



NHL Stenden University of Applied Science

Research accreditation

Research Unit Technology & Innovation

243A2021.01

Preface

This report contains the results of the evaluation of the quality and the organisation of the Research Unit Technology & Innovation (Research Unit T&I) of the NHL Stenden University of Applied Sciences (NHL Stenden). It is based on the performance and results in the time period 2014 - 2021. The external evaluation committee that has performed this evaluation was commissioned by the Academy Technology & Innovation (Academy T&I) of NHL Stenden in consultation with Netherlands Quality Agency (NQA). NQA has screened the committee members regarding their independency and expertise.

The evaluation committee consisted of:

Mr dr. G.P.F. van Strijdonck, chairman and expert in the domain of material sciences at Zuyd University of Applied Sciences.

Mr . ing H.J.Kiela MBA, committee member, former lector Robotics and expert in the domain of mechatronics and robotics.

Mr prof. dr. ir. W.G.J. van der Meer, committee member and expert in the domain of membrane technology and engineering for water treatment.

Ms ir. M. Dekker and Ms drs. P.R. Molegraaf, auditors NQA, acted as secretary of the committee. See appendix 3 for further information regarding the expertise of committee members.

The research accreditation of the Research Unit T&I is performed in line with the *Sector Protocol for Research Quality Assurance 2016-2022* from The Netherlands Association of Universities of Applied Sciences.

Evaluation performance

In order to prepare the audit visit, the evaluation committee received and studied a documentation set from the Research Unit T & I. This documentation set comprised a self-evaluation report and a representative selection of the (research) products and publications that the research unit has produced (appendix 1). The selection represents the different research lines within the research unit and represents the overall output. The documentation enabled the evaluation committee to form a good first image of the research unit.

Before the actual audit visit the committee members have shared their impressions and addressed the main topics for further questioning during a MS Teams meeting. The actual audit visit was performed on site on July 1st and 2nd, 2021. During this visit additional documentation was studied and the committee had meetings with several stakeholders (see appendix 2). All (oral and written) information have enabled the committee to reach a deliberate judgement.

Structure of this report

This report is set up conform the five standards of the *Sector Protocol for Research Quality Assurance 2016-2022* and it describes the committee's findings, deliberations, conclusions and recommendations.

The characteristics of NHL Stenden and of the Academy and Research Unit T & I are outlined in chapter 1. Chapter 2 addresses the findings and conclusions regarding the five standards of the

protocol. The judgements given are described in chapter 3. Chapter 4 presents the related recommendations.

The committee declares the assessment of Research Unit T&I was carried out independently.

Utrecht, November 3, 2021

Committee chair



dr. G.P.F. van Strijdonck

Committee secretary



ir. M. Dekker-Joziasse

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1. Short outline of NHL Stenden and Research Unit T & I

The Research Unit T & I is part of the NHL Stenden Academy T&I and consists of four professorships: Circular Plastics, Computer Vision & Data Science¹, Sustainable Polymers, Water Technology, and one professorship in formation: Smart Sustainable Manufacturing, and is connected to three centres of expertise.

The professorships formerly resided in three different research units, and were brought together in one research unit of the Academy T&I in 2019. The Research Unit T&I operates within the context of the academy and within the broader context of the NHL Stenden research strategy.

The overall research vision of NHL Stenden is formulated as: ‘Exploring to create a better world: developing knowledge for real-life innovations and supporting our students to develop themselves into skilled, innovative and service oriented professionals’.

Three focus areas are identified for NHL Stenden : Smart Sustainable Industries, Vital Regions and Service Economy. Smart Sustainable Industries is about smart and sustainable production and entrepreneurship. Vital Regions stands for strengthening the development of regions. Service Economy is committed to good service for guests, customers and patients of care hotels. Starting point is that research at NHL Stenden is in line with their Design Based Education (DBE) concept and that the topics into which they do research are closely aligned with the topics that are covered within their programmes.

The Academy T&I is one of the leading academies within NHL Stenden for the focus area Smart Sustainable Industries, and the Research Unit T&I plays an important role in this focus area and the three themes Water, Smart Technology and Circular Economy. The *Water* theme focuses on water technology and maritime issues. *Smart Technology* is focused on the improvement of enabling technologies like robotics, computer vision and data science (Artificial Intelligence). NHL Stenden works with partners to develop integrated and collaborative production systems that respond to changing requirements and conditions in factories (Smart Manufacturing). The *Circular Economy* theme focuses on the transition to a sustainable and circular economy and society.

The Academy T&I has three Centres of Expertise and a Knowledge Centre:

- Centre of Expertise Smart Polymeric Materials GreenPac (in cooperation with University of Applied Sciences Windesheim);
- Centre of Expertise Watertechnology CEW (in cooperation with University of Applied Sciences Van Hall Larenstein);
- Centre of Expertise Smart Manufacturing (in application);
- Knowledge Centre of Computer Vision & Data Science.

Former audit recommendations

The Research Unit T&I consists of professorships that were formerly in a different organizational position in the separate universities NHL and Stenden (before the merger in 2018). The professorships Computer Vision & Data Science and Water technology were part of the research group Smart Industry at NHL Hogeschool. The professorship Circular Plastics belonged to the Research Group Renewable Resources (RGRR) at NHL Hogeschool (location Leeuwarden), and the professorship Sustainable Polymers was a separate group at Stenden University (location

¹ As of October 2020, the two professorships Computer Vision and Data Science have merged to one joint professorship Computer Vision & Data Science.

Emmen). The previous audits and visitations were therefore conducted in the former structures. Relevant recommendations which were elaborated in the new research unit are:

Sustainable Polymers (2014, midterm 2018)

The audit panel recommended developing plans in collaboration with representatives from the professional field and the province in which cooperation between the professional field and university is developed and can be guaranteed.

Circular Plastics (November 2017)

The audit committee recommended to make sure that it is visible and demonstrable how peer review is performed at group level.

ComputerVision, Data Science and Water Technology (November 2017)

The advice was to form a broader research group, also containing other domains, as to be able to further the multidisciplinary approach already initiated.

With regard to quality monitoring, the audit panel suggested to the group to share more the individual quality and good systems for their own research within the professorships.

These recommendations are addressed in the research program of 2019 and include strengthening cooperation within the research unit and between knowledge institutions, companies and the public sector as described in chapter 2. As of 2021, the already present structural group meetings also have a focus on intervision, opportunities for multidisciplinary projects and cooperation on preconditions.

2. Standards

In this chapter the evaluation committee describes the findings, considerations and conclusions on the five standards of the *Sector Protocol for Research Quality Assurance 2016-2022*.

Standard 1

The research unit has a relevant, ambitious and challenging research profile and a research programme with corresponding targets that are substantiated within several indicators.

Research profile and research programme

The profile of the Research Unit T&I is directly related to all three parts of the university's focus area Smart Sustainable Industries. All three aforementioned pillars smart, sustainable and industry apply to the four professorships of the research unit, with an emphasis on sustainable for sustainable polymers, circular plastics and water technology, and an emphasis on smart for computer vision, data science and smart sustainable manufacturing (see figure below).

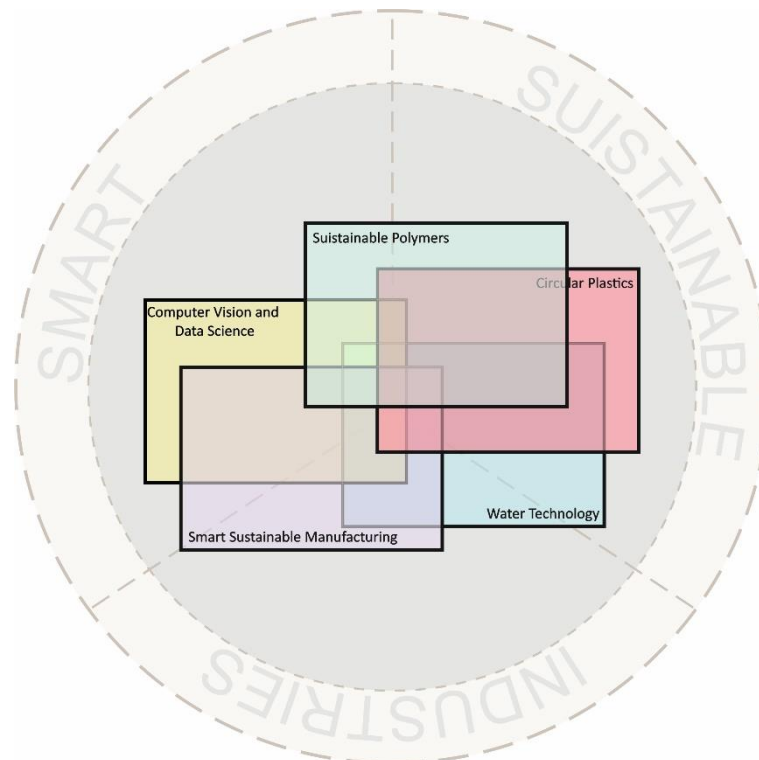


Figure 1.1. Overview of the Research Unit T&I of NHL Stenden and the three pillars of the focus area.

The research unit performs research into:

1. Sustainable polymers – biopolymers, sustainable fibres, 3D printing and biocomposites;
2. Circular plastics - mechanical and chemical recycling and product development of recyclates with a focus on packaging waste;
3. Computer vision and data science technologies including optics, lighting, camera technology, artificial intelligence and embedding in applications, and techniques with a focus on big data analyses in digital imaging using machine learning;

4. Water technology with a focus on physical systems for water and waste water treatment, electrochemical systems and electrohydrodynamic atomization;
5. Smart Sustainable Manufacturing - smart & flexible (production) technologies, alternative learning practices to bridge the gap within the regional job market and waste reduction.

The committee considers the research profile of the Research Unit T&I to be relevant for the professional and the educational field. The expertise areas are well chosen and show clear connection with the region and the regional ecosystem as well as with education. From the documentation as well as from the conversations and discussions during the visit, the committee sees that the research is clearly embedded in the university's focus area Smart Sustainable Industries and DBE concept.

Next to the central themes, a number of *cross-over* research topics both within and outside the research unit are identified. In addition to this, the committee sees many research connections between the unit and other research groups, within and outside the university, such as for example with Van Hall Larenstein, University of Groningen, Windesheim, Wetsus research unit, Naturalis museum and Innovation Cluster Drachten.

The professorships *Sustainable Polymers and Circular Plastics* contribute to regional economic development through knowledge circulation and knowledge development for sustainable plastics and plastic technology in the preliminary phase of (commercial) exploitation by the regional chemical industry.

The professorship *Computer Vision and Data Science* is operating in the joint Knowledge Centre Computer Vision & Data Science. A broad spectrum of domains is covered from industrial automation, precision agriculture and microbiology to intensive livestock farming, minimal invasive surgery and autonomous vehicles. Currently, the main research focus is on Deep Learning (Artificial Intelligence) and Hyper-Spectral Imaging.

The professorship *Water Technology* is an active part of the Water Campus Leeuwarden. Together with many different institutions, it is part of the research consortium, i.e. (Wetsus, Water Alliance, Centre of Expertise Water Technology (CEW), the Centre for Innovative Vakmanschap Water (CIV) and the Water Application Centre (WAC)). The Water Campus supports the existence and further development of this worldwide known Water Technology hub located in Friesland.

The professorship in formation *Smart Sustainable Manufacturing* is part of the Centre of Expertise Smart Sustainable Manufacturing, and intends to be a knowledge hub within the Northern High Tech Systems and Materials community (HTSM).

The key philosophy formulated by the research unit is that its strength lies within the expertise of the individual professorships, that each provide their own unique knowledge, applied research and education within their own network and societal context. And that the added value of the research unit as a whole lies in the cross-over themes between the professorships, as well as in the favourable use of supportive conditions such as the common use of management, educational and administrative facilities.

The committee recognizes this and sees three strong units and one starting professorship that is in a different stage of its development. The committee notices that cooperation within the unit is implemented more organic than strategic. The committee wants to encourage the research unit to further learn from each other and seek for cross-overs, not only where opportunity occurs in the present but also for medium and long term turn added value. The committee challenges the research unit to create a more shared profile for the research unit as a whole, that is based on the

strengths of the professorships and elaborates on the framework for research activities and especially crossovers. The committee finds that NHL Stenden's DBE-vision provides a clear starting point that can help to connect the professorships within the research unit and with the educational programmes (also see standard 4).

Research indicators

The Research Unit T&I exists in this form since 2019, and the current research program is in use since 2020. The different professorships previously resided in different research units, with different goals and targets, together with professorships that are no longer part of the current research unit. 2020 is the first year with shared set goals and targets at Academy T&I level, as described in the annual plan of the Academy T&I. In the year report 2020 the output of the research unit is related to the goals. The most important goals for research for the T&I Academy as formulated in the year report 2020 are:

- Realizing an excellent connection between education and research.
- The T&I Academy aims for top research.
- The research of the Academy T&I makes an important contribution to the focus on Smart Sustainable Industries.
- The research group's collaboration with the three CoEs in general and the Center of Expertise Water Technology in particular will be further intensified in 2020.
- The research of the T&I Academy is closely intertwined with the professional field.

These goals are translated into shared targets that consist of participation of lecturers in research activities, number of lecturer/researchers, participation of students in research activities, publications and valorisation in terms of increase in second and third tier funding.

The committee is positive about the formulated goals and finds them relevant for the research unit and the regional professional domains. However, the indicators for the unit as a whole are currently very generally formulated and focus mainly on output and less on impact. The committee therefore recommends to set up a set of targets (qualitative and quantitative) to guide and monitor the research activities in the fields of the rate of co-production, the connection with education and the research process. These can be described more clearly at academy level with distinction per professorship when necessary. The unit as a whole can profit from working more closely together on formulating KPI's that really have added value for achieving their goals. The committee thinks the research unit can gain from sharing more with each other in the field of targets and steering information.

The research profile - Relevant, challenging and ambitious

The documentation, presentations and discussions during the audit visit show the strong position the research unit has within the academy and with the educational field. Cooperation in the educational field finds place on different levels, ranging from secondary vocational education (mbo) to higher vocational (hbo) and academic education (wo). The committee finds the cooperation with external stakeholders also impressive. The different professorships have strong basis in the research unit and fit well with the strategic focus of NHL Stenden, and within the regional, national and international focus themes and transitions.

Students, lecturers and researchers are collaborating with members of other knowledge institutions as well as with members of industry to share and develop knowledge during research.

In former audit recommendations it was recommended to strengthen cooperation within the research unit and between knowledge institutions, companies and the public sector. The latter is clearly visible from the portfolio and the conversations during the visit. Within the newly formed

research unit the committee sees a clear focus on the connection between research and education and a more organic cooperation in research within the unit with maintained emphasize on the expertise of the individual professorships. The committee sees opportunities here to learn more from each other's experience and increase cross-overs and general cooperation between the professorships.

Conclusion

The committee concludes that the research profile and ambitions are relevant and well aligned with the policy, vision and mission of NHL Stenden University. The unit's profile is highly relevant for the professional partners and for education. Within the unit there are several cross-over themes, such as water-plastics synergy, next to strong professorships, which is in line with the policy of the Academy T&I. Cooperation within the unit is implemented more organic than strategic. The committee sees that the unit is in transition and has some further steps to make. They are confident however that the research unit will be able to reach a more shared profile for the research unit as a whole which is based on the strengths of each professorship and elaborates on the framework for research activities and especially crossovers. Furthermore a stronger synergy can be acquired by learning more from each other's experiences, cooperating in formulating indicators & targets and more long term strategy on cross-overs.

Based on above mentioned considerations the evaluation committee assesses standard 1 as **Satisfactory**.

Standard 2

The way in which the unit is organised, the deployment of people and resources and the internal and external collaborative links, networks and relationships enable the realisation of the research profile.

Organisation

The research unit as a whole is a relatively new construct, formed in 2019 within the Academy Innovation & Technology with a strategy to shape a strong and cohesive education and research palette. It is organized in four professorships, and one professorship in formation. The professors reside directly under the Academy Director. The other employees of the research unit are formally part of one of the education and research teams of the Academy. The organization per professorship is comparable, with one or two professors leading the group, supported in some cases by associate professors. Staff consists of lecturer-researchers, including project engineers, post-docs, PhD students and technical support staff. At the level of the research unit as a whole, consultations take place once every six weeks, in which the Academy Director, all professors and associate professors take part.

The Academy Director is responsible for the quality of education and research. There are two project coordinators who are each connected to certain professorships and are responsible for planning and control. The project coordinators also conduct the process reviews within the research unit with input from the relevant professors.

In the academy there is a close connection between research and education. The professorships, provide the Design Based Research projects and expertise for students to work on in the Multidisciplinary DBE-project (MDP), an academy wide first year atelier. Forces are combined to recruit internships within the region and professorships organize project presentations for the whole academy in which lecturers can get acquainted with the various projects and possibilities to cooperate. Furthermore NHL Stenden's hrm policy is to only recruit lecturers-researchers as to ensure this close connection between research and education.

According to the committee the organisational structure of the research unit is described clearly, with clear outlines of the roles of relevant persons as well as their integration in the management structure. The academy organisation provides a foundation for implementation of research and is supportive in terms of the execution and assurance of the research programmes.

Portfolio

The committee notes that the research unit has a very broad research portfolio in which they integrate multidisciplinary cooperation between various disciplines in teaching and research, in cross-curricular minors and research projects in workshops. According to the committee the research focus and projects clearly fit in the academies mission to link education and research. Several (associate) professors are active within the research unit; they coordinate and conduct the research, which is carried out in collaboration with students and lecturers and researchers. The enabling technologies fit well within the regional professional field. The unit's research is based on a design thinking approach, in which workshops and labs are used as creative innovation accelerators.

The committee sees a beginning of learning communities focussed on learning, working and innovating. This varies among the professorships and can be further enhanced outside of the university in mixed groups of professionals, lecturer-researchers and students.

Deployment of resources

The research resources make it possible to fund the formation envisaged within the multi-annual research program for the research unit and to realize the intended output. The research unit aims for broad collaborations (consortia) with partners from the professional practice and in projects with a multi-annual duration.

The first tier funding for the professorships in the research unit is slightly declining, due to choices at NHL Stenden level. This first tier funding is directly related to the amount of students in an academy and therefore can fluctuate on a year-to-year basis. The funding for the Centres of Expertise strengthens the position of the research unit within the University's focus area, and is stable. The 2nd and 3rd tier funding for 2020, while growing year to year, is below budget, because of the effect Covid-19 had this year. The research unit expects that this, significant, part of the financial base of the research unit will be on budget again in 2021.

The financial figures presented in the Self-evaluation report show that the research unit manages to attract relevant amounts of external funding, which is an indicator of quality. At the same time research has to be in balance with education and the first tier funding that the university receives for education & research. The amount of students in the technical domain is relatively small, as is the first tier research funding for Universities of Applied Sciences. This poses a challenge regarding the growth ambitions, the question of focus and the ability to create sufficient mass in each professorship to have sustainable impact. The overall volume that NHL Stenden can support in technical research remains limited due to the chosen balance in the combination with education and the fact that almost all external funds require up to 50% matching financially. Given these limitations, it is sometimes difficult to meet the needs and demands of the professional field to an extent which is satisfactory for all parties involved.

On a positive note, the committee is impressed by the ways the research unit and professorships are able to find creative ways and possibilities for deploying people and means. Through collaborations with one of the Centres of Expertise, within the academy or via external cooperation.

Deployment of staff qualitatively and quantitatively

The committee has met with an enthusiastic and committed team of (associate) professors, lecturer-researchers and (PHD) students. The combined capacity of the professorships within the unit in 2021 is 29,24 fte. This is divided among the professorships with 6,8 fte Circular Plastics, 8,2 fte Sustainable Polymers, 6,84 fte Computer Vision & Data Science, 5,1 fte Water Technology and 2,3 fte Smart Sustainable Manufacturing.

In 2020 10% of NHL Stenden's staff has a PHD degree. To secure the research quality, the aim is to ensure that 15% of the employees within the university have a PhD in 2024. The unit strives for a substantial appointment for lecturer-researchers to be able to do research and connect this with education. According to the professors the committee has spoken with, the DBE concept within NHL Stenden supports this, just as the recent hr policy to recruit only lecturer-researchers.

The committee sees a strong collegial and developmental orientation in the deployment of people to enable the research profile. Workload planning and allocation of research seem to happen organically and in a flexible and supportive culture. According to the committee the unit not only manages to attract substantial funding, it is also able to seek for creative ways and opportunities to hire well-equipped and skilled staff as well within its own academy as from other educational institutions such as the Instituto Federal de Ceará in Brazil.

Collaboration links, networks and relationships

According to the committee the research unit has an extensive collaboration with both internal and external partners. The external network contains a broad variety of public and private partners, both in education as in the professional field. This places the unit firmly within the triangle research-education-industry.

The work of the research unit is anchored in industry and society in the Northern Netherlands and has strong national links and an extensive international network. There are numerous partnerships with smaller and larger organizations as with other knowledge institutes such as Avans, Saxion, HAS, VHL, Hanze Hogeschool, Fontys Hogeschool and research institutes as RUG, WUR, UT Twente, Vrije Universiteit, JADS, Naturalis, NLR and Field Lab Space 53. Furthermore the Research Unit T&I has a growing international network with public and private partnerships as with IPCA University Portugal on development of a Circular Design program, a structural cooperation with Hochschule Osnabrück and Brazilian institutes in the field of polymers, collaboration with Google Learning Institute for data science and, in the field of water technology, a collaboration with different public partners in Brazil (FUNCEME).

Internal partners consist of lecturers, students and managers within NHL Stenden and the Academy T&I. There is a close connection with the Centres of Expertise GreenPac and Water Technology who enable flexibility and stability in ways of funding and employing projects.

The committee considers the internal and external collaborative links, networks and relationships an area of excellence and noteworthy praise. The academy develops highly relevant and intensive networks of relationships with both the professional as the research and educational field. They also succeed well in embedding students into research project processes. These collaborations create opportunities for greater levels of impact of research and have led to successful externally funded research projects such as the now active RAAK projects The BEAST, Focus op Vision, MARS4Earth and a project analysing the recirculation of water in the Brazilian pulp industry together with HZ University of Applied Science, UFV (Brazilian University) and Berghof (Dutch Company). Winning the RAAK Award 2016 with the project Smart Vision for Unmanned Aerial Vehicles is also a good indicator for impact (also see standard 4).

Conclusion

The organization and the deployment of resources are impressive, with steady high levels of external funding and a flexible organization in deployment of staff on research and education. The committee is particularly impressed with the close connection between research and education as is shown by the many collaborations inside as well as outside the Academy T&I. The research unit seems very effective in utilizing the strengths of the various organizational units and the talents of the staff. Networks and collaborations are a core strength of the academy.

The committee emphasises that collaboration can further improve impact by means of cross-over projects and is not a goal as such. The committee challenges the research unit and the academy to discover if a more structural setting can be provided for cooperation within the academy when the goals and targets (standard 1) are more clearly defined for a multi-annual approach.

Based on above mentioned considerations the evaluation committee assesses standard 2 as **good**.

Standard 3

The research and the research unit fulfil the standards that apply within the discipline, with respect to conducting research.

Explicit research standards

Along with the Design Based Education (DBE) concept, NHL Stenden also developed the Design Based Research (DBR) concept. The research unit's approach to DBR combines several aspects from Waterfall and SCRUM in an integrated fashion. Within NHL Stenden there is budget available for introducing the DBE concept which the academy has also appointed to the research unit. The aim is thus to create a learning environment where research and education are naturally integrated. From the critical reflection and the audit visit, the committee sees research that is methodologically sound, strongly connected to education, conducted within networks and diverse in terms of the type of research, way of publication and types of output. The output matches with the specific applied science domains.

To evaluate the quality of its applied research, the research unit applies the criteria system as proposed by the advisory committee Pijlman in 2017. This system consists of three pillars, that state that the applied research needs to be 1) practically relevant 2) methodologically grounded and 3) ethically responsible. These criteria are applicable to different elements of the research process which the research unit utilizes to assess the quality of its research.

An associate professor from the research unit is member of the NHL Stenden wide ethical advisory committee, which was created along the 'Gedragcode Wetenschappelijke Integriteit', and forms the linking pin to the research unit on this topic.

In the regular meetings of the professorships within the research unit, ongoing research projects and project proposals for new research are discussed. The ongoing research is also discussed frequently at the level of the project groups.

Furthermore the research unit often works with externally (second tier) funded research projects from, for example, SiA, Interreg, or other international grant programs. The fact that the research unit has long been successful in acquiring such extensive and prestigious projects indicates that the quality of the research process is also evaluated positively by external agencies and partners. Within the context of such subsidized research projects, in which consortia of companies and knowledge institutions are involved, the professors also contribute to knowledge development and dissemination concerning both their respective fields of work in particular and design based research in general.

From the audit visit the committee gets the impression of an open and honest atmosphere with clear communication towards stakeholders and students. The systems for monitoring research excellence in ethics and integrity are present and researchers seem to be aware of the code of conduct. The committee has the impression that this awareness can be made more explicit and shared within the unit. The committee therefore encourages the research unit to further develop the integrity and ethics system by formulating more explicit standards and by sharing them more structured within the unit as a whole on every level. By creating simple forms, checklists and templates the unit will help staff with research ethics and procedures.

Research quality

The educational concept DBE is one of the most important characteristics of NHL Stenden. Key elements of this educational concept are Design Thinking and the multidisciplinary collaboration between students, teachers, researchers, organisations and companies on real-life issues. DBR is operationalized in different ways, depending on the type of project, and on the context to which it is applied. The research follows the phases: empathize, define, ideate, concept, prototype, test, evaluate and implement in a required number of iteration loops, depending on the specific case. Typical design tools are mixed with research tools in all phases of the process.

As of 2021 the research unit has installed a system of peer review and intervision within the consultations between Academy Director, professors and associate professors, in which the quality of its research is assessed and reported. The research group discusses research quality from different perspectives, and by doing so contributes to professionalisation at the level of the individual professorships.

From the meeting with stakeholders, it became clear to the committee that the evaluation phase is not limited to a questionnaire. There is regular formal and informal contact with partners throughout the projects to steer and adapt if necessary. Stakeholders appreciate the close contact with the academy and research unit.

The committee judges the quality of the research products as very good. The research unit really has a strong position within the region with its applied science, which is a valuable addition to the more fundamental research of university network partners such as The University of Groningen. The committee is of the opinion that the working methods, project design and execution are regularly evaluated. However, the committee thinks this process can be made more explicit and professionalized by further alignment of the different professorships to the same 'process' level for the unit as a whole.

Although the committee met with an enthusiastic team of lecturer-researchers and students and enjoyed the conversations and discussions, it would have also appreciated it if learning points were more explicitly discussed by the participants, both in the critical reflection and in the interviews.

Research facilitation

The research unit has extensive facilities and works in different ateliers and case study projects. These ateliers are basically structured using ongoing projects with companies and other network partners such as Wetsus for watertechnology. The polymer engineering lab in Emmen is a high-tech environment where plastics can be processed, from polymer granulate to product prototypes. Living Labs for Circular Plastics are physical places where research and demonstration of plastic reuse takes place through material testing, sorting, separation, washing and purification, and prototyping for new products. In addition to technical and design facilities, the Living Labs also have community spaces, presentation and workshop spaces and workplaces for student groups, start-ups, consultancies and other stakeholders.

The professorship Computer Vision & Data Science works with its staff and students in the Knowledge Center Computer Vision & Data Science. Since 1996 more than 300 applied research projects have been initiated and completed. This Knowledge Center has one of the broadest collections of industrial cameras, optics and lighting equipment in the Netherlands. Furthermore, they have super-computer facilities dedicated to deep learning.

Conclusion

The committee found the quality of research to be very good. Each professorship has state-of-the-art research for its own field. There is evidence of varied research output across the range of academic and applied knowledge, with impact for society and industry.

The committee encountered sound research standards although this might be the result of frequent interaction between all players involved in a project rather than adhering to the standards set. Point of attention is that many aspects are rather implicit than explicit, and knowledge sharing and accumulation at research unit level does not yet function optimal. By introducing a more systematic approach with research standards made more explicit, the latter can be achieved and research can gain in relevance even more.

Based on above mentioned considerations the evaluation committee assesses standard 3 as **Good**.

Standard 4

The research unit realises sufficient relevance with respect to:

- 1. professional practice and society;*
- 2. education and training;*
- 3. the knowledge development within the research domain.*

The research has a sufficient degree of impact on the aforementioned sectors

In general

As the Research Unit T&I only exists in this form since 2019, and the current research program is in use since 2020 there is no coherent overview of the output of the research unit as a whole for the whole period of six years. It is possible to look at the more recent past for the unit as a whole. In the year reports of the Academy T&I the output of the research unit is related to the goals set in the annual plans of the Academy, starting with 2020.

Looking at 2020 the research unit meets the formulated targets. More lecturer-researchers and much more students than predicted are involved in the research of the unit. This is due to the strategy of the Academy T&I to strengthen the connection between education and research in which the research unit plays a significant role. The only aspect in 2020 that was below target is the amount of second and third tier funding. This is directly related to Covid-19 crisis and the restrictive measures in place since march 2020. For the bigger part of spring and summer no research in the labs was possible, resulting in delays in research projects. As of September 2020 research and education activities are resumed, though on a smaller scale.

The committee sees a clear impact of the research exerted, however as stated in Standard 1, the committee advises the research unit to recalibrate its output and impact targets into more qualitative and internally effective criteria.

The vision on research fits well with a university of applied science: to contribute to the academy's education and to innovation in the professional practice and society. The cooperation and involvement of students and industry in research project forms a good basis. This suits with the character of the educational programmes that aim mostly at research and development positions. During the site visit impressive examples were given of students being involved in research projects with industry partners. Also, stakeholders and industry are actively involved in the set-up and design of the research (co-creation).

In the paragraph below, the relevance of the research and its connections to the research domain, education and professional practice is elaborated upon. However, the committee commends the research unit on the impressive and natural way it integrates these aspects in its daily functioning.

Knowledge development within the research domain

The Research Unit T&I focuses strongly on applied research for and with its industry partners. Nevertheless, knowledge exchange is performed through collaborative projects with other academic institutes. Such institutes include Universities of Applied Sciences (Avans, Saxion, HAS, VHL, Hanze Hogeschool, Fontys Hogeschool, Hogeschool Utrecht), Universities (RUG, WUR, UT Twente, Vrije Universiteit) and research institutes. Researchers publish occasionally in peer-reviewed journal articles and regularly contribute to conferences.

The committee is positive about the (inter)national connections that the research unit has with academic universities. Although the unit is not primarily focussing on academic research, this shows that the quality of the research is up to par with international academic standards.

Without wanting to be complete some examples are given for the different expertise areas and professorships:

Professorship Computer Vision & Data Science

Over 350 applied research projects have been performed since 1996. The professorship Computer Vision & Data Science is recognized as a national center of excellence for pattern recognition and image analysis. There is an ongoing collaboration between NHL Stenden and the Saxion professorships of Ambient Intelligence and Mechatronics. At this moment, there are three active RAAK projects.

Professorships Sustainable Polymers and Circular Plastics

Knowledge is developed together with other knowledge institutions such as BERNN (Biobased Economy Northern Netherlands), WCCS (World Class Composite Solutions), Universities in Brazil (IFCE, UFPI, Living Lab Brazil) and the Centre of Expertise GreenPAC, in which research projects are carried out together with Windesheim in the field of composites and 3D printing.

Professorship Water Technology

In the last six years the group has published 11 papers in peer reviewed journals, has presented 30 posters in scientific conferences, has generated two patents and has supported the production of 33 graduation theses, being 16 MSc theses, 13 BSc theses and 4 PhD theses. The professorship has created the Gilbert-Armstrong laboratory which led to the participation of the group in big consortia together with other important academic partners in the Netherlands (WUR, UvA and Leiden University).

The professional practice and society

The research unit is actively collaborating with industry on applied research outputs. Projects are usually the result of a long term established national and international network in which the professorships are active. The results of this research lead to a variety of output which is illustrated more extensively below.

Professorship Computer Vision & Data Science

A nationwide network in the field of Computer Vision and Data Science is realized by actively participating in initiatives such as the Cluster Computer Vision Noord Nederland (CCVNN) or Dutch AI Coalition (Nederlandse AI Coalitie) and also by collaborating in regional initiatives such as the Innovatiecluster Drachten (ICD) and DroneHub Groningen Airport Eelde.

An example of a project where the professorships had a key role by using Artificial Intelligence is LapVas where the professorship developed, together with LIMIS Development B.V. and the Medical Center Leeuwarden, a software prototype that gives real time advice to the doctor during surgery. A publication of this study was published in a leading biomedical journal.

Professorships Sustainable Polymers and Circular Plastics

The vast majority of research projects are carried out together with the work field, as part of grant projects such as SNN, Interreg, ERDF, RAAK, but sometimes also with companies that want to gain knowledge from the research groups. An example is the project Closing the Loops in which the professorships, together with the companies Omrin, Philips, Lankhorst, Morssinkhof and Cumapol, have achieved a breakthrough in the recycling of PP (polypropylene). This material can

now be used in high-quality applications. Thanks to the insights gained in this project, a National Testing Centre for Circular Plastics (NTCP) is set up in Heerenveen.

Cross overs

Together with colleagues from the professorship Circular Plastics, the professorship Computer Vision & Data Science started a long-term research program in 2017 to classify plastics using Hyper Spectral Cameras and Deep Learning methods. The collaboration has led to an Artificial Intelligence train and test environment for plastics.

Professorship Water Technology

The professorship Water Technology has worked with more than 30 different companies and 24 knowledge institutes in 50 different projects in the last 6 years. There are a number of companies which are involved yearly with the group for more than 5 years, e.g. Paques, Gasunie, Wetterskip Fryslân and Hapss. The cooperation with the companies has not only provided knowledge implementation, but it is also an important source of budget.

An example of a versatile partnership project is WatMin, a SIA project with five different partners, namely a Brazilian university (UFV), a Dutch enterprise (Berghof), a Brazilian industry partner (CENIBRA), a Brazilian research centre (SENAI) and a Dutch University of Applied Science (HZ). The main objective is to improve water recirculation, decreasing thus the total water consumption.

The documents the committee reviewed as well as the interviews show that the research has an outstanding impact on practice and society. The research unit has a great network and is recognised for its expertise and its capability to transfer and disseminate knowledge for the benefit of external partners.

Education and professional training

Both research and education are an integral part of the activities of the Academy T&I.

The research unit is part of the development process of DBE within the Academy and specifically contributes to the Multidisciplinary Project for first-year students, with both project topics and coaching/teaching. There are several minors offered to students within and outside the university, and two master programmes have been developed: a master Computer Vision & Data Science and the master's program in Polymer Engineering, together with Windesheim. For the years to come attention will go to focussing the minor portfolio of the academy on the research lines of the unit, and on stimulating students to do an internship or graduation project at one of the professorships.

The committee identifies a strong intertwinement of research and research projects into the curricula, some examples of which are given below.

Professorship Computer Vision & Data Science

The professorship Computer Vision & Data Science offers a minor, (graduation) internships and is developing a professional master Computer Vision & Data Science. Within the professorship, the master-apprentice principle is applied. A lecturer-researcher at the professorship (master) is responsible for the intensive supervision of the student (apprentice). The master plays the role of both mentor/coach and content expert.

Professorships Sustainable Polymers and Circular Plastics

There is a minor Sustainable Polymers and the minor Circular Plastics has first started in February 2020. The professorships are closely involved in three other minors, namely Composite

Design Solutions, Circular Start Up and Bionics. With the University of Groningen, the Department of Macromolecular Chemistry and New Polymeric Materials, joint projects are performed, students are exchanged and PhD students are supervised. It is expected that the cooperation with the University of Groningen will lead to the University of the North, in which more joint PhD projects are proposed and a knowledge campus in Emmen will be established.

Professorship Water Technology

The water technology professorship works closely with the Life Science and Technology group, especially with the courses Chemical Technology (CT), Biotechnology (BT) and Chemistry (C). The professorship has an active role in the Advanced Water Technology module and different minors. In the Gilbert-Armstrong Laboratory, students work together with PhD and Post-docs from Wetsus and have the opportunity to participate in high level research projects with companies and other academic partners inside and outside the Netherlands. The projects combine the work of MBO, HBO, Masters, PhDs and Post-Docs.

Conclusion

The committee is impressed with the output and with the level of impact the research unit achieves. The panel sees a strong focus on applied research with good links to knowledge development and education and training. The added value is clear and very much appreciated by external stakeholders. The research unit has deeply embedded long-lasting relationships with a broad range of stakeholders, within the academic, educational as well as professional field. This is a good basis for even more innovative projects and research in which even more cross overs are established to further impact for the different domains.

Based on above mentioned considerations the evaluation committee assesses standard 4 as **good**.

Standard 5

The research unit conducts regular and systematic evaluations of the research processes and results. The research unit then, where necessary, connects the results to improvements.

Quality assurance system

The research unit follows the NHL Stenden quality vision for research as described in their paper *Systeem van Kwaliteit* (2019). In the annual plan of the academy, the research unit and the director discuss their plans for the coming year based on their long-term research program and in relation to the university of applied sciences policy. The annual plan includes indicators from the long-term research program. The research unit provides input for the reporting moments during the year.

At the level of the research unit as a whole, consultations take place once every six weeks, in which the Academy Director, all professors and associate professors are present. Within every professorship the professors and lecturer-researchers meet every two weeks. The quality of the research processes and results itself are monitored during regular evaluations that take place as part of the research projects. These evaluations are a mandatory part of the subsidy terms and conditions, and most research projects are part of subsidized projects (i.e. RAAK, NWO, Erasmus, Interreg, EFRO). Furthermore the research unit requests feedback from both students and external partners during the course of the research projects.

Peer review and intervision

In the case of new projects, peer review takes place prior to the submission of project proposals, in which a researcher from another cluster within the research unit or from another research unit also evaluates the research proposal. In the case of publications, the research group makes standard use of peer review. Researchers read each other's draft publications and provide feedback. The research unit uses an assessment procedure based on the quality criteria of the Pijlman Committee for this purpose. The research group also makes use of intervision which is part of the research group meetings.

Conclusion

From the interviews and documentation, the committee concludes that there is a system in place for evaluating and monitoring the successes in relation to the performance. The committee is positive about the fact that the professorships seem to evaluate their work regularly with partners but did not get a good insight in how this is done structurally and how this is shared in the research unit as a whole. As is stated at standard 3, the committee feels that formalizing the quality criteria and introduction of applicable KPI's for the unit as a whole will ensure high quality and an even more targeted approach to research activities and impact. By sharing evaluations and tools with each other, the system of evaluating and planning will be lifted up and become transparent to all staff. This will benefit the set-up of annual and longer-term academy plans and strategy.

Based on above mentioned considerations the evaluation committee assesses standard 5 as **satisfactory**.

3. Conclusive judgements

Assessments on the standards

The evaluation committee comes to the following judgements with regard to the standards.

Standard	Assessment
<i>Standard 1 Research profile and research programme</i>	Satisfactory
<i>Standard 2 Preconditions</i>	Good
<i>Standard 3 (Methodical) quality of the research</i>	Good
<i>Standard 4 Results and impact</i>	Good
<i>Standard 5 Quality assurance</i>	Satisfactory

The committee met with a dedicated team of (associate) professors, researchers/lecturers and students. Communication lines are short and research is well embedded and integrated within the Academy T&I, NHL Stenden and the professional practice. The committee is convinced that the staff has the quality and experience to proceed their high impact research. The intertwinement and integration of research within the academy's education is a natural situation and stimulated even more through the widely supported DBE concept.

The committee is impressed by the extensive network of the research unit, both in academia, society and industry. For further improvement, the committee points out the alignment of strategy between the professorships. To identify its successes even better, the research unit can be more clear about the KPI's and thresholds it uses to define the desired quality.

The judgements are weighed with regard to the five standards and the assessment guidelines as described in the *Sector Protocol for Research Quality Assurance 2016-2022*. Standard 2, 3 and 4 are assessed with the judgement good. Standard 1 and 5 are assessed with the judgement satisfactory. Overall the evaluation committee assesses the quality of the Research Unit Technology & Innovation from NHL Stenden University of Applied Sciences as **good**.

4. Recommendations

The evaluation committee has the following recommendations for the Research Unit T&I:

Standard 1 and 5

- The committee recommends the research unit to share experiences and best practices in a structural way within the unit as a whole to ensure that all professorships reach comparable levels of impact. The committee encourages the research unit to further learn from each other and seek for cross-overs, not only where opportunity occurs in the present but also for more structural medium and long term added value.
- The committee recommends the research unit to redevelop the system of monitoring quality and impact of the research, in which impact is much more based on the rate of co-production, common learning and the process. The committee thinks that formalizing the quality criteria and the introduction of applicable KPI's for the unit as a whole will ensure high quality and an even more targeted approach to research activities and impact. Furthermore, by sharing evaluations and evaluation tools with each other, the system of evaluating and planning will be lifted up and become transparent to all staff. This will benefit the set-up of annual and longer-term academy plans and strategy.

Standard 3

- The committee encourages the research unit to further develop the integrity and ethics system by formulating standards more explicit and sharing them more structured within the unit as a whole. By creating simple forms, checklists and templates the unit will help staff with research ethics and procedures.
- The committee thinks the system for quality assurance can be made more explicit and professionalized by further alignment of the different professorships to the same 'process' level. By introducing a more systematic approach with research standards made more explicit, the latter can be achieved and research can gain in relevance even more.

5. Appendices

Appendix 1 Documents examined

The evaluation committee had access to the following documents:

General

- Zelfevaluatie rapport Research Unit T&I
- Research Program Technology & Innovation
- Programma Visitatie 1 & 2 juli 2021
- Organisatievorm NHL Stenden
- Leeswijzer documentatie visitatie Research unit T&I

Documents referenced in the Critical Reflection Report

Onderzoeksvisie NHL Hogeschool 2015

Strategisch Plan NHL 2016-2018

Strategic Institutional Plan 2019-2024

Strategisch Onderzoeksbeleid NHL Stenden 2019-2024

Notitie Zwaartepuntenbeleid NHL Stenden 2019-2024

Inrichtingsplan Technology Innovation

Lectorale inauguratie rede

Onderzoeksplannen voormalige onderzoeksgroepen

Personeelsgegevens medewerkers Computer Vision & Data Science, Duurzame Kunststoffen en Circular Plastics en Water Technology

Overzicht geldstromen 2019-2021

Beschrijvingen samenwerking en netwerk per lectoraatsgroep

Overzichten en exemplarische voorbeelden van projecten en publicaties per lectoraatsgroep

Voorbeelden van impact en output naar beroepspraktijk, onderwijs en kennisontwikkeling voor de drie lectoraatsgroepen.

Overzicht verbinding lectoraten met opleidingen, minoren

Advies Werkgroep Kwaliteit van Praktijkgericht Onderzoek

Brancheprotocol Kwaliteitszorg Onderzoek

Kader Kwaliteit Onderzoek NHL

Nederlandse gedragscode wetenschappelijke integriteit

NHL Stenden Systeem van Kwaliteit

NHL Stenden Systematisch borgen en verbeteren

Feedback en tevredenheidsmetingen voor de drie lectoraatgroepen

Jaarplannen 2019, 2020 en 2021 Technology & Innovation

Jaarrapportages 2018, 2019, 2021 Academie T&I

Jaarverslagen Lectoraat DK 2013-2016

Onderzoeksjaarrapport 2016 NHL Renewable Resources

Onderzoeksjaarrapport 2016 Smart Industry

Agenda's en verslagen lectorenoverleg en Intervisie lectorenoverleg

Rapporten vorige en tussentijdse evaluaties per lectoraatsgroep

Via totaaloverzichten van de output en de gepresenteerde projecten bij de standaarden 3 en 4 heeft het panel goed beeld gekregen van de soorten output en de onderzoekskwaliteit van de output.

Appendix 2 Programme for the site visit

Donderdag 1 juli 2021 - Emmen

Tijd	Wat	Waar	Ruimte nr.
12.55 – 13.00	Ontvangst en welkom panel	Emmen	Hal entree
13.00 – 14.00	Voorbespreking panel (incl lunch)		Auditorium
14.00 – 15.00	Algemene introductie en gesprek lectoren en associate lectoren – profiel, standaard 1 en groep, standaard 2		
15.00 – 15.15	Pauze		
15.15 – 17.00	Presentatie en gesprek projecten/onderzoekslijnen Duurzame Kunststoffen / Circular Plastics 60 min. Rondleiding lab, incl. presentatie projecten, incl. studenten, docentonderzoekers. Aansluitend 45 min. Gesprek met lectoren, (docent)onderzoekers – standaard 4		Kunststoflab Auditorium

Vrijdag 2 juli 2021 - Leeuwarden

Tijd	Wat	Waar	Ruimte nr.
8.00 – 8.30	Opstart panel	Leeuwarden, Rengerslaan 10	B1029/32
8.30 – 10.00	Presentatie en gesprek projecten/onderzoekslijnen Computer Vision & Data Science. 45 min. Rondleiding lab, incl. presentatie projecten, incl. studenten, docentonderzoekers. Aansluitend 45 min. Gesprek met lector, (docent)onderzoekers. – standaard 4		CVDS lab B1029/32
10.00 – 10.15	Pauze		B1029/32
10.15 – 11.00	Gesprek werkveld/beroepspraktijk		
11.00 – 11.15	Pauze		
11.15 – 12.00	Gesprek lectoren – onderzoekskwaliteit, standaard 3 en 5		
12.00 – 13.30	Lunch + reistijd		B1016
13.30 – 15.00	Presentatie en gesprek projecten/onderzoekslijnen Watertechnologie. 45 min. Rondleiding lab, incl. presentatie projecten, incl. studenten, docentonderzoekers. Aansluitend 45 min. Gesprek met lector, (docent)onderzoekers. – standaard 4	Agora Leeuwarden	Ontvangst hal Watertech lab B1.09
15.00 – 15.15	Pauze en overleg panel		
15.15 – 15.45	Gesprek directie / management		
15.45 – 16.30	Overleg panel en voorbereiden feedback		
16.30 – 17.00	Plenaire terugkoppeling		B1.09 (en deels online via teams)

Appendix 3 Expertise committee members and secretary

Mr dr. G.P.F. van Strijdonck, committee chair, lector/professor Material Sciences Zuyd University of Applied Sciences, CHILL (Chemelot Innovation and Learning Labs), the Netherlands.
Mr ing. H.J. Kiela MBA, researcher and developer at Opteq Mechatronics BV, the Netherlands.
Mr prof. dr. ir. W.G.J. van der Meer, Professor Membrane Technology and Engineering for Water Treatment University of Twente and CEO Oasen NV Gouda, the Netherlands.
Mrs ir M. Dekker-Joziasse and mrs drs. P.R. Molegraaf, auditors NQA.