valuate chemical inventions with a sustainable technological character in an early stage. It is therefore intended to provide a minimalistic overview of the success probability for valorisation. In other words, many factors might require changes or different perspectives once the inventions develops. The complete scorecard has been omitted from this report due to secrecy.

SWOT Analysis

A SWOT analysis has been conducted. In this analysis, the position of Utrecht Holdings with regard to the academia in Utrecht is analysed. The Strengths, Weaknesses, Opportunities and Threats for Utrecht Holdings have been elucidated. The strengths and weaknesses are internal factors, while opportunities and threats are external factors.

Table 3: The SWOT analysis for Utrecht Holdings regarding the Utrecht' chemical academics.

Strengths	**Weaknesses**

• Experienced KTO
• Innovation vouchers
	• Lack of business developers to commit to chemistry
	  ○ Lack of academic connections
	  ○ Lack of industrial network
	• Seed fund (UHSF) aimed at start-ups and other fields

Opportunities	**Threats**

• Valorisation opportunities outside academic-industrial collaborations
• Developing value chain regarding sustainable chemistry
• Including University of Applied Sciences
  ○ More valorisation opportunities
  ○ More applied research
  ○ Value chain creation (TRL train)
• Forming TTT around chemistry
• Increasing awareness at researchers
• Broadening scope of UHSF
• Enhance ecosystem relationships
	• Disconnect with researchers
	• Losing sight of developments in chemical field
	• No ecosystem for chemical startup creation
	  ○ Lack regioselective funding
	  ○ Incubator focused on scalability
	  ○ Little sufficient infrastructure
	• No possibilities to increase TRL without commercial partners

<u>Strengths:</u>

- Utrecht Holdings is an experienced KTO, with expertise in multiple fields including other beta sciences.
- The recent Innovation Vouchers can provide researchers a monetary stimulant to continue developing their invention.

Weaknesses:

- Utrecht Holdings has little experience in the chemical field. This observation led to this business internship. Although most business developers understand beta sciences, the expertise focus on chemistry is missing.
- The seed fund of Utrecht Holdings (UHSF) aims at start-ups and focuses on different fields.

Opportunities:

- There still rise valorisation opportunities from the Utrecht University, since not all research conducted is part of an academic-industrial collaboration. The 'remaining' inventions are possibilities for increased valorisation opportunities.
- There is a need to develop a value chain regarding new (sustainable) chemistry. This might be an opportunity, as Utrecht Holdings can contribute and connect partners.
- More valorisation opportunities arise when Utrecht Holdings also includes the University of Applied Sciences Utrecht. The research conducted is more applied which might lead to an increased invention adaptation from industrial partners. As stated in the insights from the interviews, a 'TRL train' can be set up by including the University of Applied Sciences, that can continue university's research. By including third parties such as chemical companies and governmental institutions, a value chain can be created.
- By cooperating with other KTOs, Utrecht Holdings might contribute to increased valorisation by 'outsourcing'/collaborating the valorisation process to/with other KTOs. It can be assessed whether a thematic KTO around chemistry is desirable.
- Increase the awareness at researchers. Often the 'older', more experienced researchers know Utrecht Holdings' existence, but not all researchers (PhDs) are aware. This is an opportunity, since the awareness of valorisation institutes in Utrecht can easily be increased. For instance via flyers available at the secretariats, or via lectures regarding valorisation given in both the bachelor's phase as well as the master's phase.
- The seed fund of Utrecht Holdings (UHSF) may aim to support chemical start-up creation, by broadening its scope and including chemistry.
- Enhance the relationships within the ecosystem. The most easy way to improve the valorisation regarding these specific inventions in to strengthen the ecosystem. For instance by setting up practises or goals shared and supported by all included parties. Include policy makers and the institutes contributing to the full valorisation process (RSO, researchers, University of Applied Sciences, etc.).

Threats:

- A disconnect with researchers might occur/increase when Utrecht Holdings cannot fulfil an active role in the valorisation of these specific inventions. It must be assessed whether this reduces the valorisation possibilities in the broadest spectrum.
- Utrecht Holdings may lose sight on the developments in the chemical fields. One risk is that the researchers at Utrecht Holdings do not have the network and connections to support researchers in their valorisation process. A constant dynamic environment as chemistry must be kept tracked on.

Discussion

Landscape Analysis

Some remarks can be made regarding the landscape analysis. The main issue experienced was that not all interviews could be conducted that were desired for this project. Even when the project endured five months, this time frame was too narrow to conduct all desired interviews. Mostly the multinationals have been interviewed. Most start-ups gave no response to the invitations or responded that they had no interest. This incompletes the landscape analysis meant in this project. The same applies for the sustainability incentives of these companies. Looking at chemical inventions with a sustainable technological character it was thought to elucidate the companies' incentives regarding sustainability via the Sustainable Development Goals of the United Nations. The multinationals did provide this information, the start-ups did not. It is open for debate whether the landscape analysis is complete(d). However, it can be argued that the multinationals are the most important parties regarding valorisation opportunities. The multinationals operate in a wider scope of businesses, including more conservative ones (e.g. fossil fuels). Therefore the multinationals have a higher interest in these specific chemical inventions that can contribute. Their transition to being sustainable is bigger than for most start-ups, generally. Furthermore, the multinationals are more wealthy, increasing the possibilities for invention adoption. Another reason is that multinationals are more susceptible for foreign competition. This puts pressure on the firm to continuously innovate in order to produce differentiated products and services, as stated in the 'Strategic Management of Innovation' course [(6)]. The inclusion of start-ups in the landscape analysis was to scope the chemical landscape as complete as possible, knowing it cannot be fully complete. Also for the multinationals a selection was made regarding this big scope, with at least DSM and Unilever being active in the health/nutrition/personal care sector, and Shell and Total Energies as petrochemical companies, and companies such as BASF and Dow Chemical in multiple fields.

Besides the chemical companies, other interviewees also could not be included in the project. It would have been good to interview a policy maker of the Utrecht University and elucidate what the intentions of the university are. Since valorisation is a core tasks of the universities it should be clarified in what ways the university contributes hereto, what its future policy is, and what adaptations can be made regarding the valorisation ecosystem in Utrecht. Then Utrecht Holdings can form and propose a strategy contributing and increasing the (economic) valorisation of chemical inventions.

Interviews also should have been conducted with at least one professor of all research groups in the *Debye Institute of Nanomaterials Science* in order know what types of inventions are generated there. It would elucidate more possibilities regarding academic-industrial research collaborations, and moreover the possible desires of those research groups regarding the industry and valorisation. As stated before, this project forms the very beginning of gaining insights in the chemical landscape, both academic and industrial. Due to the limited time frame, the project initially focussed on the catalysis groups, since these group were more likely to come up with inventions with a sustainable technological character, based on their research descriptions.

The literature study provided a fundament for the landscape analysis, but it must be concluded that the conducted interviews are indispensable for a valid landscape analysis. The literature study does elucidate both research topics and companies' sustainability incentives, that can be matched portraying valorisation opportunities. But it is not known what type of inventions are generated and what inventions companies utilise to counteract the sustainability incentives. It is possible to elucidate the types of academic inventions by reading all published articles of the research groups. However, regarding intellectual property, publishing results can seriously compromise the IP position, which affects the patentability and therefore interest of companies. So these published inventions are less susceptible for economic valorisation.

A final remark is regarding the completeness of the landscape analysis. There is a plethora of different companies operating in the chemical landscape, which makes it almost impossible to conduct a complete analysis of the chemical landscape. For every company the necessary information must be gathered, but especially interviews must be conducted in order to gain the best insights. Especially when looking into multinationals, multiple technology directors of a specific company must be interviewed in order to complete the analysis. Although limiting the scope of the landscape by making a company selection, a good first indication is made regarding the economic valorisation and position of Utrecht Holdings.

When starting this project, a setup regarding the literature study was made. Since Utrecht Holdings has no real expertise regarding the chemical field, let alone a business developer chemistry, the literature study initiated with a selection of companies. This selection was made to set a scope for the project, and to be able to evaluate over a specific set of data to overview the project's progress.

Scorecard

The scorecard was largely based on existing scorecards already in use by Utrecht Holdings. The significant addition made is the 'Economics' section. This section is implemented after gained insights in the interviews. After the first insight, questions regarding this topic were questioned to other interviewees. They all admitted the importance of an early techno-economic evaluation of inventions. It was tried to incorporate a basic form of such techno-economic evaluation. However, these questions might be left unanswered. The questions are hard to predict and require knowledge in order to be perfectly predicted. Such techno-economic evaluations try to elucidate the costs necessary before the invention can be industrially implemented. Also, the evaluation tries to answer the question how long the payback period endures. Companies perform this techno-economic evaluation multidisciplinary, with expertise from the whole company. However, when the questions can be answered, they provide a solid foundation regarding the marketability of inventions to companies. And since its importance was emphasised multiple times, this section contributes to the determination of the success probability at an early stage of chemical inventions.

SWOT Analysis

The conducted SWOT analysis requires some debate. Not all research groups of the *Debye Institute of Nanomaterials Science* have been interviewed, let alone all faculties of the Utrecht University that might contribute to sustainability. This compromises the accuracy of the SWOT analysis significantly. It was tried to elucidate as much information as possible during the conducted interviews of the employees of the research groups, but this always lacks specific information necessary for a complete and accurate SWOT analysis. Interviews are essential in this analysis and a literature study alone is not sufficient.

Yet, several strengths, weaknesses, opportunities and threats have been deducted and are presented in the analysis. The information gathered in the landscape analysis resulted in these insights, which Utrecht Holdings can utilise in order to strengthen its position.

Theories about SWOT analyses state that a good SWOT analysis is performed when good internal- and external analyses have been conducted, to elucidate for instance the different competences from the organisation (129). An extensive internal analysis has not (really) been conducted, because of the stated time frame and the SWOT analysis being an extra deliverable. The internal analysis was conducted with information gathered during the project, but would be more elaborate if more employees of Utrecht Holdings would have been spoken, as well as researchers from the concerning research groups or faculties.

John Fahy and David Jobber describe that only those strengths that are valued by the customer should be included (91). Converging this information to this project, the strengths valued by the customers should be the strengths valued by the researchers of the university. Not enough researchers have been spoken in order to conduct a good analysis. Fahy and Dobber also states that the strengths need to be looked at objectively, as they can turn into weaknesses over time. However, it is not clear how the expertise of Utrecht Holdings or the availability of the Innovation Vouchers, both strengths in the analysis, can turn into weaknesses. Nevertheless, this statement should be kept in mind.

Concluding, the conducted SWOT analysis does portray some useful insights regarding the position of Utrecht Holdings regarding the (chemical) academia in Utrecht. For an accurate and complete SWOT analysis, more interviews must be conducted with both employees of Utrecht Holdings as well as researchers (e.g. professors) of all the research groups relevant for the analysis.

Recommendations

Utrecht Holdings

Utrecht Holdings and Utrecht's institutes contributing to valorisation can increase its contribution to the valorisation of chemical inventions with a sustainable technological character in the following ways:

- Utrecht Holdings must play an active role in the inventions coming from non-collaborative research. These 'technology push' inventions possess significant challenges. To overcome these, it is an option to employ a business developer that possesses the expertise and preferably the network to connect the academia to the industry.
- Utrecht Holdings and Utrecht University can increase to amount of chemical start-ups / spin-offs generated in Utrecht. A plan can be made together and with governmental institutions to generate an ecosystem for (chemical) start-ups, for instance by increasing the infrastructure needed for scaling-up. Although now lacking the infrastructure and region specific funding opportunities, the start-ups may also settle themselves at other locations. By connecting to such locations, for instance by contacting the interviewees of the COCI site, more possibilities open up. Utrecht Holdings may collaborate more with the incubator in Utrecht to include a focus on chemical start-ups. This does bring challenges, as the incubator for instance focuses specifically on scalability.
- Utrecht Holdings can increase valorisation opportunities by connecting more to technical universities and their KTOs. Not only in the valorisation procedure, where other KTOs might have better resources available for the valorisation of Utrecht-based inventions, but also on the academic level. Research consortia including collaboration between academic- and technical universities can be established focusing on the new chemistry. This is also a desire from industry.
- The Utrecht University can contribute by making its research more applied, for instance by incorporating chemical technology in its courses and programmes or by setting up collaborations with for instance TNO. However, as stated earlier, the fundamental chemical research is strong in Utrecht. By making the research more applied, the scope of the university drastically changes. It must be assessed whether this is worth changing in order for more economic valorisation. It may not contribute to improved valorisation in the broadest sense.
- Utrecht Holdings must look into the possibilities to set up a national thematic KTO regarding chemistry. As the area of expertise deals with specific challenges, combining resources and strengths may contribute to increased valorisation of such inventions. Other KTOs, especially from academic universities, acknowledge the lack of valorisation of such findings and their challenges. This can be a widely supported idea.
- Utrecht Holdings can easily increase the awareness of valorisation among researchers. By simply designing flyers that are made available at the secretariats of the research groups or institutes, the overview of valorisation in Utrecht can be visualised. These flyers include information about valorisation, and which institutes can contribute in which ways, at which development phases or valorisation routes. As the more experienced professors know the way to Utrecht Holdings, but often not exactly what possibilities for valorisation are in Utrecht, this can complement their knowledge and even motivation for valorisation. However, this is still a passive form of increasing awareness. To actively increase the awareness, more information must be spread, for instance by giving lectures in both the bachelor's phase as well as the master's phase regarding valorisation in Utrecht. Combining these two options provide an active and passive form of awareness increasement.

- Develop a ‘TRL train’ by setting up a value chain around Utrecht’s academic inventions. Incorporate third parties for assistance and (government) funding. When university’s research ‘stops’, the University of Applied Sciences can use that invention for a new research project, in which the TRL is raised. This procedure contributes to invention development, making it more interesting for economic valorisation by companies. The modern value chain, as described by Alain Verbeke (130) consists of modern marketing, design, R&D, production, distribution and recycling. These consecutive steps can be interpreted regarding the TRL train: modern marketing consists of bringing together the right parties, ‘advertising’ the strategic roadmap in order to include third parties that might provide funding or function as possible sales markets. The design is the strategic roadmap, which clearly describes the pathway the invention development follows, and which parties contribute in which way. The R&D is the actual research conducted at the knowledge institutions. Then, production, distribution and recycling is implemented in the companies adopting the invention.
- It is highly recommended to enhance the relationships with other institutes contributing to the valorisation of chemical inventions generated at the Utrecht University. This action requires no (monetary) resources to include an extra business developer, nor does it have to change the universities research programmes. Besides, collaboration is the fundament of valorisation. By determining a collectively supported strategic roadmap regarding the valorisation incentives of these specific inventions, shared goals are stated. This will benefit both the researchers as well as the valorisation-supporting institutes, as it shares the workload as well as capabilities and strengths of the organisations. It must be discussed whether setting up the ‘TRL Train’ is an opportunity, and how the ecosystem can be improved furthermore.

Follow-up research

If follow-up research of this project is desirable, some recommendations are stated:

- Gain more information from start-up companies (SMEs). Mostly the multinationals have been interviewed. Although it is expected that start-ups have less interest in academic inventions because of their own scaling activities, conclusions cannot be drawn regarding the interest. Speaking to as much different companies as possible increases the knowledge about potential sales markets for inventions.
- Speak to more technology directors of the companies (multinationals). As presented, the multinationals operate in a plethora of businesses. Often only one technology director was interviewed. Gain insights from multiple technology directors working for the same company increases and fortifies the insights gained in the landscape analysis. It is possible that one certain directors has a different view, opinion, or strategy compared to his colleague from another division.
- Broaden the scope to other institutes of the Faculty of Science. For instance the biochemistry groups, where also research regarding sustainability is conducted. By discovering overlap in disciplines, hopefully new valorisation possibilities are found.
- Broaden the scope to all research groups from the *Debye Institute for Nanomaterials Science*, to know what type of inventions arise from those groups and which collaborations are already established.
- Talk to as much KTOs and other institutes (e.g. incubators) of different cities to track down their best practises. ‘Better a good copy than a bad original’.
- Elucidate the interest to set up a ‘TRL train’ in Utrecht, by talking to policy makers of the Utrecht University and Utrecht University of Applied Sciences. If possible, change the scope by including this.
- Determine the total amount of valorisation activities over the past ten years. Set that as a baseline case and determine specific goal how much the Utrecht University and Utrecht Holdings wish to achieve in the upcoming years.

Appendices

1. Questionnaires

1.1 Questionnaire Industry

- Who are you?
- How did you get to this place?
- What exactly do you do? What is your function? What role do you fulfil within your company?

To find out the role of the industry:

- When is it interesting for the industry to adopt inventions from the academia?
    - What requirements must an invention meet?
    - What Technology Readiness Level should an invention have?
        - Are there trends in this, or does this differ per invention?
    - Are there topics that are avoided by the industry? In other words, does your company focus on certain research directions?
    - Is there a preference in which form the industry adopts an invention? For example licensing deals, or setting up startups or creating joint ventures?
    - Are there tactics/step-by-step plans for collaboration with academia?
- What is the role of industry's own R&D?
    - Are most inventions generated in-house, or is there a lot of collaboration with universities?
    - Is a lot of R&D combined with the academia? For example, by funding research groups to research specific themes?

The industry and the valorisation process:

- What role does industry play in the valorisation process?
- How is funding from the chemical industry structured? Are there certain trends in this?
    - How does the ownership of the generated IP relate to this?
- How does a collaboration with KTO/TTOs work?
    - Do these KTO/TTOs approach the industry, or have deals been concluded in them (approach for findings on theme X)?
    - What could be improved in this process?
- Are there unmet needs from industry towards academia?

Sustainability / green tech:

- How does the focus on sustainability relate to collaboration with academia?
- Which sustainable topics are leading in your company? Are there topics that differentiate themselves from other companies?
- What is your vision on sustainability for the next 10 years, for both industry and academia?

- How does that relate to the collaboration?
- How could UU valorise better in the field of sustainability by implementing certain changes in the ecosystem?

General insights:

- Are there actions or roles in which KTOs/TTOs can provide better support in the valorisation process?
- Are there unmet needs from the industry towards the KTOs/TTOs?
- Do you have a 'best practice' regarding collaboration with universities?
- Do you have an example of a successful valorisation process, and can you describe how it went?
- Are there any questions that I have not asked, but that are useful to know?
- Do you have any tips for my research?

1.2 Questionnaire KTO's

Finding out other KTO's methods:

- Who are you?
- How did you get to this place?
- What exactly do you do? What is your function? What role do you fulfill within your KTO/TTO?
- What is the approach in the valorisation processes?
- What stages are there in the valorisation process?
- How is the chance of success of inventions tested?
- Are there tools that are used for these assessments?
    - If so, which tools are these?
- Does your KTO operate in an ecosystem to valorise research? Are several organs involved that increase the chance of success for valorisation?
- What is a differentiating body in this respect compared to other cities, so that valorization may be better than in other cities?
- Do you have a standard procedure, or best practice?

To find out the role of the industry:

- What role does industry play in the valorisation process? How is funding from the chemical industry structured? Are there certain trends in this?
- Is there a common denominator in valorisation processes with the chemical industry? In terms of Technology Readiness Level, distribution, ownership, etc. etc.?
    - What development stage must an invention possess before the industry steps in?
    - Is there a trend here, or does this differ per invention?

Looking at sustainability / green tech:

- Are the academia's findings focused on sustainability?
    - When is an invention considered 'sustainable'?
- Do you notice a trend regarding sustainable initiatives, both in academic research and in the desire/aspiration of companies?
    - Which sustainable topics are a hot topic?
- What criteria must sustainable inventions meet before companies want to participate?
- Do these requirements differ from other inventions with a chemical background?
- How could UU valorise better in the field of sustainability by implementing certain changes in the ecosystem?

General information:

- Do you have an example of a successful valorisation process, and can you describe how it went?
- Are there any questions that I have not asked, but that are useful to know?
- Do you have any tips for my research?

1.3 Questionnaire Academia / Utrecht

Imaging academia:

- Which research directions are there within the university regarding chemistry and sustainability?
- What proportion of inventions can be commercialized?
- What is the purpose of scientists?

Relationship between academia and industry:

- What is the role of industry in academia?
    - Is a lot of research funded?
        - If so, what agreements are made about this (funding, collaboration, ownership, IP)?
- What are unmet needs from academia to industry?
- Do you see a trend in Technology Readiness Level, collaboration, ownership when the industry wants to adopt/finance inventions?

Relationship between academia and KTO/TTO:

- Is it known that inventions have to pass through Utrecht Holdings to be brought to the market?

- What is your experience with the collaboration with UtrechtHoldings?
- How can cooperation be improved in your view?
- What are the unmet needs from the academic world, towards the KTO/TTOs?
- Are there other parties (call the ecosystem) that support research, including helping to market?

Sustainability:

- What role does sustainability play in the research conducted within the university?
- Which sustainable topics are leading in this?
- How do you see the future for sustainable inventions for the next 10 years?
- Does the academia have a say in this, or is this dictated by the industry?
- How could UU improve valorisation in the field of sustainability by implementing certain changes in the ecosystem?

General insights:

- Are there topics that you miss in academic research?
- Are the topics being researched in line with societal needs?
- Do you have a 'best practice' regarding cooperation with the business community?
- Do you have an example of a successful valorisation process, and can you describe how it went?
- Are there any questions that I have not asked, but that are useful to know?
- Do you have any tips for my research?

2. Interview's insights

2.1 Insights from the industry

Number Interviewee	Anonymised Function
1	***Technology Director Chemical Multinational #1***
2	***Vice President Technology Chemical Multinational #2***
3	***Sustainable Technology Director Chemical Multinational #3***
4	***Partnership Director Chemical Multinational #4***
5	***Sr. Sustainability Manager Chemical Multinational #5***
6	***Technology Scout Chemical Multinational #5***
7	***Research Engineer Chemical Multinational #6***
8	***Chief Technology Officer Small-Medium Enterprise #1***
9	***Sr. R&D Manager – Chemical Multinational #7***
10	***Development Manager Small-Medium Enterprise #2***
11	***Technology Transfer Officer Technical University #1***
12	*Technology Transfer Officer University #2*
13	*Technology Transfer Officer University #3*
14	*Technology Transfer Officer University #4*
15	*Technology Transfer Officer University #5*
16	*Technology Transfer Officer University #6*
17	*Startup Manager COCI site*
18	***Director COCI site***
19	***Professor Beta Faculty Utrecht University #1***
20	***Professor Beta Faculty Utrecht University #2***
21	***Manager Research Consortia Utrecht University***
22	*Incubation Lead – incubator Utrecht University*

- **Why does the industry collaborates with academics?**

    - *"Joining forces to meet challenges"* (1,3,4,8,9)
    - *"Pre-competitive: discovering new terrains"* (1,2,3,5,9,10,19,20,21)
    - *"Competitive: joining specific forces" (1,2,3,5,9,21)*
    - *"Next generation training (employees)" (1,4,8)*
    - *"Academic image"* (19)

- **What requirements must an invention meet?**

- *"Cannot be generalized, very project specific"* (1,2,3,4,5,6,8,9)
- *"Fitting into core businesses"* (1,2,3,4,5,6,8,9)
- *"Higher TRL (>4); otherwise too great a risk with scaling up"* (1,3,4,5,6,9)
- *"Lower TRL because company is not financially strong enough"* (8)
- *"Higher TRL because company is not financially strong enough"* (2)

- **How can the academia and KTOs make an extra contribution to valorisation?**

- *"Share one-pagers / patent overviews"* (1,4,7,9)
- *"No sharing, no time for and often mismatched with strategies"* (5,6)
- *"No container, focus on specific businesses"* (3)
- *"Patents on the edges of interfaces, for new insights"* (2)
- *"More consortia for new chemistry"* (4)
- *"Scouts and contacts"* (10)

Q1: Why collaborate with academics?

- ***Technology Director Chemical Multinational #1***
    - *"We're looking for ways on how to improve chemistry. By cooperating, new things can be discovered but it also really leverages the results that can be obtained."*
    - *"Also, by collaborating with academics, potential new employees are educated."*
    - "*For inventions it must be clear that the potential is there to go to a higher TRL!*"

- ***Partnership Director Chemical Multinational #4***
    - *"To tackle global challenges, this is not possible without collaboration."*
    - *"Shell is transferring to more 'open science'."*
    - *"Being involved in the training of the next generation."*
    - *"There must be a match in technology needs. Either core business or strategic plans."*

- ***Sustainable Technology Director Chemical Multinational #3***
    - *"To discover new possibilities."*
    - *"Collaborating speeds up this discovering process."*

- ***Chief Technology Officer Small-Medium Enterprise #1***
    - *"Internships are provided; the way to attract new talent."*
    - *"By collaborating, research slowly becomes more applied."*
    - *"By collaborating you increase the chance it results in something that can be valorised."*
    - *"Technology Push inventions do often not match regarding the economics. Technical Universities do pay attention to this, for instance the decision for recycling or the type of solvents used."*

- ***Sr. R&D Manager – Chemical Multinational #7***
  - *"Nice to combine between specific business matters, where a university has a lot of knowledge or specialism. Then there is the greatest chance that something patentable will come out."*
  - *"Open Innovation (consortia) is aimed to discover new areas (not so much to gain IP directly). Internal research teams make this unaffordable. It's a way of scouting; which way does this field go? Within a few years it will become clear where something can be achieved in this area."*
  - *"Many collaborations are aimed at concept formation, not product formation. With technical universities more on the process development side."*
  - "*Internal research teams make it too expensive to conduct research to discover new areas.*"

- ***Technology Transfer Officer Technical University #1***
  - *"Companies invest and know the potential; it flies easier."*

- ***Professor Beta Faculty Utrecht University #1***
  - *"Company's might want an academic image / collaborating with university's publishing in Science and Nature."*
  - *"Companies want to increase the scientific level of their research."*

Q2: In what way/form are academic inventions adopted?

- ***Technology Director Chemical Multinational #1***
  - *"Type A: research is requested by the company: IP is the company's."*
  - *"Type B: in between, some patents are bought (sometimes nothing is done with it - yet / this does not lead to a product within the next five years)."*
  - *"Type C: IP stays to the university and the company can buy it. Not too much of interest to the company → not directly related to core business or strategic plans."*

- ***Partnership Director Chemical Multinational #4***
  - *"Most common: Open; students must publish results, the company has no exclusivity."*
  - *"Second: technologies close to core businesses of the company. IP is for requested for the company itself."*
  - *"Third model: consortia; to apply for subsidies and grants. These are open deals; IP is shared."*

- ***Sr. Sustainability Manager Chemical Multinational #5***
  - *"The preference is for bilateral collaborations, driven from a need. There are also interesting themes but we do not know in which direction those are heading. Then a consortium suits."*

- ***Technology Scout Chemical Multinational #5***
  - *"Consortia are pre-competitive. Competitive matter is almost always a one-on-one collaboration. And everything in between. Pre-competitive research is not utilised so much, since it seldom leads to a patent application. "*

- ***Sr. R&D Manager – Chemical Multinational #7***
  - *"Three projects; 1 = multilateral, with other companies, open innovation. Then there are two types of bilateral collaborations; direct collaboration between university and industrial partners. In 1 there is a lot of subsidy involved and in 2 there is little subsidy. The latter, then we are the direct owner of where IP comes from. In the Netherlands it is more expensive if you want to have it for yourself. Usually you don't really know what you can get out of a project. Then you opt for subsidised collaboration to discover this for yourself."*

Q3: What TRL must inventions possess before companies adopt them?

- ***Technology Director Chemical Multinational #1***
    - *"This cannot be generalized, but it is preferable for inventions to have a higher TRL."*
    - *"When inventions have a lower TRL, it must be clear that there is potential to grow to a higher TRL."*

- ***Partnership Director Chemical Multinational #4***
    - *"As a guideline; higher TRL's. We don't license fundamental research concepts. As a guess; TRL 4. We don't need to license a technology to do further research on it. It has to be something that can be deployed outside."*
    - *"In some cases it might be lower TRL's, but then we see that it is going to work and that it is critical somewhere."*

- ***Sustainable Technology Director Chemical Multinational* #3**
    - *"When it is a short-term case in search of an answer: more mature technology."*
    - *"Collaborations with universities focus on pre-competitive research; it is to build knowledge and to explore new topics and see where these topics develop to. Collaborations with 'A and B start-ups' (to pilot- and demo phase) gives more certainty because they have shown (very basic) that it works. By collaborating (not per se acquisition) you contribute to the star-up's development. This might be a future supplier or customer (developing a value chain)."*

- ***Chief Technology Officer Small-Medium Enterprise #1***
    - *"There often is a disconnect that the University thinks an invention is interesting, but it is not clear which problem(s) it solves. Then nobody is interested!"*
    - *"TRL 7 is often already 24/7 operations, integrated recycling, 10 à 20 tonnes production annually."*
    - *"The big companies looking for technologies, they often want TRL 7 or higher."*
    - *"For our company it is more interesting to look at lower TRL, since we do not have the capital to take over expensive (more developed) inventions."*

- ***Sr. Sustainability Manager Chemical Multinational #5 & Technology Scout Chemical Multinational #5***
    - *"Preferably higher TRLs, regardless that it is more expensive, because the coupled risks are smaller since there is a path forward."*
    - *"We start looking at TRL 4, the absolute minimum. Venturing also looks at higher TRLs (4, 5, 6, 7). The business also searches, but at TRL 6, 7, 8 or 9."*

- ***Vice President Technology Chemical Multinational #2***
    - *"We work with higher TRLs. We do not have the budget to continue the development of an invention with lower TRL."*

- ***Technology Transfer Officer Technical University #1***
    - *"It does differ, for chemistry it is more difficult/trickier; research is more expensive and heavy resources are necessary. TRL is a tricky one."*

Q4: What characteristics of inventions is the industry looking for?

- ***Technology Director Chemical Multinational #1***
    - *"Sustainable topics, yes. But it has to be specific. Energy transition is covered by the government. Feedstock transition is more at universities and suppliers. Material transition is something the companies can contribute to."*
    - *"The story has to fit. If someone presents an idea that is not in our market, but the story is very good and interesting, then we are interested."*

- ***Partnership Director Chemical Multinational #4***
    - *"It depends on the technology itself."*
    - *"Not the invention, but the partner must have a good reputation and are compliant with rules and regulation in the region."*

- ***Sustainable Technology Director Chemical Multinational* #3**
    - *"It has to suit our core businesses."*
    - *"Keep track of projects; if they suit our strategy then we might want to cooperate."*
    - *"Looking at the ANSOFF-matrix, the diversification strategy when incorporating a new product into a new market, that is something companies avoid. The risk is too big."*
    - *"The technology of start-ups triggers attention. A techno-economic evaluation is extremely important; which market, the size, percentages, viewed with a realistic perspective (most start-ups overestimate)."*

- ***Research Engineer Chemical Multinational #6***
    - *"It must suit our businesses or products: is it applicable and is it feasible technically."*
    - *"What are the costs for implementation and development? And what are the financial benefits; the techno-economic feasibility."*

- ***Sr. R&D Manager – Chemical Multinational #7***
    - *"Often it is about specific material properties, not per se material knowledge. It is always focused on something we think that commercialization is possible. To know this, extensive analyses are performed."*

- ***Technology Transfer Officer Technical University #1***
    - *"Look at the market potential. Can it be used in different markets?"*
    - *"We look strongly to the team; is there an entrepreneurial spirit?"*

Q5: Why can invention characteristics not be standardised or generalised?

- ***Technology Director Chemical Multinational #1***
    - *"It differs per company."*
    - *"It depends on the core business of the company, or better, the strategic plans (often company's secret)."*
    - *"Regarding SDG's, every company contributes in its own ways."*

- ***Development Manager Small-Medium Enterprise #2***
    - *"This is not so strict. We need to know if something will work, and this can be indicated by several requirements."*

- ***Technology Transfer Officer Technical University #1***
    - *"It is always a different ball game."*

- ***Director COCI site***
    - *"The chemical environment is too dynamic."*

Q6: Can Knowledge Transfer Offices still fulfil roles in the chemical valorisation process?

- ***Partnership Director Chemical Multinational #4***
  - *"Yes, there's always a gap. KTO's can help to connect. Especially for newer technologies."*
  - *"Also in bridging TRL's; KTO's can advise universities to continue research. The Energy Transition Campus (Shell Amsterdam) has facilities for universities to continue research if resources are depleted. Utrecht University already signed such agreements."*

- ***Sr. Sustainability Manager Chemical Multinational #5 & Technology Scout Chemical Multinational #5***
  - *"Not really. KTOs do not have good insights in what companies are looking for exactly."*
  - *"We also do not want to share our needs, this relates to strategies."*

- ***Vice President Technology Chemical Multinational #2***
  - *"The value chains of the new chemistry must be established. KTOs only can assist herein when an employee (e.g. Business Developer) has the network and connections."*

Q7: Are there desires from the industry to academia / KTOs?

- ***Partnership Director Chemical Multinational #4***
  - *"It would be preferable if more consortia are set up regarding newer technologies."*

- ***Development Manager Small-Medium Enterprise #2***
  - *"Scouts and contacts!"*

2.2 Insights from other KTOs

Number Interviewee	Anonymised Function
1	*Technology Director Chemical Multinational #1*
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4	*Partnership Director Chemical Multinational #4*
5	*Sr. Sustainability Manager Chemical Multinational #5*
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15	***Technology Transfer Officer University #5***
16	*Technology Transfer Officer University #6*
17	*Startup Manager COCI site*
18	*Director COCI site*
19	*Professor Beta Faculty Utrecht University #1*
20	*Professor Beta Faculty Utrecht University #2*
21	*Manager Research Consortia Utrecht University*
22	*Incubation Lead – incubator Utrecht University*

- **How does valorisation of chemical discoveries proceed?**

- *“General universities recognize the lack and challenges of chemical valorisation.”* (8,11,12,14)
- *"ASAP. in discussion with commercial partner.”* (14)
- *“Technical Universities are doing better in terms of valorisation.”* (11,13)
- *“Start-ups (in chemistry’s breadth) in a favourable ecosystem.”* (11,13)
- *“Combining chemistry with chemical technology (process technology).”* (11)
- *“Professors' affinity with valorisation.”* (13)
- *“Chemical start-ups often run by former employees.”* (2)

- ***Technology Transfer Officer Technical University #1***
    - *"It all starts with awareness and attracting projects."*
    - *"Get involved early on."*
    - *"Most of the time it is technology push."*
    - *"Assess whether there is a need in the market."*
    - *"Done deals are the most important! If certain requirements are not fully met."*
    - *"Spin-off creation works good, since scientists are often 100% dedicated, but a lot of money is needed."*
    - *"Sometimes industry is looking for acquisition."*
    - *"What works is the entrepreneurial ecosystem, to develop spin-off companies."*
    - *"Around 10-15 IDF's per year: chemistry is combined with chemical engineering → so more applied research is being done. Also strong entrepreneurial ecosystem."*

- ***Technology Transfer Officer University #2***
    - *"Biggest part of the job is to set up collaborations."*
    - *"Little chemical valorisation projects. We work with a technology push, instead of pull; then you have scientists with the right entrepreneurial spirit."*

- ***Technology Transfer Officer University #4***
    - *"Always look for an industrial partner. Then the development goes much quicker."*

- ***Technology Transfer Officer University #5***
    - *"TRL 3 or 4 is applicable for universities. Work together with Universities of Applied Sciences of MBOs, to eliminate the danger of not continuing the invention development. Organise companies and institutions interested in the research early on, build this value chain, a TRL train, specified by a strategic roadmap."*
    - *"Scientists know their research and have opinions and ideas where the research must head to. They are the starting point for developing the value chain. When research at the university 'ends', projects at Universities of Applied Sciences can start. Having other parties involved is a success formula to further develop inventions. This is a large process, it does not work outside-in (that companies request research). Is has to be build inside-out, meaning that the professors know where to research must head to and then collaborative parties are coupled."*

2.3 Insights regarding valorisation in Utrecht

Number Interviewee	Anonymised Function
1	*Technology Director Chemical Multinational #1*
2	***Vice President Technology Chemical Multinational #2***
3	***Sustainable Technology Director Chemical Multinational #3***
4	***Partnership Director Chemical Multinational #4***
5	***Sr. Sustainability Manager Chemical Multinational #5***
6	***Technology Scout Chemical Multinational #5***
7	*Research Engineer Chemical Multinational #6*
8	*Chief Technology Officer Small-Medium Enterprise #1*
9	*Sr. R&D Manager – Chemical Multinational #7*
10	*Development Manager Small-Medium Enterprise #2*
11	*Technology Transfer Officer Technical University #1*
12	*Technology Transfer Officer University #2*
13	*Technology Transfer Officer University #3*
14	*Technology Transfer Officer University #4*
15	*Technology Transfer Officer University #5*
16	***Technology Transfer Officer University #6***
17	*Startup Manager COCI site*
18	*Director COCI site*
19	***Professor Beta Faculty Utrecht University #1***
20	***Professor Beta Faculty Utrecht University #2***
21	***Manager Research Consortia Utrecht University***
22	*Incubation Lead – incubator Utrecht University*

- *"No chemical start-ups (low TRL, incubator focuses on scalability)"* (16,19,20,21)
- *"Beta Faculty.: alternative energies/sustainability already captured in collaborations, materials more options for valorisation (but fundamental)"* (16)
- *"Pre-competitive collaboration is all about insights."* (16)
- *"UU is not a Technical University or TNO, it is at the forefront of development."* (15)
- *"Chemistry has a strong network for classical subjects."* (3,6,16)
- *"A value chain is in development for the new, sustainability chemistry."* (4,5)
- *"Experienced scientists know the way to Utrecht Holdings."* (3,6,16)

- ***Manager Research Consortia Utrecht University***
  - *"Fundamental research: TRL around 3. Companies often look for higher TRL (9), or they need a lot of funding."*
  - *"Our research topics require huge investments (monetary/resources) regarding scalability."*
  - *"Researcher are often naïve when it comes to the applications for their inventions, which might result in a undeveloped entrepreneurial mindset."*
  - *"There is still a lot of work to do regarding the understandings of valorisation at the students. This must be checked if this aligns the university's policy."*
  - *"You need the 'big guys' if you want to scale up to an industry's level."*

- ***Professor Beta Faculty Utrecht University #1***
  - *"Most research is funded by the industry → IP goes to companies."*
  - *"Not much IP is applied for."*
  - *"Already one lecture is given regarding Intellectual Property, in the bachelor phase."*
  - *"Why not much IP flows to UH: it is more regarding the scientist's nature, then to do with the UU or UH."*

- ***Technology Transfer Officer University #6***
  - *"Faculty Beta Sciences has two major research topics:*
    - *Materials; this is something Utrecht Holdings can gain on, but it conducts the most fundamental research.*
    - *Alternative energies, carbon-capture, sustainability/circularity; this is particularly where the collaborations with industry plays a role. Most research is done in these collaborations."*

- ***Professor Beta Faculty Utrecht University #2***
  - *"There is already a lot of cooperation with industry in Utrecht. From catalysis with multinationals, but also with upcoming companies and the 'new chemistry'."*
  - *"In bilateral collaborations, it is often agreed that the application will be submitted by the company."*
  - *"But something bottom-up, a researcher has something and is looking for a partner, that happens much less. I don't know whether this is because the inventions are too fundamental or because of the scaling problem in chemistry. It is also possible that everything ends up in the PPPs."*
  - *"The BASFs and Shells (multinationals) do a lot of pre-competitive research anyway. These techniques cannot be patented/valorised, because it concerns the insights that come from them. We are a general university and not a technical university or TNO; we are more at the front of the development and that makes the step towards market implementation even bigger."*
  - *"There are indeed more start-ups around technical universities, but I think mainly focused on biochemistry or chemical engineering and reactor science. In terms of chemistry, not many startups are established there either. In Delft and Twente, more can be tested at process level and there are larger set-ups, so you can come to TRL 5 or 6."*
  - *"Scientists need to know what the Holdings are doing and how they can help."*
  - *"The chemistry already has a strong network. The challenge is not necessarily in finding new partners, but in valuing the invention (what do we actually have?). And that also differs greatly per the groups, also within this department."*
  - *"Traditional partnerships with large companies are well-founded. Links with SMEs and industry organisations are also interesting; the networks do not yet overlap there."*
  - *"There is not much chemistry in the Utrecht region, we are more of a service province than a manufacturing province. In Groningen you have the Eemshaven, Eindhoven has the triangle in Geleen with Maastricht and Aachen. There are also many regional and interregional forms of funding that other universities make greater use of and*

which have a valorisation component. Utrecht is less able to draw from that vessel due to the nature of the region, which is specific to Utrecht. There are many forms of financing and subsidies that target regions, from provinces, for example."

- *"Setting up the network between the chemical academia and the 'new chemistry' must be done. There is no real role for Utrecht Holdings in this; you really have to have the network or specialism. Finding the way to the Holdings, that's the main thing."*

- ***Sustainable Technology Director Chemical Multinational* #3**
  - *"As a KTO, do not present a container of patents. Be specific for the companies' businesses."*
  - *Utrecht does not create start-ups. Technical universities do that. So collaborate more with technical universities."*

- ***Vice President Technology Chemical Multinational #2***
  - *"Academic universities are focused on materials (surface reactions, kinetics). Technical universities focus more on process technologies."*
  - *"Desirable to share patents, including those that may be on the edges of the interface. This mainly for the new chemistry. To do this, there must be someone who can map the edges of the interfaces and who knows how to properly assess inventions. This person must therefore also have knowledge of various institutes within Utrecht University, perhaps even of several departments (although this can also be combined with Business Developers who are in other fields by communicating well with them)."*

3. Personal Reflection

The internship concluded the landscape analysis, scorecard and SWOT analysis. The landscape analysis was done by a literature study and interviews. The landscape analysis started with the literature study, by looking into as much information as possible. The internship started by getting a feeling for knowledge transfer and intellectual property. A course was successfully completed regarding these topics. Then, a discussion regarding the scope of the project arose: where do we start? What is already known by Utrecht Holdings? How are we going to proceed? These questions were directed at me which I experienced positively as I was given the freedom to direct my own project. This also led to some uncertainties, since I did not know much about the project or the chemical landscape, except from the knowledge built up during my bachelor's and research internship. I decided just to make a start and evaluate regularly to make sure I was heading in the right direction. First I selected the 20 companies, 10 multinationals and 10 start-ups. Second, I looked into the businesses and markets that these companies operate is. This took a lot of time, since I wanted to do it completely and not miss any useful information. This resulted in a document of over 65 pages where all this information was stated. In consultation with Tjeerd it was decided to then look into the sustainability incentives, since the inventions we were focusing on included chemical inventions with a sustainable technological character. This part went much more smooth, since it was decided to compare the companies by looking into the Sustainable Development Goals of the United Nations. Most companies provided this information quite clearly, except for the start-ups. It was then tried to link the SDGs to the innovative and often sustainable core businesses of these start-ups, in order to make it comparable and to determine possible sales markets for inventions that contribute to specific SDGs. Overall, the literature study took around 8 weeks to complete.

The literature study was followed by the interviews, where I put in the most effort. Contact persons were searched for all selected companies, selecting on the position and experience of the interviewees. For the multinationals this information was gathered easily, for the start-ups not always contact information was provided. I proceeded by emailing every selected employee, explaining the internship and reasoning for this interview. Most employees responded enthusiastic, however, it was not succeeded to interview all selected companies. Most interviews were conducted via a Teams call, and in some cases I was invited over to the location. I visited the Chemelot campus in Geleen, Albemarle in Amsterdam, and made an effort to visit Novel-T in Twente, but due to an switch failure the train never passed Almelo. As stated, most interviewees responded enthusiastic and provided a lot of useful information. It was sometimes difficult to plan a meeting and this resulted in the fact that the last interview was conducted a week before the end of the internship. Not all desired interviews could be conducted in this stated time-frame of the internship, unfortunately.

Besides, other assisting tasks have been completed. The time division of the internship consisted of 60% spent on the project, 30% spent on other tasks and 10% on thesis and presentations. In one project I helped a business developer colleague with a feasibility analysis of a project concerning chemical recycling of plastics. I found this an interesting project as it was relevant for my project, since it concerned a chemical invention (with sustainable technological character). I worked out which third parties are operating in the same field, to elucidate sales market potentials. Also, since the inventors want to file a patent application, it was searched for whether this specific technique or relatable techniques are already deployed. I tried to make a cost indication and determine what was needed to implement this new technique. A presentation was made and presented to the researchers, in presence of the concerning business developer of Utrecht Holdings.

Furthermore, I accompanied my supervisor Tjeerd on multiple conversations/introductions with other researchers. I experienced this positively, as I got the chance to see directly experience this part of business development and was given the option to ask questions. From an intern perspective this allows you to ask all questions, even when you have little knowledge of the topic. One project that was introduced to Tjeerd concerned a tool for sustainable construction. We listened to the researcher and her professors and came to the conclusion that the expertise of other business developers inside Utrecht Holdings suit this project better. Therefore, I arranged a meeting and presented this case to the other business developers, in the presence of Tjeerd. The conclusion was that these other business developers understood the field better and were excited about the invention. Therefore, I arranged a meeting between the researcher and the other business developers, explaining to the researcher what we have done in the meanwhile and that the new business developers suit this project perfectly. Thereby I transferred the project from Tjeerd to his colleagues.

Regarding the personal development, a lot was learned during this internship. I have found the link between the theoretical business courses and the activities during the internship less than I thought, as almost no discussed theory was applied during this internship. Nevertheless, the focus of this internship, as well as the daily tasks of business developers working at Utrecht Holdings, has everything to do with ‘business’. Thinking about sales markets, what companies might desire and request in academic inventions, shareholder management, etc. It is just that these aspects were less present in the theoretical courses. For instance the course ‘International Business’ does not overlap significantly with this internship: the course is really focused on conquering shares in international markets, something not applicable for Utrecht Holdings. As I stated in the Company Profile section, my interpretation is that Utrecht Holdings holds a unique position as it has no real competitors. It does not have to conquer a market share. Utrecht Holdings does not have to position itself in a market, as described by John Fahy [(91)]. This was the major difference between the theoretical courses and the internship. What was especially useful was the application of an agile workflow. Especially during the interviews, where an agile workflow was applied in conducting the interviews and steering the questionnaires regarding obtained insights. Described by Krajewski and Malhotra [(131)], an agile work form is change-driven, adaptive and often ‘knowledge work’ that relies on empirical processes, all factors that were included in the conducting of the interviews.

However, much was learned during the internship. Apart from the substantive tasks, such as conducting a market analysis or feasibility analysis, much was learned regarding project management. Supervisor Tjeerd and I often discussed the progress of the project, and deadlines were set regularly. This helped me in the end with finishing my presentations and thesis, as most research work was already done. I already completed the literature study by presenting the businesses of the companies to Tjeerd. I already dug into the sustainability incentives and presented this. Finishing this thesis, most work regarding those topics was to copy and paste the crucial information and designing and rewriting it into this report, followed by drawing conclusions and discussions. The biggest challenge I encountered will be the -somewhat- passive form of communicating results. As I dug into the information, I often worried if the information was complete or not. Therefore I mostly tried to look into more references, trying to find that one source disagreeing with what I had found. However, it would have been better to just set deadlines for myself and just send the work gathered by then to Tjeerd, even though I would find it still incomplete. Still being a student, I am allowed to make mistakes or to sometimes miss references. I was so focused on delivering the best results that this often took more time than necessary, while also not contributing to better results (as those specific sources were still not found while spending more time searching for them). This is a very important insight that I will utilise more often in the future.

What also contributed to my professional development were the interviews. It required some persistency to come in contact with all the people interviewed. Often I had to send reminders to the concerning people asking for their interest. At first this was uncomfortable, as I still needed something from them and I did not want to sound rude. However, I have learned that this persistency only contributed to the project and internship. Furthermore, the people I have spoken to often claimed higher positions in often large chemical companies. This had me preparing the interviews very well, but also to steer the interviews while conducting them. It is challenging for me to always pick the right messages out of conversations, to really know what people are saying. Being somewhat of an insecurity, it was exciting at first to conduct these interviews and to ask deeper questions during the interviews. But when transcribing the interviews and hearing it back, I was actually surprised how well it went. This boosted confidence and contributed to the following interviews that I conducted, for instance by having more 'guts' to ask deeper questions. It felt that I was a bit more 'rude', while often this was not experienced by the interviewees. Call it this typical 'Dutch directness', this was the largest personal development I learned during the internship.

Regarding the research internship in the first year, a lot of links could be made. My research internship was completed at one of the research groups of the *Debye Institute for Nanomaterials Science*, the institute focused on in this internship. Having done research in the Inorganic & Catalysis Group, I knew some researchers already. When helping a business development colleague with a feasibility analysis of an invention coming from that group, I already knew who the researchers were. This gave more easy introductions to those people. Also, since I experienced that group, I already knew somewhat what type of research was conducted and knew some contacts that I could interview. The experienced gathered during the research internship, as well as during my bachelor's degree 'Chemistry' at the University of Applied Science could be used during this business internship, for instance when selecting the chemical companies.

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