Evaluation report for the research review of the

Chemical Engineering Department

and the

Biotechnology Department

at

Delft University of Technology

for the period 2015-2020

February 2022

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Preface

This report documents the findings of the assessment committee that was appointed by the Executive Board of Delft University of Technology to review the scientific research of two departments of the Faculty of Applied Sciences during the period 2015-2020. These departments are the department of Chemical Engineering and the department of Biotechnology. 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 had available the self-evaluation report prepared by the departments, and conducted a site visit in Delft in October 2021.

The main goal of this assessment is to evaluate the research of both departments in light of their own aims and strategies and is therefore future-oriented what makes this assessment protocol clearly different from the previous one which was more focused on a review of past performance. The committee was very pleased with this new protocol, which provided the opportunity to have a focused, substantive discussion with the rector, dean and management and research staff of both departments about their plans for the future and how they want to achieve them. The committee would like to suggest that this new protocol includes, for example, setting up a website in addition to the self-evaluation report, where useful supporting information is available, which may enable the committee to form a complete picture of the research unit that is being assessed. During the current assessment, and especially during the site visit, committee members felt compelled to collect this information themselves from various accessible web-based sources.

I speak for the entire committee in congratulating the Faculty of Applied Sciences with the high quality of the research of both departments in the period of the evaluation. It was a pleasure to talk to the enthusiastic and committed research staff and PhD students, and to get a tour of the outstanding research infrastructure. The details of our findings are included in this report. We draw out some recommendations, most of which are aimed at consolidating and further enhancing the performance of both departments.

On behalf of the committee, I would like to thank all participants in the interviews, whose contributions to the review were insightful, open and helpful. Furthermore, I should like to thank the committee members for their dedication, creativity, diligence and good humour throughout the review process. Finally, I thank our secretary for her support in the review process and the preparation of this report.

Professor Jaap Schouten
Chair research assessment committee
December 2021

1. Introduction

1.1. Scope of the assessment

In June 2021, the Executive Board of Delft University of Technology (TU Delft) commissioned a review of the research conducted in the Chemical Engineering (ChemE) Department and the Biotechnology (BT) Department of the Faculty of Applied Sciences. The review is part of the regular six-year quality assurance cycle of the university and is intended to monitor and improve the quality of the research and fulfil the duty of accountability towards government and society. The quality assessment in this report is based on the assessment system in the Strategy Evaluation Protocol for Public Research Organizations 2021-2027 (SEP, appendix 1) by the Association of Universities in the Netherlands (VSNU), the Netherlands Organization for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW).

In accordance with the SEP for reviews, the committee was requested to assess within specified guidelines. The committee was asked to judge the performance of both departments on the main assessment criteria specified in the SEP and to offer its written conclusions and recommendations based on considerations and arguments. The main assessment categories are Research Quality, Societal Relevance and Viability.

The committee was asked to include four specific topics. These relate to how the research programme organises and performs its research, how it is composed in terms of leadership and personnel, and how the research programme is run on a daily basis. The topics are: Open Science, PhD Policy and Training, Academic Culture and Human Resources Policy.

Finally, the Executive Board of TU Delft asked the committee to reflect on one additional question, namely: which organisational structure (e.g. a group-oriented section model, an individual-oriented Principal Investigator (PI)-model or any other model) would fit each department best in light of their research aims and strategies?

1.2. The review committee

The Executive Board of the TU Delft has appointed a review committee (hereafter: committee) of seven external peers, including a mid-career researcher and a PhD candidate. The committee consisted of:

- Prof. Jaap Schouten (chair), Eindhoven University of Technology, the Netherlands;
- Prof. Lars Angenent, University of Tübingen, Germany;
- Prof. Tom Breugelmans, University of Antwerp, Belgium;
- Prof. John Woodley, Technical University of Denmark, Denmark;
- Prof. Matthias Wessling, RWTH Aachen University, DWI – Leibniz Institute for Interactive Materials, Germany;
- Dr. ir. Diana Visser, Corbion, the Netherlands;
- Laura Dijkhuizen, PhD candidate, Utrecht University, the Netherlands.

The TU Delft Executive Board appointed dr. Meg Van Bogaert as the secretary to the committee.

Members of the committee signed a declaration and disclosure form to the effect that they would judge without bias, personal preference, or personal interest. Their judgment is made without undue influence from the institute, the programmes, or other stakeholders. Any existing professional relationships between committee members, and programmes under review were disclosed. The committee concluded that there

was no risk in terms of bias or undue influence.

1.3. Information provided to the committee

The committee received detailed documentation consisting of the following parts:

- Self-evaluation report 2015-2020, including appendices;
- Standard Evaluation Protocol 2015-2021;
- Terms of Reference for the research assessment Chemistry.

1.4. Procedures followed by the committee

The site visit of the research program took place on 25, 26, and 27 October 2021 in Delft. Before the site visit, the committee members were asked to read the documentation and formulate questions for the interviews. Several weeks before the site visit, the committee received a presentation with an introduction to the SEP, specifics about the Dutch research landscape and the working methods. In an online kick-off meeting, one week prior to the site visit, the committee agreed upon procedural matters. On the evening of 24 October, the committee discussed its preliminary findings.

During the site visit, the committee met with representatives of the University, Faculty and Departments and discussed its findings of the two departments. To conclude the visit, the committee chair presented the main preliminary conclusions to the departments, Faculty, and University. The schedule for the site visit is included in appendix 2.

This report describes the findings, conclusions, and recommendations of the committee. The departments are assessed in relation to departments and institutes worldwide in similar disciplines and on similar topics. The texts for the assessment report were finalised through e-mail exchanges. The final version of the report was presented to the departments, Faculty, and University Board for factual corrections and comments. The report was finalised on 4 February 2022.

2. Faculty of Applied sciences

Introduction

The research and education in chemical engineering and biotechnology are embedded in the Faculty of Applied Sciences, one of the eight faculties of TU Delft. The research in the faculty is fundamental and application-oriented in nature and is spread over six departments. In addition to the departments in this evaluation, Chemical Engineering (ChemE) and Biotechnology (BT), the faculty includes four applied physics departments (Imaging Physics, Quantum Nanoscience, Bionanoscience, and Radiation Science & Technology). The faculty offers four bachelor programmes and five master programmes. The ChemE and BT departments are strongly involved in the bachelor's curriculum Life Science &Technology and the bachelor's curriculum Molecular Science & Technology, which are shared programmes with Leiden University.

Organisational structure

The Dean heads the faculty and has overall responsibility for education, research, management and education, the Head of Department (HoD) is responsible for the distribution of resources (personnel and budget), for education and research, for overall quality and quantity of the research and for the departmental budget.

The additional question posed by the Executive Board of TU Delft to the committee concerned the organisational structure of the departments, namely which structure would best fit in light of the research aims and strategies. Both departments implemented a Principle Investigator (PI) based organisational model. The committee noted that both departments embrace this model, while the extent to which this model has been implemented varies between the two departments. The committee observed that the PIs of both departments see important advantages of the PI model over the former, strict section model. The most important argument for this is the possibility to formulate one's own research line independently. Sections still have their roles in the PI model, in particular in community building, technical support of research infrastructure and social cohesion. Therefore, the committee suggests that PIs, section heads and HoDs clearly define the duties and responsibilities that the PI model entails for all involved, as obviously more personal freedom and more scientific independence go hand-in-hand with shared responsibilities. According to the committee, these shared responsibilities include administrative responsibilities to support the organisational management of the department as a whole.

The committee emphasises that the role of the HoD may also change when the PI model is further adopted. If the PIs collectively share more administrative responsibilities, the HoD might retain more time for their own research. This may subsequently make this position more attractive for the department's younger, talented and ambitious PIs. Therefore, with the introduction of the PI model, also the position of the HoD needs to be rethought and redefined, including the option to delegate more executive duties to a formally appointed managing director. The committee understands that such thoughts already exist within ChemE, and it calls on those involved to give further shape to this.

When PIs (and also Tenure Trackers, TTs) act independently in the formulation and definition of their (individual) research lines, there is a risk for the department's research portfolio to become fragmented. For that reason, the committee strongly recommends that new research directions be specifically embedded in larger partnerships (e.g., interdepartmental collaborations and institutes or larger scale programmes at the national level). This promotes the necessary focus and coordination of research activities, helps to identify blank spots in the expertise in the department, and contributes to the coordination of the appointment of new PIs and TTs. Of course, this should not and will not affect the importance of creative freedom in

research, which also has to keep its place in the departments. It is the joint responsibility of PIs, TTs and HoDs to maintain the right balance.

Collaborations and partnerships

TU Delft is in the process of clustering its research capacity in several university-wide institutes. At the moment of the site visit, a total of 17 institutes were in place. Both departments in this evaluation are particularly involved in the e-Refinery institute. The faculty emphasised that fundamental science, as well as application-driven research, is part of the departments and faculty. The committee thinks that this is appropriate for a technical university.

According to the committee, the fields of application of the research of both departments, such as energy and circularity, show strong similarities. There are opportunities for strengthening the collaboration between the departments significantly in these and other corresponding areas of application. This would undoubtedly lead to new and surprising forms of collaboration and exciting scientific outcomes. The committee recommends to both departments to explore this, especially since it is considered important in maintaining the world-leading positions of both in the application areas of the research in an international setting. The international competition in these highly societal fields will become stronger in the upcoming years. The committee considers that there are many concrete opportunities to strengthen the collaboration between departments (e.g. by making seed funding available for joint projects). Such seed funding for collaborative initiatives is available at the level of the institutes but is missing in the Faculty of Applied Sciences between departments. To stimulate a more collaborative culture, in particular now that the two departments are housed in the same building, the committee recommends starting a specific seed funding program at the Faculty level (30-40K EUR). This will solidify new collaborative efforts.

The committee strongly recommends that (relatively) new research directions, such as Health (ChemE) and Food (BT), be specifically embedded in larger partnerships. Starting new initiatives is strongly suggested by the committee, though it should always be kept in mind that departments cannot do this on their own. Both departments require partnerships (e.g. interdepartmental forms of collaboration or programmes at the national level). The Convergence with Erasmus MC and Leiden (e.g. in health), offers exciting opportunities. The committee encourages the faculty to, indeed, make use of that, which will allow the initiatives to become successful and be able to compete at the highest international level.

Facilities and infrastructure

In 2016, three departments moved to a new building (Chemical Engineering, Biotechnology and Bionanoscience). This building offers offices, labs and educational facilities and is situated close to the Reactor Institute Delft (RID), enabling the sharing of facilities. It also offers possibilities for the PIs to meet and will form the centre of a new cluster of Applied Sciences buildings together with the RID, fostering a collaborative environment. Representatives of both departments informed the committee to be very pleased with the new building, even if it already tends to become too small for the growing departments. The committee agrees that the move to this building was a major improvement. It has a pleasant atmosphere and encourages cooperation between the three departments that it houses.

The responsibility for the acquisition and maintenance of infrastructure lies at the faculty level but is mandated to the departments. Increasingly, labs and other infrastructure are used by multiple departments. At the faculty level, there are discussions regarding the future strategy on infrastructure. The committee was impressed by the high quality and state-of-the-art infrastructure, which is important for technical departments.

The fact that both departments are housed in the same building opens up unprecedented opportunities for

further mutual collaboration. They now have the opportunity to actually physically meet each other. The committee cannot stress enough the importance of collaboration and joint community building and recommends taking advantage of this.

Funding

The faculty receives a yearly lump sum funding from the Executive Board, based on teaching efforts and research output. Allocation to the departments occurs on strategy (60%), research output (20%) and teaching efforts (20%). For both departments in this review, approximately 40% of the total budget is direct or lump sum funding. According to the committee, the balance between direct funding, grants and contract funding seems appropriate for a university of technology.

The committee knows that the research funding landscape is changing considerably for technology universities. The so-called mission-driven and application-oriented programmes at the national level offer great opportunities, and the departments are in the advantageous situation to be working on topics that are in need of societal solutions for which funding is available. It requires the replacement of former large scale programmes to these new opportunities, and the committee is fully aware of the highly competitive world. Still, the committee is convinced that it can be done by these departments. It requires positioning the leading PIs at a national level, where research agendas and programmes are taking shape. Senior PIs have been very successful in that. With joint efforts, it is possible to have the younger generation step in. To be successful, active planning from management is required, as well as on personal development and coordination on a continuous basis.

HR policy

The principles of the European Charter for researchers and the European Code of Conduct for the recruitment of researchers are endorsed by TU Delft. Researchers are encouraged to develop themselves in the areas of research, education, valorisation and leadership. Working in (multidisciplinary) teams, good supervision and open learning climate are considered important aspects in the development of research staff. The university expects that everyone displays personal leadership in performing their role; leadership skills training is offered at different career stages. Although the organisational structure of the departments differs somewhat, both ChemE and BT emphasised in the interviews with the committee the need for younger faculty members to grow and find their role and position in academic research.

The committee endorses the attention for professional development of the young PIs and TTs in both departments. Senior PIs play an essential role in this development, such as in coaching and mentoring (both formal and informal). They also have a role in helping junior PIs and TTs to participate in existing networks of senior PIs, both academic and industrial. The e-Refinery and the Bioengineering Institute can be very useful vehicles in building communities and sharing experiences. The development of younger PIs and TTs may be very important and instrumental in the long run in maintaining the impressive level of external and industry-related funding.

Since the previous assessment, TU Delft and the Faculty of Applied Sciences have improved procedures for tenure track agreements and promotion, which has improved the career perspective for junior staff. All TT candidates prepare a five-year plan themselves, with support from a mentor where needed. There is freedom for the candidates to set their ambition. They perceive the shift from quantitative to qualitative objectives and more focus on self-assessment and reflection as positive. Still, some metrics can be helpful to illustrate the progress made, but not as a goal in itself. Progress is evaluated annually with the HoD, and a Midterm Review is held with the Dean and the HoD. The TT candidates interviewed by the committee were very positive about the newly introduced system of incentives and assessment. Guidelines and assessment criteria seem to be sufficiently clear, and the availability of a mentor next to daily supervisor and coach is

appreciated. It is, indeed, important that such a person is there when needed. The TTs furthermore mentioned to appreciate the qualitative approach of the system, which allows them to build on their strengths.

Increasingly, the faculty and departments make strategic hiring choices. A newly instated Faculty Search Committee plays a key role in the selection of applicants. One of the results of this strategy is the appointment of a shared full professor. Further, experts from other departments, faculties and sometimes universities are involved in the recruitment of new PI's. The committee is pleased with the increasingly collaborative approach in hiring strategy. Collaborative initiatives promote the necessary focus and coordination of research activities. It helps to identify blank spots in mutual discussions in the field and on the expertise in the departments and contributes to the coordination of the appointment of new PIs and TTs.

Open science at TU Delft level

TU Delft has an Open Science Programme with the aim to take open science to the next level and make it a default way of practising research and education. The programme tackles areas of scholarly engagement and proposes new approaches to the processes of research, education and innovation, with a focus on transparency, integrity and efficiency. The implementation of this programme is facilitated by faculty appointed data-stewards, to whom researchers can turn for advice and help implement open science. The committee recognises the opportunities and importance of the "open era" school of thought and the open questions and challenges researchers face in shaping a new scientific practice. However, open science initiatives often focus on open data and open access, whilst other aspects of open science remain relatively underappreciated or unknown amongst scientific staff.

Academic culture

With its core values: Diversity, Integrity, Respect, Engagement, Courage, and Trust (DIRECT), TU Delft strives to be not only a leading university but also a great place to work. The Integrity Office coordinates the TU Delft policies and activities on integrity. A dedicated policy advisor is involved in topics such as social safety, (un)desirable behaviour, wellbeing and health. This policy advisor works closely with the Diversity & Inclusion Office on the topics of diversity and inclusivity. A dedicated policy advisor works on the portfolio Academic Integrity, including Research Integrity, Research Ethics, and Educational Integrity. A clear policy of research integrity was visible in both departments, in particular with an emphasis on the checking of data and peer review (also within the departments).

TU Delft aims to be as inclusive as possible. This includes socio-economic, cultural or religious background, nationality, gender, sexual orientation, age, physical appearance and ability, as well as roles and positions. A diversity policy at the TU Delft level was founded in 2021 with dedicated policy advisors. The Faculty of Applied Sciences has appointed a Faculty Diversity and Inclusivity Officer. The hiring of PhD candidates and temporary staff is done at the level of the research sections, under the final responsibility of the HoD.

According to the committee, both departments were very open and showed impressive levels of inclusivity. The ChemE department has a different gender balance to the BT department, which reflects the disciplines as a whole. In the chapters on the respective departments, the topic of diversity and inclusiveness is further discussed. The committee urges the departments to keep diversity and inclusion high on the agenda. Both ChemE and BT will have to show the necessary creativity to further improve the gender balance. This may still be difficult, but it should be done. The committee calls on the faculty and departments to consider carefully whether the targets set in this respect are still sufficiently ambitious.

Graduate School

The committee's findings on the training and supervision of PhD candidates are provided in the chapters of

the respective departments. The TU Delft Graduate School prepares and trains doctoral candidates to become highly qualified, autonomous and leading researchers and skilled professionals. The Faculty Graduate School coordinates the Faculty PhD policy, consisting of guidelines for the selection and interim evaluation of PhD candidates, support for promotors and the objectives and guidelines for research and discipline-specific courses.

The committee met with PhD candidates who are overall pleased with their projects, supervision and training. The major point for improvement that was mentioned is the sharing of information, for example, regarding the requirements for the thesis. The committee furthermore noticed that the PhD candidates, in contrast to the TT candidates, perceive a quantitative pressure.

As a general observation, the committee noticed that the collaborative atmosphere and easy crossing of organisational boundaries were less clear at the PhD candidate level. This might be an impact of the Covid-19 restrictions but is a signal that the social integration of some PhD candidates might be at risk. The committee recommends specifically taking care of the re-entry into normal operations, in particular for those PhD candidates who were hired during the Covid-19 period. The committee recommends involving PhDs themselves in organising and improving social integration; the PhD council might be an important partner in this respect.

The committee is positive by the way that both departments shape the PhD training and supervision program. It is important to continuously pay attention to this, in particular concerning the mental wellbeing of PhD candidates during the different stages of their appointment. Concerning the reduction of time to thesis, the PhD duration policy of the BT department is a best practice. It is a useful tool in which mutual expectations and responsibilities of both PhD candidate and supervisor are very clearly stated. Especially the planning meeting at the end of the 3rd year is considered an important measure in this practice. The committee suggests to roll this out in the faculty.

ASSESSMENT OF THE DEPARTMENTS

3. Chemical Engineering

3.1. Introduction

The Chemical Engineering Department (ChemE) consists of 35 PIs, loosely organised into eight sections. The group of PIs jointly supervises 103 PhD candidates, approximately 40 PDEng trainees and 30 postdoctoral researchers. A group of 20 technicians supports teaching and research activities. ChemE is actively involved in two TU Delft Institutes, namely the e-Refinery and the Delft Process Technology Institute.

3.2. Mission and strategy

The ChemE department's central aim is to define and explore new directions in chemical engineering. To achieve this goal, the department intentionally has a breadth in disciplines, combining the chemical engineering core-expertise of designing chemical processes and reactors with related fields in materials science, chemistry and physics. According to the self-evaluation report, the integrated approach puts ChemE in a unique position to address a range of urgent societal and industrial challenges (e.g., the energy transition and innovative engineering approaches in healthcare).

ChemE developed a research portfolio based on four themes. The theme **Fundamentals** of chemical engineering and chemistry covers the fundamental basis that is needed to enable application-driven research. The theme **Materials** relates to the notion that chemical engineering is increasingly about complex materials. The theme **Energy** is broad and includes the generation of renewable energy, storage of that energy and the conversion to fuels, chemicals and products. The fourth theme **Health** encompasses the use of materials and processing for medical and health applications.

In the period of the evaluation, ChemE focused on improving its internal culture and management and on strengthening the profile, *advanced materials for energy and health* by building on the fundamentals of chemistry and chemical engineering. In the self-evaluation report, it is stated that this profile has not yet given much structure to the research of individual PIs of the Department. It is recognised that strategic choices are necessary to shape research consortia, in particular, to be effective in mission-driven programmes such as the e-Refinery institute.

According to the committee, the shaping of the mission and strategy of the ChemE department is an ongoing activity that may have had an inhibiting effect on the shaping of the organisational structure of the department. The further shaping of the mission and strategy is a priority of the department, which is encouraged by the committee (recommendation B).

From the interviews and the self-evaluation report, the committee senses that researchers have a wish for steady leadership. The committee was pleased to learn that the ad interim HoD holds the position for the upcoming two years while the faculty and department search for a permanent replacement. This period has to be used effectively to lead to a permanent situation with clarity about the nature of the position of HoD for the longer term.

The department should consider the responsibilities of the HoD position with the option to delegate more executive duties to a formally appointed managing director. In such a model, the tasks and responsibilities associated with the position of HoD can be further shared with other PIs in the department. That way, the HoD position will include time for doing research and may become more attractive to younger PIs. The committee understands that such thoughts already exist in the department and the committee calls on

those involved to give further shape to this (see recommendation A).

3.3. HRM

The 2015 research assessment resulted in several HR-related recommendations: addressing the increasing workload, providing a clear career path for junior staff, and gender balance. Steps have been taken to address these topics. As described in chapter 2, ChemE has become increasingly PI-based in its structure and operation. Already prior to the period of the evaluation, the ChemE department started changing from a hierarchical section structure to a flat PI structure. This change was driven by the need for increased freedom and visibility of all PIs and resulted in a shift of the financial control of projects from sections to PIs. PIs are now independently establishing their research direction, while – according to the self-evaluation report - there still is a culture of shared responsibility and collaborations. PIs support and help each other in tackling workload issues and the writing of research proposals. This move towards a PI-based structure also entails a shared responsibility of the day-to-day operations of the department, moving away from all responsibility lying with the department management. However, the section leader, together with the HoD, remains responsible for the progress of PIs at the assistant and associate professor levels (see recommendation C).

In the current structure, PIs are more involved in the strategic discussions and the selection of new faculty members. A newly instated faculty search committee plays a key role in the selection of new PI's and in balancing of individual quality and strategic needs. The entire faculty is involved in the discussion of applications, and a joint decision is made on the hiring of candidates. In the evaluation period, this led to the hiring of excellent new faculty members in the ChemE department, both at junior and more senior positions. The establishment of the faculty search committee might have contributed to the improvement of gender balance in the past period.

According to the committee, the flat PI-based structure attracts talented researchers and allows them to develop their own independent direction of research. The young PIs the committee interviewed were very enthusiastic and appreciative of the TT program. The committee was given the impression of a strong collaborative atmosphere and easy crossing of the boundaries of the sections, department and faculty.

Diversity

Diversity and inclusivity were an explicit focus of ChemE in the past period. The department went from only one female assistant professor to five female PIs (two assistant professors, two associate professors and one full professor). Furthermore, 40% of the hires in the past six years were female, indicating that the measures taken are effective. The benefits of a more diverse staff are also becoming visible. However, the current percentage of female staff is still low at 16% and needs continued attention to achieve the aim of 30%. This target is based on the fraction of female graduates of the Master's program and is, according to the committee, not very ambitious. The committee is of the opinion that, in addition to positive action, many actions can be taken to further improve the gender balance.

To reap the benefits of a diverse staff, inclusion is a critical element. The committee noted that initial steps to address this are being taken, driven by the inclusion and diversity officer hired at the faculty level. It is important not to only hire but also to retain female employees. In particular, the transition from PhD to an academic career is a point of attention. Clear HR policies on work-life balance, part-time work, flexible working hours, and impact requirements are essential, and management should discuss these policies with TT candidates.

Talent management

The increase of younger, talented TTs provides many opportunities to the department. The committee wants to underline that ChemE has hired a large pool of young TT's in the evaluation period, which is an excellent group of young talent. The committee recommends to clearly define a strategy for the nurturing and stimulation of this group. After all, they are the future academic leaders and have to be stimulated to grow into scientific and administrative lighthouses. This strategy should include earning capacity (grant acquisition) as well as complementary scientific and leadership competencies.

Workload

The workload issue has not visibly improved, and especially the PIs perceive a high workload. The change to a flat PI model has increased their involvement in leadership-related activities. Due to the doubling of the student population, PIs need to supervise a larger number of students. Adjustment of the formal requirements for evaluating MSc students and PhD candidates and cutting out unnecessary administrative tasks can optimise the workload for all involved. However, it is vital to maintain the personal involvement of PIs in the coaching and evaluation of students. In addition, the committee recommends a (more) open discussion amongst PIs about setting realistic expectations, sharing responsibilities, and supporting each other to share the burden of administrative tasks. The committee also advises coaching where necessary and to include shared responsibility and realistic expectations in appraisal meetings.

3.4. PhD policy and training

The ChemE department houses 108 PhDs at the time of the report, while 72 (66.7%) candidates finished their PhD during the reporting period, and 21 (19%) are still working on their dissertation. The ius promovendi is awarded to associate professors, and the steps required to become full professor are clarified.

Time to PhD

One of the ChemE department's primary goals in PhD policy is to increase the number of dissertations finished within four years to 80%; specifically, the dissertation will be in a state that is suitable for the reading committee. The strategy towards this goal is to support PIs in identifying issues with PhD projects, focus more on quality when assessing dissertations, and clarify to PhDs that their project must complete in the contract time because no extensions will be granted. The committee finds the main aim and ambition appropriate and feasible. However, the strategy is balanced towards identifying issues in PhD projects and increasing pressure amongst PhD candidates, with less attention for the planning of a PhD project as a team. PhDs indicated that missing a dissertation deadline is likely caused by either scientific enthusiasm of the PIs and PhDs or a lack of clear requirements and expectations. The committee deems the dissertation requirements modern, realistic, and appropriate for the field. More clarity amongst PhDs on the dissertation requirements may relieve the perceived pressure and increase focused efforts towards finishing a dissertation on time (see recommendation G).

Besides clear requirements, the committee finds that proper and realistic planning in the final stage is essential towards the ChemE aim of reducing the time-to-dissertation. Therefore, the committee applauds the 2-supervisor principle: all PhDs have two research staff members as supervisors. Formalising the final planning of a PhD and including an external party, such as the second supervisor in this process, may help towards realistic planning of the final quarter of a PhD project. This external party should weigh in whether planning is realistic and balance the enthusiasm of PhDs and supervisors with a realistic goal.

Faculty Graduate School

The ChemE department's PhD programme has support from the faculty graduate school (FGS). The FGS facilitates soft skill courses for broader development. Additionally, the FGS reminds PhD candidates at

specific intervals to plan the remaining time in their project, but this is not perceived as helpful by the community. PhD candidates appreciate opportunities for broader development but mention the process can be paperwork laden. Additionally, the faculty graduate school organises a mentor programme; PhDs are assigned a mentor from the academic staff, who then functions as the first point of contact whenever a PhD experiences issues. The committee applauds the initiative to have a more active mentor role in the PhD programme where mentors have regular meetings with their mentees.

Career perspectives

Historically, most graduates of the ChemE PhD programme will pursue a job in industrial companies. Of the PhD graduates in the period of this evaluation, the majority (61%) obtained a job in large industrial companies in positions like industrial researchers, R&D engineers, senior scientists. Approximately 40% pursued an academic career at a university or in national research institutes. Of the PDEng graduates, most joined industrial or small start-up companies. Post-doc researchers make up another group of junior researchers. It is also important that the FGS supports this group of personnel members for a career outside the academic world. Post-docs are encouraged to attend various workshops (e.g., on business development) and visit key industrial partners. In addition, they follow training and courses to develop leadership and soft skills.

With their research skills, young PhD graduates of the ChemE department are attractive to other research institutes. Additionally, the committee values the network PhD candidates build while working at the department. However, the impact of COVID-19 seems to have impaired the feeling of community amongst PhD candidates. The committee suggests the ChemE department may support community feeling amongst PhDs, possibly within the entire department, whilst ideally involving their local PhD committee.

3.5. Research quality

To quantify the use of research output, a full citation analysis was conducted. By using the normalised scores, differences in the subfields of the PIs were eliminated to compare and analyse the scientific performance. The number of publications was similar to that of the previous evaluation period, but the field-weighted citation impact increased from 1.45 to 1.87. Further, nearly 65% of the papers were published in the top 10% journals by CiteScore and 22% belong to the top 10% most cited publications worldwide. The committee explicitly wants to congratulate ChemE with the scientific performance and high-quality research over the past six years (2015-2020). With a field-weighted citation impact of 1.87 and being ranked as number 14 on the QS world university ranking in Chemical Engineering, it is evidenced that the department has a leading role in the field of Chemical Engineering.

The high quality of the department is also reflected in the staff and in its infrastructure. ChemE consists of 35 principal investigators that are organized in 8 sections within the department. Recently, a substantial amount of young tenure tracked assistant professors were appointed. The committee has experienced a very dynamic group with a lot of potential for the future. The new, more flat PI-model will allow that those young colleagues will evolve more quickly in a leading role in the department. It was mentioned however that a lot of hires were primarily focused on covering substantial needs in education. The committee wants to underline the importance of a good strategy for the future of the department. Drafting a clear strategy towards thematical organization is crucial for the department to maintain its leading position in the next decennia. The PI-model is very important and as an aggregate level considered good and important. On the other side, the committee wants to emphasize the importance of team science. Individuals are important but will not change the large transformations. The PIs mentioned that recently a work group has started to work out a detailed strategy for the next years. The committee strongly advises to continue these efforts,

not only for new hires, but also to determine the thematic pillars for future research.

In principle, the ChemE department funds long-term ambitions with first stream funding, while ad-hoc investments are funded with project revenues. This implies that salaries of permanent staff are fully covered by the lumpsum funding from the university. Strategic investments are paid from project results; for this department, the strategic investments have a maximum of 15% per project. The department has invested in supporting the acquisition of external funding by the PIs, leading to awareness of PIs on funding possibilities and streamlining of administrative aspects of grant application and management. The department is successful in acquisition of external grants, overall between 100% and 150% of the lumpsum contribution of the university. Further, the freedom of individual PIs to shape their own research and portfolio led to success in obtaining personal grants.

Laboratory space is divided based on research sections but is often used in a fluid way. This allows research staff from all groups to share the space and equipment. The open culture and shared purpose are essential in avoiding the idea of lab ownership and protectionism. Between 2014 and 2016, the department has invested in larger research equipment, for instance, the renewal of the SRD and SPM facilities. A M€6 investment in industrial-catalysis infrastructure was received to ensure valorisation, leading to the opening of the Industrial Catalysis Lab to perform experiments under industrial conditions. According to the committee, the laboratory infrastructure is a major asset of the department; in particular, the new catalysis lab is very impressive. The challenge of maintenance of the infrastructure was mentioned as a weakness in the self-evaluation report. ChemE has introduced the system that part of project funding is spent on this, which is a commendable strategy but leads to insufficient funding for maintenance. It is recognised that for technical universities, it is a challenge to get large infrastructure grants (see recommendation D).

The TU Delft core values (DIRECT) are adopted by the ChemE department. Possible cases of scientific misconduct are discussed with PIs and often lead to reflections on underlying causes, like workload. This way, issues around authorships have been clarified.

Open Science

The ChemE department made substantial steps in implementing open science in the evaluation period. First, the wide usage of the 4TU data repository is an excellent concrete example of how mainstream open data is becoming, and the availability of publication associated data is now mandatory within the department. Second, the committee applauds the increase in open access publications to 75%, thereby, doubling the 2015 fraction of open access publications. Third, the open science mindset is implemented already at the bachelor and master level by requiring submission of associated data sets with the final thesis.

The ChemE department's future policy on open science focuses on FAIR data. Past efforts made data findable and accessible but making data interoperable and re-usable remains a substantial challenge. The reuse of data in the chemical engineering field is, more often than not, irrelevant due to specifics in the experimental setup. The committee regards the digital catalysis lab (DCL) as an opportunity seized to become leading in the reuse of data and to make catalyst screening data interoperable and re-usable. The DCL may well be an example to other PIs in the department and perhaps even the international chemical engineering community. Besides FAIR data management, thorough and accessible experiment documentation is essential for reliable and open science. In the 21st century, some digital lab journal solution should be achievable. Therefore, the committee applauds that the primary aim of the ChemE department on the aspect of open science is to find a suitable solution to document ChemE experiments digitally. Finally, the committee appreciates the intensive list of outreach activities performed by ChemE members during the past reporting period. In addition, the appointment of an outreach communication officer sets a clear

direction to promote and support future action to reach and educate a broad audience.

3.6. Relevance to society

Impact on society includes visibility and impact to private individuals and valorisation to small-medium enterprises and industry. ChemE strives for a well-balanced portfolio of personal grants and industrial investments. Historically, recruiting senior hires from the industry was common, ensuring a good understanding of the industrial needs and financial support. This is no longer the case, which is a risk for the valorisation agenda. With some additional focus on this issue, the department hired two PI's from industry in the past five years, which increased the industrial presence. The committee suggests to the department to look for other opportunities to ensure that the PI's understand industrial needs, for instance, through industry traineeships.

A particularly good example of a programme with significant impact is e-Refinery. e-Refinery is an interesting cross faculty initiative, which is integrated to allow developments in materials, processes and scale-up to help the future chemical/energy industry electrify and decarbonize. The ChemE department plays a leading role in this visionary program of significant societal relevance, which is an excellent example of the broader collaboration of the department.

The Intellectual Property (IP) output is comparable to other departments at TU Delft. Most of the recent patents originated from a small group of senior PI's. Therefore, the committee emphasises that these PI's should involve and coach junior PI's to stimulate them to generate IP. During the period of this evaluation, several patents resulted in spin-off companies, demonstrating valorisation of the patents.

A variety of outreach activities, from MOOCs to book publications and videos for Dutch television, has been conducted. However, compared to the number of scientific breakthroughs, the level of outreach activities can be increased. A new communication officer has started to help PIs in the communication of their work to a broader audience. According to the committee, the objectives of the outreach activities are not clearly defined, and the committee advises developing a strategy based on stakeholder research to determine where to focus. The impact of a website and newsletter is limited. More modern tools to interact with stakeholders, including social media, workshops, and demonstrations, will allow ChemE to reach a broader audience. Role models in the department can be deployed to coach more junior PI's who are motivated to increase their visibility. It is important that communication about research is conducted at all stages of the research, not only at the moment of a breakthrough result (see recommendation E).

3.7. Viability

In the self-evaluation report, the ChemE department provided a SWOT analysis. Throughout the report, the committee reflects on the aspects described in this SWOT. The conclusion by the department is that it could and should make much more use of its strengths and opportunities, for example, in mission-driven large programmes in the areas of circularity, renewable energy and health. By taking the lead in larger initiatives, the visibility of the department will increase. The SWOT furthermore led to the reformulation of ChemE's mission to developing "solutions for societal problems, leveraging the broad expertise in chemical engineering, chemistry, physics and materials science. The department harnesses the scientific curiosity to define emerging fundamental questions and educate future leaders in the field of chemical engineering.". The theme of Health was mentioned as a strength for the future in the SWOT. The committee suspects that the convergence with the Erasmus Medical Centre is a driver for this. The committee also considers this theme as an opportunity, provided it is embedded in a larger consortium and does not develop as a stand-

alone, internal activity.

As was mentioned in chapter 2, ChemE introduced the PI-based organisational model. The sections still play a role in the organisational structure, albeit less dominant. PIs are formally still part of a section, but this is predominantly a social and lab-safety connection. The committee favours the introduction of the PI-based system and understands that the department wants an additional structure to ensure social cohesion. It suggests the department to think about whether the sections are the best form for this. Perhaps a more thematic approach would work better.

The ChemE department has moved to a new research and teaching building that is characterised by exquisite experimental infrastructure. The architecture of the building invites comprehensive cooperation within the department and across department borders. This agile environment is the home of a ChemE department in transition from a former, more rigid section model to a flat PI-based model. This so-called flat PI model allows maximum individual freedom on all seniority levels, down to the starting PIs in a tenure track. Nonetheless, the committee observes that the coherence of the PIs within the department is strong. The sections have no financial responsibility but serve as an entity of HR strategy and development. PIs mentioned that they experience the section as a community of shared scientific interest as well as a social anchor point. The observed coherence between PIs is a significant asset for the future viability of the department and a prerequisite to continue the strategic thematical positioning which has recently started.

In the SWOT analysis, the involvement of ChemE in the decision-making process of national and European funding is mentioned as a weakness. However, according to the committee, this might also be considered an opportunity. There are several senior PIs that have positions in decision-making bodies and with impressive international networks. By defining a strategy and applying focus, the department might well be capable of being part of decision-making processes (see recommendation F).

Leading up to this evaluation, the ChemE department went through a period of rejuvenation of the PI team with, as a result, an agile and resilient PI team. In the past, a more classical, disciplinary competence analysis led the recruiting process. However, new hires will be motivated by strengthening research themes and strategic topical choices in the future. These research themes and strategic choices have not been clearly defined yet but fall within the broad domains of circularity, energy and health-related chemical engineering. The strategic positioning and sharpening of the profile need to be achieved as soon as possible. Managing this unique opportunity well will be of utmost importance and requires altruistic leadership. Continuity in departmental leadership has been under pressure due to frequent changes in the HoD position. For the upcoming period, the viability of the future transformation process requires leadership measures that finalise the balancing process between the PI-based and section model and proceed to define strategic thematical focus.

3.8. Recommendations

In the light of the above findings, the committee has the following main recommendations for the ChemE department:

A. Regarding the search and appointment of a new HoD, the faculty and department should consider the option to delegate more executive duties to a formally appointed managing director. In such a model, the tasks and responsibilities associated with the position of HoD can be further shared with other PI's in the department. This might lead to the position of HoD being more attractive to young, talented PI's who want to continue doing research as well.

B. The department should draft a clear strategy towards thematical organization to help maintain its leading position in the next decennia. The committee strongly advises to work out a detailed strategy for the next years. Not only for new hires, but also to determine the thematic pillars for future research. New hires will have to be motivated by strengthening research themes and strategic topical choices in the future.
C. The PI-based organisation is still in development with the sections providing an organisational and social cohesive role. The committee suggests to reconsider the sections and look for another form – like a thematic approach – to support the PI-based organisation.
D. The department has introduced a financial system in which, by way of reserving part of the project funding, the department has some budget to maintain the research infrastructure. This is commendable, but further action is needed to obtain sufficient funding. This might be a faculty- or even university-wide challenge.
E. Although the level of outreach activities already increased, more can be done. It might help to clearly define the objectives of the outreach activities and developing a strategy based on stakeholder research.
F. The department should define a strategy and clear focus, to establish that PIs will have positions in national decision-making bodies and in important international networks.
G. Implement and communicate clear PhD guidelines amongst both PhDs and PIs, including the Biotechnology 'PhD duration policy', as detailed in the self-evaluation report. This includes emphasising the importance of a third-year review meeting in which PhD candidate and supervisor make a realistic planning for the final part of the PhD project.

4. Biotechnology

4.1. Introduction

The research of the Biotechnology (BT) department focuses on industrial biotechnology and environmental biotechnology and integrates application-inspired, fundamental research with design and engineering. The research addresses all relevant levels of organisation in biotechnological processes, from enzymes, cells and cellular networks, to populations, bioprocesses and socio-economic impact.

The BT department houses 29 PIs, of which eight are full professors, and ten are tenure-track assistant professors. In addition, there are four part-time full professors and 22 staff technicians, 100 PhD candidates and 22 post-docs. The BT department has five sections that match the organisational levels of biotechnological systems. An inclusive organisation model is adopted, in which PIs shape their individual research agendas within the shared strategy, and cross-section collaboration is strongly encouraged. Monthly PI meetings include the discussion of strategy and organisation.

4.2. Mission and strategy

The dynamic context in which the department acts, requires continuous evaluation and alignment of the research focus and strategy. Over the evaluation period, the BT department looked at consolidation and strengthening of its position as an internationally leading centre for industrial and environmental biotechnology research. Strategic aims were formulated based on the input of previous evaluation committees and in response to external developments. These aims are divided into three main categories.

The strategy on *personnel* includes recruitment, retainment and development of research staff, facilitation and support of scientific independence, visibility and involvement of PIs, increasing diversity and reduction of the average duration of PhD trajectories. Concerning *research*, the strategy includes 1) the nurturing of a shared attitude to research, combining application and fundamental questions, 2) continuing to build on strengths, 3) further increasing multidisciplinarity, 4) explore related research challenges in areas related to health and nutrition, 5) selection of Industrial Biotechnology and Environmental Biotechnology as spearheads for investments and new PI positions, 6) investing in an ultramodern infrastructure, and 7) to adopt, communicate and abide by scientific integrity policies. The third category, *funding*, includes addressing a structural, growing gap between fixed costs and lump sum funding by TU Delft and encouraging and supporting early-career PIs in the acquisition of personal and collaborative grants.

4.3. HRM

In 2019, the former organisation model was replaced by a 'PI teams' model to improve the visibility and scientific independence of the PIs. The sections were kept as thematic, organisational and social units. Strategic issues are now discussed in monthly PI meetings, and the management team handles running business in biweekly meetings. In addition to the HoD, Department Manager, Financial Controller, project manager and HR advisor, two PIs have a position in the management team. The committee compliments the setting up of the management team, which includes two PI's, rotating at half-year intervals. This increases engagement, awareness and the understanding of internal processes.

Diversity

Of the 29 PIs, nine are female, and 15 have non-Dutch nationalities. The composition of the BT department regarding age and nationality (Dutch vs non-Dutch) is well balanced. In the period under evaluation, the BT

department used opportunities to hire young talent, and after a dedicated effort in 2020, also the percentage of female research staff increased up to 31% of the PIs. There is a clear awareness of the relevance of diversity for the quality of research at the different organisational levels (HoD, PIs and TTs). The department aims at (better) reflecting the composition of the student population and Dutch society. According to the committee, the approach to achieve this is sound: seizing opportunities to increase the percentage of female staff without sacrificing quality. It is, however, important to actively communicate this, both inside and outside the department, to make clear to all involved that the 'diverse staff' meets the quality requirements. Increasing the non-Western population of the staff is an excellent next focus area to achieve the desired composition.

Attention to inclusion is essential to be able to benefit from and retain a diverse staff. The level of inclusion is measured via a TU Delft survey and is at an acceptable level. The department ensures inclusion and diversity when appointing committee members or assigning specific tasks.

Talent management

The committee appreciates the initiative of the department to allocate budget on the topic zero-emission biotechnology. This strategic plan provides the TTs with an incentive (PhD candidate) around a joint theme, which is an excellent way to have a strategy and implement a topic. It pulls the disciplines together and fosters collaboration on developing initiatives and the joint writing of strategic proposals.

Workload

The workload of technical support staff is structurally too high, caused by several trends that led to an increase in their workload. The management team demonstrated awareness of the issue and had regular discussions with the people involved. One of the measures taken is that PIs are urged to include temporary technician positions in their grant applications to manage the workload better. Amongst the PIs, workload did not appear to be a major issue. PI's feel free to discuss workload issues and challenges openly. There is a healthy balance between busy periods and less-busy periods, which allows time to re-charge. (see recommendation D).

4.4. PhD policy and training

Time to PhD

The BT department harbours 100 PhD candidates at the time of the report and graduated 61 PhDs (66%) during the reporting period (enrolment from 2012-2016), while 25 PhDs (22%) still work on their dissertation. The average time-to-dissertation was reduced from 5 years to 4,7 years in the aforementioned period. The primary aim of the BT department for the upcoming reporting period is to reduce the time-to-dissertation to 4 years further. Towards this primary aim, the strategy was intensively discussed with PIs, the Faculty PhD Council, and the Department's PhD Committee. The committee applauds the active inclusion of PhD representation in constructing this PhD duration policy. The efforts resulted in a set of clear and accurate statements that provide expectations to both PhDs and supervisors. In the committee's opinion, the framework for tackling excessively long PhD projects is an example for other departments and perhaps faculties. However, the committee observed that not all PhD candidates were equally or fully aware of the details of the policy.

Additionally, the committee deemed one specific policy particularly important and effective towards the 4-year time-to-dissertation objective, namely the third-year review meeting. This meeting of PhD and PIs involved entails a discussion of the dissertation outline and planning towards graduation. The policy further states that an independent PI should play a key role in this process. However, the committee observed that this final detail is not consistently implemented. The committee's impression is that the well-meant ambition

and enthusiasm of PIs and PhDs might obstruct realistic planning. Therefore, it is recommended to ensure an independent PI's presence at this 3-year mark meeting (see recommendation B). The committee is confident that the current policy, combined with the suggestions above, will provide additional opportunities to relieve the pressure and increase focused efforts towards finishing a dissertation on time.

Faculty Graduate School

The BT department PhD programme has support from the faculty graduate school (FGS). The FGS facilitates soft skill courses for broader development. PhD candidates appreciate this. Additionally, the FGS reminds PhD candidates at specific intervals to plan the remaining time in their project in concordance with the department PhD duration policy. Further, the FGS organises a mentoring programme; PhDs are assigned a mentor from the academic staff, who then functions as the first point of contact whenever a PhD experiences issues. The committee applauds the initiative to have a more active mentor role in the PhD programme where mentors have regular meetings with their mentees.

Career perspective

With their research skills, young PhD graduates of the BT department are attractive to other research institutes. Additionally, the committee values the network PhD candidates build while working at the department. However, the impact of COVID-19 seems to have impaired the feeling of community amongst PhD candidates and staff alike. Recent efforts by the department's management and the department PhD committee to revive the sense of community seem both effective and appreciated by PhDs and the whole department. The committee recommends sustaining these efforts to deliver their PhD graduates to either academia or industry supported by a vast professional network.

4.5. Research quality

In the reporting period, over 1100 papers were (co)authored in peer-reviewed scientific journals. The field-weighted citation impact is 1.6. Over 50% of the papers appeared in the top 10% of journals, and 19% were amongst the top 10% most cited worldwide. Further, 93 PhD candidates successfully defended their theses, and 65 post-docs were employed. In the self-evaluation, it is mentioned that over 70% of publications stem from international collaboration. Also, academic-corporate collaboration is reflected in co-authorship of industrial colleagues on 12% of the publications. The department produced an excellent number of publications (also against the benchmark of the Toulouse Biotechnology Institute). In part, this reflects the increased number of PhD candidates.

According to the committee, the quality of work from the BT department is outstanding, which is well illustrated by the award of many competitive grants between 2015 and 2020, including NWO grants (four VENI, one gravitation and the Stevin prize). Internationally, ERC grants were obtained at every level (one Starting grant, two Consolidator grants and one Advanced grant), as well as other EU grants (MSCA). Given the fundamental nature of ERC grants, this is an excellent signal of the quality in an applied science department.

The committee explicitly commends the high-quality leadership, with an outstanding current HoD. This leadership is reflected at every level in the department, from PIs to PhD candidates, with all taking responsibility. This was particularly clear from the interviews; it is clear to the committee that future leadership of the department is being developed.

The development of younger staff is of great importance for the future research quality of the BT department. The committee noticed that all contribute well to the development of the next generation with excellent grants from the younger staff. The award of PhDs in targeted future research areas such as zero-

emission biotechnology to all tenure-trackers is an excellent way to ensure relevance as well as the quality of the next generation of PIs. All TTs develop suitable projects in discussion with more senior colleagues.

To maintain the present high-quality level, it is essential that suitable support is present; technicians (22 in total) are particularly important. The leadership made clear to the committee that there are some work pressure issues in this respect. Further development of technical support will be of great importance since the vast majority of research is experimental. This could be achieved by more effective use of technicians in laboratory course teaching or alternatively through the addition of extra technicians.

Open Science

The BT department open science strategy focuses on data policy. All recent PhD projects have data management plans implemented, data stewards regularly sit-in during group meetings, two BT employees were appointed a TU Delft "data Champion" for their open science practices. Additionally, the BT department nearly doubled its fraction of open access papers to 83 per cent over the reporting period. Storage and accessibility of data associated with BT publications are well taken care of. Still, future challenges remain for making that data integratable and re-usable due to a lack of standards for some data types. The EnzymeML initiative, of which BT is a part, is an excellent example of an effort towards enabling the interoperability of data uploaded to relevant repositories. The current recruitment of a new PI with a computational/AI profile signifies the department is interested in both making the data more interoperable and researching the emergent properties of many datasets combined.

Societal relevance is a goal of the BT department, most notably via collaborations with private partners such as DSM, Heineken, RIVM and many others. Many of these projects in the department focus on emission reduction, circular economy or wastewater recovery. Such corporate cooperation allows for science to be close to implementation but may interfere with the open science ambition set by TU Delft. Experiments and publication thereof may not follow open science standards, and data may be embargoed for longer times depending on existing agreements with companies. The committee and the BT department agree that raw data behind publications should always be available, and future improvements are needed.

Finally, two honourable mentions on the aspect of open science. First, the section Biotechnology and Society sets a fantastic example of what can be achieved when actively involving the societal perspective in the research environment. This section is also a great demonstration of dividing tasks and expertise; not every PI is equally equipped or enthusiastic about public engagement. Instead, collecting this expertise in a dedicated group makes it a priority of those people involved, rather than another task PIs have to be involved with. Second, open science is about openness to the public and scientific peers. Perhaps a creative interpretation of the latter aspect is open management: the BT department management team has two rotating seats. All BT PIs take place in an alternating fashion, six months each. Via this structure, the department succeeds in including all PIs more actively in decision making and increases the community feeling in the department.

4.6. Relevance to society

Several successful large-scale applications of patented inventions, such as Anammox, Nereda, and bioethanol production and spin-off companies (some still under development), demonstrate the societal relevance of the Biotechnology department. The dedicated advanced courses, organised by the BioTechDelft foundation, are an excellent way to transfer recent academic insights to other scientists, both in academia and industry. The department recognises the relevance of industrial acceptance and implementation and is exceptionally well-connected to the industry.

According to the committee, the work in the BT department is of great societal relevance. This is well-

illustrated by the substantial collaboration with industry, using the results in the implementation of new processes, with added economic value and sustainability. The latter being validated via new process assessments in the section on 'biotechnology and society'. The profile of the BT department is unique, going all the way from discovery and characterisation of enzymes and cells to process evaluation. This ensures the relevance of the more fundamental work. The profile is reflected in the five sections: biocatalysis, industrial microbiology, environmental biotechnology and bioprocesses and society. The section Biotechnology and Society is part of the unique profile of the department. This section ensures that social aspects and public acceptance of the research activities are considered. Outreach receives considerable attention, even at an international level (e.g., in Brazil). PI's and PhD candidates are regularly involved in public communication activities. The section on 'biotechnology and society' is of particular importance to help understand the value of shifting from a petroleum-based economy to a bio-economy and brings a unique profile to the department. The results are being spread in a number of environments such as industry, schools etc. Still, further development of the outreach from the section (e.g. to politicians) is to be further encouraged.

In taking the next steps from bench results to implementation, BT has an excellent track record by utilising the excellent facilities at DSM (Bioprocess Pilot Facility) and also by working with companies (Kaumera and Nereda was given as an example). Products are forthcoming across a range of industries (e.g. the development of Kaumera from the section of 'environmental biotechnology'). This is impressive. It is also clear that senior faculty members are very good at including the TT's in their networks for maintaining this connection to industry into the future. This is pertinent to make sure that the funding percentages from the industry does not dry up after retirements of the current senior PI's. Thus, the younger faculty are being introduced to industry contacts to allow the building of a network for future generations. New research areas have been identified, which run across each of the sections: computational approaches, zero-emission biotechnology, scalable e-biorefinery and e-biocatalysis concepts, as well as cell-based agriculture and health-related applications of biotechnology. These areas reflect both scientific curiosity as well as societal relevance. There are many opportunities here which need to build on the strengths of the department and can provide excellent collaborative opportunities.

The BT Department is very well connected to policy-making bodies in the Netherlands and abroad, and it will be important to ensure younger members of faculty and introduced to these bodies in due course. The development of further links with the ChemE department appears to be an excellent opportunity as the two departments share the same building. For example, opportunities for combining catalysis with bioprocesses (see recommendation C).

In quality of research, the quality control at the analytical instrumentation and methodology is of importance. As an example, within each of the omics techniques, there is a strong need for core strategies for strong collaboration within research labs. The committee has found that within the BT, there is a great willingness to collaborate on the methodology and that cores already exists. A good understanding is present that for quality control, this is of utmost importance. This collaborative nature should be further nurtured.

4.7. Viability

The BT department is blessed with excellent leadership. This will aid not only in keeping the department on track in reaching its current goals but also in delivering on its future vision. The department has hired a large pool of young TT's, which is an exciting, diverse group of new talent. During the interview, the committee met with a coherent, excited, and content group of research staff. Of course, the challenge of the department is to not only attract and hire new talent but also to retain them in order to create a strong pool of mid-career and senior researchers (see recommendation A). The future leadership will have to come from this group of people. The Faculty and BT department are extremely well organised, and many mentoring

programs are already in place. This was applauded by the committee.

Overall, the committee found it hard to identify problems or deficiencies in the department. One of the few issues is the two-body problem (which can also be referred to as a two-body opportunity). Especially for a diverse group of researchers, it is essential to have a strong two-body opportunity program at the university level (between departments and faculties). Without such a program, many talents might leave again, especially the female and international TT's.

The committee emphasises the importance of clear communication towards (new) TT's regarding the collaboration opportunities within institutes. It seems confusing to new research staff what the opportunities are; it was also confusing to the committee.

4.8. Recommendations

In the light of the above findings, the committee has the following main recommendations for the BT department:

A. The committee recommends that the BT department pays special attention to the large pool of TTs. Retention of this pool is vital for the future success of the department.
B. The committee has the impression that part of the long duration of PhD projects is lack of realistic planning. It is recommended to ensure an independent PI's presence at the 3-year mark meeting. Clearly communicate the PhD duration policy to all PhDs involved and consider implementing this as faculty policy.
C. The committee considers further development of links with the ChemE department to be an excellent opportunity.
D. The department should lower the workload of technical support staff. This is structurally too high, caused by several trends. The idea mentioned during the site visit by the BT department urging PI's to include temporary technician positions in their grant applications to manage the workload better, should be implemented.

Appendices

Appendix 1: THE SEP 2021-2027 CRITERIA AND CATEGORIES

The committee was requested to assess the quality of research conducted by the UHS as well as to offer recommendations to improve the quality of research and the strategy of the UHS. 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: Programme of the site visit

Sunday 24 October		
18.30	19.30	Preparatory meeting committee
Monday 25 October		
8.30	9.00	Welcome by Rector, Dean and Heads of Department
9.00	10.00	Chemical Engineering Management interview
10.00	10.15	Break
10.15	11.45	Chemical Engineering PI's
10.45	13.00	Lunch and committee meeting
13.00	14.00	Chemical Engineering Tenure trackers
14.00	14.15	Break
14.15	15.15	Chemical Engineering PhD candidates
15.15	15.30	Break
15.30	16.45	Lab tour
16.45	18.00	Committee meeting
Tuesday 26 October		
9.00	10.00	Biotechnology Management interview
10.00	10.15	Break
10.15	11.45	Biotechnology PI's
10.45	13.00	Lunch and committee meeting
13.00	14.00	Biotechnology Tenure trackers
14.00	14.15	Break
14.15	15.15	Biotechnology PhD candidates
15.15	15.30	Break
15.30	16.45	Lab tour
16.45	18.00	Committee meeting
Wednesday 27 October		
8.30	9.45	Committee meeting and writing of the report
9.45	10.15	Final meeting with Dean and Heads of Department
10.15	10.30	Break
10.30	11.00	Feedback session

Appendix 3: Quantitative data

Table 1: Research staff in FTE

Chemical Engineering

	2015	2016	2017	2018	2019	2020
	FTE	FTE	FTE	FTE	FTE	FTE
Assistant professor	12.6	11.3	9.0	8.4	8.9	9.3
Associate professor	7.0	7.1	9.1	9.2	10.4	8.9
Full professor	12.8	12.9	12.5	10.4	9.8	11.3
Total PIs	**32.4**	**30.3**	**30.6**	**28.0**	**29.1**	**29.5**
Postdoc	25.5	26.4	25.5	30.3	30.7	30.1
PhD candidates	96.3	99.5	98.2	103.4	103.6	102.9
PDEng	34.4	36.9	34.9	37.4	37.7	37.8
Total research staff	**188.6**	**194.1**	**189.2**	**199.1**	**201.1**	**200.3**
Support staff	18.3	19.5	19.6	20.3	19.4	19.4

Biotechnology

	2015	2016	2017	2018	2019	2020
	FTE	FTE	FTE	FTE	FTE	FTE
Assistant professor	12.3	11.9	13.2	13.0	13.0	11.6
Associate professor	3.1	3.7	4.0	5.0	5.7	6.7
Full professor	11.0	9.4	6.6	6.7	6.0	6.9
Total PIs	**26.3**	**25.1**	**23.8**	**24.7**	**24.6**	**25.2**
Postdoc	15.3	15.0	17.6	22.0	21.7	15.9
PhD candidates	98.1	100.9	108.5	113.6	110.0	104.0
Researchers (other)	6.9	6.1	3.0	3.4	2.6	2.4
Total research staff	**146.7**	**147.0**	**152.9**	**163.7**	**158.9**	**147.6**
Support staff	27.3	27.2	26.4	26.4	27.7	25.2

Table 2: funding in k€

Chemical Engineering

	2015	2016	2017	2018	2019	2020
	k€	k€	k€	k€	k€	k€
Direct funding	6.733	6.395	6.676	6.824	6.972	6.664
Research grants	2.256	3.865	2.982	3.202	3.444	3.849
Contract research	5.554	5.699	4.384	7.053	6.182	6.516
Other	28	52	139	88	-3	109
Total funding	**14.571**	**16.011**	**14.181**	**17.167**	**16.595**	**17.137**

Biotechnology

	2015	2016	2017	2018	2019	2020
	k€	k€	k€	k€	k€	k€
Direct funding	6.039	5.908	6.014	6.365	5.848	5.650
Research grants	5.102	1.138	2.262	4.171	5.057	6.302
Contract research	8.103	7.739	5.825	669	3.401	5.033
Other	240	526	342	223	173	121
Total funding	**14.570**	**14.860**	**16.041**	**15.430**	**18.068**	**13.421**