EVALUATION REPORT

Research assessment

Department of

Chemical Engineering & Chemistry

Eindhoven University of Technology

Period 2015 – 2021

Preface

This report documents the findings of the assessment committee that was appointed by the Executive Board of Eindhoven University of Technology to review the scientific research of the Department of Chemical Engineering & Chemistry during the period 2015-2021. The quality assessment in this report is based on the assessment system in the Strategy Evaluation Protocol for Public Research Organizations 2021-2027. In reaching its findings, the committee used the self-evaluation report prepared by the Department and visited the Institution from October 31 to November 2, 2022.

The main goal of this assessment is to evaluate the research in light of the proclaimed aims and strategies. While assessing in detail the state and past performance, it is oriented towards the future. The committee highly appreciated the format of the on-site visit and found the discussions rich in content and well-balanced. The extended personal contact with all stakeholders and the spontaneous feedback of the rector, the dean, the management and the research staff on all levels helped to understand the plans, aspirations, and the points at which improvements were deemed to be required. The information provided was exemplary and could serve as role model for other evaluations.

In the name of the committee and personally, I would like to complement the Department for achieving an excellent level of science, education, and self-organization across the Department. We commend the University for enabling such development. We would like to especially emphasize that the chosen research directions and plans together with linking Chemistry and Chemical Engineering closely ensure that the Department can successfully tackle the challenges in energy, circularity, and health. Even with the existing resources, concentrating collaborative efforts on selected topics within these areas could further elevate the international standing of the Department.

It was a pleasure to communicate with the enthusiastic and committed research staff and Ph.D. students, and to get a tour of the outstanding research infrastructure. The details of our findings are included in this report. We formulate some recommendations, most of which are aimed at consolidating and further enhancing the performance of both domains.

On behalf of the committee, I would like to thank all participants involved in the reporting and on-site visit for the straight and open communication that was critical to obtain insight. Personally, I would like to thank the committee members for their dedication, creativity, diligence, and focus throughout the review process. We all are grateful to the Secretary in this process, Dr.ir. Herry Nijhuis, for his guidance and support in the review process and the help in preparing this report.

Prof. Johannes Lercher
Chair research assessment committee
December 2022

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1. Introduction

1.1 Terms of Reference

The quality assessment of research of the Department of Chemical Engineering & Chemistry is carried out in the context of the Standard Evaluation Protocol for Public Research Organisations 2021 – 2027 (SEP, appendix 1) by the Association of Universities in The Netherlands (VSNU), the Netherlands Organisation for Scientific Research (NWO), and the Royal Netherlands Academy of Arts and Sciences (KNAW).

The committee is requested to assess the quality of research conducted by the research unit in Chemical Engineering and Chemistry between 2015 and 2021 as well as to offer recommendations in order to improve the quality of research and the strategy. The evaluation includes a retrospective and a prospective component. Specifically, the committee is asked to judge the performance of the unit on the main assessment criteria and offer its written conclusions as well as recommendations based on considerations and arguments. The main assessment criteria are:

- Research quality;
- Societal relevance;
- Viability of the unit.

During the evaluation of these criteria, the assessment committee is asked to incorporate four specific aspects, which are included because they are becoming increasingly important in the current scientific context and help to shape the past as well as future quality of the research unit. These aspects are the following:

- Open Science: availability of research output, reuse of data, involvement of societal stakeholders;
- PhD Policy and Training: supervision and instruction of PhD candidates;
- Academic Culture: openness, (social) safety and inclusivity; and research integrity;
- Human Resources Policy: diversity and talent management.

The committee was asked to pay special attention to the following additional questions as well as to offer its assessment and recommendations:

- for the CE&C in relation to its international position;
- the extent to which the implementation of the sector plan invigorates CE&C in the Netherlands and how it prepares CE&C for the future.

1.2 Composition of the committee

The committee is chaired by prof. Johannes Lercher of TUM. The committee was selected with the criteria specified in Appendix G of the SEP in mind. This leads to the following composition of the committee:

- Prof. Johannes Lercher, chairman, Technical University of Munich (TUM)
- Prof. Katja Loos, University of Groningen (RUG)
- Prof. Nicolai Cramer, École polytechnique fédérale de Lausanne (EPFL)
- Prof. Brigitte Voit, Leibniz Institute of Polymer Research Dresden (IPF) and TU Dresden

- Prof. Em. Guy Marin, Ghent University (UGent)
- Dr. Marcel Wubbolts, Corbion
- PhD student: Luc Smulders, Utrecht University (UU)

Care was taken to ensure a diverse committee with a broad and balanced expertise that allows it to evaluate the research of the unit in an unbiased manner. The Department Board appointed dr.ir. Herry Nijhuis as the committee secretary.

All members of the committee signed the statement of impartiality before they conduct their assessment work to ensure that the committee members made their judgements without bias, personal preference or personal interest, and that the judgment was made without undue influence from the institutes or stakeholders.

1.3 Information provided to the committee

The committee received detailed documentation consisting of the following parts:

- Terms of Reference: Research Assessment Chemical Engineering and Chemistry TU/e 2015-2021;
- Standard Evaluation Protocol 2015-2021;
- Self-evaluation report 2015-2021, including appendices and group descriptions;
- Additional information:
  - IP Policy
  - Breakdown of contract research funding
  - Staff appointed on sector plan financing plans.

1.4 Procedures followed by the committee

The site visit of the Department of Chemical Engineering & Chemistry took place on 31 October, 1 and 2 November 2022 in Eindhoven. Before the site visit, the committee members were asked to read the information provided to the committee.

In an on-line kick-off meeting on 19 October 2022 the committee members were acquainted with the SEP protocol, agreed on the site visit program, discussed about the scope of the evaluation, and formulated the first questions for the interviews. Couples of committee members were formed who looked into the various aspects of the evaluation per research group, which delivered the building blocks for the overall evaluation.

During the site visit, the committee met with representatives of the Department, department board, department council, professors, tenure trackers and PhD students.

To conclude the visit, the committee chair presented the main preliminary findings and recommendations to the university rector, department board as well as the department employees.

The schedule for the site visit is included in Appendix 2.

This report describes the findings, conclusions, and recommendations of the committee. The content of the assessment report was finalized through e-mail exchange. The final version of the report was sent to the department board, for factual corrections and comments. The report was finalized on 18 January 2023.

2. Department of Chemical Engineering & Chemistry

2.1 Introduction

The Department of Chemical Engineering and Chemistry is one of the nine departments of the Eindhoven University of Technology, the Netherlands. The department is currently organized into two thematic research domains:

1) Molecular Systems and Materials Chemistry, addressing research involving atomic-scale molecular design and the nanoscale organization of new functional materials, and

2) Chemical and Process Technology, focusing on the design of integrated multiphase reactors, process engineering and equipment concepts.

The *Molecular Systems and Materials Chemistry domain* focuses on the design, synthesis and dedicated molecular engineering of novel molecules, macro- and supramolecular assemblies, and functional, responsive or bio-inspired materials. Researchers investigate how to control the chemistry, structure and morphology of materials and interfacial phenomena at different length scales of polymers and supramolecular constructs and relate the material features to the functional performance of such advanced and interactive materials. Moreover, this involves new routes to polymer materials using renewable resources and polymer recycling.
This domain involves the following research groups:

- Bio-Organic Chemistry
- Macro-Organic Chemistry
- Molecular Materials and Nanosystems
- Physical Chemistry
- Polymer Performance Materials
- Self-Organizing Soft Matter
- Stimuli-responsive Functional Materials and Devices
- Supramolecular Chemistry and Catalysis
- Supramolecular Polymer Chemistry

The *Chemical and Process Technology domain* performs research in the field of chemical engineering sciences, ranging from fundamental investigations of chemical conversion processes to targeted engineering applications and industrial innovation. Research focuses on the design, development and innovation of integrated and intensified reactors, separation technology, process intensification, and molecular heterogeneous catalysis across the relevant length scales through experimental and modelling activities. There is a strong emphasis on bio-based and, more recently, electrocatalytic conversion to fuels and chemicals and energy storage processes.
The domain involves the following research groups:

- Chemical Process Intensification
- Inorganic Materials and Catalysis
- Membrane Materials and Processes
- Multi-Scale Modelling of Multiphase Flows
- Sustainable Process Engineering

All academic staff members in the Department are embedded in research groups of, on average, 2-5 principal investigators, who share responsibilities in education and research within a specific scientific

area. The permanent staffing of such a research group typically consists of a chair with one or more professors and associate professors, one or more (tenure-track) assistant professors and several technical support staff members.

The committee was impressed by the level of coordinated planning and cooperation between the two domains of the department as well as between the different research groups in the two domains. Internal collaboration is strongly anchored in the core values and culture of the department. This is promoted by the financing of the research instruments and the accompanying infrastructure. Expensive infrastructural facilities are shared, contributing to the internal coherence of the department.

Beyond that level of interaction, the deliberate choice of research topics and the combination of chemical engineering and chemistry puts the department in a unique position to address the grand challenges in energy, circularity and health. The committee sees this coordinative and focused planning and a further promotion of internal collaboration as an essential asset for addressing the outlined future research goals of the department. An important role is seen in the overarching interdisciplinary centre structures, e.g. ICMS and EIRES, which needs to be even more exploited in the future. The committee encourages the department board to further promote these structural choices and to enhance the visibility of existing strengths and future planned research.

2.2 Organisational structure

In the evaluation period (2015-2021) the Department Board, appointed by the Executive Board of TU/e, consists of a dean, a vice-dean and a managing director and steers as well executes all aspects of the department's business. Mid 2022 a second vice dean was added to the department board. The dean coordinates and leads the members of the department and represents it towards the University and the outside academic, industrial and public environment. The dean is responsible for decisions on all aspects of the department operations, including strategic organization, finance, appointments of assistant professors, proposals for appointments of associate professors, education (together with the director of education), staff and quality assurance. The research groups have a direct communication with the Department Board without any intermediate administrative layer.
The evaluation committee finds the organisational structure sufficiently clear and functional, and it complements the department for the low number of decision-making levels. Involvement of the department members, including PhD students is well organised through a departmental and a PhD council. Both councils operate independently and have the opportunity to schedule discussions with the department board. This also includes the possibility of private discussions with individual board members.

In case of further growth of the department the introduction of a third domain should be considered differentiating within the quite diverse fundamental molecular- and materials-oriented research.

2.3 Collaborations and partnerships

Many researchers of the department are actively involved in interdisciplinary TU/e research at the Institute for Complex Molecular Systems (ICMS) and the Eindhoven Institute for Renewable Energy Systems (EIRES). The department was closely involved in the foundation and creation of the two institutes.

Apart from collaboration within the TU/e, the department puts much effort into collaboration with other universities and universities of applied science at the level of individual (groups of) researchers and in strategic alliances.

The committee notes positively that the department is involved in various collaborations, both on a local as well as on a national level. An important new source of funding is the Dutch National Growth Fund, stimulating national cooperation related to societal challenges. Traditionally the collaboration with industry focussed on the bulk and specialty chemicals sector. Currently, the attention is shifting more towards the food and pharma sector. The committee sees good opportunities for growth of the contract research in these areas. In order to facilitate this growth, the committee suggests, however, to re-evaluate the practiced university IP policy and governance (i.e., proximity of The Gate to the Departments) to improve IP output and further increase societal relevance. If a stronger IP portfolio is built up, a clear strategy on which subjects are patented, licensed or handed over is required.

2.4 Facilities and Infrastructure

The department is housed in the Helix building on the TU/e Science Campus. The Helix building was constructed in 1998 and was scheduled to be renovated in 2025. Due to changing priorities, this has now been delayed to after 2030. To address the most critical aspects (ventilation, heating system, etc.), €10 M has been reserved to keep the building's operations running until its renovation.

The department hosts a range of state-of-the-art scientific equipment, instruments and facilities over the length scales of the different expertise areas, which enables it well to perform its educational and research activities. The basic experimental equipment is up to date, though in some cases reaching the end of its lifetime. All research groups have dedicated equipment specialized for the specific fields of expertise of the respective groups.

Investments by the department in new apparatus and on keeping the quality of the equipment up to date are generally funded through external research grants (such as NWO Groot, ARC CBBC, Gravitation programs, ADEM, NanoNed and NanoNextNL). Only with these grants the department can maintain its state-of-the-art equipment at a high, internationally-competitive level, despite the fact that resources for standard, basic but essential equipment are limited.

The evaluation committee wishes to emphasize that excellence in science requires research with state-of-the-art equipment. The committee is impressed by the extent and the quality of the current department infrastructure. At the same time the committee acknowledges the problems associated with funding of the increasingly expensive equipment. The envisaged re-introduction of the Equipment Committee is, therefore, seen as an important step to develop a strategic plan in this respect.

With respect to building infrastructure the department board is encouraged to request a clear timeline for the necessary upgrading.

2.5 Funding

The department uses direct university funding for the salaries of permanent research staff, educational and support staff and the department's exploitation costs of housing. The running costs for research projects, including the salaries of temporary research staff (PhD students and postdoctoral research fellows), bench fees, consumables and capital investment in research infrastructure are covered to a

larger extent by external funding. This external funding encompasses research grants and funding from contract research.

About 50% of the total budget is direct funding. Additional funding is obtained through research grants from NWO (13%) and contract research, incl. EU grants (37%). See also Appendix 3, Table 1.

The additional question posed in the Terms of Reference was "the extent to which the implementation of the sector plan invigorates CE&C in the Netherlands and how it prepares CE&C for the future."

In the last year of the evaluation period (2021) about 5% of the total funding of the department is related to the sector plans.

At large, the outlook on funding possibilities within the Netherlands looks promising. Besides the roll-out of the sector plans, NWO budgets are increasing (€5 billion / 10 years) and large budgets are available with the National Growth Fund (€ 20 billion between 2021 and 2025) for project investments in the two fields, which have the highest potential for structural and durable economic growth, i) knowledge development, and ii) research, development and innovation.

The committee is pleased to note that the positive trend in direct funding already observed in the previous review period has continued. This is mainly related to the implementation of the sector plans.

Sector plan funds have been crucial to attract talent and strengthen the critical mass in supramolecular and polymer chemistry, physical chemistry, separation technology, catalysis, and chemical reactor engineering, and electrochemical energy conversion and storage. On a national level the Dutch Growth Fund offers new possibilities for long term research funding. In addition, we point to the minister of Education, Culture and Science having announced additional budgets for personal grants, scientific research and infrastructure. However, at the moment, the acquisition of external funding remains highly competitive, leading to high workloads.

2.6 Open Science at the TU/e level

The publication landscape is in transition. The total number of manuscripts submitted worldwide has significantly increased and open access publishing is obligatory for projects funded by e.g., the Dutch Research Council and the European Commission. TU/e and grant organizations encourage open access publishing. TU/e has created a website with information on open access publishing and provides dedicated support from library experts. At a national level, a website listing journal agreements and the associated costs for university researchers is available. The significant share of academic-corporate publications (ca. 15%) underpins the successful collaboration with industrial partners on frontier topics in science and technology.

The observation of the committee is that through these measures the university supports the open science goals, provides information, and stimulates a bottom-up approach.

2.7 Academic Culture

The department wants to provide an inclusive environment in which they work in a collegial, collaborative atmosphere with interaction, knowledge sharing and open debate and where all people can flourish and develop their talents while contributing to the shared mission of the department. Scientific independence, scientific integrity and social safety are core values in the department. All employees and bachelor's/master's/PhD students in the department are trained to follow the TU/e

Code of Conduct for Scientific Integrity based on trustworthiness, intellectual honesty, openness, and independence. A complaints procedure for scientific integrity is in place for confidentially reporting scientific misconduct. On TU/e level, counsellors and an ombudsman that act independently and impartially are installed.

Social safety is added as a standard item to the agendas of all departmental meetings (e.g., the Council of Full Professors, scientific staff meetings, the PhD Council, management assistant meetings, lab safety meetings). As a recent example, all employees were strongly encouraged to watch Mindlab, a theater play offered at TU/e on scientific and social integrity.

Social safety measures and plans at the university level are very well implemented in the department. The committee is impressed by the collegial atmosphere and the openness in the department. One manifestation of this is the seamless integration of interdisciplinary institutes into the department activities. During the site visit the committee had open discussions with the department employees. They regularly voice opinions and feel a low threshold to approach management. Core values are explicitly addressed in the visualization of the new department strategy.

3. Assessment of the department

3.1 Introduction

The past seven years show a very stable and steady number of scientific staff and PhD students (Appendix 3, Table 2). At the end of the review period (2021), the scientific staff of the department totals 35.2 FTE (full-time equivalent): 15.3 FTE full professors and part-time professors from industry and research institutes, 4.0 FTE associate professors, 15.9 FTE assistant professors, 24.8 FTE technical staff and 24.7 FTE support staff. There are 353 bachelor and 270 master students, 216.4 FTE PhD students, 45.3 FTE professional doctorate trainees and 44.9 FTE postdoctoral fellows. The department's total annual budget in 2021 was €31.6 M.

3.2 Mission and strategy

The mission of the department is to be a centre of inspired learning in chemical engineering and chemistry, encouraging the pursuit of new knowledge and innovative scholarship. To fulfil this mission, the department's vision is to provide strong chemical engineering and chemistry education on solving complex societal problems to advance basic science and technology while impacting the chemical industry, other associated industries and broader society. By interlinking molecular systems, materials chemistry and chemical engineering sciences, the department bridges fundamental research and marketable applications and commits itself to excellence in education, research and valorisation.

Overall, the committee is impressed by the quality of research, education, and self-organization of the department. The committee commends the university for shaping an environment that enables such development.

To realize this mission the department's strategic aims are based on three key pillars:

People: The department considers the people that they employ and educate as the most important aspect. This refers to students (bachelor's/master's/professional doctorates/PhD students) and faculty and support staff. The department wants to provide an inclusive environment with room for everyone's talent and where all students, researchers and scientific and support staff can flourish and develop their talents while contributing to the shared mission of the department.

The committee notes that the department is in the transition from a (more) hierarchical structure to a structure in which the principal investigator (PI) is decoupled from the position in the department. Especially personal evaluation criteria, such as (internal) collaboration, knowledge sharing and contribution to the department goals, are under discussion. The committee advises to make the required transition an important topic for the new strategy period.

Science: The department aims to perform top-notch research with state-of-the-art equipment at the forefront of science and technology in the selected areas of materials chemistry, molecular systems and chemical engineering sciences. The members are committed to excellence in scientific and applied research and to address fundamental science with societal relevance. To maintain scientific excellence and an internationally leading position in research, the department aims to reinforce their focus and bench depth in core research themes by retaining existing staff and hiring new talent. Given the growing importance of and the strong societal need for renewable energy (harvested as electricity) the recommendation is to actively strengthen the department's chain of knowledge in the field of electrocatalytic energy conversion and storage. Digital technology is of strongly increasing societal importance and its impact in the chemical industry will grow. Technologies such as machine learning

and artificial intelligence, in combination with online/inline sensing, will also find application in the chemical industry. This topic will see increased attention in the coming years.

The evaluation committee endorses the formulated strategic directions of the department. It should be emphasized that this will require a substantial effort in hiring and retaining outstanding talents as well as leaders. The plans require additional commitment by the executive board in fostering the needed research environment which provides sufficient room for own development, but also allows a coordinative research planning and to focus on the most promising topics where joining forces within the department has the highest impact.

Societal relevance: A number of upcoming external and internal changes affect the department. Society is changing rapidly, driven by economic, technological and environmental megatrends such as (reversed) globalization, climate change, the associated energy transition, the transition to a circular economy, health, resources and digitalization. The growing role of multidisciplinary research across all length scales is evident in solving the complex problems in the above-mentioned context.

It is highly appreciated that the department puts substantial effort on sustainability. The committee encourages to make it more explicit, e.g., by choosing up to a maximum of four UN Sustainable Development Goals and link projects to it. This could further clarify the societal impact. The chosen research directions and plans for the future should contribute to the selected goals.

3.3 Human Resource Policy

In compliance with its mission, scientific quality remains a leading principle in all hiring/promotion trajectories. Candidates are evaluated according to formal appointment and promotion protocols. The departmental Promotions Committee, completed with additional experts related to the field of expertise of the candidate, advises the Department Board on the hiring/promotion of a candidate. The department aims at increasing gender diversity and uses specific search committees to proactively scout talented (female) candidates for open positions. For new hires at a scientific staff level, the department provides start-up packages (typically a PhD position and €50 k of investment for starting tenure-track staff; more extensive start-up packages are required when hiring senior staff, done in conjunction with the Executive Board). All senior scientific staff (i.e., associate and full professors) have the right of accepting and graduating PhD students (ius promovendi).

The committee positively notes the increase in diversity. The department made progress in talent management since the last report, but there is room for further improvement. Attention should be paid to unambiguous criteria with respect to selection and promotion, reflecting the department strategy. The committee sees enhanced visibility of young talents and flexibility in their career path as a crucial element in attracting and retaining the best talent in global competition.

The committee recommends to formulate a well-laid-out strategy for recruiting, development and retention of staff. Additionally, it is advised to strengthen the individual career planning, training, and promotion of visibility for assistant professors.

3.4 PhD policy and training

The department has more than 200 PhD students. PhD trajectories are demanding and require support in terms of science and professional development tailored to the needs of the individual PhD student. Much of this is arranged at the individual level between a PhD candidate and the assigned supervisors in order to provide dedicated guidance, with support, monitoring and advising bodies (e.g., HR

advisors, PhD Council) in place at the department level. In terms of mental health, TU/e has made support available to all PhD students in the form of a PhD counsellor, a company social worker and a company doctor. Each PhD student has at least two academic supervisors. All PhD students in the department can participate in content-based courses (regularly organized by graduate schools such as NIOK, OSPT, JMBC and the TU/e Graduate School) and courses related to soft skills (e.g., PROOF courses at a TU/e level, including the obligatory course 'Scientific Integrity'). PhD students contribute to the educational tasks of the department (supervising guided self-study elements of bachelor's and master's courses, co-supervising laboratory courses and co-supervising bachelor's and master's graduation projects). The expected time effort for educational tasks sums up to 600 hours in 4 years on average.

At a higher level, the Department Board has regular meetings with the PhD Council of the department, composed of a PhD representative of each research group in the department. The PhD Council also organizes regular social gatherings for all PhD students in the department. In addition, the dean of the department has an exit meeting with each PhD student leaving the department. About 50% of students graduate in four years while the average time needed before graduation is 4.5 years. Close to 100% of PhD students find a new position quickly after graduation (Appendix 3, Table 3).

The committee appreciates the current policy and implemented measures, such as a very active PhD council. In light of social safety, the committee encourages the installation of a PhD mentor without hierarchical relations to the student.

3.5 Research Quality

In the last six years – with the availability of resources due to additional sector plan funds, the promotion of scientific staff of the department to positions at other universities, and natural attrition – the department has been able to strengthen its staff in supramolecular and polymer chemistry, physical chemistry, separation technology, inorganic materials and catalysis, and chemical reactor engineering in line with the identified areas of gravity of the department. Also, the department's chain of knowledge in the field of electrochemical energy conversion and storage has been empowered.

In summary, the department has been able to strengthen its foundation, rooted in the thematic domains of molecules, materials and processes in the application areas of energy, circularity and health, by reinforcing staff with early-career and experienced hires, promoting promising researchers to the rank of full professor and establishing a more diverse staff.

The department clearly excels in research quality and attracting funding, as illustrated by the number of ERC grants and the role of department staff in the prestigious national gravity programs. However, these grants and programs are coming to the end of their duration and key persons within the department will retire soon. This will lead to uncertainties with respect to the success rate of new applications. The succession of these highly and widely appreciated researchers requires full attention of the Department Board.

The department organizational structure and culture in general nourishes the chain of knowledge on various research themes such as electrochemistry, supramolecular synthesis, affinity separations, energy storage, liquid crystals, and energy materials. The cooperation in institutes like EIRES, ICMS and ARC-CBBC further contributes to the department being successful in moving results from fundamental to applied scientific research. In the area of Health, the chain of knowledge within the department seems less developed and will require attention.

The committee lauds the plans implementing data science, artificial intelligence, and machine learning and recommends to establish a center of competence in this area. Aligned with that, the committee strongly recommends to strengthen theory and computational chemistry in the department.

Open Science

Most of the publications of the department (~80%) are published open access nowadays. It is part of a self-sustained culture in the department without written rules (except for rules regarding open access publishing from funding agencies). The consensus is that quality is more important than quantity. This is especially advocated with respect to publications in the framework of PhD projects, which make up the largest share of the scientific output.

The department is very active in open access. First steps towards FAIR principles have been undertaken. Examples are the use of electronic notebooks and the efforts made in data standardization. Still many challenges need to be addressed in the field of open science and data science also with regard to AI and machine learning. One of these challenges may also be the increasing focus on open access leading to possible conflicts with the university IP policy

3.6 Societal Relevance

To guarantee societal impact, the department actively participates in initiatives like the Dutch Science Agenda (NWA), public-private partnerships and the National Growth Fund. As the targeted societal challenges of energy, circularity and health require a multidisciplinary approach, this will be done in collaboration with the TU/e institutes ICMS and EIRES, scientists in other TU/e departments and relevant industries, other institutes, and other universities.

The department will continue to stimulate and facilitate spin-off activities. The university has the intention to create an incubator on campus to support staff members and (PhD) students in creating a company based on research in the department.

The staff members of the department are very active in outreach to the public as well. They give presentations and interviews on TV and the radio, provide their opinions on current affairs in newspapers, give guest lectures at schools and are frequently consulted by different societal actors. An example of the appreciation for these effects is the Academic Society Award of the Dutch Royal Institute of Engineers received by Prof. Kitty Nijmeijer.

In the light of the forthcoming changes and challenges, it is recommended to further focus within the 3 grand challenges (energy, circularity, health). With respect to circularity aspects like 'design for reuse', up-/recycling should be considered in the process of setting this focus.

With respect to outreach the committee finds the activities undertaken by the staff members to be satisfying, but it is encouraged to formulate a clear strategy and delegate the corresponding responsibilities to specific members of the department.

3.7 Viability

During the last decade, the academic landscape and its interactions with the environment have largely changed. Since the previous research evaluation, the department has invested in its two scientific domains, as defined back in 2015: Molecular Systems & Materials Chemistry and Chemical & Process Technology. These investments have now resulted in critical mass over different length scales, from

molecules to materials and processes. Simultaneously, with the increasing importance of science to society, the research has naturally converged towards a focus on the grand societal challenges of energy, circularity and health. At a TU/e level, the organization has changed from a central board and several departments focusing on specific scientific disciplines to an organization with these departments but also with research institutes in which researchers from different disciplines (i.e., departments) join forces and collaborate on multidisciplinary topics directly connected to societal challenges, often in collaboration with other universities and polytechnics, industrial partners and societal organizations. At a national level and globally, strategic alliances, and partnerships are essential in contributing to solving complex societal challenges as this requires highly multidisciplinary approaches. At the same time, there is a strong battle for talent, impacting the attraction of top talent and support staff needed to stay at the forefront of science and technology.

The SWOT analysis in the table below builds on these perspectives.

	Strengths	**Weaknesses**
Internal	Expertise over length scales covering knowledge chains (molecules, materials and processes) in focused application areas (energy, circularity and health) Strong, state-of-the-art experimental infrastructure covering the department's expertise in chemistry and chemical engineering Research and education are highly intertwined Collaborative and entrepreneurial nature of the people across the department Research staff in the department have strong ties and collaboration with other universities, industry and societal organizations in their respective fields of expertise	Limited financial resources (limited direct university funding and very strong competition for external research funding) Relatively small department with an unbalanced distribution of scientists in different career stages (relatively large number of young scientific staff but low number at associate professor level) Retirement of internationally renowned scientific staff in the coming years End of life of the Helix building, its laboratories that host the department and the basic infrastructure
	Opportunities	**Threats**
External	Positioned in strong ecosystems with ample opportunities for collaboration Solutions for societal challenges need multidisciplinary science and technology over length scales and strong collaboration Strong increase in demand for well-educated, highly-skilled scientists and engineers (bachelor's, master's and PhD level) Funding opportunities for large research programs (e.g., National Growth fund) Large governmental investments granted to higher education $\geq$ 2023	Complexity of the local, national and international playing fields Battle for talent: unable to attract the top talent and support staff needed to stay at the forefront of science Other academic institutions take a leading position in global collaboration across disciplines to solve societal challenges Very strong competition for external research funding Internal affairs can distract from empowerment at a national and global scale Higher costs, longer delivery times of equipment and high inflation

The committee highly appreciates the current breadth and depth of the department, which will ensure its viability. Because of sector plan support, the amount of direct funding has increased, allowing strategic investments in new adjacent research lines. Based on the well worked out SWOT analysis a new strategy is developed in which the department will make explicit choices in order to establish sufficient focus and bench depths in selected research lines. The evaluation committee advises to compose an external advisory board, which supports the department in making these choices. The committee supports the department vision on the necessary investments (AI, machine learning, data science).

A significant concern is the high workload of the department staff. This is partly caused by the competition in securing research funding, but mainly by the increase of student numbers in the beta and technical sciences. On a national level the demand for graduate engineers has increased drastically. This development asks for thoughtful steering from the university board and has consequences for the different department boards. It requires careful planning and substantial financial commitments to accommodate the challenges associated with growing student population.

3.8 Recommendations

In the light of the above findings, the committee has identified nine specific recommendations for the Department of Chemical Engineering and Chemistry of the Eindhoven University of Technology:

1. The committee highly appreciates the current breadth and depth of the department. In the light of the forthcoming changes and challenges, it is recommended to sharpen the focus of activities within the three grand challenges (energy, circularity, health) to further strengthen its currently high scientific reputation and position in global comparison. Topics should be selected where joining forces within the department and in collaboration with existing centers has the most impact.
2. Enhance visibility of existing strengths and planned research.
3. Develop a clear strategy for recruiting, development, and retention of staff.
4. Strengthen the individual career planning, training, and visibility for assistant professors.
5. Strengthen theory and computational chemistry in the department.
6. The committee lauds the plans implementing data science, artificial intelligence, and machine learning and strongly supports establishing a center of competence.
7. The committee encourages the department board to obtain a clear timeline for the necessary upgrading of the building infrastructure.
8. The committee encourages the installation of PhD mentors without hierarchical relation, in light of social safety.
9. It is highly appreciated that the department puts substantial effort on sustainability. The committee encourages the department to make it more explicit, e.g. by choosing up to four UN Sustainable Development Goals and link projects to it, further increasing and specifying societal impact.

On the basis of the evaluation and site visit the committee would also like to suggest the Executive Board of the University the following:

1. Growth in the number of students is very challenging and requires careful planning and substantial financial commitments from the side of the University.
2. The committee sees enhanced visibility of young talents and flexibility in their career path as a crucial measure for attracting and retaining scientists.
3. Rethink the university IP policy and governance (i.e., the proximity of The Gate to the Departments) to restore IP output and further increase societal relevance.

Reflection on the recommendations of the previous evaluation (2015)

1. <u>*Ensure broad funding covering fundamental and applied research*</u>: During the evaluation period, most of the research of the department was funded by a healthy mix of curiosity-driven fundamental research on the one hand and more applied research on the other. This holds not only for the many relatively small projects but also for larger consortia covering fundamental research and applied research.
   With the increasing focus of national research funds on societal relevance and earning capacity the balance between curiosity-driven fundamental research and more applied research remains challenging.

2. <u>*Decline in direct university funding, resulting in a higher workload of staff*</u>: In recent years, the direct funding situation of the department has improved due to a redistribution of the university funding. This has, to some degree, relieved the pressure on staff members. At the end of the current evaluation period, direct funding covered nearly all costs for permanent staff, education and general operations. For the coming years, the sector plans provide additional funding for newly attracted staff members in key research areas. The acquisition of external funding remains very competitive though, implying that staff are forced to put substantial effort into grant applications.
   The increase in direct funding by the sector plans has been crucial in advancing the department into a stronger and more viable condition.

3. <u>*Career prospects for non-tenured/tenured staff*</u>: Following a change in Dutch law on higher education, associate professors now also have *ius promovendi*, which aligns with the notion that associate professors may develop independent research lines within the university. Expectations on career prospects and promotion have been clarified, while procedures have been streamlined such that the Department Board is more closely involved in the career paths of younger staff members, including through direct discussions between staff members and the board.
   Important steps with respect to career prospects are taken, but there is still room for improvement.

4. <u>*Time to doctoral degree*</u>: A new online system to monitor the progress of PhD projects and homogenize procedures with respect to the defense trajectory has been implemented. The time between the finalization of the thesis and the actual defense remains about the same (ca. 3.5 months).
   The time to obtain the doctoral degree has stayed constant and monitoring it should be continued.

5. <u>*Gender issues*</u>: During the review period, the department has strived to broadly increase gender diversity, specific attention is paid to the number of female full professors, who are role models. The department hired several female tenure-track assistant professors in the recent sector plan

round. Dedicated search committees are regularly tasked to identify gender diverse talent for specific positions. As presented the number of female scientific staff increased from 15 to 26% during the review period.
Due to the preconditions in the sector plans, the number of female scientific staff has increased. In the coming years, due to a competitive labour market, it will become increasingly difficult to continue this growth path and even retaining female staff.

6. *Visibility of young researchers on the TU/e website*: The TU/e website has been redesigned and all researchers have their own research pages in line with the policy that all staff, including junior staff, develop their own research lines.
The visibility of young researchers has increased. However, indications exist that expectations of PI's go beyond what is realized until now.

APPENDICES

1. SEP protocol
2. Visit program
3. Quantitative data
    a. Table 1: Funding of the department
    b. Table 2: Research staff of the department from 2015 to 2021.
    c. Table 3: Information on the duration and success rate of the PhD program.

Appendix 1: The SEP 2021-2027 Criteria and categories

The committee was requested to assess the quality of research conducted by the Department of Chemical Engineering & Chemistry of the Eindhoven University of Technology (CEC) as well as to offer recommendations to improve the quality of research and the strategy of CEC. The committee was requested to carry out the assessment according to the guidelines specified in the Strategy Evaluation Protocol. The evaluation included a backwards-looking and a forward-looking component. Specifically, the committee was asked to judge the performance of the unit on the main assessment criteria and offer its written conclusions as well as recommendations based on considerations and arguments. The main assessment criteria are:

1) Research Quality: the quality of the unit's research over the past six-year period is assessed in its international, national or – where appropriate – regional context. The assessment committee does so by assessing a research unit in light of its own aims and strategy. Central in this assessment are the contributions to the body of scientific knowledge. The assessment committee reflects on the quality and scientific relevance of the research. Moreover, the academic reputation and leadership within the field are assessed. The committee's assessment is grounded in a narrative argument and supported by evidence of the scientific achievements of the unit in the context of the national or international research field, as appropriate to the specific claims made in the narrative.

2) Societal Relevance: the societal relevance of the unit's research in terms of impact, public engagement and uptake of the unit's research is assessed in economic, social, cultural, educational or any other terms that may be relevant. Societal impact may often take longer to become apparent. Societal impact that became evident in the past six years may therefore well be due to research done by the unit long before. The assessment committee reflects on societal relevance by assessing a research unit's accomplishments in light of its own aims and strategy. The assessment committee also reflects, where applicable, on the teaching-research nexus. The assessment is grounded in a narrative argument that describes the key research findings and their implications, while it also includes evidence for the societal relevance in terms of impact and engagement of the research unit.

3) Viability of the Unit: the extent to which the research unit's goals for the coming six-year period remain scientifically and societally relevant is assessed. It is also assessed whether its aims and strategy as well as the foresight of its leadership and its overall management are optimal to attain these goals. Finally, it is assessed whether the plans and resources are adequate to implement this strategy. The assessment committee also reflects on the viability of the research unit in relation to the expected developments in the field and societal developments as well as on the wider institutional context of the research unit.

During the evaluation of these criteria, the assessment committee was asked to incorporate four specific aspects. These aspects were included, as they are becoming increasingly important in the current scientific context and help to shape the past as well as future quality of the research unit. These four aspects relate to how the unit organises and actually performs its research, how it is composed in terms of leadership and personnel, and how the unit is being run on a daily basis. These aspects are as follows:

4) Open Science: availability of research output, reuse of data, involvement of societal stakeholders.

5) PhD Policy and Training: supervision and instruction of PhD candidates.

6) Academic Culture: openness, (social) safety and inclusivity; and research integrity.

7) Human Resources Policy: diversity and talent management.

Appendix 2: Program of the site visit

Day 1: 31 October 2022		**Participants**	**Location**
During the day	Arrival Assessment Committee members		Hotel
17:00 h	**Start formal program**		**Hotel**
17.00 - 17.30	Welcome presentation Department Board	Assessment committee Department Board	Hotel
17:30 - 20:00	Dinner Topic: Getting acquainted, specifying questions	Assessment committee Department Board	Hotel
20:00 - 22:00	Assessment Committee Private kick-off meeting	Assessment committee	Hotel
Day 2: 1 November 2022		**Participants**	**Location**
09:00–10:00	Department Board Topic: Department strategy and organizational structure	Assessment committee Department Board	Helix building STW 2.91
10:15 -11:00	Representatives cluster Molecular Systems and Materials Chemistry Topic: Science highlights	Assessment committee ST representatives: Prof. Van Hest, Prof. Tuinier, Prof. Palmans, Prof. Schenning; Listener: Prof. Nijmeijer	Helix building STW 2.91
11:15–12:00	Representatives cluster Chemical and Process Technology Topic: Science highlights	Assessment committee ST representatives: Prof. Kuipers, Prof. Gallucci, Prof. van der Schaaf, Prof. Hensen; Listener: Prof. Nijmeijer	Helix building STW 2.91
12:00-13:30	Lunch with assistant professors of the department Topic: Discussion on research, teaching, leadership and support	Assessment committee Assistant professors	Atlas building University Club
13:30-14:00	Delegation Department Council	Assessment committee Ivo Filot, Bart van den Bersselaar, Timon Roose	Helix building STW 2.91
14:00-15:30	Lab tour by post docs/PhD students STO Helix labs	Assessment committee Post docs/PhD students	Helix STO
15:30-16:00	University professors Past, present, future	Assessment committee Prof. Meijer, Prof. Janssen; Prof. Nijmeijer	Helix building STW 2.91
16:00-16:30	Department Board Topic: Additional questions of Assessment Committee	Assessment committee Department Board	Helix building STW 2.91
16:30-17:30	Drinks with representatives PhDs and PhD Council Topic: View on research, education and support	Assessment committee PhD students (no staff)	Helix building Pantry
18:00-20:00	Dinner (Assessment Committee only)	Assessment committee	t.b.d.

Day 3: 2 November 2022		**Participants**	**Location**
09:00-10:00	Department Board Topic: Social Safety, PhD policy and Recognition&Rewards	Assessment committee Department Board	Helix building STW 2.91
10:00-11:30	Lab tour by post docs/PhD students STW Helix and Matrix labs	Assessment committee Post docs/PhD students	Helix STW
11.30-12:00	Meeting with Department Board	Assessment committee Department Board	Helix building STW 2.91
12:00-16:00	Private final meeting Assessment Committee, drafting report (including lunch)	Committee	t.b.d.
16:00-16:15	Short presentation first findings to Department Board and TU/e Rector Prof. F. Baaijens	Assessment committee TU/e Rector Prof. F. Baaijens, Department Board	Helix building STW 2.91
16.15-17:00	Short presentation first findings to CE&C community (including drinks)	Assessment committee CE&C community	Helix building Pantry
17:00 h	**End formal program**		
18:00	Optional: Dinner	Assessment committee Department Board	t.b.d.

Appendix 3: Quantitive Data

Table 1: Funding of the department

Table : Funding at the department in the review period (in k€)

Year	2015	2016	2017	2018	2019	2020	2021
Research funding	**€ k**	**€ k**	**€ k**	**€ k**	**€ k**	**€ k**	**€ k**
Sectorplan 1.0	*5*	*465*	*572*	*572*	*976*	*572*	*572*
Sectorplan 2.0	*0*	*0*	*0*	*0*	*0*	*508*	*1,044*
Other direct funding	*11,508*	*10,710*	*11,640*	*12,529*	*13,923*	*13,394*	*13,941*
Direct funding	**11,513**	**11,175**	**12,212**	**13,101**	**14,899**	**14,474**	**15,558**
*NWO **	*2,422*	*2,760*	*3,532*	*3,752*	*3,710*	*3,417*	*2,778*
*Other research grants ***	*814*	*1,116*	*1,996*	*1,385*	*1,156*	*1,592*	*1,432*
Research grants	**3,236**	**3,876**	**5,528**	**5,137**	**4,865**	**5,009**	**4,210**
Bilateral with industry	*3,890*	*3,832*	*4,155*	*4,155*	*4,183*	*2,698*	*3,014*
EU	*1,612*	*1,945*	*1,819*	*1,965*	*2,130*	*2,832*	*3,169*
EU-ERC	*1,192*	*1,444*	*1,500*	*1,815*	*1,161*	*1,041*	*490*
*Other contract research ****	*4,677*	*4,947*	*4,168*	*3,602*	*4,481*	*5,586*	*5,162*
Contract research	**11,371**	**12,167**	**11,642**	**11,537**	**11,954**	**12,157**	**11,834**
Total funding	**26,120**	**27,219**	**29,382**	**29,775**	**31,718**	**31,640**	**31,601**

** Incl. Veni/Vidi/Vici*

*** Gravitation program*

**** a.o. ARC CBBC/DPI/Insite*

Table 2: Research staff of the department from 2015 to 2021.

FTE[1]	2015	2016	2017	2018	2019	2020	2021
Full prof.	15.2	13.3	13.0	14.1	14.7	15.8	15.3
Associate prof.	7.5	8.6	8.3	7.0	5.7	4.7	4.0
Assistant prof.	15.4	13.0	12.8	12.6	16.2	16.4	15.9
Total prof.	*38.1*	*34.9*	*34.1*	*33.7*	*36.6*	*36.9*	*35.2*
Postdocs	48.8	50.7	49.6	53.9	52.0	51.4	44.9
PhD students[2]	200.3	191.5	204.1	205.6	204.8	211.3	216.4
Total research staff	287.2	277.1	287.8	293.2	293.4	299.6	296.5

1 Full-*time equivalent, i.e., total time of appointment; available for research, education and organizational tasks*

2 PhD students, including both fully employed by the department and externally or internally funded but not employed by the department

Table 3: Information on the duration and success rate of the PhD program.

Enrollment			**Success rate (graduated in …)**						
Starting year	*Enrolment (M/F)*	*Total*	*Year 4 or earlier*	*Year 4.5 or earlier*	*Year 5 or earlier*	*Year 6 or earlier*	*Year 7 or earlier*	*Not yet finished*	*Discontinued*
2013	21 / 11	32	17 / 53%	23 / 72%	24 / 75%	29 / 91%	-	-	3 / 9%
2014	32 / 13	45	20 / 44%	29 / 64%	33 / 73%	40 / 89%	-	3 / 7%	2 / 4%
2015	36 / 7	43	21 / 49%	30 / 70%	37 / 86%	40 / 93%	-	2 / 5%	1 / 2%
2016	35 / 12	47	23 / 49%	36 / 77%	40 / 85%	41 / 87% [1]	-	2 / 4%	4 / 9%
2017	39 / 14	53	24 / 45%	35 / 66%	38 / 72% [1]	-	-	14 / 26% [1]	1 / 2%
Total	163 / 57	220	105 / 48%	153 / 70%	172 / 78%	188 / 85% [1]		21 / 10% [1]	11 / 5%

[1] *Data taken into account until June 1, 2022.*