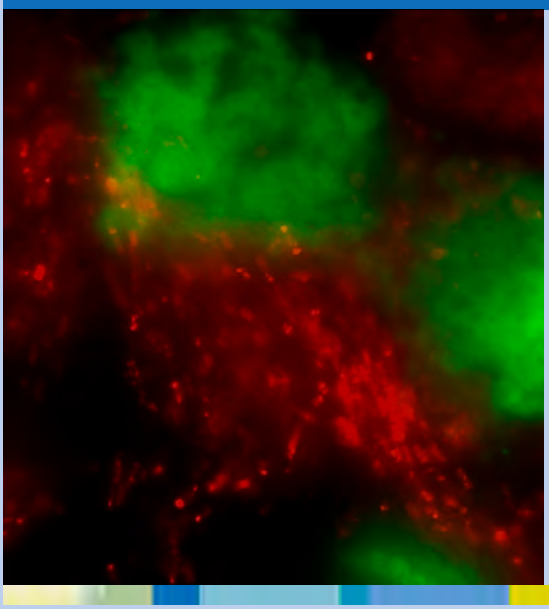

# Scientific Audit Report

wetsus
european centre of **excellence**
for sustainable **water technology**

2023

## Self-Assessment 2017-2022

**combining scientific excellence with commercial relevance**

# Preface

With pleasure and pride we present the 2023 Wetsus Scientific Audit report and the self-assessment report we prepared for the audit.

The scientific audit has been performed by a diverse and international committee of five respected scientists from the field that reflects the wide span of enabling water technology. Wetsus has this type of peer review assessment performed every six years, as a tool to independently measure the scientific quality, relevance, impact and viability of our program and its outcomes. The 2023 audit covers the 2017-2022 period.

The assessment is performed according to the Dutch SEP protocol for scientific evaluations. This protocol has evolved towards a forward-looking formative evaluation of a research unit in light of its own aims and strategy, including the sufficiency or appropriateness of the aims and strategy.

The judgment of the committee is based on a site visit to Wetsus in May 2023 and on the self-assessment report drafted by Wetsus. During the site visit, the committee not only spoke to Wetsus staff members and PhD students, but also to numerous representatives of companies and universities connected to the Wetsus research program.

We are proud on the outcome of the 2023 evaluation that is presented in the audit report. In short, Wetsus is again assessed to perform excellently. To quote the committee:

> *"Overall, Wetsus is a highly successful, well-established and extremely valuable institute with a unique innovation environment that enables world-class research-to-practice collaborations between academic and commercial partners."*
>
> *"Overall, the peer review committee finds the quality of research in Wetsus excellent."*
>
> *"The 'Wetsus model' clearly offers an effective pathway from leading research work to practical applications with significant economic and societal impact, that is one of the most effective academic-industry collaboration environments that the peer review committee has seen."*
>
> *"The panel concludes that the future of Wetsus is sound and very promising."*

The full findings of the committee can be read in the audit report. The audit report also contains recommendations. We will use these in our mission to continuously improve the quality and impact of our organization, program and network and to foster the Wetsus values.

The very positive outcome of the audit is the result of an inspiring team effort of the Wetsus staff in close cooperation with the companies and know-how institutes connected to Wetsus. We sincerely thank everyone who has contributed to this; the scientists and technologists from our partners, the Wetsus scientific and organizational staff and our excellent PhD and MSc students. Thank you for creating excellence in innovation!

**Prof.dr.ir. Cees Buisman & Johannes Boonstra**
Wetsus Executive Board

technopolis group

*July 2023*

# Assessment of Wetsus 2017-2022

**Final report**

Version 4.0

*July 2023*

# Assessment of Wetsus 2017-2022

## Final report

Report assessment committee

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# Foreword

The Wetsus peer review committee is grateful to the Wetsus staff, students, professors and industry partners for their full cooperation and their engaged participation during the site visit. The Wetsus community was consistently open and transparent – and this was very much appreciated by the committee. Wetsus' self-assessment report gave a good overview on the current and past activities, aims and strategies. Overall, the meetings with staff and PhD students added depth and nuance to the committee's understanding of Wetsus, its achievements and its plans for the future. The separate discussions with academics and industry partners who are actively involved in Wetsus projects also provided some very valuable and convincing information on how the "Wetsus model" was working for them and why they were participating in these projects. We would like to thank all of these groups again for their valuable insights and honest contributions.

The committee is confident that Wetsus will benefit from the assessment, comments and recommendations that were given during the review process and are included in this report. We sincerely hope and indeed expect that the influence and impact of Wetsus will grow further as it has achieved very sound and stable operating conditions both financially and structurally. We certainly wish the Wetsus team the very best for the further development of this unique and highly valuable concept to achieve an even more influential and prominent position in the local, national and global spheres.

Jurg Keller,

Chair of the Wetsus peer review committee 2023

# 1 Introduction

In May 2023 an independent assessment committee conducted the **Research Assessment of Wetsus, European Centre of Excellence for sustainable water technology.** This report contains the findings, recommendations and conclusions of the assessment committee.

**The assessment covers the time period 2017 – 2022.** The goal of the assessment was to evaluate the Institute in light of its own aims and strategy and provide recommendations. The assessment builds on several written sources, including the self-evaluation of the Institute, and the Strategy Evaluation Protocol 2021-2027. The assessment committee conducted a site visit of the institute on May 23-25.

In accordance with the Strategy Evaluation Protocol 2021-2027 for Research Assessment in the Netherlands (SEP), the committee's task was to assess the research on the following criteria: Research Quality, Societal Relevance, and Viability (extent to which the Institute is equipped for the future). The assessment encompassed four further aspects: Open Science, Academic Culture, Human Resources Policy and PhD Policy and Training.

The committee gave a qualitative evaluation and recommendations.

## 1.1 Composition of the assessment committee

The composition of the committee was as follows:

- Chairperson: Emeritus Prof **Jurg Keller** FTSE, IWA Distinguished Fellow; Australian Centre for Water and Environmental Biotechnology, The University of Queensland, Australia
- Prof Dr Ing **Andrea Iris Schäfer**; Professor of Water Process Engineering, Faculty of Chemical and Process Engineering; Director, Institute for Advanced Membrane Technology (IAMT); Karlsruhe Institute of Technology (KIT), Germany
- Prof **Jeffrey R. McCutcheon**, Ph.D.; Department of Chemical & Biomolecular Engineering, University of Connecticut; Executive Director, Connecticut Center for Applied Separations Technology (CCAST); Deputy Topic Area Lead, National Alliance for Water Innovation (NAWI); Associate Editor, Journal of Membrane Science Letters, USA
- **Hakim Fadil,** MSc, Researcher in the membrane technology group at the Catholic University of Leuven (KU Leuven), Belgium.
- Prof. Dr. **Gerard van der Steenhoven**; Special advisor (Ministry of the Interior, The Netherlands); Professor of Meteorological and Climatological Disaster Risk Reduction, University of Twente; The Netherlands. Chair of the Steering Committee of The Netherlands' Climate Research Initiative (KIN).

Ir. **Geert van der Veen** (Technopolis Group) was appointed as secretary to the committee.

## 1.2 Procedures followed

The committee proceeded according to the Strategy Evaluation Protocol 2021-2027 (SEP). On April 17th, 2023, an online introduction session was organised with the committee where the committee members introduced themselves to each other and the secretary briefed the committee about the Strategy Evaluation Protocol (SEP) and the process of the evaluation and the site visit.

Before the start of the site visit, the committee reviewed the relevant documentation (Wetsus self-evaluation, case studies[1] and the Wetsus 2023 Research Programme).

The site visit started on the evening of Tuesday 24 May and lasted the entire days of Wednesday 25 May and Thursday 26 May (see Appendix A for the programme of the site visit).

After the interviews, discussions and lab tour, the committee discussed the assessment of Wetsus as a whole and presented the preliminary assessment to management representatives of Wetsus.

In the weeks after the site visit, the committee drafted this assessment report based on all the documentation and inputs received during the site visit. The report was sent to Wetsus for a check on factual inaccuracies, after which it was finalised and submitted to the board of Wetsus.

[1] Innovations, Examples 2015-2020, Wetsus, Leeuwarden, 2020

# 2 Evaluation of the research unit

## 2.1 Aim and strategy

Wetsus was founded in order to strengthen scientific research and industry collaboration in the area of water technology in The Netherlands. The vision of Wetsus is to "create a unique environment and strategic cooperation for our partners in order to develop profitable and sustainable state of the art water treatment technology for the world." To realise the vision, Wetsus is organised in a unique and highly interactive structure, aka the "Wetsus model". In this structure a close cooperation between academic researchers and industry partners is created within research themes, each supported by significant funding from at least two (non-competing) industrial parties. Within each theme a highly effective and trusting collaboration is fostered between the industry partners and leading professors in relevant fields across various universities who supervise the PhD students performing their research studies predominantly at the location of Wetsus in Leeuwarden (Friesland). To ensure good academic guidance, the supervisors meet with the students frequently in person (often in Leeuwarden) or by virtual means. A theme coordinator from Wetsus coordinates the research in each theme, supports the students on a day-to-day basis and maintains the connections with the industry representatives. The theme coordinators also organise regular meetings (at least 3 per year) with all theme participants plus additional interactions as required.

The peer review committee assessed all aspects of this unique Wetsus model in detail and concludes that **the Wetsus model is well developed and proven over the years and is serving all participants in this highly effective innovation environment very well**. A key strategic advantage is created through the close connections with 60+ Professors in relevant fields across many universities and the relevant and engaged industry partners – creating PhDs with real cross-disciplinary backgrounds and highly valuable industry-relevant expertise and experience. A key feature and critical component in this model is the 'high trust' environment, which is highly valuable and well regarded by the industry and university representatives as well as the PhDs.

The recently secured **long-term funding as an "Institute for Strategically Important Research"** (Dutch: SBO instituut) and other funding successes put Wetsus on a strong footing for further positive impact and development in the coming years. The 'new' business plan 2021-32, as presented in the self-evaluation and in the discussions during the peer review, is "breathing continuity and stabilisation" more than step changes in impact and size. It is certainly a dramatic turn-around from the more 'survival-focused' perspectives of the last 3-4 years.

## 2.2 Research quality

Overall, the peer review committee finds **the quality of research in Wetsus excellent**.

The publication output in **number of publications** of Wetsus is very good, predominantly driven by the requirement for PhDs to publish four (4) peer reviewed publications in a PhD. Besides being an important KPI and output parameter of public funding, publications also serve to i) teach communication skills to the emerging researchers, ii) widely disseminate knowledge generated and iii) enhance the academic and public visibility of Wetsus. The **quality of journals where Wetsus publishes its findings is impressive** with a large fraction of publications in high impact refereed journals like *Water Research*, various ACS journals, *Chemical Engineering Journal*, *Desalination*, *Nature Geosciences*, etc. This demonstrates a healthy and vibrant research and mentorship environment and should be continued. Publications in lower quality

journals, such as certain open access journals including Membranes, *Molecules*, *Water*, etc. ought to be reduced/avoided in future due to quality concerns in the review process. **The relative citation rate of publications of Wetsus researchers is also very high relative to their peers, providing further evidence of publication quality.** Wetsus also has a well-developed process around **EU project acquisition and development** engaging most research staff and their university partners. The growing success rate in these very competitive funding schemes is also a clear indicator of the high research quality at Wetsus and the faith of funding agencies in Wetsus' capabilities.

The peer review committee was **particularly impressed by those projects that have over many years developed from small scale laboratory studies to full-scale implementation in practice.** A leading example of this is the distributed greywater/blackwater source separation and reuse project for new housing developments that is now implemented on a commercial scale in Helsingborg and Sneek (and is under implementation in Leeuwarden). Such 'lighthouse' projects clearly demonstrate both the quality of the research at Wetsus and its partners but particularly also the distinctive and scarce ability to translate this into high-impact benefits to industry and society.

One observation of the committee was, however, that the posters presented during the site visit as well as the **publications appeared to carry many author names** (8 being very common) **with unclear contributions of the individuals**. While this may simply indicate an 'inclusive' approach when it comes to authorship selection, it would be beneficial to have a clear authorship policy (if not yet existing) that would also allow to document the specific contributions of each of the authors. There are many inter/national and journal authorship contribution guidelines that can be adapted to also be consistent with the relevant research integrity policies and procedures. It would set unambiguous expectations for students and post docs to achieve authorship status on papers and presentations.

The "**Sustainability in the making**" **theme is an interesting and valuable new addition** to the research portfolio of Wetsus, attempting to integrate social sciences in order to accelerate and increase impact further. It could be beneficial for Wetsus to assess whether and how the approaches developed within this theme or the results from its work could be implemented across other themes and projects. It would also be useful to link this theme with emergent expectations in EU funding calls (i.e., funding calls requiring "convergence" based research).

## 2.3 Societal relevance, impact

Wetsus has successfully established robust and mutually beneficial relationships with various companies. Their ability to facilitate productive dialogues among diverse groups stands out. They have effectively bridged the gap between scientific theories and their practical, industrial applications, focusing on projects with potential for high scientific and industrial impact. There appears to be a harmonious collaboration between professors across different disciplines and industry partners across various value chains. This trust-based, effective communication accelerates the innovation process, transforming ideas into reality, and making a real-world impact.

**Industrial partners value Wetsus as reliable and capable innovation 'hub'** that is able to provide them with **faster and more relevant scientific insights.**

Wetsus effectively concentrates on key water technology areas, including projects in emerging fields that are related to its expertise/values and are relevant to its industry partners. Wetsus collaborates closely with around 100 industry partners (mainly from private sector but including

a number of waterboards and drinking water companies) who often employ PhD graduates after the completion of their research degree. This unique model allows for a smooth transition of the graduate's work from research to practical application, helping to upscale solutions within the industry.

Wetsus created (from the start) almost 100 patents[2], of which 45% are transferred to companies in the network. 28% of all companies stated that in the past 5 years Wetsus projects led to (use of) patents in their company. Companies also indicated that participation in Wetsus projects led to additional R&D activities within their company, outside the Wetsus programme. 12 spin-off companies were founded in the evaluation period, based on Wetsus patents or founded through the Wetsus network. 10 of these companies still exist. Total employment in spinoffs of Wetsus that were created after the start of Wetsus is 120-170 fte in the region.

One third of all companies participating indicate an increase in turnover as a result of innovation and knowledge from the Wetsus programme. About 40% state that this knowledge has contributed to new products and services; 93% state that they expect this will happen in the next five years. About half of the end users participating in the Wetsus programme state that new technology applications were realised based on Wetsus knowhow, which in part also lead to savings on operational or production costs.

The '**Wetsus model' clearly offers an effective pathway from leading research work to practical applications with significant economic and societal impact**, **that is one of the most effective academic-industry collaboration environments that the peer review committee has seen.**

The committee also recognised that many Wetsus partner companies (around 25%[3])employed Wetsus graduates after the end of their projects, which is an important way of knowledge transfer and likely very valuable for both the companies and the graduates. Companies have an opportunity to recruit from a pool of candidates that they have worked with. The students have the entire consortium of companies that they can interface with. Wetsus draws in more companies after successful projects and talent acquisition.

During the audit process, the review committee sensed that the requirement for multiple industry partner participation and funding in the creation of new projects may at times limit the possibility for a more ambitious and inspiring strategy or project direction. While this principal requirement is valuable to ensure industry-relevant research topics are addressed, the Wetsus management should nevertheless be aware of this potential impediment and therefore ensure that alternative funding sources (like EU projects) are used to support some more ambitious and 'blue-sky' research topics even when there is only limited industry partner funding available.

Given the diversity and number of research themes, there is a risk of creating separations and 'silos' within the Wetsus research community. To reduce this risk, it is important to further encourage synergies and collaboration across the various research groups within Wetsus. By fostering cooperation and combined efforts, more complex and increasingly cross-sectorial water challenges can be better addressed through comprehensive and integrated water and environmental solutions, such as the various resource recovery projects and carbon capture/use. In that way Wetsus can serve as a one-stop shop for water/environmental-related challenges, hence increasing its appeal and value to a wider range of industry partners. Inter-theme collaboration will also foster more of an integrated research community and allow the

[2] All figures in this paragraph from Wetsus Evaluation 2020-2022, BBO, Leeuwarden April 2023

[3] idem

sharing of resources between themes. Some concerns exist about the relatively large number of research themes (20) in comparison with the total research budget (15 MEUR). Starting more themes requires more budget.

## 2.4 Viability

In recent years, Wetsus has achieved major improvements regarding the future financial perspectives of the institute. **Financial stability has been realised** now that Wetsus has been appointed as a special research institute of strategic importance to the ministries - as an SBO institute. The financial future has further been strengthened with the approval of a 10-year project paid by the National Growth Fund. Finally, the executive board has been successful establishing a dedicated fund for future research initiatives and infrastructure investments.

**Scientifically the viability of the institute has been strengthened** as well: Output indicators such as publications, citations, number of projects approved, student satisfaction, and number of companies involved all reflect the growing success of the institute. This bodes well for the future.

Furthermore, the institute is continuously renewing its research portfolio, in close consultation with the participating companies and knowledge institutes. In particular, novel subjects have entered the research program of Wetsus, such as natural water production, the sustainable carbon cycle, and the social implications of innovations developed by Wetsus. Such developments clearly demonstrate the ability and willingness to continuously adapt and evolve through identifying new projects and themes, which is critically important for an advanced innovation institute like Wetsus.

Wetsus has a strong reputation abroad as well, demonstrated by the participation of many non-Dutch partners in Wetsus and the strong scores and success rate of Wetsus proposals in the EU Horizon programmes. Continued expansion with non-Dutch partners will be valuable in establishing a strong and reliable revenue stream from non-Dutch sources.

The panel concludes that **the future of Wetsus is sound and very promising**.

To further strengthen the long-time future of the institute on a 10-year time scale the review committee has identified a number of aspects that could help the Wetsus board and management in further improving the scope and operations of the institute.

The **new base funding** is organised through a new entity (the SBO-programme) that has been created in order to ensure long-time funding of research institutes like Wetsus and the high-tech innovation centre Holst in Eindhoven that are considered of relevance for Dutch society. To strengthen the long-term viability of this construct, it is important that the Wetsus supervisory board and management **promote this concept (and the Wetsus model of course) such that the continuation of the SBO initiative in future is not subject to debate**. It may even be beneficial to support the establishment of similar initiatives along the 'Wetsus model' in other industrial fields to further spread the 'sphere of influence' to other academic-industrial collaboration opportunities in the Netherlands. This would not require large time or other commitments from the Wetsus management, but it could cement the 'Wetsus innovation approach' as a preferred and proven model to achieve this crucial, but highly difficult transformation of research outcomes to industrial and societal impact. It may also be prudent to have base funding adjusted for inflation.

Wetsus has **a strong and successful leadership team** with an excellent track record in not only establishing and rapidly growing the institute over the last 20 years, but also successfully guiding the institute through challenging times in recent years with considerable uncertainties

regarding the long-term funding. To ensure the long-term viability of this enviable track record, the selection and performance of the leadership team in the future is absolutely critical. The current plan that was presented during the review discussions (but not included in the self-evaluation document), does not address this important aspect adequately. Therefore, it is recommended that the **leadership evaluation and succession policy** be further strengthened. This should be undertaken in close collaboration with the supervisory board and the senior management team so that an open and transparent process of regular performance evaluation, task/responsibility distribution, knowledge/risk sharing and succession planning for all management and leadership roles is realised. The aim would be to further enhance and strengthen the recruitment and appointment processes for leadership roles, particularly also for internal candidates. It is also important that such a procedure also addresses relevant diversity considerations (gender, skill sets, level of experience, discipline areas, working styles, cultural backgrounds, etc.) in order to improve the strength, resilience and balance of the overall leadership team.

Wetsus has the opportunity to **play a central role in the ongoing development of water technology research in the Netherlands**. It is already collaborating with many research teams in the country, and the approved 10-year projected funded by the National Growth Fund is evidence of the feasibility of such national collaboration. It is recommended to fully utilise this collaboration in the initiative to develop a **national roadmap for water technology**. A good example of such an effort is the National Alliance for Water Innovation in the United States, which created a master roadmap for water and desalination in the U.S. and 5 additional roadmaps dedicated to certain economic sectors (Power, Resource Extraction, Industrial, Municipal, Agriculture). This has the advantage that the field will better position itself among other sectors that may compete for recognition and funds. Moreover, such a network will better enable the field to exert their influence at the level of policy makers.

Given the much-improved stability and very sound operational platform, the committee is of the view that **a more 'bold' outlook and vision, together with more ambitious directions and aims for the future** could be beneficial for Wetsus.

The panel is not convinced that a strict zero-growth policy for the next 10 years is the best strategy for the institute and is of the opinion that Wetsus has the potential to develop from a leading Dutch initiative with strong ties outside the Netherlands to a leading institute in Europe with a global reach and reputation. Expanding connectivity outside of The Netherlands also grows the breadth of expertise available to Wetsus.

The needs from society - from companies to universities and policy makers alike - should be the leading factors. Maximising the societal impact - explicitly mentioned in the Wetsus mission - should be the guiding light in this re-evaluation of various operating models.

A vision on whether this can be done within the present Wetsus model, or whether (considering the risks in doing so) it is worthwhile to adapt the Wetsus model in some way, should be developed with staff and stakeholders as an addition to the current business plan 2021-32. Changes or additions to the Wetsus model in anticipation of potential market and economic shifts would be prudent. Wetsus also needs to decide how much of a role non-Dutch entities (companies, professors, and funding sources) should play in its future and how this objective could be best achieved.

## 2.5 Specific aspects

### *2.5.1 Open Science*

One of the core principles of the Wetsus model is to ensure that information can flow freely, while at the same time enabling commercial activities based on that information for their industrial members. For example, the creation of theme-based memberships allows for different partners that may be (potential) competitors to be in different teams focusing on different processes and/or products.

Wetsus has been able to implement this without hampering open communication between all PhDs and researchers, which is highly valuable to support real collaboration, innovation and joint development of knowledge and transfer of knowledge from universities and companies.

Open science therefore fits Wetsus well. **Wetsus is actively promoting an open science policy** as is reflected by the large number of Wetsus publications that have appeared in open access journals. The institute should be congratulated to the progress that has been made on this issue during the review period. At the same time, national (and international) developments are imposing more requirements on the way research data (and IT-based systems in general) need to be organized. Not only the publications, but also **the underlying data need to be publicly available and comply with the FAIR principles.** Wetsus policy in this respect appears to be less developed. Therefore, it is recommended that the institute develops an open data policy and related IT strategy to enable open access to relevant data while managing the related cyber security as well as commercial risks. This has intrinsic value, but also ensures that all Wetsus employees, students, guests and stakeholders are aware of the Wetsus policies in this domain.

### *2.5.2 Academic culture*

**Wetsus has created a welcoming environment** for students and professors. Training and social opportunities are numerous for students and staff, promoting a positive and welcoming culture. The **openness of the innovation process at Wetsus seems to benefit students**. Open lab and offices provide opportunities for students to interact regularly. Also the shared and unrestricted access to the common analytical facilities and the mechanical-electrical workshops is extremely valuable and conducive to create a strongly collaborative and open academic culture. There is a **strong emphasis on publishing**. This is helpful to the students and provides incentives for academic participation of all supervisors. There is clearly a focus on generating high-quality publications as further outlined in the Scientific quality section above.

**Safety culture appears to be well-developed and adequate**. All researchers were wearing PPE when we interacted with them, and guests were provided with required PPE. All experimental set-ups were well built and contained and very clearly described with project summary and safety assessment.

Although the panel was informed that **Wetsus largely adheres to the rules set out by the Netherlands Code of Conduct for Research Integrity**, they are not officially member of the corresponding organisation (LOWI). Such membership would provide the institute with a framework and advise on how to further strengthen their position in integrity issue might emerge.

### *2.5.3 Human Resources Policy*

Wetsus has developed a **convincing set of core-values** that are seriously conveyed to all (new) employees of the institute, PhDs as well as other staff. This has a positive effect on the Wetsus community in terms of creating a proper corporate spirit and reducing the number of conflicts. There is a strong emphasis on gender diversity amongst the students and staff. **The overall**

**gender balance in the institute is quite good but the leadership lacks gender diversity,** which could have its effects on organisational culture and innovation. **There is limited emphasis on broader diversity and inclusion aspects** (cultural, racial, abilities, etc.) among the Wetsus staff, although the student body has many international students from a diverse range of backgrounds. Also a standard test for personal preferences/working styles is required for each staff member with the aim to create management teams and working groups with a relevant set of personal traits and working preferences for the required tasks.

**Wetsus has outstanding career development structures and processes** (both for PhDs and staff). The recruitment and selection process for the PhDs is extremely well developed and organised (see below in PhD policy section) and also the recruitment and staff progression processes seem quite open and transparent. There is a strong emphasis on organically growing the skills and professional expertise of the Wetsus staff to enable them to take on more responsibility and potentially management and/or leadership roles in future. This has resulted in a high retention rate of their staff members, which is important to maintain the culture and quality of the work at a heavily knowledge- and skill-based institute like Wetsus. Overall, based on the observations of the audit committee, all sections of Wetsus appear to have a very pleasant, collegial and respectful working environment.

**In contrast to the well-developed and open HR policies for attracting students and staff, the related processes for the (senior) leadership roles do appear less clear and transparent** (see also comments in previous Viability section). To strengthen the long-term leadership team of Wetsus, we would encourage the (further) active inclusion of more of the highly dedicated and well-performing staff members in (executive) leadership roles. To ensure this process is undertaken in a fair and open way, clear and transparent selection policies and procedures should be established in close collaboration with the senior staff members and under the guidance of the Supervisory Board. While we do not want to be prescriptive of how these policies and procedures should be formulated, we specifically would advise against having strict rules like fixed term appointments or requirements for external recruiting etc. Given the unique nature of Wetsus and the strong, organically grown internal culture, the appointment of candidates for key leadership roles needs to be very carefully evaluated. While in some cases external appointments could be beneficial, in our view first-hand experience with the Wetsus model is also important for senior leaders to ensure continuity and in-depth understanding of the Wetsus concept and its culture.

### *2.5.4 PhD Policy and Training*

Wetsus has a **well-developed PhD policy,** both for the recruitment as well as for their education and career development during their PhD projects.

The **PhD recruitment and selection process is exemplary in quality and transparency.** At Wetsus twice a year a new cohort of graduate students is recruited, with an open, international call for applications. From an initial 50-80 applications per open position, two candidates per position are selected through a multi-stage selection process involving Wetsus staff and academics. These short-listed applicants are then invited for a personal experience and assessment day at Wetsus, with one of them (typically) being offered the position. In many cases, the second-ranked candidates may also receive an offer either for another open Wetsus position or for a university-based PhD project offered by one of the academic supervisors who are part of the assessment process.

During their PhD studies, **a dedicated educational program has been developed which provides the PhD students with an extensive suite of techniques, courses and other means to enhance their personal skills.** The program is evidently highly successful with low drop-out

figures and very good career perspectives for graduate students after obtaining their degree. A typical PhD student stays at Wetsus for four years, which is the funding duration for a PhD project. A small percentage of high performers finish faster. Approximately 1/3 of students take more than 4-4.5 years (including examination process), but most of them do complete their degree, although at a slower rate over the following 1-2 years. While the PhD project durations are relatively long compared to other countries they are shorter than the average PhD project duration in The Netherlands. It is good to see that there are no strictly enforced completion times (e.g. 3 years in UK, France), which can compromise the quality of the final thesis and ultimately the PhD degree.

While the PhD program at Wetsus is clearly excellent, during the individual discussions with students, the review committee members made some interesting observations. Surprisingly few students had a clear understanding of the company role (and more recent students couldn't even name their company partners). A few were working closely with the company, but it seemed to not be the majority of students. While this clearly demonstrated that the companies did not dictate the PhD research, it did raise some concerns about the level of collaboration between the students and the company partners. Another impression from the poster session was that in some cases the PhD research goals were not clearly identifiable and, for some PhDs the depth in scientific understanding seemed somewhat limited, ranging from details and validation of analytical methods and results through to basic principles. **Some further improvements should be considered regarding the PhD research approaches and in-depth understanding (basic principles) and the industry partner involvement in the PhD supervision.**

A student is advised by a team comprising a university professor, a Wetsus staff member, and company representatives. The professor is the primary supervisor and formal academic promoter of the student, enrolled at the professor's university. Wetsus staff provide day-to-day supervision, mentorship, training and local support. The company advisors contribute ideas and guidance on the project approaches and goals. This approach seems to work well, but it may be beneficial to evaluate professors in some way to ensure high quality of mentorships for all students. Furthermore, if Wetsus expands to include more professors or university partners located far from Leeuwarden, it would be important to set out explicit mentorship expectations for all academic supervisors and have a monitoring system in place to maintain a high standard of PhD advisory activities.

Four international journal publications are expected as academic output from each PhD student. There is no description of how paper quality is measured, although metrics like journal impact factor are common. As already outlined above in the Scientific Quality section, Wetsus papers are generally published in high-quality/top tier journals in their respected fields, hence most PhD publications are considered to be of a high quality. This is ultimately also being assessed by three external examiners during the formal PhD examination process.

**Career perspectives of PhD students are very good**, with low dropout rates during the PhD and strong employment opportunities upon completion. **Many students end up working for Wetsus partners after graduation.** The committee would suggest Wetsus provide statistics of PhD placement a certain time after degree and identify the percentage of students that work for consortium members. Likewise, the committee suggests that they track the number of international students that stay in the Netherlands as a key metric for talent acquisition for the country. The 4-year funding timeline for PhDs is central to the Wetsus model as it requires companies to commit to a 4-year membership in the Wetsus consortium. In turn, the review committee got the impression that the talent recruitment opportunities are a significant motivator for companies to actively participate in Wetsus projects.

The new **MBA pilot program is an interesting addition to the overall PhD education and seems to be highly valued by the recently enrolled students.** It will be informative to assess the outcomes of this cohort in comparison to previous PhD students in terms of employability and career directions.

# 3 Recommendations

*Recommendations for the Wetsus Board (together with Wetsus management)*

- Improve the leadership evaluation and succession policy to further strengthen the leadership team, which is critically important to ensure the long-term viability of Wetsus. Through a collaborative effort with all relevant stakeholders an open and transparent process of regular performance evaluation, task/responsibility distribution, knowledge/risk sharing and succession planning for all management and leadership roles should be realised. Diversity and inclusion aspects and maintaining a strong collaborative culture should be key points of attention.
- Promote the SBO-concept with the relevant Dutch ministries, and possibly help to expand it, in order to ensure the long-term value and success of this construct and therefore also the financial viability of Wetsus.

*Strategic recommendations for Wetsus*

- Consider a more ambitious 10-year outlook and vision for Wetsus to further grow its 'sphere of influence' and its reach and reputation on a global scale. Maximising the societal impact should be the guiding light in this consideration.
- Certainly continue with the current overall research-to-impact value chain and process while also looking for further enhancements and opportunities. In particular, some room for more ambitious future projects should be created, even when there is not (yet) full industry support available.
- Explore the inclusion of additional industry partner sectors involved in Wetsus.
- Lead a new initiative to develop a national roadmap for water technology in The Netherlands

*Operational recommendations for Wetsus*

- Enhance the authorship policy and clearly document contribution of authors
- Improve the open data policy, possibly with a new or existing data repository.
- Create a more firm framework for handling integrity issues by becoming member of the Dutch LOWI organisation.
- Clearly specify the expected physical presence and other interactions between Wetsus-based students and their professors and have a system in place to monitor such interactions.
- Consider improvements in the PhD program at Wetsus regarding the PhD research approaches and in-depth understanding and the industry partner involvement in the PhD supervision.
- Consider initiating a 'transition agreement' with employers who employ finishing PhD students who have not yet completed their thesis. The aim would be to allocate time for the PhDs to finish their PhD theses in parallel to their company employment (with appropriate financial conditions) to help accelerate post-project completion rate of PhDs.
- Assess whether and how the approaches and results from the new "Sustainability in the making" theme can be implemented across other themes and projects.

# 4 Summary

Wetsus was founded in order to strengthen scientific research and industry collaboration in the area of water technology in The Netherland and "create a unique environment and strategic cooperation for our partners in order to develop profitable and sustainable state of the art water treatment technology for the world." To realise the vision, Wetsus is organised in a unique and highly interactive structure, aka the "Wetsus model", with a close and effective cooperation between academic researchers and industry partners. The peer review committee concludes that the Wetsus model is well developed and proven over the years and is serving all participants in this highly valuable innovation environment very well.

The recently secured long-term funding as an "Institute for Strategically Important Research" (Dutch: SBO instituut) and other funding successes put Wetsus on a strong footing for further positive impact and development in the coming years. The current business plan 2021-32, is "breathing continuity and stabilisation" more than step changes in impact and size. It is certainly a dramatic turn-around from the more 'survival-focused' perspectives of the last 3-4 years.

Based on the publication output in number of publications the quality of journals where Wetsus publishes its findings, the citation rate of the articles and the successful participation in EU projects, the quality of research in Wetsus is excellent, specifically shown in those projects that have over many years developed from small scale laboratory studies to full-scale implementation in practice.

Wetsus is actively promoting an open science policy as is reflected by the large number of Wetsus publications that have appeared in open access journals. An associated open data policy is also in existence but could be further improved.

Wetsus has created a welcoming environment for students and professors. The openness of the innovation process at Wetsus seems to benefit students. There is a strong emphasis on publishing. Safety culture appears to be well-developed. The subject of research integrity was only discussed off-line. It was concluded that the basic concepts are properly addressed, and no breaches of research integrity were reported.

Wetsus has successfully established robust and mutually beneficial relationships with various companies. Industrial partners value Wetsus as reliable and capable innovation 'hub' that is able to provide them with faster and more relevant scientific insights. Patents are developed and transferred to companies that actually use them in their operations. Almost all companies in the Wetsus network state that they are using Wetsus knowledge and innovation, or will be doing this in the near future, and get economics benefits from that. 12 spin-off companies were founded in the evaluation period, based on Wetsus patents or founded through the Wetsus network. 10 of these companies still exist. Total employment in spinoffs of Wetsus that were created after the start of Wetsus is 120-170 FTE in the region.

The 'Wetsus model' clearly offers an effective pathway from leading research work to practical applications with significant economic and societal impact, that is one of the most effective pathways that the peer review committee has seen. The committee also recognised that many Wetsus partner companies are interested in employing the Wetsus graduates after the end of their projects, which is an important way of knowledge transfer and very valuable for both the companies and the graduates.

The future of Wetsus is sound and very promising. Financial stability has been realised now that Wetsus has been appointed as a special research institute of strategic importance, and with the approval of a 10-year project paid by the National Growth Fund. Scientifically the viability

of the institute has been strengthened as well by its strong scientific results and its continuous renewal of its research portfolio. Furthermore, Wetsus has a strong and successful leadership team, which could be further enhanced through improved policies on recruitment, succession planning and diversity

Given the much-improved stability and very sound operational platform, the committee is of the view that a more 'bold' outlook and vision, together with more ambitious directions and aims for the future could be beneficial for Wetsus. The committee is of the opinion that Wetsus has the potential to develop from a leading Dutch initiative with strong ties outside the Netherlands to a leading institute in Europe with a global reach and reputation.

Wetsus has developed a convincing set of core-values that are seriously conveyed to all (new) employees of the institute. The overall gender balance in the institute is good except at the leadership level, which could have effects on organisational culture and innovation. There is so far limited emphasis on broader diversity and inclusion aspects (cultural, racial, abilities, etc.). Wetsus has outstanding career development structures and processes (both for PhDs and staff). In contrast to the well-developed and open HR policies for attracting students and staff, the related processes for the (senior) leadership roles do appear less clear and transparent. Wetsus has a well-developed PhD policy, both for the recruitment as well as for their education and career development during their PhD projects. The PhD recruitment and selection process is exemplary in quality and transparency. During their PhD studies, a dedicated educational program has been developed which provides the PhD students with an extensive suite of techniques, courses and other means to enhance their personal skills. Some further improvements should be considered regarding the PhD research approaches and in-depth understanding and the industry partner involvement in the PhD supervision.

A student is advised by a team comprising a university professor, a Wetsus staff member, and a company representative. This generally works well.

Career perspectives of PhD students are very good and many end up working for Wetsus partners. The new MBA pilot program is an interesting addition to the overall PhD education and seems to be highly valued by the recently enrolled students.

Overall, Wetsus is a highly successful, well-established and extremely valuable institute with a unique innovation environment that enables world-class research-to-practice collaborations between academic and commercial partners. The future of Wetsus is very promising and the review committee is hoping that the findings in this report will help the Wetsus leadership to achieve the maximal potential and impact of this excellent innovation concept in the future.

# Appendix A Site visit programme

## Tuesday, May 23

19.00 **Dinner of the peer review team & executive board, and program directors at Post Plaza, Leeuwarden**

## Wednesday, May 24

8.30 **Private meeting of Peer review panel**

9.00 **Welcome and coffee** by Cees Buisman

9.05 **Presentation & Discussion of Research strategy of the past 6 years and results Wetsus**

Mission, objectives, policy, structure, activities, management, and financing of Wetsus, Cees Buisman

Managing network, themes and multidisciplinary staff, Jan Post

Performance Analysis, Bert Hamelers

11.15 Tour with an explanation of facilities (Elmar Fuchs)

12.15 *Lunch with the research management team and business director*

13.00 **Discussion on quality and strategy around projects in research themes**

| | **Theme** | **Wetsus** | **University Representative** | **Company Representative** |
|---|---|---|---|---|
| 13:00 | AWT<br>Desalination<br>Biofilms<br>Natural Flocculants | Maarten Biesheuvel, Jan Post<br><br>Cristina Gagliano<br>Carlos Contreras | Walter van der Meer<br>Louis de Smet<br>Henny van der Mei | Joris de Grooth<br><br>Gijs Doornbusch<br>Hilde Prummel |
| **GROUP SWITCH** | | | | |
| 13:45 | Source Separated Sanitation +<br>Water Innovations Uptake<br>Groundwater Technology<br>Smart Water Grids | Lucia Hernandez<br><br>Roel Meulepas<br>Doekle Yntema | Heike Schmitt<br>Barbara van Mierlo<br>Huub Rijnaarts<br>Richard Loendersloot | Sybrand Metz<br><br>Johan Driessen<br>Werner Jousma |
| 14:30 | Discussion with Company Representatives | | | |
| 15:00 | Discussion with University Representatives | | | |

15.30 **Poster Market (all PhD's present).**

17.00 *Drinks*

18.00 **Committee meets to discuss and conclude Day 1**

19.30 *Dinner at Eindeloos with the research management team and executive board*

## Thursday, May 25

9:00 **Discussion with Wetsus staff on specific topics:**

European Collaboration, Roel Meulepas

Ph.D. Recruitment & Personal Development Program, Inez Dinkla

Scientific Staff: Needs & Development, Jan Post

9.45 **Presentation & Discussion of Wetsus Strategy & Viability for the future:**

Strategy, Cees Buisman

Finance, Johannes Boonstra

SWOT, Bert Hamelers

11.15 **Discussion on quality and strategy around projects in diverse themes**

| | **Theme** | **Wetsus** | **University Representative** | **Company Representative** |
|---|---|---|---|---|
| 11:15 | Resource Recovery<br>Phosphate Recovery<br>Sustainable Carbon Cycle | Philipp Kuntke<br>Leon Korving<br>Michel Saakes | Annemiek ter Heijne<br>Ekkes Bruck<br>Gert-Jan Euverink | Paula vd Brink<br>Pim de Jager<br>Eugene Roebroek |
| **GROUP SWITCH** | | | | |
| 12:00 | Soil<br>Natural Water Production | Valentina Sechi<br>Jolanda Theeuwen | Paul Bodelier<br>Chiel van Heerwaarden | Sybrand Metz<br>Johan Driessen<br>Werner Jousma |
| 12:30 | Discussion with Company Representatives | | | |

13.00 *Lunch with scientific staff members & University Representatives*

13.30 **Drafting of conclusions 2nd day of evaluation**

15.00 **Presentation of the conclusion to the board members and research management team of Wetsus by the chairman of the evaluation committee**

15.30 **Closing**

# Appendix B Quantitative data on the research unit's composition and funding

## B.1 Input of research staff

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Science staff | 19 | 22 | 24 | 22 | 20 | 19 |
| Post-docs | 7 | 8 | 5 | 5 | 6 | 12 |
| PhD-candidates | 59 | 58 | 67 | 52 | 52 | 58 |
| Tech/lab support | 17 | 17 | 17 | 15 | 16 | 17 |
| Overhead | 18 | 21 | 21 | 17 | 17 | 20 |
| Total | 120 | 126 | 134 | 111 | 111 | 125 |

Source: Self-assessment report evaluation 2017-2022

## B.2 Funding

(in MEUR/year)

| | | 2017-2020 | 2021-2022 |
|---|---|---|---|
| **Core funding** | Regional (Friesland, Leeuwarden) | 1.5 | 1.6 |
| | National (Ministry Economic Affairs) | | 1.9 |
| **Programme funding** | NWO | 0.5 | 2.0 |
| | Topsector Water | 0.8 | 1.1 |
| | Ministry Economic Affairs | 4.8 | |
| | EU | 1.5 | 1.5 |
| **Participant funding** | Companies | 3.4 | 3.4 |
| | Universities (in kind supervision) | 2.3 | 2.4 |
| | Universities (cash core funding) | | 1.0 |
| **Total** | | **14.8** | **14.9** |

Source: Self-assessment report evaluation 2017-2022, additional data Wetsus

## B.3 PhD candidates

Cumulative number of PhD graduates over time

| Starting year | M | F | | <= 4 year | <= 5 year | <= 6 year | <= 7 year | <= 8 year | Not yet finished | Dis-continued |
|---|---|---|---|---|---|---|---|---|---|---|
| 2014 | 9 | 4 | 13 | 0 | 7 | 7 | 8 | 9 | 3 | 1 |
| 2015 | 6 | 3 | 9 | 1 | 3 | 6 | 6 | 6 | 2 | 1 |
| 2016 | 10 | 10 | 20 | 2 | 14 | 16 | 17 | | 2 | 1 |
| 2017 | 6 | 4 | 10 | 0 | 3 | 4 | | | 4 | 2 |
| 2018 | 7 | 7 | 14 | 0 | 6 | | | | 8 | 0 |
| Total | 38 | 28 | 66 | 3 | 33 | 33 | 31 | 15 | | |

Source: Self-assessment report evaluation 2017-2022

wetsus

european centre of **excellence**
for sustainable **water technology**

# Self-Assessment Report Wetsus 2017-2022

**combining scientific excellence with commercial relevance**

SBO-instituut

*Dutch Institute for Strategically Important Research*


**Wetsus, European Centre of Excellence for Sustainable Water Technology**

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WATER CAMPUS Leeuwarden


**Wetsus is cofunded by**

- Dutch Ministry of Economic Affairs and Climate Policy
- Dutch Ministry of Education, Culture and Science
- TKI-Water Technology (Topsector Water & Maritime)
- European Union (Horizon Europe, Horizon 2020, EIT and Interreg)
- Wageningen University, University of Groningen, University of Twente, NHL Stenden
- City of Leeuwarden, Province of Fryslân

Ministry of Education, Culture and Science of the Netherlands
Ministry of Economic Affairs and Climate Policy of the Netherlands

WATER & MARITIME
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NWO

# Table of contents

# 1. Summary

The current Dutch standard evaluation protocol (SEP 2021-2027) focuses on strategy. Wetsus has developed a new strategy for 2021-2032, which is thus the central topic for the current Wetsus audit (2017-2022) and self-assessment. This self-assessment is composed of three parts: the first describes in detail the strategy and organization; the second describes the achievements concerning science quality, societal relevance, and future innovation leaders; the third part describes the viability of Wetsus based on a SWOT analysis, advice of the previous audit committee and the reported achievements.

**Strategy & Organization**

The strategy starts with the newly formulated mission. With this mission, Wetsus clearly expresses its ambition to create a societal impact through the outcomes of its research program. This ambition is translated in three strategic lines:

- The program strategy defines the areas to which Wetsus wants to contribute; sustainable water, healthy environment, recovered resources, and drought resilience.
- The impact strategy describes how the research program creates maximally beneficial outcomes that enable our partners to create societal impact.
- The innovation strategy describes how multidisciplinary cooperation by basic sciences, key technologies, engineering sciences, and environmental sciences leads to breakthrough technologies. The strategy describes how the need for various disciplines can be balanced with the need for critical mass.

The organization of Wetsus is value-based, valuing personal growth as a basis for organizational growth. The organization comprises three (interrelated) key elements, the network, the research organization, and the facilitating organization.

- The network is organized around open innovation communities, the so-called themes. These themes consist of companies and universities running a focused research program. The theme is organized such that maximum trust between partners is enabled. This organization allows for innovative project selection and fair access to IP for those involved.
- The research organization aims to deliver breakthrough technologies and future innovation leaders that will lead to societal impact in the network context. Idea and Ph.D. researcher selection occur with all partners, merging multiple perspectives. The double supervision model (University & Wetsus) leads to multi-disciplinarity. Company involvement during the projects continuously evaluates the project's relevance. Dedicated multidisciplinary facilities are in place.
- The facilitating organization is responsible for the smooth operation of the network and research organization.

**Achievements**

Achievements are first described by the realization of the Key Performance Indicators (KPIs) as defined in the Business Plan 2021-2032. These data are discussed and placed in their context by additional insights obtained from an extensive economic and network evaluation and an evaluation of the publication record. Both studies were performed by independent specialized consultants. The following main results were realized.

*Finance*

The finance of the program part and the company contribution were stable, high, and in line with KPIs. Long-term core funding, however, was uncertain in 2021-2022, enforcing a temporary reduction of new program Ph.D. projects and staff. Fortunately, the drop in Ph.D. projects could be compensated via competitive EU funding and due to the obtained clarity about long term funding in 2022.

*Research Quality*

The research quality is very high. The number of science projects is higher than the KPI (124%), the number of papers is concomitant higher (121%), and a very high citation impact is observed in all years.

The citation analysis revealed that nine core disciplinary fields accounted for 75% of the papers. Five of the core fields are engineering disciplines, while four are smaller basic science fields. This disciplinary distribution aligns with that of Ph.D. candidates and science staff, while that of university supervisors is much broader. This is in line with our innovation strategy, where engineering disciplines connect basic sciences, key technologies, and environmental sciences to create breakthrough technologies.

The citation analysis revealed that Wetsus is active in a competitive research arena. While for the core fields, the average citations per paper rose (MCS) from 14 in the previous period to 24 in the current period, the field normalized

citation score (NMCS) remained stable and high. For the non-core fields, the NMCS was average. These findings underline the need to create disciplinary critical mass to be successful in such a competitive research arena.

*Competitiveness & Innovations*

The number of spin-offs associated with Wetsus is clearly higher than the KPI (140%). This reflects both the innovation power of the Wetsus program and the increasing attractiveness of the Water Campus innovation ecosystem. The number of patents filed was according to the expectation of the KPI (106%). The total number of patents was lower than in the previous period due to a stricter patent policy. This did not negatively influence the number of patents transferred, this was somewhat higher. It was, however, lower than the KPI for transferred patents (83%). The knowledge generated in the research program is widely used, as 50% of the tech companies use it to improve existing products and technologies, and 40% use it to develop innovative technologies.

*Innovation Community*

The size of the innovation community is very stable, because the funding allows for a certain number of projects, which regulates the size of the innovation community. The number of companies joining Wetsus is according to the KPI (102%), the same holds for the number of small companies joining (108%), and also the number of professors and principal investigators is stable.

The trust and cooperation experienced by our partners have grown over the years and have reached a level of 8.6 on a scale of 1-10. This trust is both benevolence and competence-based.

*Future Innovation Leaders*

The Ph.D. graduates are trained to become future innovation leaders. The population is highly international (75% outside the Netherlands) and has an even gender balance. The graduation success rate is around 80%, slightly higher than the graduation rates at technical universities. The median period to achieve graduation is almost six months shorter than the Dutch average. This high graduation rate and shorter graduation period indicate the double supervision model works well and that the Ph.D.– Wetsus Supervisors ratio is well balanced. The corona period has caused delays, compensated for via project extensions.

There is a personal development program in place that helps Ph.D. candidates to overcome setbacks quicker by giving them more insight into their functioning and being. This program is well evaluated both by current participants and alumni. HR has acquired the HR Excellence in Research Award from the EU, showing that a well-balanced HR policy is in place.

**Viability**

The long-term secured core funding (until 2034), the stable basis of the company funding, and the proven success in competitive program funding all add to a very stable financial position.

The new Business Plan 2021-2032 is based on a new mission emphasizing the societal impact. A balanced strategy for the research program, impact, and innovation has been defined. Drought Resilience and Healthy Environment have been defined as new impact areas next to the existing ones of Sustainable Water and Recovered Resources.

The new Business Plan will strengthen the innovation power of Wetsus. To further understand and refine our strategy Wetsus has started a new research theme “Sustainability in the Making” that uses state-of-the-art social science concepts.

New disciplines, like social sciences and hydrometeorology will be connected to the Wetsus research program. These new disciplines will expand the disciplinary field and create unique opportunities for innovation.

A new Ph.D. model, including an MBA, will be tested with 14 Ph.D. students. By bringing business science closer to the Ph.D., a stimulus for both innovation and impact will arise.

**Overall**, with the Funding and Business Plan 2021-2032 in place, Wetsus (leadership) can entirely focus on network, innovation, and impact, supported by; the well-functioning network, high-quality research program, experienced facilitating organization, and proven leadership. Wetsus can look confidently toward the future, all elements are in place to make the next ten years an even bigger success.

# 2. Introduction

This self-evaluation is the basic document informing the audit committee of the 2017-2022 scientific audit. The Strategy Evaluation Protocol (SEP) 2021-2027, as set up 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) is the basis for the audit. This protocol is used in the Netherlands for evaluating all public funded research in universities and research institutes alike.

The previous SEP protocol was evaluative, aimed primarily at benchmarking research groups with peers based on specified metrics and evaluating with a grade. Wetsus scored the highest score possible.

The current protocol is formative and aims at improving research strategy and organization. Research groups are evaluated in view of their aims and strategy. Research groups present their aims, strategy, organization, SWOT, and achievements and propose a refined strategy based on these outcomes. The audit committee comments on all these aspects and proposes further improvements and refinements for strategy and the organization.

The previous audit committee concluded that Wetsus, with its unique highly successful set-up, needed to acquire more stable long-term funding to maximize its potential and viability. Therefore, the last six years, Wetsus has worked hard on developing a new broader strategy, securing long-term funding, and redirecting the research program towards this new strategy and this long-term stable funding.

This new strategy, as laid down in the business plan 2021-2032, will be the focal point for this audit. The strategy is mission-oriented; the mission describes the 'why' of the organization, that gives sense and direction to the actions and motivates partners to join. A coherent strategy has been formulated for the research, its impact, and innovation.

The SEP protocol uses three dimensions to analyze the strategy and organization, **research quality**, **societal relevance**, and **viability**. The organization must supply evidence of the achievements within these dimensions. As stipulated by the SEP protocol, Wetsus will use its own Key Performance Indicators (KPIs) to supply evidence. Where necessary additional context will be provided with additional data and cases. Next to these criteria, four aspects should be discussed, Open Science, PhD Policy and Training, Academic Culture and Human Resources Policy. These aspects will be presented in the context of associated KPIs.

Chapter 3 describes the **mission and strategy**. The mission represents the bigger 'why' of Wetsus. It is this mission that brings all partners together. Wetsus deploys three strategic lines on how to strive for its mission, (i) a **program strategy**; which areas the research will be directed at, (ii) an **impact strategy**; how will the impact of the research be achieved and (iii) an **innovation strategy**; how can the opportunities for innovations be maximized.

Chapter 4 describes both the wider Wetsus network, the research organization, and the facilitating organization. The network and the research organization are the entities realizing the strategy and enabling impact. The network is described in terms of an open innovation community that creates unique opportunities for identifying innovations and bringing them to impact. The research organization describes how the Ph.D. program is organized to generate outputs that help in creating the desired impact. Finally, the facilitating organization is described, that makes it possible for the network and research program to function and focus.

Chapter 5 describes the evidence and accomplishments. Leading in this are the Key Performance Indicators as defined in the Business Plan. These indicators try to capture the state of the functioning of Wetsus. Additional research has been performed to supply more context to the KPIs, especially in relation to the strategy. Two studies by external organizations have been done, one into the functioning of the network and innovation impact (BBO) and a bibliometric study on the research impact (CWTS). Next to these, data from internal databases, beyond the KPIs, have been studied, to discern trends.

Chapter 6 describes the viability of Wetsus. First, a SWOT analysis is described. Next, we will analyze how the current strategy is able to respond to the challenges identified in the SWOT and the findings of Chapter 5.

# 3. Mission and Strategy

## Wetsus Mission

### Our Society Depends on Water

Society depends on natural and built environments to supply all kinds of tangible resources (materials, water, energy, food) as well as intangible services related to climate, recreational space, transport, degradation of pollutants and pathogens, and so forth. As a consequence of growing resource exploitations and ecosystem service use, the environment is however negatively impacted by emissions, depletion, and ecosystem damage and stress. This impact undermines the potential of the environment to continue to deliver resources and ecosystem services for future generations. Humanity has, in this way, become the dominant driver causing changes in ecosystems worldwide. It is abundantly clear that certain environmental changes go beyond a carrying capacity to support our current society and economy. As an illustration, the planetary boundary concept identifies nine essential processes that regulate the resilience of ecosystems (Figure 1). It aims at identifying boundaries within which humanity can successfully develop. Risks for severe and irreversible environmental damage increase dramatically when these boundaries are violated. Water plays a pivotal role in the cluster of these nine processes. Water is crucial in transmission (geochemical flows) and vital conversions of chemical components, including both nutrients and pollutants. Virtually all phosphorus and a substantial portion of all nitrogen are transported via drainage and wastewater. The boundaries of land system change and biosphere integrity are determined by water availability, water quality, and a lack of circularity in consumption. The planetary freshwater use and availability has already exceeded its safe planetary boundary.

Also, according to the late prof. dr. Arjen Hoekstra (University of Twente), our current freshwater use is not sustainable, and at least four billion people suffer from water stress, subject to regional conditions. A global water demand gap from 30 to 40% is expected in 2030.

Water is a principal environmental compartment, and it is the enabler of the biosphere. Sufficient water of the right quality is an essential functional element for environmental compartments, soil and atmosphere, feeding an array of ecosystem services that we, in turn, rely on. So, it is no exaggeration to say that water is the sine qua non of a productive well-functioning society. Access to safe drinking water is at the foundation of any functioning civilization. Worldwide today, 3 out of 4 jobs depend on sufficient water availability. A diversity of industries, from agriculture and food to power, pulp and paper, and chemical, to name a few, are all heavy consumers of freshwater. Industries like these drive our economies, as well as our way and quality of life. To enable all people today and future generations tomorrow, to have access to quality of life with resources and ecosystem services, society needs to innovate in its relationship to the environment, meaning to a huge extent, its relationship to water.

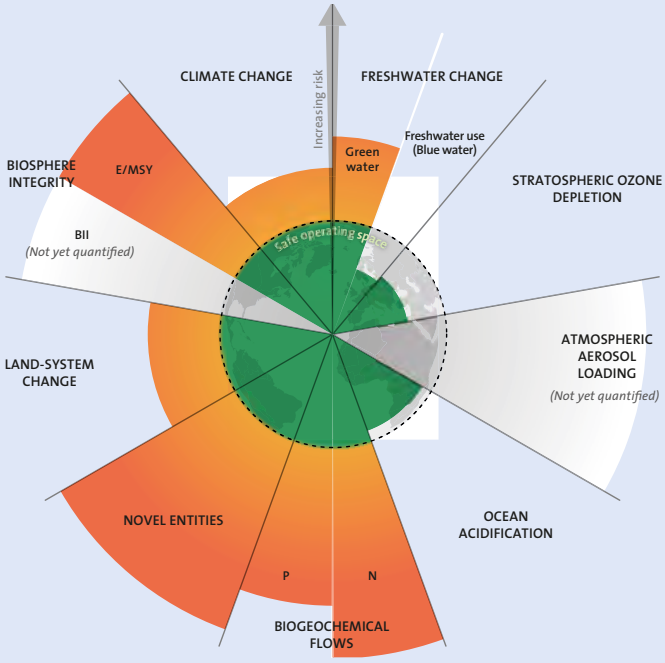



*Figure 1: The planetary boundary concept showing the status of nine processes, concerning the safe boundary, specified by the inner green circle (1).*

## Key-enabling water technology innovations are needed

Technology and society have become increasingly productive with the downside of resource and ecosystem service depletion, leading to progressive environmental degradation. Ultimately, enabling technology and good practices are key elements for resolving an imbalance between societal behaviour and what the natural environment can offer. There is a clear and present need for breakthrough technology that cares both about intrinsically reducing our negative impacts like resource depletion and about enabling a productive, competitive economy for sustainable societies.

Water will play a central role in the pathways for keeping society and economies within the boundaries of the earth's carrying capacity. Strategically placed efforts on water technology innovation will contribute to a sustainable relationship between society and the environment by integrating sustainable water use into society, intrinsically protecting water resources.

Water technology contributes to this by enabling large-scale and knowledge-intensive (process technological) solutions for water sourcing, treatment, products and services, circularity, energy, climate control, storage, and transport.

## Breakthrough Innovations are multi-stakeholder undertakings

Breakthrough innovations need to be developed to scales that are commercially self-supporting, creating benefits that society can enjoy. Innovations that make a difference are achieved by creative scientists in an interplay with public water authorities, technology companies and end-users who are all anchored in the real world. Time and again, it has been shown that the implementation of research results can take surprising and innovative directions that stakeholders and inventors are best suited to explore and discover together. Risks, real or perceived, for implementation of breakthroughs that bridge the so-called "valley of death", require active involvement from all stakeholders. The earlier the collective involvement, the better the chances are to mitigate risk, and to capture opportunity.

## Our mission

From this context, Wetsus has defined its purpose as follows:

Wetsus develops key-enabling water technology to foster a sustainable and fair society, in a healthy and circular environment.

To achieve this, Wetsus creates an innovation community via trust-based networks of companies, universities, and public bodies for generating, testing, and evolving innovative ideas and science based approaches within interdisciplinary Ph.D. programs that shape innovations all the way towards fruitful implementation, and where graduates become leaders in sustainable innovation.


*Figure 2: Enabling water technology enables industries to keep on producing (economic value) without depleting water resources, while regenerating the environment. The development of such technology gives the water tech industry involved a competitive edge. Wetsus focuses on four impact areas where novel technology is expected to generate the biggest benefits, namely sustainable water, healthy environment, recovered resources and drought resilience.*

## Program Strategy

Wetsus' purpose is to create enabling water technologies that allow for societal value creation while supporting and regenerating a sustainable world. Figure 2 shows an overview of the benefits of enabling water technology (to be created in the Wetsus program) for water-dependent industry, technology suppliers and environmental regeneration.

Water is of prominent importance to our economy. The World Economic Forum has listed water scarcity for eight consecutive years as a top-five global risk for a prosperous economy. Water dependency in combination with growing scarcity, makes enabling water technology a must-have to run a productive economy. Industries that require water of good quality need enabling water technology to be productive and competitive as these technologies no longer rely on scarce water resources and help regenerate the industry's environment. Water tech companies providing enabling water technology will be leading in the highly competitive 150 billion dollar world market of water technology.

To create this novel enabling technology, Wetsus organizes a research program together with water-dependent industry, water supplying industry, water tech providers, water management organizations and knowledge institutes. To accommodate a) the wide diversity and nature of the sustainability challenges, b) the diversity of stakeholders involved and c) the wide scope of water technology, the research program is organized along the following four lines:

1. Sustainable Water
2. Healthy Environment
3. Recovered Resources
4. Drought Resilience (green water)

All four lines have in common that the water tech industry will be able to gain international

competitiveness as new tech concepts are developed that can be applied and exported worldwide. This strongly increases the **competitiveness of the water tech companies**, involved especially the water tech SMEs.

Research opportunities are identified through involvement of all stakeholders. This creates unique opportunities for research and promotes scientific cutting-edge contributions and new discoveries. In this way all program lines promote **scientific progress**.

These lines will be further introduced below and the more specific involvement of and benefits for our different stakeholders will be addressed. In Chapter 4.

## Sustainable Water

This research line contributes to reducing the use of chemicals to ensure sufficient and safe water by aiming for chemical free and natural treatment. Water access is vital for citizens, industries, and agriculture to support health and quality of life, with stable economic security. Sustainable sourcing aims at securing the right water quality in sufficient quantity within the boundaries (Figure 1) and avoiding negative impact on ecosystem services. In this cluster, the focus is on creating new purification processes in the water chain that do not consume chemicals, by using natural systems in combination with biological, physical and chemical conversions and smart purification techniques. In this way sufficient water is made available to society without depleting resources and damaging health and ecosystems. Access to innovative technology, methods, and ideas for a sustainable freshwater cycle is a crucial lifeline for many industries to stay on top. Staying connected to progress in sustainable water cycle advancements is a ticket to produce today and stay in the game even better tomorrow. Some examples of progressive developments of sourcing water include low energy production of fresh water from saline water, PFAS, water reclamation.

## Healthy Environment

Water treatment processes are crucial to protect our health and our environment. Integrity of pipes is also essential for safe drinking water and safe treatment of polluted water. To guarantee reliability of these protective functions, real time monitoring and control is of the utmost importance. Artificial intelligence allows interpretation of a new level of data generation enabled by advanced sensor development. The size and data complexity (including genomics data) provides the basis for artificial intelligence to improve predictability of the processes with respect to a healthy environment. Substances that still can be discharged as contaminants with "cleaned" water, carry the risk to negatively impact environment and human health sooner or later. Examples of contaminants include antibiotics that promote pathogen resistance, hazardous chemicals such as fluorinated tensides (PFAS), priority pollutants like pesticides, and pathogens such as viruses, just to name a few. Management of hazardous substances in water (prevention, removal, conversion, destruction) contributes to preserving ecosystem services, and sustained quality of life. Furthermore, easy cost-effective measurement methods and tools to detect such substances, for development of novel management technologies and "just" for routine monitoring remains an area that demands progress.

## Recovered Resources

This research line contributes to the ambition to enable the recovery of, among others, polymers, macro- and micronutrients, energy and metals from diluted water and waste flows. In this way water treatment enables a truly circular economy. Ecosystem services are under stress because of mining of raw materials. Materials and energy can also be mined from contaminated water streams, and in so doing, treatment can contribute to reducing impacts through a circularity in societal supply of renewable resources. Water mining includes technologies to deliver biodegradable biopolymers for chemical and bioplastics industries, to recover nutrients for agriculture (materials), and/or to yield platform chemicals and fuels like hydrogen or methane. Circularity from recovery creates regional economic flows in the form of products and services. It also avoids potential for environmental damage due to mitigated mining and refining of fossil supplies for resources. For instance, ammonia recovered from wastewater supplies fertilizer of value and it also saves water treatment costs while avoiding fossil energy consumption needed to produce ammonia via the Haber-Bosch process.

## Drought resilience

By developing technological concepts for restoring water cycles and degraded lands this program lines contributes to restoring the balance in the water cycle. This is becoming increasingly important for the Netherlands and even more in the rest of the world. Our focus will be developing new concepts that rely on the combination of water technologies with predictive sciences such as meteorology. Technology that facilitates suitable water supply can be used for restoring degraded land or for protecting the organic matter in peat areas. Water technology can also advance completely new ecosystem services.

## Impact Strategy

To generate the maximum impact from the research program, Wetsus opts for an open innovation strategy within a high trust network. A high trust network, where partnerships are built on a foundation of trust, enables faster development of breakthrough technology. Partners are connected for longer terms, resulting in strong relations and enough trust to share ideas and knowhow for effective cooperation.

Open innovation makes it possible to efficiently propagate ideas and to innovate. It improves the profitability of innovation as costs are shared, while the prospective benefits of breakthrough innovations are huge. An SME, especially, cannot typically bear the financial costs of extensive infrastructure and resources with in-house R&D on high-risk ideas. Wetsus addresses this problem since, at the same time, SMEs are genuinely the key players in water tech innovations.

The open innovation strategy, including blue sky research, is devised with real-world applications in mind, leading to intense cooperation and to sustainable relationships between all stakeholders.

Public-private coupling as organised in the Wetsus program, as the interplay between knowledge institutes, businesses, private individuals, and governments, is needed to effectively develop, launch and implement enabling water technology.

Our impact strategy can be described as both a multi-step and a multi-partner approach towards the goal of positive impact on the trajectory of societal-environment interplay. The impact strategy, as schematically depicted in Figure 3, starts at the inception and selection of strategic opportunities and ideas. Further steps lead progressively, with determination, to the target of a positive impact with increasingly sustainable relationships between society and the environment and an increase in sales and investments in every next step.

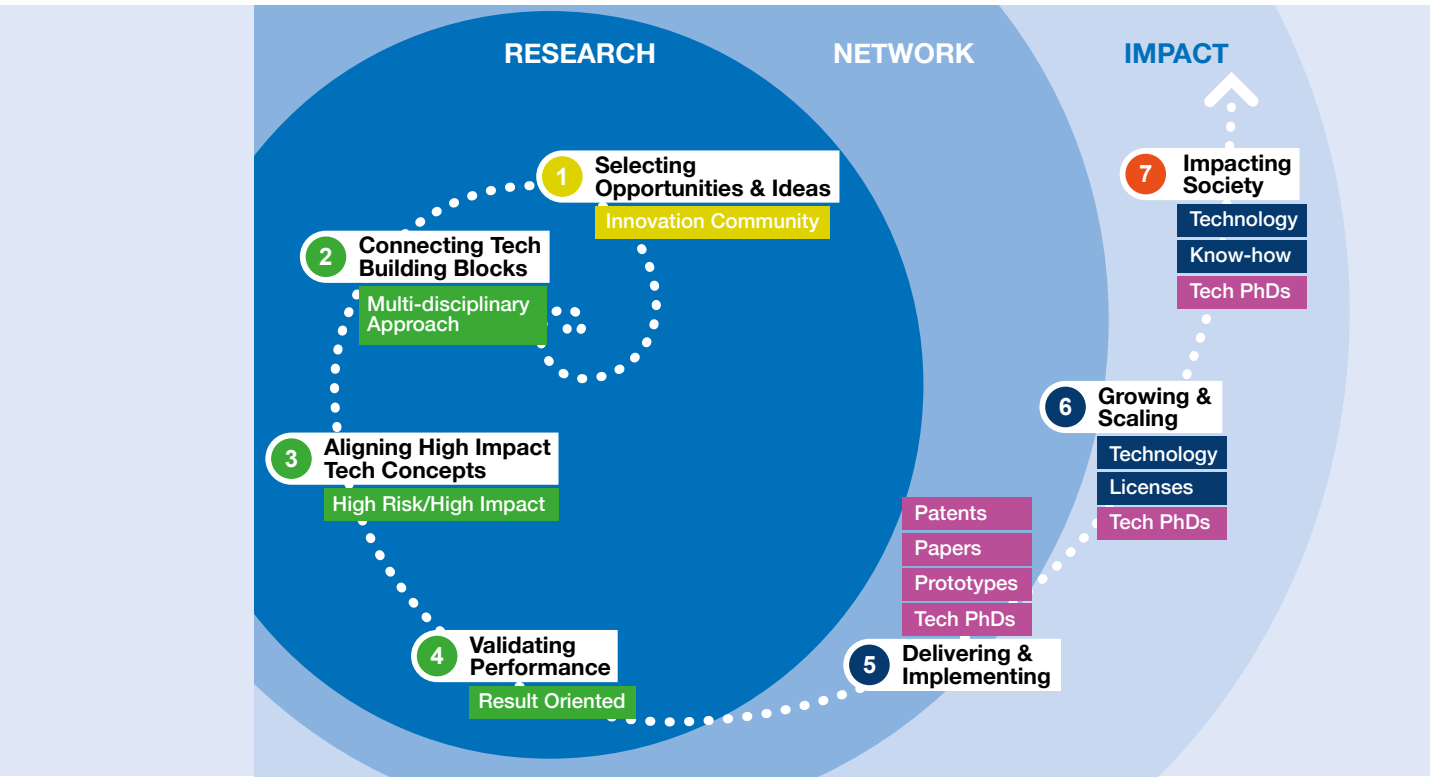



*Figure 3: The innovation impact strategy of Wetsus. Steps 1-7 of this Innovation Spiral describe the evolution of ideas to real-world contributions, resulting in meaningful societal impact. The dark blue circle demarks the steps taken within the Wetsus research program, and the adjoining lighter blue areas extend the steps to the efforts of implementation through the wider Wetsus network. At each step multiple stakeholders in the network are actively engaged. The green boxes at 5,6,7, indicate the outcomes of the Wetsus research program, contributing to generating impact in the network and the outside world. The primary outcomes are patents, papers, prototypes and the graduated Tech PhD's with the added skill to connect science to innovation. The Wetsus program (step 1-4) is in many cases still connected to step 5-7.*

Success in meeting societal challenges depends critically on **(1) selecting opportunities and connecting with novel ideas from science**. The Wetsus network with social and commercial actors and universities united in a trusted network is well-placed to identify, modulate, and select unique blue sky pairs of opportunities and ideas from a well of potential scientific proposals. Wetsus will generate new research ideas, which will be selected based upon impact and risk. The generation of blue sky ideas is the source of the total program.

Innovations in Water Tech can very well be speeded up by **(2) connecting scientific disciplines to create new technological building blocks**. Scientific disciplines, notably unconventional ones, and emerging technologies will be connected transdisciplinary. These links of opportunity are embraced within the Wetsus research program. Interdisciplinary research and a day-to-day working environment that fosters these connections, are crucial for innovations that reach, by their nature, outside and across conventional disciplinary boundaries. Trans- and multidisciplinarity are key for Wetsus.

**(3) Aligning the technology building blocks to concepts for high-impact outcomes** is the next step in the strategy. Scientists are challenged to further develop and optimize these new research opportunities. This alignment is a process where many viewpoints are required. Not only scientific and engineering perspectives are needed but also additional practical perspectives, including but not limited to the market potential for the idea or for spin-off applications. High-risk topics are often those that also have the most scope in opportunity for the most profound of impacts - the real game-changers.

**(4) Validating the performance of the high-impact concepts** addresses whether or not technology can give the intended or required output. This output can often not be caught by one simple number, like in the case of health or environmental damage. Water technology developments can often be characterized by a complicated matrix and mix of technical, social and economic considerations. There can be trade-offs, such as in the case of UV treatment technology. UV irradiation can be applied to degrade pharmaceutical contaminants in water, and this could be a simple performance metric of efficacy. However, one needs to account for a risk of toxicity from the reaction by-products. End-users and public water authorities have the most experience to share in this field. Validation is a crucial step from which to assess the potential of the idea to grow into a breakthrough innovation while holding sights for both chances of side risks and unforeseen side benefits. Insight in this validation gives unique opportunities for new scientific insights in the principles and is a source for new ideas for technology building blocks and creation of high-impact outcomes.

**The first four steps** captured in the big blue circle of Figure 3 constitute the core activities within the Wetsus research program. Wetsus chooses for PhD research programs to advance science connected to innovative ideas. This inherently brings forward waves of young, highly skilled, and intrinsically motivated individuals to drive sustainability innovations in roles as leaders, drivers and doers, designated in Figure 3 as Tech PhD's. The research is performed within the richness of international experience from a dynamic multidisciplinary central research laboratory in Leeuwarden, fostering the exchange and synergy of cross-pollination between the flows of individuals and ideas. The outcomes of the program take the form of new scientific knowledge embodied in methods and processes, disseminated ultimately in the form of peer-reviewed scientific publications. These deliverables are the basis for evolving impact.

Stakeholders, public and private, can further develop competitive technology implementation. The network is already in place to help influence regulatory frameworks and to reach out in their respective networks for broader support for **(5) necessary steps of industrialization commercially and community benefits**. The Wetsus program creates all outcomes in conjunction with one and another. This coupling gives additional robustness to the outcomes, and that strengthens the chances and collective vested interest for successful technology developments further and wider afield. Patents are an important instrument to secure and protect already vested interest. IP is also often necessary to attract financial support bringing innovations to real-world reference cases that can lead to return on investment. Within the high-trust Wetsus network, the effects of spin-off companies and mutual investments are furthermore encouraged and expected.

Tech companies and end-users are involved in growing the technology via **(6) scaling and first commercial reference applications**. In this phase, a lot of tacit know-how is built up that is needed for **(7) reaching out internationally in applications.** End-users and suppliers of the technology are the driving force here to spin the value chain to the global market. In many cases, Wetsus research projects are still connected to steps 5,6,7 creating many opportunities for new scientific insights on the research side and optimization and trouble-shooting on the industrial side.

# Innovation strategy

## Water Tech Definition

Water technology can be defined as the technologies and processes that change the quality of water, to meet certain demands, mostly via removal or conversion of certain compounds. A wide array of materials, energy and organisms is present in the water as a complex mixture of for example salts, heavy metals, toxic substances, nutrients, organic matter, heat, bacteria, viruses, genetic information etc. This diversity in compounds makes that multiple mechanisms need to be employed for detection and treatment. Any successful water technology consists of multiple building blocks from different technology families.

Innovation thus can start from a wide array of scientific disciplines. This makes it hard to make a narrow disciplinary definition of water technology as it encompasses many disciplines on the one hand and many applications in many industries on the other hand. This is the reason why Wetsus aligns multiple scientific disciplines with stakeholders and missions with its Innovation Spiral as described in the previous Chapter. As outlined there, science plays a crucial role in all steps of the innovation cycle. In this Chapter we will focus on the role of science in the research program.

Innovation, as organized via our vision on impact from innovation, starts with identifying the right opportunities and ideas. As science aims at creating new knowledge and ideas, it is the natural partner to look for ideas to create successful innovation. Science is by nature infinite, so it is **crucial to make choices both in disciplines and research topics**, to maximize the effectiveness of the program. Such choices evolve over time as insights advance during research and innovation, the program needs to be able to accommodate these dynamics. Scientific disciplines active within the Wetsus program can be clustered in **three key groups, (1) basic science and key technologies, (2) engineering science, and (3) environmental science**. It is one of the unique characteristics of the Wetsus program that these three fields are brought together to effectively progress technology development (see Figure 4).

## Wetsus Integrated Research Program

Any successful water technology consists of multiple technological building blocks from different technology families. For instance a single water treatment plant is made up of all kind of connected processes, like chemical (e.g., P-precipitation), biological (e.g., biogas formation), and physical (e.g., particle removal). For good operation, crucial processes are monitored and controlled. A first way of innovating is thus via developing new technological building blocks.

Given the diversity of the processes, control and materials, new opportunities can come from a wide array of scientific disciplines or key enabling technologies. To give a few examples: insight in the microbiology of extracellular storage of polymers by bacteria has led to technology that transforms organic material into renewable platform chemicals for industry; selective passage of water through membrane leads to the production of freshwater from seawater via RO; RNA fingerprinting techniques can be used to steer drinking water operation and have effective quality control.

Defining and creating new building blocks based on blue sky ideas is thus a first strategy for high impact as it leads to innovation potential for a broad class of innovations within the field of water technology. Engaging unconventional science disciplines (i.e., unconventional with respect to water technology) to create new building blocks lies at the start of the innovation strategy of Wetsus.

A new building block is in itself not a technology; translation of it into in technological concept is a prerequisite for success. An additional strategy for innovation is to develop new high-impact/ highrisk technological concepts enabled by the new building blocks. Combining the strategy of new building blocks with technology development greatly increases the innovation speed and reduces risk of reaching dead ends. Information obtained from technology development can be used iteratively to foster the development of the new building block and vice versa. For instance, better selective ion exchange membranes can lead to improved performance in desalination by electrodialysis, however, also new high impact high-risk technologies, like energy production by reverse electrodialysis, can be developed. Developing such high-risk/high-impact concepts requires the combination of engineering sciences with the sciences involved in developing building blocks (which can also be engineering sciences).

Validating and prototyping under (simulated) real-world conditions is crucial for application in the complex world of water technology. Wetsus aims at rapid prototyping to assess the assumption underlying any tech development. This validation is crucial to make a case for a technology in relation to the expected impact. For instance operation on RED with sea water has led to the insight of the importance of bivalent ions for RED performance, and also gave rise to new scientific models and insights. Such insights derived from the technology application can subsequently be used to steer the development of selective membranes.

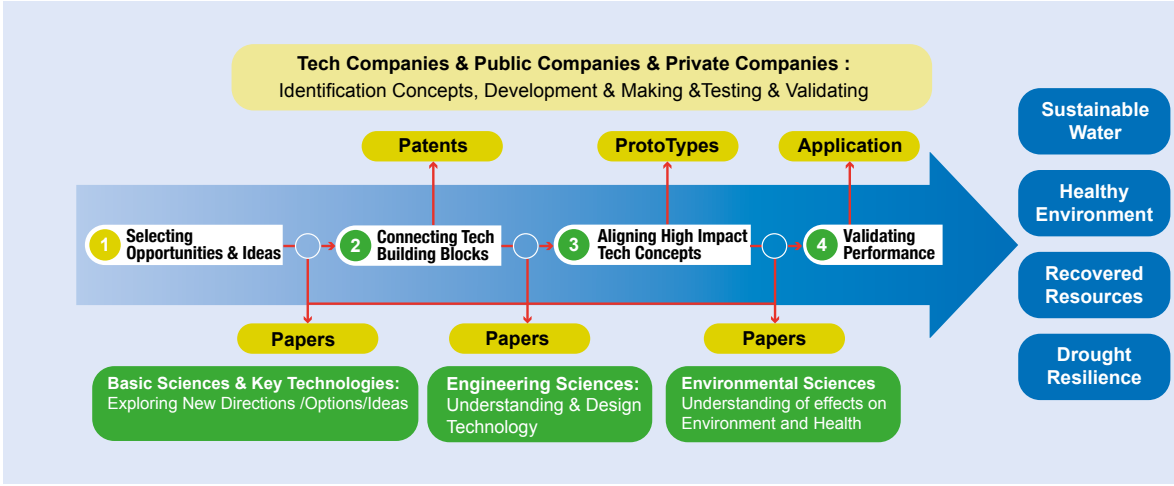



*Figure 4: Multidisciplinary multistep approach of technology development within the Wetsus program. The blue arrow is the Wetsus innovation route. Outcomes of each step feed the subsequent steps. However, to create maximal innovation speed, projects are running part of the time in parallel. This enables the maximum exchange of knowledge and ideas.*

This broad array of technological building blocks and development steps shows that many science fields are potential contributors to innovation. Roughly four types of sciences are relevant to the Wetsus program: Basic Sciences, Engineering Sciences, Key Technologies, and Environmental Sciences.

- Basic sciences are (more classical) discipline-oriented and try to advance the discipline in unravelling the truth, and advances result from changes in ideas and methods. Technological developments, e.g., electron microscopy, often drive scientific methods.
- Engineering science is more aiming at developing technologies, using scientific knowledge and methods. Specific engineering science often has a strong bond with a specific basic science, e.g., chemical engineering and chemistry.
- Key technologies, like photonics and genomics, are selected emerging technologies that are developed on the interface of basic science and engineering science.
- Environmental science aims to understand the complexity of the environment and study environmental quality using scientific methods and knowledge. Technology plays an important role in gathering data, like satellites, but it is underestimated as the basis of new technological concepts.

Given the unequivocal definition of the water tech field and the wide array of potential contributors, it becomes clear that as of practical considerations, not all scientific disciplines can be connected to the Wetsus program. It is important to create an effective disciplinary portfolio.

## Wetsus Disciplinary Portfolio

Within the water tech field, the number of possible scientific projects is countless because many disciplines can contribute due to the wide impact of water tech on sustainability, as expressed by the program lines. Especially as there are many disciplines not yet connected to the water sector that can create even more opportunities. On one hand innovation therefore requires a broad portfolio of disciplines to create a maximal number of options, but on the other hand achieving scientific quality asks for a focused attention. It is expected that science not only contributes to innovation but that the Innovation Spiral leads to unique opportunities for scientific advancement for the different disciplines. Creating such a focused portfolio with maximum impact is a delicate process that requires leadership from all stakeholders, since the water tech field itself cannot unequivocally be defined.

Innovation explores unknown territories and thus comes with a high risk of failure, but also with potential for unexpected outcomes of unforeseen opportunities that can become future gamechangers. Innovations are in that respect very demanding, and to be successful in the competitive international scientific world, the use of top-notch science is therefore essential. A certain critical mass of a discipline within the Wetsus program is required to operate at and expand the state of the art. This critical mass is necessary to reach world-leading innovations. Only then can the maximum potential be obtained from the interdisciplinary research.

In the search for the Wetsus strategic niche in the water tech field, considering the research/know how of university labs and research/experience at companies, the following choices are made:

1. **Innovation within a mono discipline active in the water field is not sought for.** Universities are far better equipped to do this in-house.

2. **Relevant disciplines that have no link to the water field can become connected to water technology via the Wetsus program.** In this way, new input to the water tech field can be realized through Wetsus. By a state-of-the-art Water Tech lab and a core of tacit in-house expertise, new connections to other disciplines become possible. This synergy of crosspollination is considered less likely to achieve for any given single project at an academic or commercial group's lab without connection to the Wetsus program.

3. **Bringing disciplines together, and seeing interconnected opportunities, is at the basis of innovations for new building blocks.** Wetsus tries to make new combinations, and connecting the dots of knowledge in couplings for opportunities, that are not yet seen, foreseen or existing in practice. By performing the research at a single location focused on the same challenge, gives the highest chance of fruitful exchange towards recognizing new perspectives. To make the research focused on the water tech building blocks, in many cases at least one of the disciplines is active in the field of water tech engineering. Environmental Sciences are conventionally more concerned with the validation of technology, but in the Wetsus program, the ambition is to combine engineering sciences and environmental sciences to create a platform that can pollinate new approaches.

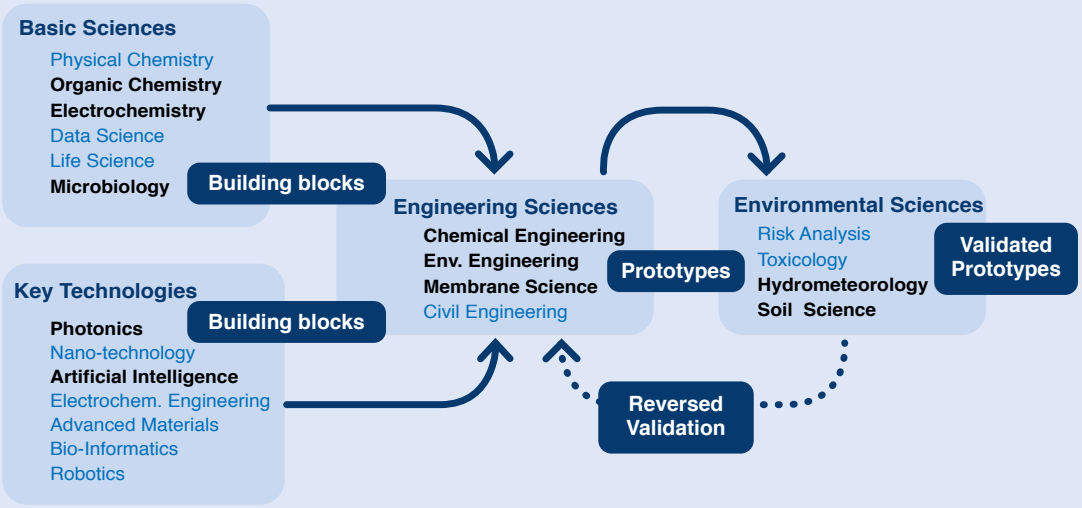



*Figure 5: Disciplines with sufficient critical mass (black) and associated disciplines (blue). The arrows indicate the flow of knowledge and insight between the different disciplines. The Figure shows the middle position of the engineering science, to maximise the speed of the innovation pathway. The role of environmental sciences will be strengthened in our coming 10 year program, by better integration with new technological concepts*

The pre-selection of (high-potential blue sky) disciplines is a crucial decision, shaping the program. This is necessary as the extent of the program is determined by financial means and workability of the organizational concept. The organizational resources allow a disciplinary portfolio limited to ten disciplines with a critical mass of researchers associated with a specific discipline. We believe that with this selection the program remains internationally leading in the water tech field.

Figure 5 shows all disciplines (blue & black) that are contributing to the broad field of water technology, this is based on insights derived from bibliometric analysis and experience, together with an assessment of the Dutch government on key enabling technologies. Figure 5 summarizes the selection of the fields for the next 10 years.

To structure the contribution and selection of disciplines, we first consider the **engineering disciplines** as the centre step (3) of the development process. Engineering sciences are par excellence equipped to connect new building blocks into new high impact concepts and able to translate the experiences derived from early prototyping. At the centre are therefore broad engineering disciplines that are well connected to multiple basic sciences and not the more specialized engineering disciplines. Based on the track record of the different engineering disciplines, it can be said that *(bio)Chemical engineering, Environmental engineering and*

*Membrane Technology* form the central engineering disciplines.

Engineering disciplines are by nature well connected to more **basic disciplines**. For instance chemical engineering is well connected to physical chemistry as physical chemistry is required to study mass transfer processes. The required physical chemistry enters thus in the slipstream of chemical engineering. Physical chemistry is also connected through other engineering fields in the program, e.g., crystallization processes via environmental engineering. Choosing well connected engineering yields a broad coverage of more basic science fields.

This still implies, that basic disciplines need to be connected if (1) they are not yet connected, or (2) that in a connected discipline a scientific innovation has taken place, e.g., genomics as it revolutionizes microbiology. Based on this the following suit of basic science disciplines has been selected: *Genomics & Microbiology, Organic Chemistry, and Electrochemistry.* Furthermore, the key technologies of Photonics and AI are expected to contribute to the development of new building blocks.

**Environmental Science disciplines** are typically involved in validating the performance, assessing if the proposed technology brings, in environmental terms, what it is expected to bring. To innovate we focus within Wetsus on: (1) new type of emissions like antibiotic resistance, and (2) we propose to use reverse validation, i.e., the environmental sciences are used to steer technology development such that an environmental gain is reached, thus moving from protection, to enhancement of the ecosystem, or in other words from reducing loss to enhancing ecosystem services. By involving environmental sciences in this way the science itself can shift from a more observant mode to a more pro-active science. Especially *Soil Science and Hydrometeorology* will be involved in this way. For validation also other disciplines can contribute notably, Microbiology/Genomics, Photonics and AI.

## Need for Long Term Program Support

As explained, it is the alignment of different scientific disciplines (Figure 4) that yields new technological concepts that can lead to breakthrough innovations. Connecting new blue-sky research into the Wetsus impact spiral, in cooperation with 130 scientific, public and private partners needs more time than the four years of a PhD project. To make this process more effective and increase the innovation speed, different disciplinary projects need to be operated next to each other. This makes that a maximal exchange of insights is possible. All this makes the scope of the program a long-term program that needs to be operated at a single location. As an example, assume there is basic discipline, e.g., organic chemistry that starts delivering a material that selectively adsorbs virus materials. To make a meaningful technological concept one also needs then to start up a membrane technology project that uses the material to develop a point-of-use application. However, validating whether such technology actually reduces the virus load and the disease load, is a complex question, one also needs genomics and photonics projects to assess the virus loads. All these projects needs be operated quasi-parallel to give an integrated effective development of a validated prototype (Figure 5). This will take more than the duration of one PhD project and thus long-term funding and stakeholder involvement is required.

# 4. Wetus Network, Research & Organization

## The Wetsus Trust-Based Open Innovation Community

The role of the Wetsus institute in the water technology sector is the organization of an innovation community in which companies and universities have a unique opportunity to manage and cooperate in a research program aimed at breakthrough innovations, and thereby co-shaping pioneering research projects and training of future leaders needed for research and implementation of the resulting innovations.

An institute like Wetsus is essential for the leadership of such a community. Wetsus drives at creating a trust-based environment that works, with openness and a shared objective, towards innovation, going beyond short-term objectives. This leadership can only work if it is valued and trusted by leading professors and, in a different way, by technology companies as well as end users, because all groups have different working practices and objectives. The scientific staff of Wetsus is crucial in shaping this leadership.

The Wetsus research program is divided into some 20 research themes and the participant network is built around these themes, which are co-steered by Wetsus and the associated companies and professors. The themes function as an innovation community, yielding maximum value for solving societal challenges while creating economic competitiveness for companies and scientific advances for universities. Such a community based on pioneering science can bring about innovations that are not only economically sensible, but also contribute towards long term sustainability goals. Figure 6 shows the characteristics of such an open innovation community, to which the Wetsus leadership strives together with its partners. The research themes do this via pre-selecting topics from the large field of research disciplines that are within the water tech domain and align these topics and research opportunities into a strategic program.

Partners, all with their specific knowledge of and experience with the relevant content, context and values, come together and develop a shared focus. Different partners in the value chain will bring forward their unique perspective: knowledge institutes and universities bring the science perspective; private end-users bring their perspective on economic value and markets; public endusers bring the public value context; and technology companies bring their innovation and commercial strength. The shared focus and partnership result in a long-term perspective and pioneering research program. Within the program, projects will not be limited by disciplines, and progress will be monitored by the community, which values multiple aspects, including peer review and commercial and societal value. In this way meaningful progress is accelerated.

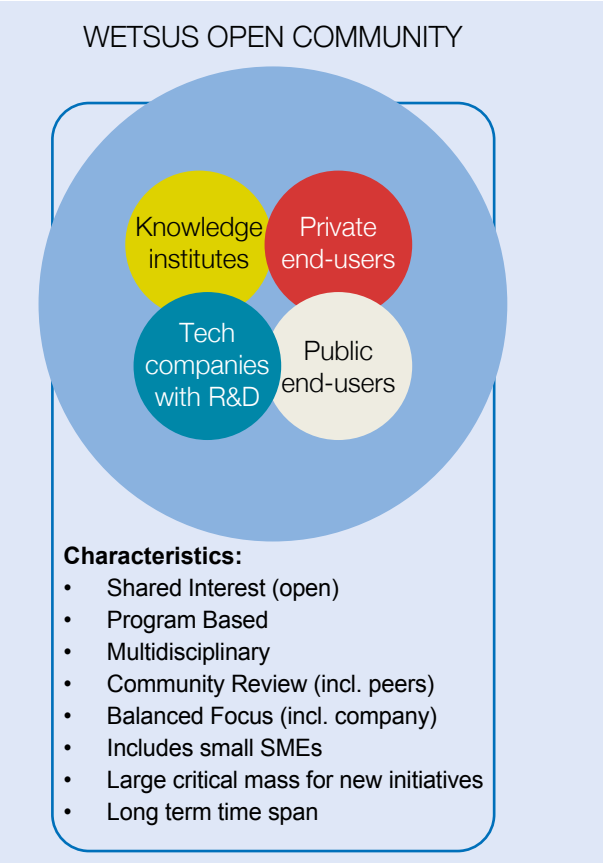



*Figure 6: Characteristics of the Wetsus open innovation community*

### Trust based network

Characteristic of the Wetsus community is its considerate attitude and investment in trust. A trust-based network relies on three elements, Reputation, Integrity, and Benevolence.

- Reputation: as the required knowledge involved is often complex, it is important that partners are available with a high reputation and experience, to trust the knowledge exchanged;
- Integrity: as the exchange of knowledge may lead to newly created value, integrity is of importance. Partners must feel assured that their interests are taken into account.

- Benevolence: knowledge is only exchanged in an atmosphere of goodwill, if there is a propensity to share.

To strengthen trust, we create an organizational framework that stimulates benevolence and integrity. Separate research themes and a clear IP structure are at the foundation of this framework The clear IP rules enhance integrity, while the long-term commitment of partners enhances an attitude of benevolence. Reputation is enhanced by seeking partners with a good reputation, both knowledge and business partners.

## Theme structure and participation forms

The Wetsus network is open. Companies and universities can become participant in one or more of the approximately 20 research themes in which the overall Wetsus program is divided into. The current themes are depicted in Figure 7. Each research theme is centred around (a) certain (group of) topics which define the theme research program. These topics are prioritized by the theme companies and should fall within the framework of the overall Wetsus research program as described before. Typically, a theme has around four to six member companies, and two to three universities connected to it, so cooperation is essential.

Companies are contractually connected to a theme with a running commitment for an initial period of at least four years. *Theme participant companies* pay a cash annual fee e.g. for 2020 (€ 29.000/theme/year and € 17.500 theme/year for companies with a turnover less than € 3 million per year) to co-finance the research and in return they obtain voting rights on the theme research projects and they have the right of first refusal on all theme IP developed.

Further, a *platform membership* with network function is available for companies e.g. for 2020 (annual fees ranging from € 3.400 to € 11.500, subject to annual turnover). Platform participants have no voting rights on the research program and only indirect access to the intellectual property of Wetsus.

The actual research in Wetsus is performed by the *know-how institute participants* who second their PhD researchers in the Wetsus program. Leading universities from all over Europe are invited to enter into long term participation agreements with Wetsus for this purpose.

## Intellectual Property

Clear appointments, applicable to all participants in the network, are conditional to create trust and sharing of ideas and know-how. To foster this, Wetsus has developed a dedicated IPR policy, containing working appointments about confidentiality, publications and ownership and valorization of know-how. A research theme can be considered to be an Intellectual Property (IP) cluster. At least three times a year the research themes meet to discuss progress, identifying potential patents, and discuss and decide on new project ideas. Any new patent is offered for transfer first to the companies in the theme where the IP originates from. If none of the theme companies is interested, the patent is offered to all other company members of Wetsus. Connected knowhow institutes can publish research results, can use the developed know-how for education and research purposes and can profit from successful valorisation of the patents they facilitated.

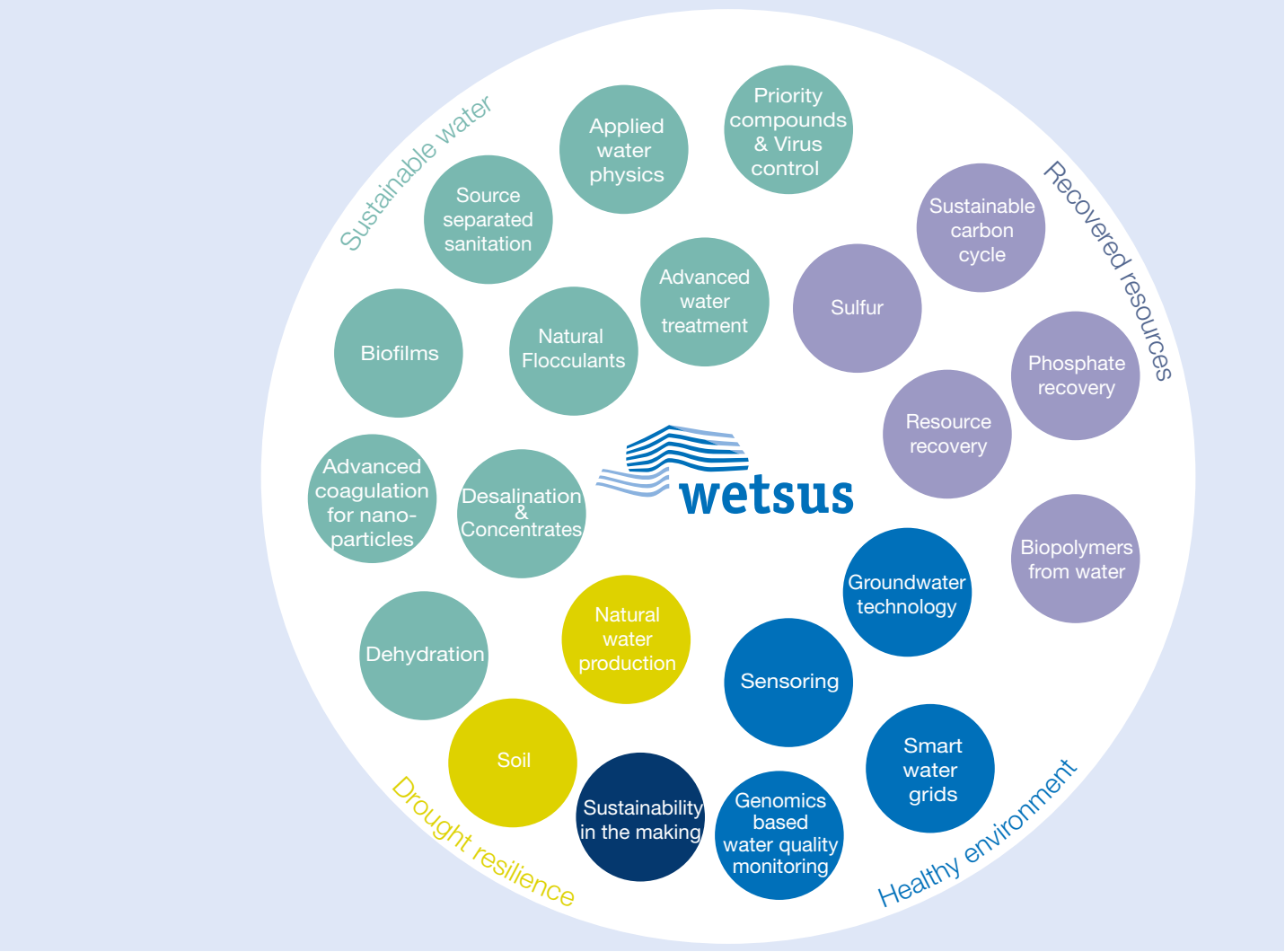



*Figure 7: This overview shows the themes that are part of the current research programs. Every year one or two new themes start, while also some stop. The sustainability in the making theme (Water Innovations Uptake) is a cross-cutting theme through the whole of the Wetsus reserach program. In this way innovation is stimulated. More information on the specific themes can be found in the brochure Research Program 2022, that is made available.*

## Added Value of the Wetsus Community

Wetsus defines the following benefits for members participating in the Wetsus open innovation community:

1. Tacit knowledge mobilized
2. A multidisciplinary environment is created
3. A long-term research program starting from blue sky projects
4. An accessible community for open innovation
5. Mission-based continuous programming
6. Consortia formation and end-user engagement
7. International visibility
8. Training of Future Leaders in sustainable water technology
9. Enabling crossovers

### Tacit knowledge mobilized

An important element of the Wetsus innovation community is that also other sources of knowledge, such as tacit knowledge, are easier mobilized because of the involvement of the different partners in Wetsus. To transfer tacit knowledge, defined here as non-teachable knowledge (Figure 8), as opposite to teachable knowledge, intimacy and trust are prerequisites.

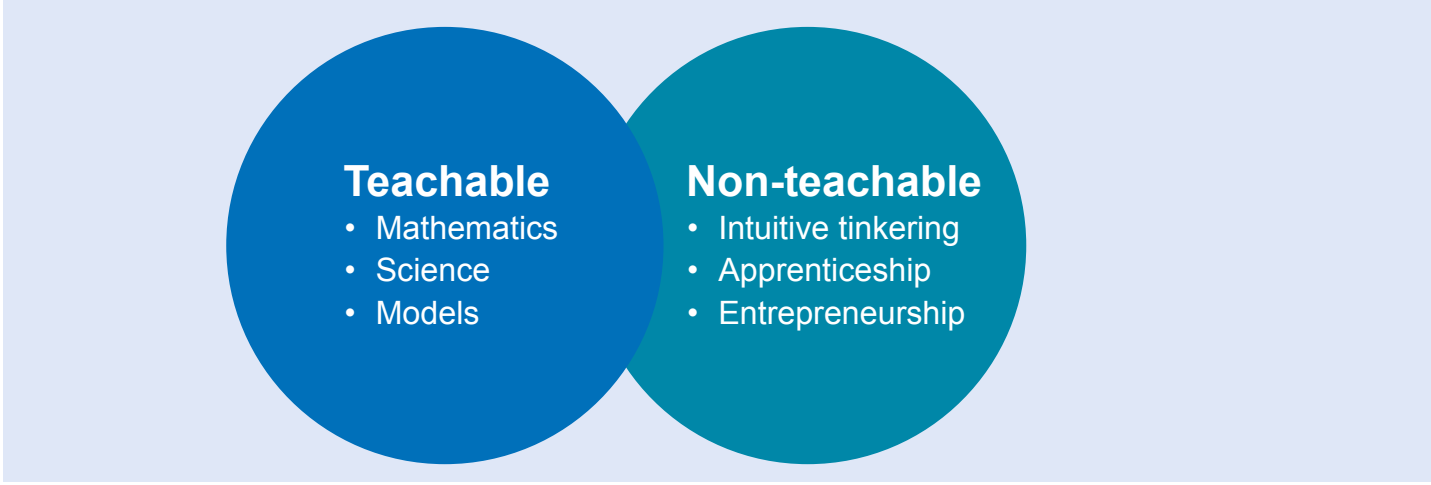



*Figure 8. Two types of knowledge: Teachable and Non-teachable or tacit knowledge.*

It is because of this fusing of teachable and non-teachable knowledge that patents and spin-off activities originate more frequently at Wetsus, relative to other research groups in this field. Strengthening only either one class of knowledge will not result in the outcomes of the Wetsus program. Instead, we combine the transmission of teachable knowledge (research) and nonteachable knowledge (entrepreneurial programs). This approach has the potential to achieve excellence in innovation, characterized by a very high innovation efficiency per euro invested. The efficiency of the Wetsus programs translates in a high patent transfer rate as well as in a high number of spin-off companies.

## A multidisciplinary environment is created

In the Wetsus laboratories, PhD students from 50 research groups work side by side. PhD students not only have easy access to their promotors' research group, but also to the knowledge made available by the PhD students who are supervised by other groups. This exchange is supported by the Wetsus scientific staff that has itself a wide disciplinary background. The broad mix of easily accessible disciplines at Wetsus has been described in Chapter 3.

## A long-term research program starting from blue sky projects

Wetsus allows to have blue-sky PhD projects with a high-risk/high-gain profile, because risks are shared by a large community and the multidisciplinary approach of Wetsus ensures a higher chance for success as defined by innovation efficiency. As projects are based on the perspective of stakeholders in the value chain, meaningful new blue-sky topics are initiated regularly. Progress is monitored at least three times per year by companies participating in the particular theme.

## An accessible community for open innovation

A disadvantage for small companies is that the cost of an open innovation network can be prohibitively high. However, by joining Wetsus, these costs are shared in a very cost-effective way, enabling a truly open innovation network with some 50% SME participation. Also, for larger companies the Wetsus community is a cost-effective method to expand their network. Especially the presence of many small innovative companies is of great interest to them. The openness of the Wetsus community has led to a connection of small SMEs to university research that was impossible before. The Wetsus research theme structure gives small companies the same influence as large companies, increasing their interest to participate. The cost-effective network allows innovators to find partners that can use their innovation, but who are outside the traditional water technology value chain. Furthermore, clear IP rules that are proven to be effective, are in place, which takes away a major hurdle for companies to join open innovation.

## Mission based continuous programming

As the companies form a theme and have a "rolling" commitment (their participation can only be terminated with a four-year delay), every theme organizes its long-term program that is defined by a certain mission. These missions can be framed in terms of either a technical or societal objective and will fall within the Dutch and EU missions. As there is a broad range of actors present in a theme and the focus is on pioneering research, there is no chance that research will be duplicated that is already done at universities. Also, because the companies make an annual cash contribution, they are very eager to prevent overlap.

## Consortia formation and end-user engagement

Since the interests of companies are complementary in many cases, new business consortia or joint ventures develop from Wetsus, like the REDstack Blue Energy initiative. Research themes grow in time with complementary partners. In many cases these companies become business partners in new consortia. For instance, REDstack was until recently owned by the Wetsus participants W&F technologies, A. HAK and Alliander. Vitens provides an example of end-user engagement. They tested a novel anti-scalant for which the exact dosing was made possible because of a model developed within the Wetsus program. Next to consortia formed around technology developed in a theme, Wetsus also functions as a broker to set up new consortia of companies and research institutes around research ideas and business opportunities. This broker role is made possible through the high trust network.

## International visibility

Water technology in The Netherlands was until recently not seen as a separate science field. It was divided on the one hand between civil engineering, biotechnology, membrane science and some other disciplines, and on the other hand between sectors, including municipal, chemical, food, and the paper sectors. In Wetsus the relevant disciplines and sectors have found each other in a joint research program. In The Netherlands, the Wetsus community clearly put water technology on the agenda. This has created new light on the sector internationally and increases the reputation of The Netherlands in this field significantly.

## Training of Future Leaders in sustainable water technology

Organizing a PhD training in the Wetsus innovation community gives a unique opportunity to shape future leaders, needed to enable sustainable innovations to flourish and develop in the long run. Therefore, Wetsus has devised a tailored training program for their PhD students, with elements like communication, talents, values, entrepreneurship, and intervision (Figure 9). The PhD student has unique access to multidisciplinary knowledge and equipment and is in close contact with business ideas, visions and opportunities. On top of the Wetsus training program, the PhD students seconded at Wetsus are also supported by the relevant integrated training programs offered by several Dutch graduate schools.


*Figure 9: Unique elements of the learning environment of Wetsus PhD students.*

## Enabling crossovers

Many industries and public sectors depend on water technology. Quite often these parties are like isolated worlds, each of them regularly re-inventing the wheel, leading to less innovation efficiency and less optimal solutions. Wetsus is a natural place for different industry sectors to join forces in water technology. Wetsus labelled this as 'enabling water technology'.

# The Organization of the Research Progress

At the core of the Wetsus innovation network lies the PhD program. To maximize results and quality, the organization of the PhD program is aligned according to the diagram shown in Figure 10. The PhD program can be imagined to be a continuous flow of PhD projects, each a unique combination of an idea/objective and a PhD-student/talent. A large part of the success of a project depends on selecting the best ideas

and the best talents. Once a project starts it receives much input to help the project progress and flourish. On the one hand these are “visible inputs” such as supervision, company interest, and research facilities, on the other hand there are less tangible factors including procedures, culture and personal growth. Although these factors are more elusive to define, they are essential for any organization, and especially for a knowledge-generating organization as Wetsus.

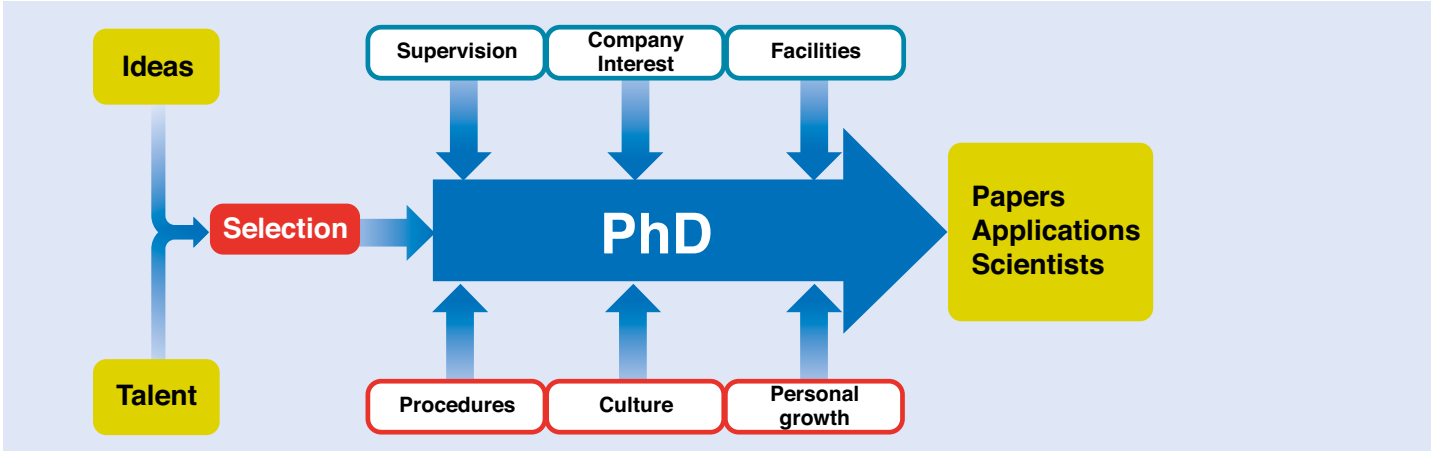



*Figure 10: Process flow model of the Wetsus PhD program. On the left, the main inputs in the PhD-program, being ideas and talent, are selected. On the right the main outputs of the program, being trained scientists, scientific papers and technological applications evolve. In between is the PhD-program that is supported by several factors, including supervision, company interest and facilities (top), and less tangible inputs, including procedures, culture and personal growth (bottom).*

## Idea selection

The projects are defined and discussed within the themes between companies, universities and the theme coordinator. The companies prioritize and choose which projects are to be supported. Projects need to have a strategic fit with the Wetsus vison, and this fit is assessed by the executive board. Within the Wetsus innovation strategy two types of projects can be distinguished: blue-sky and Impact-driven. Blue-sky projects aim at realizing technological breakthroughs that have the potential to alter the technological landscape (e.g., early MFC research that promised to make anaerobic digestion obsolete). Impact-driven projects aim at substantial improvements of existing technology, e.g., a 50% reduction of the energy demand of sea water desalination. Wetsus cherishes blue-sky projects and aims that of all projects at least 50% belong to this category. Project proposals are reviewed by the program council, consisting of independent senior researchers. All proposals are evaluated according to the following three criteria: Innovation Potential, Scientific Quality, and Team Composition. As each type of project has its own characteristics, the yardstick by which to assess each criterion might differ. In case of a negative review, the proposal requires adjustment. Withdrawal may follow if the adjustment is judged insufficient. The functioning of the Program Council has been re-evaluated recently, and new members have been appointed. The evaluation and the new guidelines are available as additional document.

## PhD researcher selection

Recruiting the right candidate for a particular PhD-position is crucial because the quality of the research population is the foremost important factor influencing the reputation of Wetsus. Recruitment is currently based on the WaterSeed procedure, developed by Wetsus. WaterSeed is a European Horizon 2020 program awarded to Wetsus, to promote student mobility between EU countries. Recruitment of all research positions is organized in two or three annual calls with 6-15 positions. The response, on average 65 per position, is a 10-fold increase compared to earlier years, reflecting the increased reputation and credibility of Wetsus. The candidates go through a four-step procedure with as last step a visit to Wetsus for a challenge session. During all these steps, Wetsus staff is assisted by university supervisors. On average 3% of the candidates makes it to the challenge, and during each challenge approximately two-thirds of the open positions are filled.

## University & Wetsus supervision

Wetsus PhD students receive supervision both from Wetsus and from their university. This dual supervision is needed because of the geographical location of Leeuwarden, quite remote from most universities. The advantage is, however, a more multidisciplinary supervision because of the involvement of a university and a Wetsus supervisor, both with their own expertise. For the university it is attractive to supervise Wetsus PhD researchers for several reasons: the

multidisciplinary environment, expansion of their research portfolio, and access to a large network which helps to increase their reputation. The number of daily supervisors at Wetsus and the coverage of disciplines is increasing every year.

## Company involvement

During theme meetings and contacts outside these meetings, PhD researchers and their supervisor receive frequent feedback. Especially the feedback reflecting the company's perspective broadens the relevance of the research. PhD researchers may even be seconded at companies for some period to intensify the collaboration and accelerate progress.

## Facilities

State-of-the-art facilities are made available to the PhD researchers. These facilities are available at the Wetsus multidisciplinary laboratory in Leeuwarden (Appendix E). For highly specialized equipment also the laboratories of the connected universities can be used.

## Culture & Values

The Wetsus organization has a culture that is value-based. These values make it possible to have an organization where only the truly essential issues are efficiently regulated (safety, legal, HRM, etc.) and where there is a maximum of flexibility to maximize talents and energy. The values of Wetsus are Innovation, Partnership, Joy, Cooperation and Reliability, all described in Table 1. The values have been defined and translated into more specific working appointments by the Wetsus staff. The values and working appointments are described in more detail in our booklet "Vision and Values". At the start of their employment, all new employees of Wetsus, including the PhD researchers, formally declare that they will act in accordance with these values.

*Table 1: Wetsus values and their description*

| | |
|---|---|
| **Innovation** | searching actively for and the development of trendsetting technological innovations which are applicable to society |
| **Partnership** | focusing on inspiring relationships with our partners in order to create an effective network |
| **Joy** | creating a pleasant working atmosphere in which colleagues can grow professionally and personally |
| **Cooperation** | supporting and respecting each other in an open and safe environment |
| **Reliability** | our ability to keep promises and providing declared standards |

## Procedures

As described before, the Wetsus organization is value-based and this enables simplification of the procedures for idea selection to get the flexibility needed to achieve innovation. Selection of projects is based on iterative improvements of proposed ideas, see Figure 11.

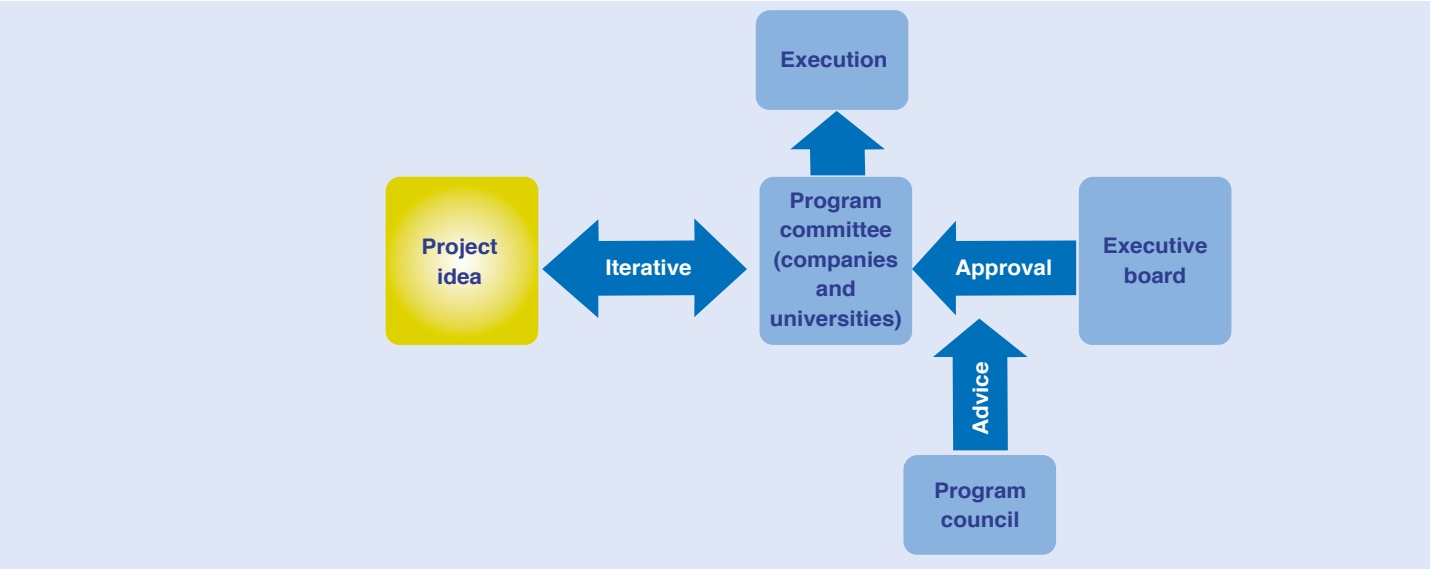



*Figure 11: Procedure for idea selection for PhD research*

## Personal Growth

As mentioned earlier, a dedicated PhD training program has been set up. This program is additional to the training provided to the PhD students from the different research schools, and focuses on "soft skills" and covers the full PhD research period.

# The Organization of the Facilitating Organization

## Legal form and management

Wetsus is a not-for-profit foundation, managed by a two-person executive board, prof.dr.ir. Cees Buisman and Johannes Boonstra. Given their respective expertise, they form a highly complementary team. The Wetsus supervisory board consists of four members, appointed by company participants, four members appointed by knowledge institutes and two independent members, the chair and vice-chair.

## Organization of research program

Wetsus' international research program is coordinated by a multidisciplinary team of Wetsus scientists. The research is mainly performed by PhD students, employed and supervised by the participating knowledge institutes. These researchers are typically full time seconded in the Wetsus organization. The PhD students work in Wetsus' multidisciplinary laboratory on WaterCampus Leeuwarden, where a multidisciplinary team of scientists takes care of their day-to-day supervision. In the Wetsus lab, dedicated analysts and technicians ensure the 24/7 availability of world class research facilities for the research program. Wetsus employs staff to manage and facilitate the execution of the research program and to perform the activities in the fields of education and entrepreneurship. In addition, a small staff team ensures dedicated support and control functions (Figure 12).

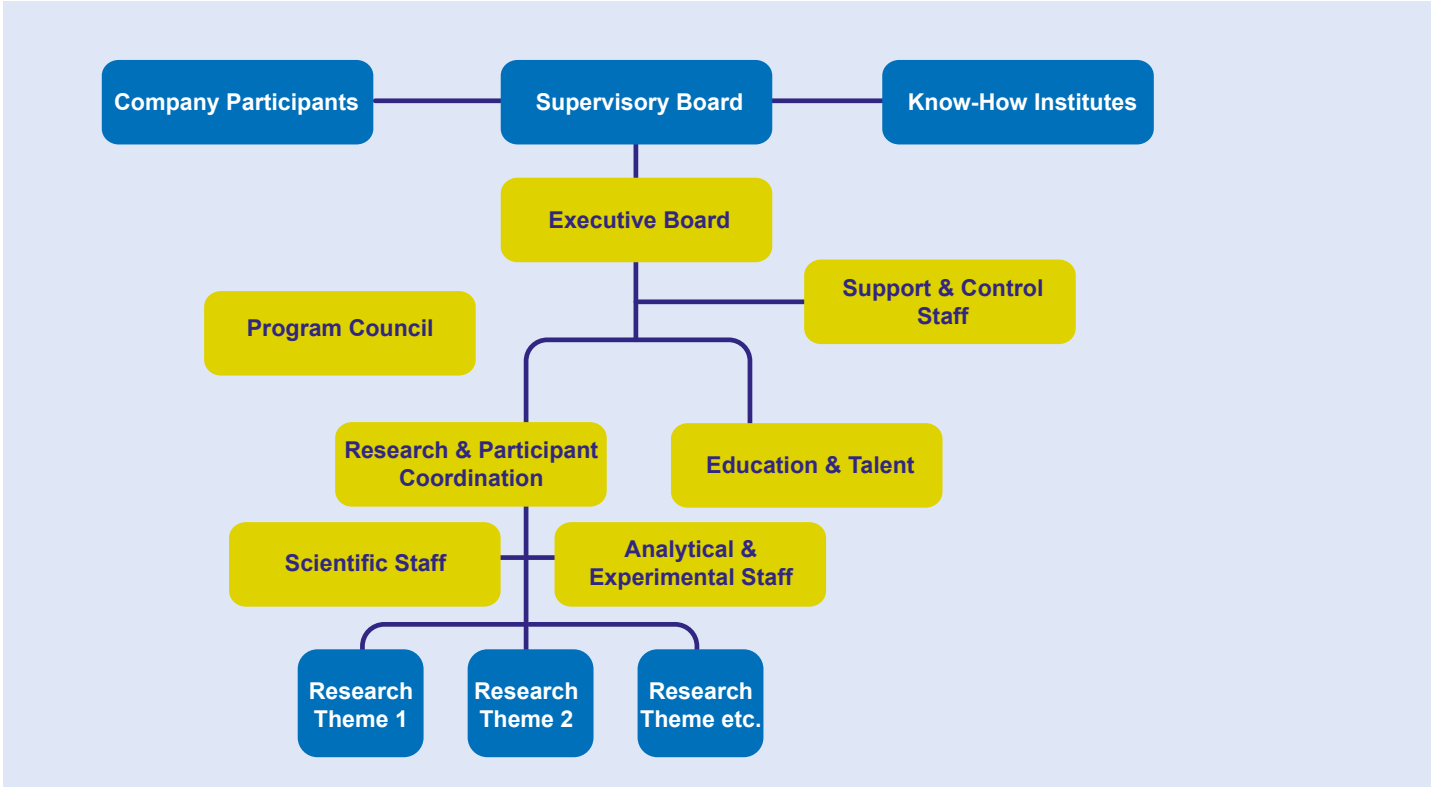



*Figure 12: Organization of Wetsus and its program. The blue areas are directly influenced by the Wetsus participants*

## Facilitation of network

In order to stay in close contact with its participants, other important stakeholders, and society, Wetsus puts significant effort in facilitating the network and communicating with the world at large:

- Wetsus organizes its annual international external congress for a target audience of companies, governments, universities and research institutes. One day is dedicated to strategic issues in the water sector, and one day to the latest scientific developments in water technology. This external congress is also open for non-participants.
- The Wetsus annual internal congress is meant for participants only and gives an in-depth view of the latest developments in the Wetsus research program.
- Each research theme meets three times a year. In principle, all themes meet on the same day, in Leeuwarden. By meeting at

the same day at one location, interaction between different themes, companies and universities is facilitated.

- Once a year, jointly with one of the theme meetings, the so-called workshops are organized. These workshops aim at exploring new business opportunities in relation to technology, e.g., patents are presented to interested company participants.
- Wetsus aims to organize, at least once a year, international scientific conferences together with scientific co-organizers, like the European Desalination Society (EDS), Interfaces against Pollution (IAP) or European Federation of Chemical Engineering (EFCE).
- All Wetsus scientists have regular contact with participating companies.
- General and program developments are communicated by means of newsletters, website, brochures, annual reports, etc.
- Relevant technological developments for society are broadly communicated through newspapers, television, internet, social media, dedicated magazines, etc.
- Scientific results are communicated through workshops, conferences, publications in international peer reviewed journals, patents, etc.

Obviously, a confidentiality policy is in place for discussion about classified business and scientific information between the partners that together constitute the Wetsus network.

# 5. Evidence and Accomplishments

## Wetsus' overall key performance indicators

For impact to occur, it is essential that many conditions are in place, e.g., there should be a societal need, a good idea, motivated and experienced people, finance, and a supporting context, to name some. Wetsus thus needs to excel in several areas but always in a balanced way. Wetsus has therefore identified a set of performance indicators that reflect the most critical aspects and criteria of the Wetsus ecosystem. The idea behind this approach is that all the key performance indicators taken together provide a representative **status of the whole ecosystem**. In line with the SEP, the strategic indicators Wetsus defined structure the presentation and discussion of evidence and accomplishments.

The key performance indicators are thus not individual objectives to be maximized, e.g., one could put much effort into writing many papers at the expense of innovating with spin-offs. This would give great science numbers but less impact on society. Vice versa, one could put much effort into spin-offs and pay little attention to science, leading to incremental improvements but not to breakthrough science and innovations.

The indicators must thus be judged in their totality so that KPIs can be considered an indicator of the Wetsus ecosystem health. The KPI selection of the current business plan is leading, reflecting a stronger emphasis on impact and innovation than before.

The KPIs are shown in Table 2 and arranged into five groups, finance, science progress, competitiveness, innovation community, and future innovation leaders. The accomplishments will be discussed under these headings. The KPIs are the starting point; further data and analysis will be supplied where needed. As Wetsus is part of the Dutch science landscape, the data will be put context of that landscape. Data sources are indicated by abbreviations and further explained in Appendix A.

*Table 2: KPI target Table period 2017-2022. Leading in this table are the indicators as defined in the Business Plan 2021-2032. Most indicators were also present in the previous Business Plan 2016-2020 and could be easily merged. This table represents thus the targets set in the previous (2016-2020) and the current Business Plan 2021-2032. The KPIs unique to the Business Plan 2021-2032 are discussed in the Chapter 6 on viability.*

| Wetsus KPI Targets | cumulative results 2004-2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|
| Finance | | | | | | | |
| Total Wetsus Budget (mln €) | | 15.5 | 15.6 | 15.3 | 15.4 | 14.4 | 14.5 |
| Company Contribution (mln €) | | 3.3 | 3.4 | 3.4 | 3.5 | 3.4 | 3.5 |
| Science Progress | | | | | | | |
| Science projects started (PhD/postdoc) (cumulative) | 197 | 9 | 24 | 39 | 56 | 69 | 82 |
| Papers total (cumulative) | 505 | 55 | 110 | 165 | 220 | 283 | 327 |
| Citation impact (-1y) | | very high | very high | very high | very high | very high | very high |
| Competitiveness | | | | | | | |
| Number of spin-off companies (cumulative) | 28 | 2 | 3 | 5 | 7 | 9 | 10 |
| Number of patents generated (cumulative) | 79 | 3 | 6 | 9 | 11 | 14 | 16 |
| Number of patents transferred (cumulative) | 30 | 4 | 7 | 11 | 15 | 16 | 18 |
| Innovation Community | | | | | | | |
| Number of participating companies (active) | | 109 | 111 | 113 | 115 | 106 | 107 |
| Number of principle investigators and professors (cumulative) | | 54 | 55 | 56 | 57 | 52 | 53 |
| Future Innovation Leaders | | | | | | | |
| Ph.D. Graduates (cumulative) | 76 | 7 | 22 | 32 | 44 | 57 | 71 |
| Research Students (non-PhD) (cumulative) | 491 | 80 | 160 | 240 | 320 | 385 | 485 |

# Finance and personnel

## Funding

Table 3 shows that the Wetsus budget has fluctuated slightly between € 14.3 and 15.3 million per year. This fluctuation is mainly due to external project funding like EU projects. Overall, the realized budget over the six-years period is in line with what was anticipated in the business plan (98%). The company cash contribution was well in line with the targets, illustrating the continuous commitment of companies to Wetsus, despite the funding uncertainty described below.

*Table 3: Financial indicators*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | % Realised |
|---|---|---|---|---|---|---|---|
| Total Wetsus Budget (mln €) | 14.5 | 14.9 | 15.3 | 14.3 | 14.8 | 14.9 | 98% |
| Company Contribution (mln €) | 3.3 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 100% |

It should be noted that in 2020, a long-term government financing scheme expired that was needed for the facilitating organization & research infrastructure, the so-called core funding. Unfortunately, a new long-term funding solution for those means could not be secured until early 2023, leading to a period of financial insecurity. For the Wetsus program to continue in that period, the funding gap was solved via so-called bridging financing from the Dutch Science Foundation (NWO) and the Ministry of Economic Affairs (EZK) for 2021 and 2022. However, financial uncertainty for the years after 2023 remained. As a consequence, budget had to be

reserved for future obligations, which has put a strain on starting new projects, resulting in a temporary shrinking of the program. From 2022 onwards, with the funding secured until 2034, the program size is rapidly increasing again.

## Personnel

Figure 13 shows the development of different personnel categories over time. The period 2017-2019 saw a slight increase in personnel size, due to the growth of the Ph.D. program. After 2019 there was a drop in personnel to accommodate a stricter budget, achieved by starting fewer Ph.D. projects, not filling all positions when people left, and sharing scientists with other knowledge institutes.

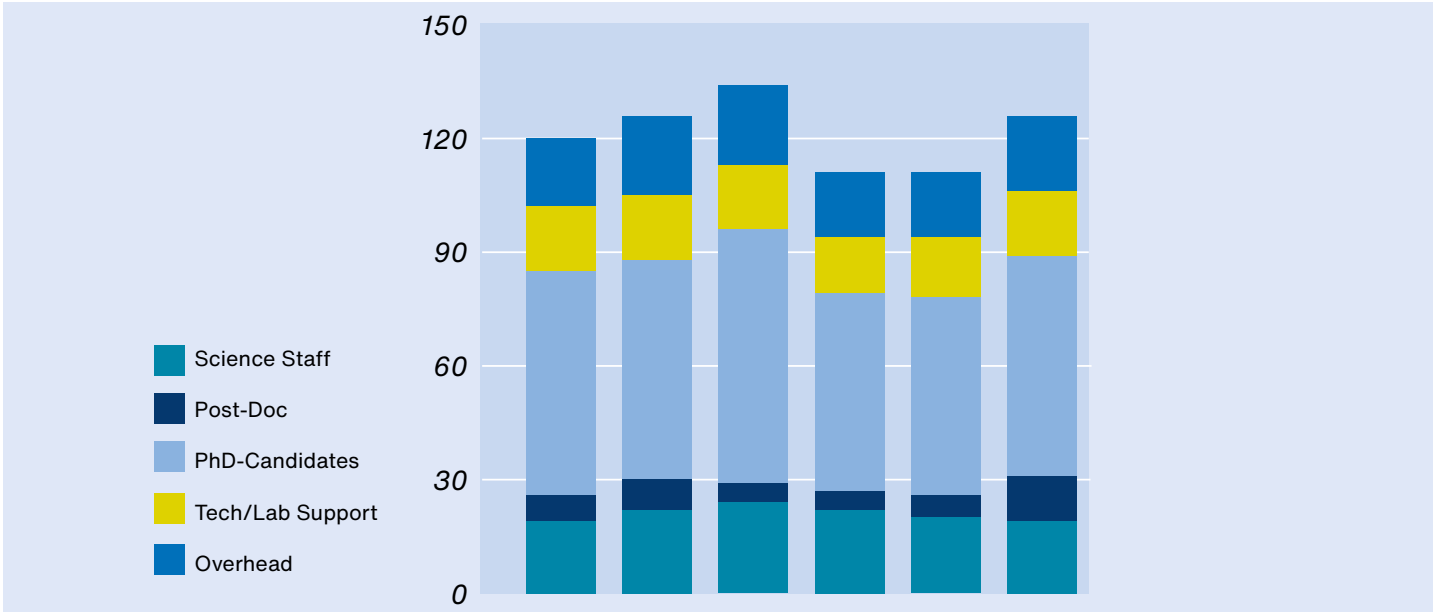



*Figure 13: Development of various categories personnel over the years. Specific definitions are given in Appendix B.*

In 2022, as the financial future became apparent, the personnel size increased again, mainly due to the number of new Ph.D. projects. The development of the Ph.D. program is discussed in more detail in the next section.

The gender distribution at Wetsus is shown in Table 4. For Wetsus, the F\M distribution seems to have nearly reached parity. For Ph.D.-candidates, it is above 50%, while for the science staff, this number is lower. Mind that personnel groups have been merged to make the data more meaningful and comparable to the Rathenau data on Dutch universities. The main difference compared to Dutch universities is that the percentage of women is higher for the Ph.D.-candidates at Wetsus. This translates into a higher rate for Wetsus overall. Just as at universities, there is a lower percentage of women among the science staff. As analysed by the Rathenau Institute, this discrepancy will dissolve as for future vacancies more well-trained graduated female scientists are available.

*Table 4: Fraction of female employees for different function categories at Wetsus compared to university groups in similar research areas (agriculture/technology & life science). The data were based for Wetsus on the 2022 situation as earlier data were strongly influenced by the funding uncertainty. The data for similar groups were based on the most recent 2021 data. (RAT)*

| | Wetsus | University |
|---|---|---|
| Science Staff | 32% | 28% |
| PhD-Candidates | 57% | 42% |
| Support | 48% | 55% |
| Total | 47% | 42% |

# Research Quality

Research is at the heart of creating impact; the vision of Wetsus is that innovative science in a multidisciplinary setting working on relevant topics is the basis for a maximum likelihood for societal impact.

Table 5 shows the realization of the Wetsus science progress KPIs.

The first indicator is the number of science projects started. This indicator is composed of: (1) Ph.D. projects that are defined and executed within the Wetsus themes and (2) post-doc projects from primarily European funds.

The second indicator is the number of papers published in peer-reviewed journals. This number is the primary outcome of research and serves as a (partial) measure of scientific productivity. The number of papers also serves as a proxy for measuring the progress of the Ph.D. projects. As a rule of thumb, for a Ph.D. thesis in the Netherlands, one needs to have an output work equivalent to four high-quality papers. This work should preferably already be published or at least accepted at the time of the thesis defence.

The third indicator is the relative impact of the papers (RI). Based on the citations garnered by the papers published, a measure of the impact of the papers can be calculated. The citations are counted and compared to the world average for the two main fields. The choice of fields was identified in an earlier bibliometric analysis. All data, citations, and world averages are retrieved from the Web of Science. The highest ranking is acquired if this RI is above or equal to 1.5. This methodology was state-of- the-art during the previous audit and is yearly used by Wetsus as it is a method that can be performed in house and gives a parameter to track scientific quality. Nowadays more sophisticated methods are used, but however are not freely available.

Table 5 shows that KPIs for papers and projects are higher than projected. The citation impact remains all the time (100%) very high, i.e. >1.5.

*Table 5: Realization of the Wetsus Science Progress KPIs.*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | % Realised |
|---|---|---|---|---|---|---|---|
| Science projects started (PhD/ postdoc) (cumulative) | 17 | 34 | 50 | 56 | 71 | 101 | 123% |
| Papers total (cumulative) | 64 | 129 | 198 | 264 | 335 | 395 | 121% |
| Citation impact (-1y) | 2.4 | 2.7 | 2.7 | 2.6 | 1.8 | 3 | 100% |

We compare the performance to the previous audit period. It should be noted that the bibliometric analysis period lags two years behind. This lag period is needed to generate citations; thus, the papers from the 2015-2020/21 period are considered for this audit period, while the previous period was 2010-2014/15.

## Science projects

Overall Wetsus has realized a higher number of projects than anticipated by the KPIs. Figure 14 shows the number of yearly started new Ph.D. projects, indicating that after three stable years (2017-2019), the inflow in 2020 and 2021, was reduced due to the unclarity about the long-term funding. In 2022 more projects started again as the long-term funding outlook was sufficiently established and secured. Furthermore, Wetsus was highly successful in obtaining EU grants allowing the start of new post-doc projects, boosting the total number of science projects.

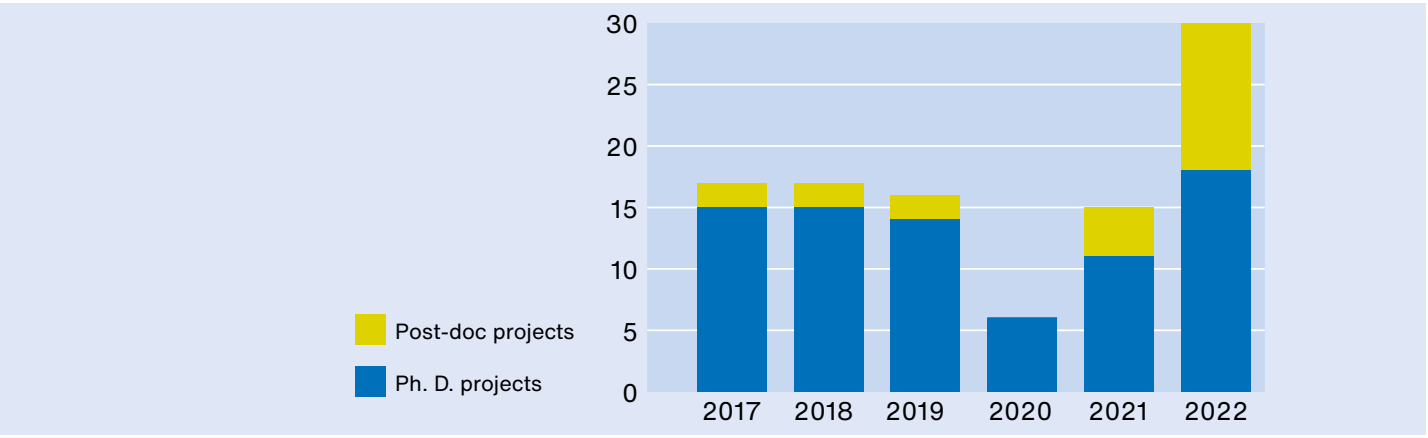



*Figure 14: New Ph.D. and post-doc projects started in time. The dip starting in 2020 is caused by insecurity in the long-term funding for which reservations had to be made.*

Although the science projects overall are above expectation, the number of Ph.D. projects started is lower, while the number of post-doc projects was above expectation. Obviously, this will have consequences for the number of graduations in the near future. This will be discussed in the section on future innovation leaders.

## Multidisciplinarity

Wetsus wants to connect basic disciplines, validating disciplines together with engineering sciences. In this way, new scientific developments can be rapidly taken up for technological innovations.

These scientific developments are introduced into the program via the universities. Table 6 shows the names, universities and disciplines of all professors and PI associated with Wetsus during the audit period.

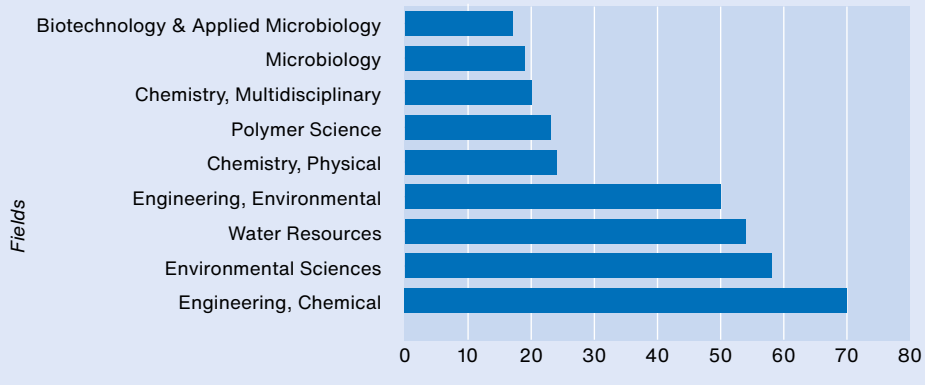
*Table 6: Overview of all 65 professors and PI's associated to the Wetsus research program during the audit period.*

| | | |
|---|---|---|
| Prof. dr. ir. T. Ertl | Univ. Vienna | Basic Science |
| Prof.dr.ir. J. van der Gucht | WUR | Basic Science |
| Prof.dr. J. Herek | UT | Basic Science |
| Prof.dr.ir. K. Keesman | WUR | Basic Science |
| Prof.dr.ir. C.R. Kleijn | TU Delft | Basic Science |
| Prof.dr.ir. W. Loiskandl | BOKU Wien | Basic Science |
| Prof. dr. ir. G. Pemen | TU/e | Basic Science |
| Prof.dr.ir. M. de Rooij | UT | Basic Science |
| Prof.dr. P.J. Stuyfzand | TU Delft | Basic Science |
| Prof.dr. E. Sudholter | TU Delft | Basic Science |
| Prof.dr.ir. L. van Vliet | TU Delft | Basic Science |
| Prof.dr.ir. J. Woisetschaeger | TU Graz | Basic Science |
| Prof. dr. J.T. Zuilhof | WUR | Basic Science |
| Prof.dr.ir. M. Alves | Univ. Minho | BioTechnology |
| Prof.dr.ir. R.H. Wijffels | WUR | BioTechnology |
| Prof.dr.ir. R. Lammertink | UT | Chemical Engineering |
| Dr.ing. Z. Borneman | TUE | Chemical Engineering |
| Prof.dr. A. Cipollina | Univ. Palermo | Chemical Engineering |
| Prof.dr. S.R.A. Kersten | UT | Chemical Engineering |
| Dr.ir. S. Lindhoud | UT | Chemical Engineering |
| Prof.dr.ir. D.C. Nijmeijer | TU/e | Chemical Engineering |
| Prof.dr.ir. E. Roesink | UT | Chemical Engineering |
| Prof.dr.ir. W.M. de Vos | UT | Chemical Engineering |
| Prof.dr. G.J. Witkamp | TU Delft | Chemical Engineering |
| Prof.dr.ir. C.J.N. Buisman | WUR | Environmental Engineering |
| Prof.dr. N. Graham | Imperial College | Environmental Engineering |
| Prof. dr.ir. B. Hamelers | WUR | Environmental Engineering |
| Dr.ir. A. ter Heijne | WUR | Environmental Engineering |
| Prof.dr.ir. A.J.H. Janssen | WUR | Environmental Engineering |
| Prof.dr. M. Kennedy | TU Delft | Environmental Engineering |
| Dr.ir. R. Kleerebezem | TU Delft | Environmental Engineering |
| Prof.dr.ir. M.C.M. van Loosdrecht | TU Delft | Environmental Engineering |
| Prof.dr.ir. W.G.J. van der Meer | UT | Environmental Engineering |
| Prof.dr.ir. I. Nopens | Univ. Gent | Environmental Engineering |
| Prof.dr.ir. L. Rietveld | TU Delft | Environmental Engineering |
| Prof.dr.ir. H.M.M. Rijnaarts | WUR | Environmental Engineering |
| Prof.dr. A.R.D. Verliefde | Univ. Gent | Environmental Engineering |
| Prof.dr.ir. A. van der Wal | WUR | Environmental Engineering |

| | | |
|---|---|---|
| Prof.dr.ir. G. Zeeman | WUR | Environmental Engineering |
| Prof.dr.ir. R.M. Boom | WUR | Food Technology |
| Prof.dr.ir. C.G.P.H. Schroën | UT | Food Technology |
| Prof.dr.ir. T. Tinga | UT | Key Technology |
| Prof.dr.ir. R. Akkerman | UT | Key Technology |
| Prof.dr.ir. M. Claessens | UT | Key Technology |
| Prof.dr.ing. P.J.M. Havinga | UT | Key Technology |
| Prof.dr. F.G. Mugele | UT | Key Technology |
| Prof. dr.ir. H. Offerhaus | UT | Key Technology |
| Prof.dr. F. Picchioni | RUG | Key Technology |
| Prof.dr. A. Velders | WUR | Key Technology |
| Prof.dr.ir. N. Boon | Univ. Gent | Microbiology |
| Prof.dr. M. Dopson | Univ. Sweden | Microbiology |
| Prof.dr. G. Euverink | RUG | Microbiology |
| Prof.dr. A. Friedrich | RUG | Microbiology |
| Prof.dr. K.J. Hellingwerf | UvA | Microbiology |
| Prof.dr. J. Huisman | UvA | Microbiology |
| Prof.dr. J. Kok | RUG | Microbiology |
| Prof.dr. H.C. van der Mei | UMCG | Microbiology |
| Prof.dr. G. Muyzer | UvA | Microbiology |
| Prof.dr.ir. A.J.M. Stams | WUR | Microbiology |
| Prof.dr.ir. W. Verstraete | Univ. Gent | Microbiology |
| Prof.dr.ir. M. Bierkens | Univ. Utrecht | Environmental Science |
| prof. dr. S.C. Dekker | Univ. Utrecht | Environmental Science |
| Prof.dr.ir. D.J. Mevius | Univ. Utrecht | Environmental Science |
| Prof.dr. A.J. Murk | WUR | Environmental Science |
| Prof.dr. A.M. de Roda Husman | Univ. Utrecht | Environmental Science |

However, to guarantee the scientific quality, the disciplines should have a certain critical mass regarding supervision, methods, experience, and the like. It has been described in Chapter 3 that Wetsus expects there to be room for ten such core disciplines and that engineering disciplines are crucial for connecting them by creating breakthrough technologies from disciplinary innovations.

The bibliometric analysis (by CWTS, discussed later in more detail) allows us to identify to what extent such core fields (disciplines) are present. A field is classified as core if the field has 12 publications or more (as identified by WoS). This number has been chosen as it implies that, at any time, at least research effort equivalent to 2 Ph.D. students is active in such a field. Figure 15 shows the identified core fields, ordered by the number of papers published. The biggest field in both periods is chemical engineering, with a share of 16 % of the total output for the current audit period.



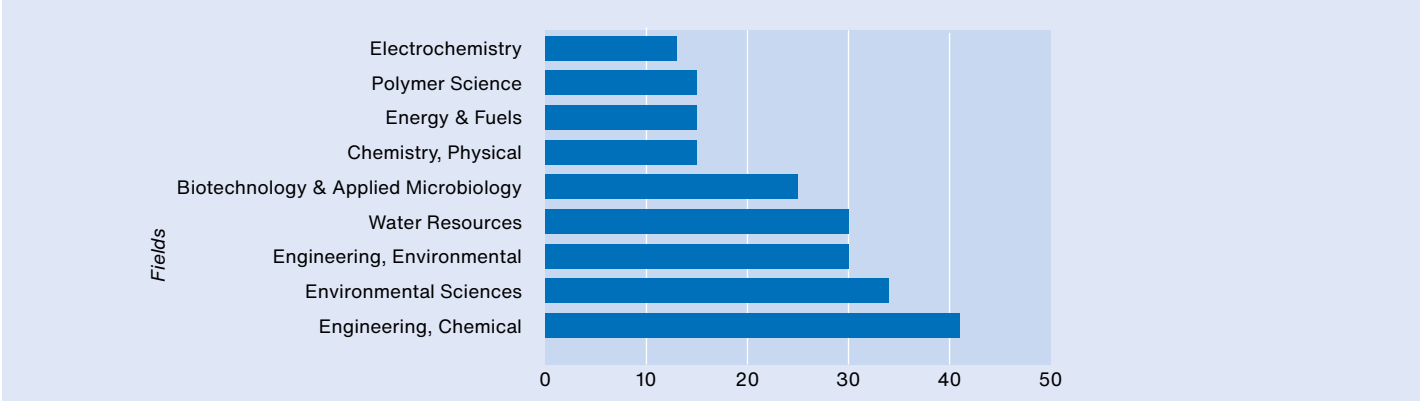



*Figure 15: Identified core fields for the current audit period (top panel) and previous audit period (bottom panel). For each field is indicated how many papers were published.*

In both periods, 9 fields are identified, of which only two differ. These 9 fields represent 75% of the papers for the current audit period and 72% for the previous period. At first, this may seem surprising because the total number of fields identified is 64 and 48 for the current and previous period, respectively. The total research effort linked to the core disciplines is thus fairly constant, while the remaining research effort is distributed over more fields. It is unknown to what extent the wide spread of these non-core fields is a result of the multi-disciplinary nature of Wetsus or whether this is an effect of the field identifying algorithm. These non-core fields have on average 1.7 publications over the whole period.

The fields "water resources" and "environmental sciences" are broad, but the Wetsus contributions are here in the technology field. If we accept these fields as engineering, we find five engineering fields and four more basic science fields, as shown in Table 7.

*Table 7: Identified core fields in the current and previous audits. Blue are the engineering fields, and yellow are the basic science fields. Two basic science fields are no longer present in the current analysis (italic), while two new fields have emerged (bold).*

| Audit 2017-2022 | Audit 2011-2016 |
|---|---|
| Engineering, Chemical | Engineering, Chemical |
| Environmental Sciences | Environmental Sciences |
| Water Resources | Engineering, Environmental |
| Engineering, Environmental | Water Resources |
| Chemistry, Physical | Biotechnology & Applied Microbiology |
| Polymer Science | Chemistry, Physical |
| **Chemistry, Multidisciplinary** | *Energy & Fuels* |
| **Microbiology** | Polymer Science |
| Biotechnology & Applied Microbiology | *Electrochemistry* |

Two new disciplines (in bold: chemistry multidisciplinary, microbiology) emerged, and two fields dropped out compared to the previous audit period (in italic: energy & fuels, electrochemistry), demonstrating the dynamics of the Wetsus research program.

The fields listed in Table 7 were compared to the disciplines among university and Wetsus staff and Ph.D. candidates. Based on the Ph.D. degree of the staff and the MSc degree of the Ph.D. candidates, an allocation was made to basic sciences, engineering, or validating sciences. The results are shown in Figure 16.

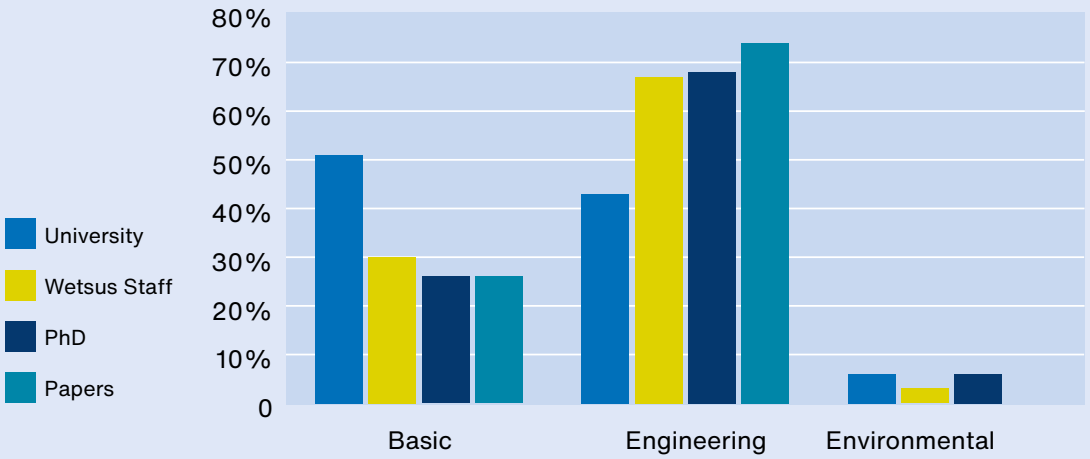



*Figure 16: Distribution (%) over the different disciplines for university supervision, Wetsus supervision, Ph.D. candidates, and papers. Environmental disciplines are not yet available in the papers as they only recently got connected to the research program. Basic is the sum of basic sciences and key technologies.*

Papers align well with the expertise and background of Wetsus staff and PhD candidates. For universities we see a shift towards more basic sciences compared to engineering. The dominance of Engineering and the number of core fields identified reflect the Wetsus strategy: a strong focus on engineering disciplines bridging basic science (including key technologies) with environmental disciplines, to create breakthrough concepts. The basic sciences come from universities, indicating that the supervision of the Ph.D. candidates is multidisciplinary. Environmental disciplines are only recently connected to the Wetsus program. Therefore, they do not (yet) account for a high fraction. This is even more so for the citation analysis as these lags two years behind the audit period.

## Open Access

Open access (OA) publishing is essential as it creates maximal access to the findings of the Wetsus research. OA is not at loggerheads with patenting when patenting is done ahead of the publication's submission. OA can even be helpful, as the publication makes others aware that this knowledge can no longer be patented before the patent is published.

Wetsus follows the call of NWO and the EU to publish open access. Dutch Universities have negotiated more open-access options with science publishers, increasing the possibilities of publishing OA. Figure 17 below shows the development of the fraction open access publication of the Wetsus program and that of the Dutch Universities. The Wetsus OA fraction stabilizes around 90%. This fraction is higher than that of papers published by Dutch Universities and comparable to that of NWO-funded research.

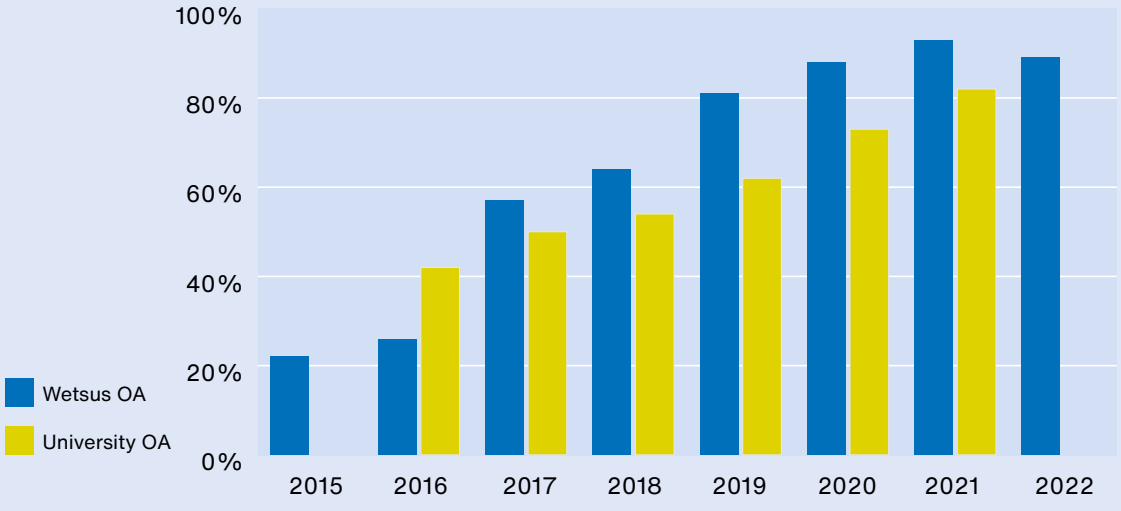



*Figure 17: Fraction open access of Wetsus papers (blue) and those of Dutch Universities (green) over the years. Data from the Universities of the Netherlands (UNL).*

Open Access is only an element of Open Science. Next to open publishing is that data must be made available. Wetsus needs to build on the efforts of the universities, as those are responsible for the scientific quality and integrity of the Ph.D. projects. Wetsus has just developed its own policy, that is that every Wetsus publication should have a companion data-publication in a public repository.

## Impact of papers

### *Wetsus RI score*

To track the impact of the papers, Wetsus uses a simple field normalized citation score, comparable to the citation impact indicator used in the first audit report (2004-2009). Important to note, this analysis does not give such detailed analysis that of CWTS, discussed later. The KPI asks for a score above or equal to 1.5, which indicates a very high impact.

Figure 18 shows the cumulative number of papers published and the overall RI.

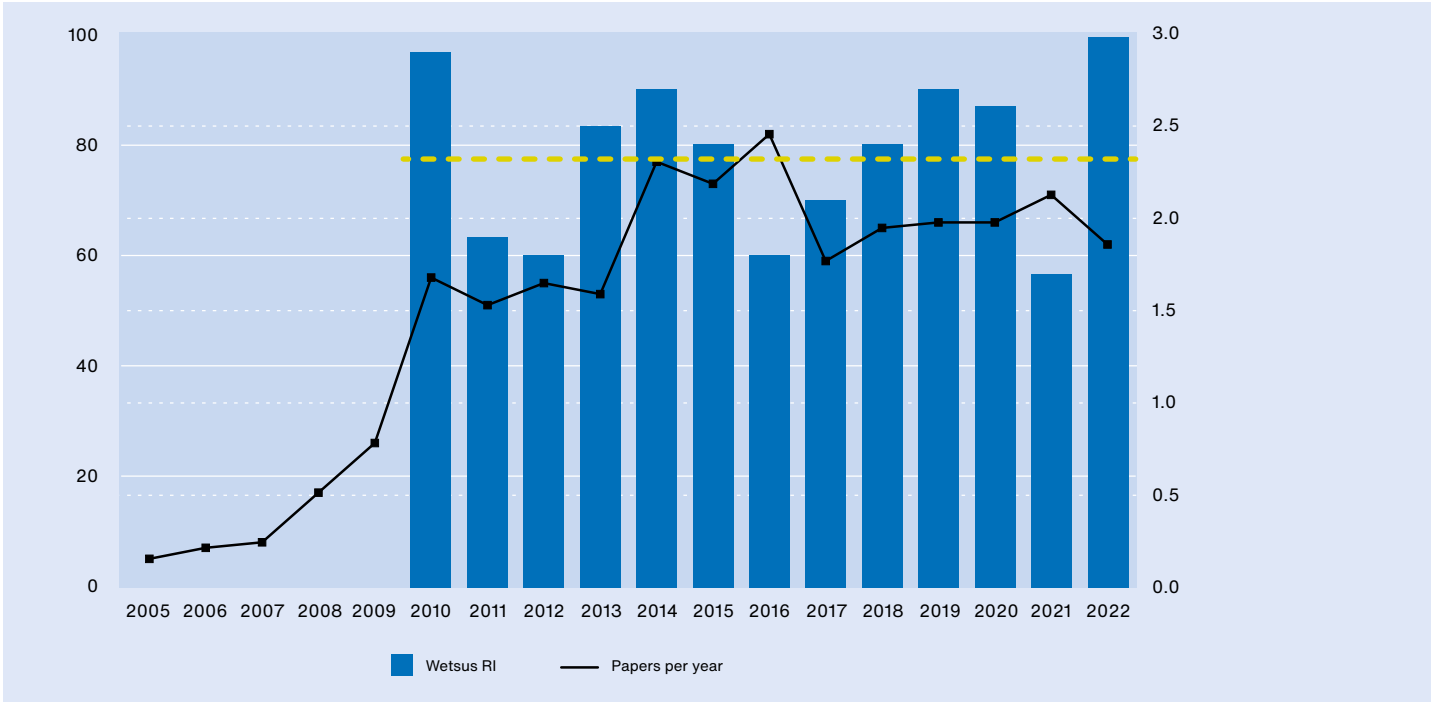



*Figure 18: Wetsus papers published (black line paper/year, left y-axis), Wetsus RI score (bars, right y-axis), average RI score (green line, right y-axis). Meaningful RI scores can only be calculated for 50 papers or more.*

The Figure shows that after the start-up period, from 2010 on, the number of papers published fluctuates from year to year between 51 and 82. The average is 62 papers per year. The RI fluctuates from year to year, a result of the sensitivity of this indicator to high-impact papers. The number of papers with high impact is not constant over the years, hence the variation in overall impact. The average RI score is 2.3, for both the current and previous audit period, demonstrating that Wetsus keeps up with producing papers of high scientific impact (the average RI value of papers worldwide is 1.0).

### *CWTS indicators*

In addition to our own RI analysis as outlined in the previous paragraph, we aimed for an evaluation performed by an independent party, i.e., CWTS, a world-leading institute in bibliometric tools, and science evaluations expertise. The indicators supplied by CWTS are determined over the publication period of 2015-2020. Table 8 shows the definition and type of the main bibliometric indicator used by CWTS.

*Table 8: Definition of bibliometric indicators used in the CWTS analysis.*

| Name | P | TCS | MCS | MNCS | PP top 10% |
|---|---|---|---|---|---|
| Dimension | Output | Impact | Impact | Impact | Impact |
| Definition | Total number of publications. | Total number of citations. | Average number of citations. | Average normalized number of citations. | Proportion of publications that belong to the top 10% of their field. |

Both the RI an MNCS are normalized parameters but differ in their normalization. However, unlike RI, the CWTS algorithm for MNCS classifies each individual publication within a particular research discipline. The normalization factors for the MNCS are much finer grained as citation structures within a field are considered. Also, the evaluation criterion of the indicators has become different. In case of RI, its value should be above 1.5 in order to be classified as very high.

An equivalent classification requires the MNCS value to be higher than 1.2. Because of this difference, the MNCS values cannot be numerically compared with the RI values of Wetsus as period and normalization are completely different. More meaningful therefore is to compare trends in both data sets.

Following the distinction between core and non-core disciplines, Figure 19 shows the MNCS values of the core-fields (Figure 15), for the current and previous audit period.

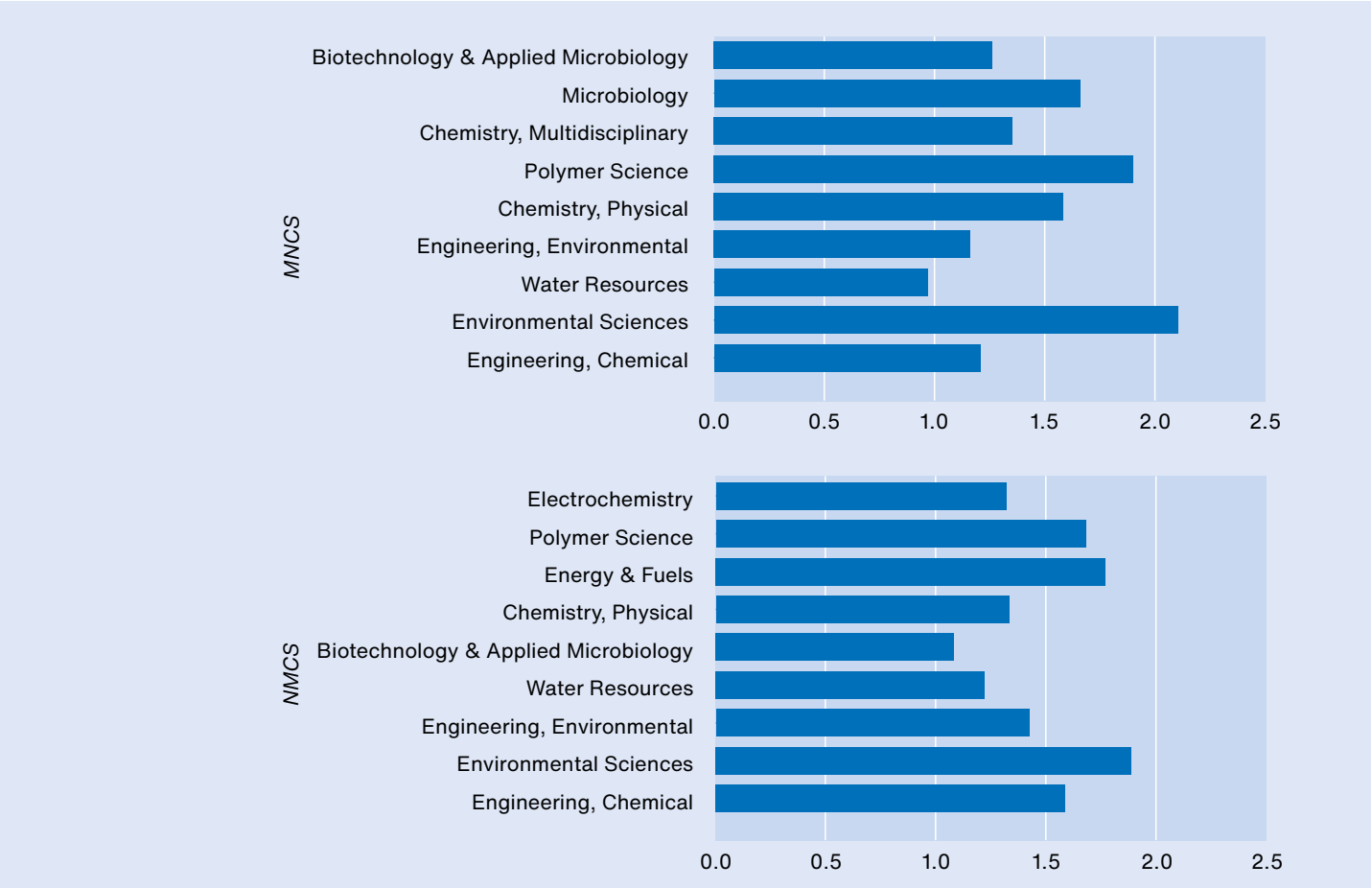



*Figure 19: MCNS of core fields for current audit period (top panel ) and the previous audit period (bottom panel ).*

All areas have a high MNCS value (>1.2), only chemistry multidisciplinary (1.0) in the current period and biotechnology and microbiology in the previous period (1.1) were lower than the cut-off of 1.2.

As shown in Table 9, the impact of the papers clearly rose, as the average citations per paper (MCS) increased from 14 in the previous period to 24 in the current period. Figure 20 summarizes the MNCS value of the core fields, the non-core fields and the overall MNCS. We see that the core fields remain at the same high level, despite the strong increase in impact. This shows that Wetsus is active an extremely competitive field as this strong increase in the MCS does not translate into an increase of the MNCS.

The non-core fields slide back in the MNCS, leading to a small decrease (8%) in the overall MNCS. As pointed out by CWTS, such a decrease is more observed in the Dutch (technical) research landscape and attributed to fierce competition due to China's emerging role in the worldwide science arena. The fact that the core fields do retain their high impact underlines that critical mass is essential to retain a leading position in competitive research disciplines. The top 10%, also listed in Table 9, shows the same trend as the MNCS, i.e., top 10% remains constant for core fields while that of the non-core fields drops.

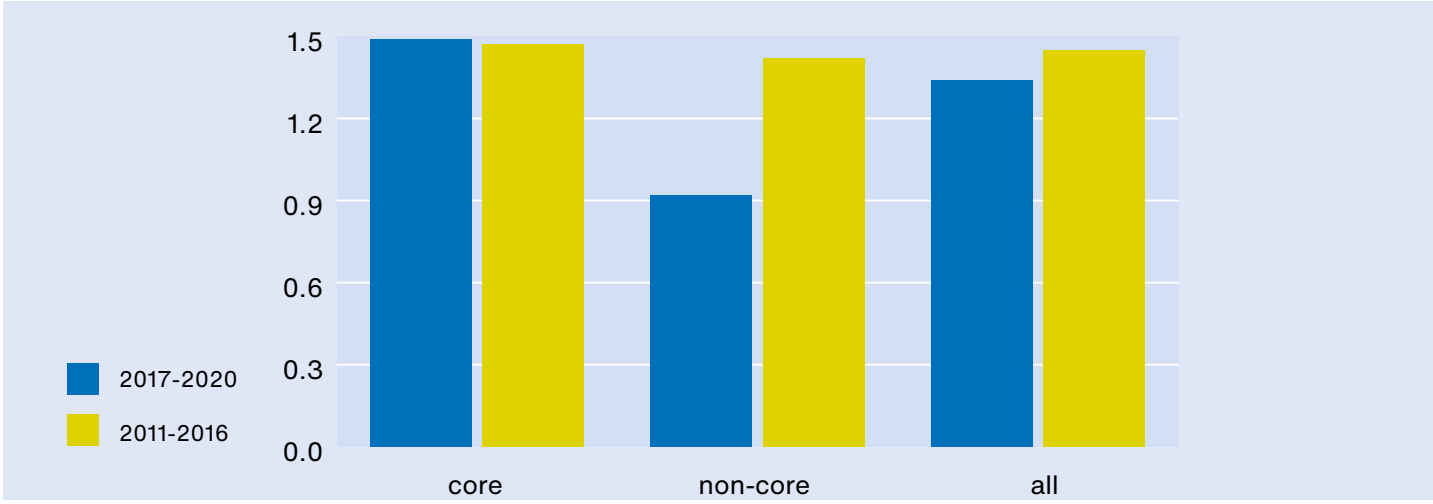



*Figure 20: Comparison between the current and previous audit period of the average MNCS score for core fields, non-core fields and all fields.*

*Table 9: Bibliometric data of core and non-core fields*

| | 2017-2022 | 2011-2016 |
|---|---|---|
| core fields | 9 | 9 |
| papers | 335 | 217 |
| MCS | 24 | 14 |
| MNCS | 1.5 | 1.5 |
| top 10% | 17% | 17% |

| | 2017-2022 | 2011-2016 |
|---|---|---|
| non-core fields | 55 | 39 |
| papers | 114 | 83 |
| MCS | 14 | 14 |
| MNCS | 0.9 | 1.4 |
| top 10% | 9% | 18% |

*Top twelve papers*

To give an impression of the multidisciplinary nature of the program, 12 papers have been selected reflecting of the width and depth of the Wetsus program. Two papers from the top 10% for each year were selected (Table 10).

*Table 10: Papers from the top 10% fraction, representative for year (2/year) and diversity of themes within Wetsus.*

| | Publication | Year | Theme | MCS |
|---|---|---|---|---|
| 1 | Parmentier, D.; T. Vander Hoogerstraete, S.J. Metz, K. Binnemans, and M.C. Kroon, Selective Extraction of Metals from Chloride Solutions with the Tetraoctylphosphonium Oleate Ionic Liquid, Ind. Eng. Chem. Res., 2015, vol. 54, pp 5149–5158. DOI: 10.1021/acs.iecr.5b00534 | 2015 | Desalination & Concentrates | 46 |
| 2 | Water desalination via capacitive deionization: what is it and what can we expect from it?ME Suss, S Porada, X Sun, PM Biesheuvel, J Yoon, V PresserEnergy & Environmental Science 8 (8), 2296-2319 (2015) | 2015 | Capacitive Deionization | 898 |
| 3 | Tedesco, M.; H.V.M. Hamelers, P.M. Biesheuvel, "Nernst-Planck transport theory for (reverse) electrodialysis: I. Effect of co-ion transport through the membranes," Journal of Membrane Science (2016), http://dx.doi.org/10.1016/j.memsci.2016.03.012. | 2016 | Blue Energy | 141 |
| 4 | Semitsoglou-Tsiapou, S.; M.R. Templeton, N.J.D. Graham, L. Hernández Leal, B.J. Martijn, A. Royce, J.C. Kruithof, Low pressure UV/H2O2 treatment for the degradation of the pesticides metaldehyde, clopyralid and mecoprop – Kinetics and reaction product formation, Water Research, vol. 91 (2016) pp. 285-294, http://dx.doi.org/10.1016/j.watres.2016.01.017 | 2016 | Priority Compounds & Virus Control | 32 |
| 5 | Lei, Y.; B. Song, R. D. van der Weijden, M. Saakes, and C. J. N. Buisman, Electrochemical Induced Calcium Phosphate Precipitation: Importance of Local pH, Environ. Sci. Technol., 2017, vol. 51, pp 11156–11164. http://dx.doi.org/10.1021/acs.est.7b03909 | 2017 | Resource Recovery | 95 |
| 6 | Dijkshoorn, J.P.; M.A.I. Schutyser, R.M. Wagterveld, C.G.P.H. Schroën, R.M. Boom, "A comparison of microfiltration and inertia-based microfluidics for large scale suspension separation", Separation and Purification Technology, Vol. 173, 2017, pp. 86-92, http://dx.doi.org/10.1016/j.seppur.2016.09.018 | 2017 | Advanced Water Treatment | 25 |
| 7 | Dykstra, J.E.; S. Porada, A. van der Wal, P.M. Biesheuvel, "Energy consumption in capacitive deionization – Constant current versus constant voltage operation", Water Research, Vol. 143, pp. 367-375 (2018), https://doi.org/10.1016/j.watres.2018.06.034 | 2018 | Capacitive Deionization | 68 |
| 8 | Wilfert, P.; A.I. Dugulan, K. Goubitz, L. Korving, G.J. Witkamp, M.C.M. Van Loosdrecht, "Vivianite as the main phosphate mineral in digested sewage sludge and its role for phosphate recovery", Water Research, Vol. 144, pp. 312-321 (2018), https://doi.org/10.1016/j.watres.2018.07.020 | 2018 | Phophate Recovery | 102 |
| 9 | Pallares-Vega, Rebeca; Blaak, Hetty; van der Plaats, Rozemarijn; Husman, Ana M. de Roda; Leal, Lucia Hernandez; van Loosdrecht, Mark C. M.; Weissbrodt, David G.; Schmitt, Heike, Determinants of presence and removal of antibiotic resistance genes during WWTP treatment: A cross-sectional study, WATER RESEARCH 2019, 161, 319-328; http://dx.doi.org/10.1016/j.watres.2019.05.100 | 2019 | Source Separated Sanitation | 57 |

| | | | | |
|---|---|---|---|---|
| 10 | Kumar, Prashanth Suresh; Korving, Leon; Keesman, Karel J.; van Loosdrecht, Mark C. M.; Witkamp, Geert-Jan, Effect of pore size distribution and particle size of porous metal oxides on phosphate adsorption capacity and kinetics, CHEMICAL ENGINEERING JOURNAL 2019, 358, 160-169; http://dx.doi.org/10.1016/j.cej.2018.09.202 | 2019 | Phosphate Recovery | 106 |
| 11 | Ajao, V; Nam, K; Chatzopoulos, P; Spruijt, E; Bruning, H; Rijnaarts, H; Temmink, H, Regeneration and reuse of microbial extracellular polymers immobilised on a bed column for heavy metal recovery, WATER RESEARCH 2020, 171, -115472; http://dx.doi.org/10.1016/j.watres.2020.115472 | 2020 | Natural Flocculants | 25 |
| 12 | Legrand, L; Shu, Q; Tedesco, M; Dykstra, JE; Hamelers, HVM, Role of ion exchange membranes and capacitive electrodes in membrane capacitive deionization (MCDI) for CO2 capture, JOURNAL OF COLLOID AND INTERFACE SCIENCE 2020, 564, 478-490; http://dx.doi.org/10.1016/j.jcis.2019.12.039 | 2020 | Sustainable Carbon Cycle | 22 |

### Marks of Recognition

It is hard to separate the recognition of a group and that of its members. This distinction is not meaningful if a group consists of members with a single affiliation, being the group in question. This is different for Wetsus, where many scientists have a double affiliation. Most of our part-time scientist have their primary affiliation at their home institute. Therefore, we restrict marks of recognition to those scientists that spend most of their time at Wetus, and we mention only grants at least partially spent at Wetsus. Appendix D gives an overview of the marks of recognition.

## Competitiveness and Innovations

The KPIs describing the Wetsus' contribution to competitiveness are the number of new spin-off companies associated with Wetsus, the number of patents generated and transferred. Table 11 lists the realization of the KPIs.

*Table 11: Realization of the KPIs in the area of competitiveness and societal relevance*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | % Realised |
|---|---|---|---|---|---|---|---|
| Number of spin-off companies (cumulative) | 3 | 4 | 6 | 8 | 10 | 14 | 140% |
| Number of patents generated (cumulative) | 4 | 7 | 9 | 11 | 14 | 17 | 106% |
| Number of patents transferred (cumulative) | 5 | 7 | 9 | 12 | 12 | 15 | 83% |

### Spin-offs

The number of spin-offs surpasses the expectation. The reason for this is that apart for spin-offs from the Wetsus program, the Water Campus ecosystem becomes increasingly attractive for other spin-offs not directly originating from Wetsus. They like to join the Water Campus for the network and connect to the talent pool. In 2022, the Water Campus showed the largest growth rate compared to other tech campuses in the Netherlands.

### Patents

In our vision, patents are essential for creating impact with technology. A patent has the advantage that investments in the technology can be recuperated. It should be noted that although community money has been invested in the generation of the patent, the investment needed for further development, creating production facilities, and bringing to market are, as a rule, much larger than the initial investment.

Figure 21 shows the generated and transferred patents in each audit period. In the current period, fewer patents were generated, but the number of transferred patents remained constant. This resulted from our decision to be more critical about patent submission. Only patents for which companies upfront expressed a clear interest were filed. The resulting drop in patents was expected as the number of filed patents aligned with the KPI.

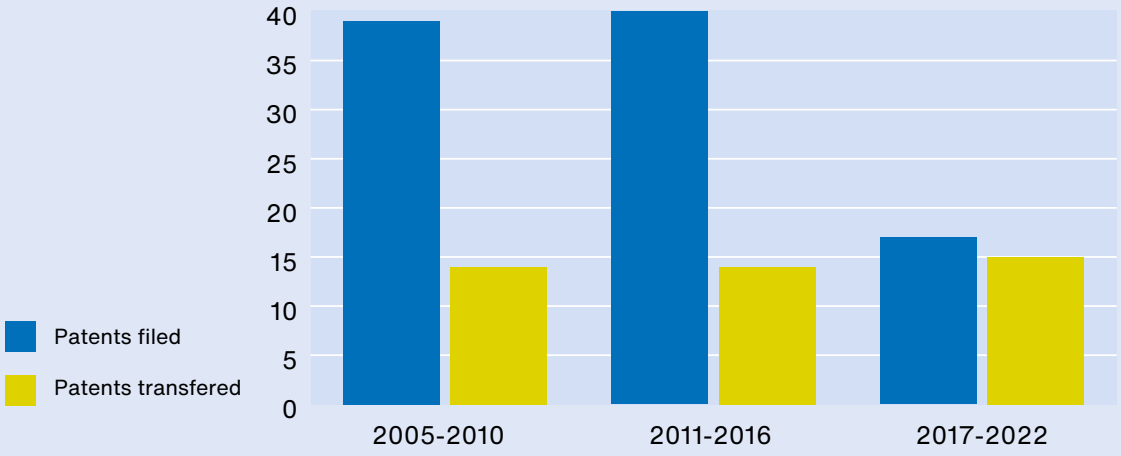



*Figure 21: Patents filed, and patents transferred for all audit periods*

The number of transferred patents was lower than expected (83%). To better understand (and for predictions in the future) the effect of our new patent policy, we calculated the transfer probability for the patents generated during this audit period (the patents transferred in this audit period were partly filed in the previous period). The results are shown in Figure 22. The probability increases with time and reaches a final transfer probability of 65%, which is 1,5 times higher than the probability of the previous audit period, 41%. The stricter patent policy enhanced the efficiency of our patent handling; however, the transfer probability is lower than assumed in the Business Plan 2021-2032. Therefore, it is important to strengthen the innovation so that more patents can be generated. This will be discussed further in the viability Chapter 6.

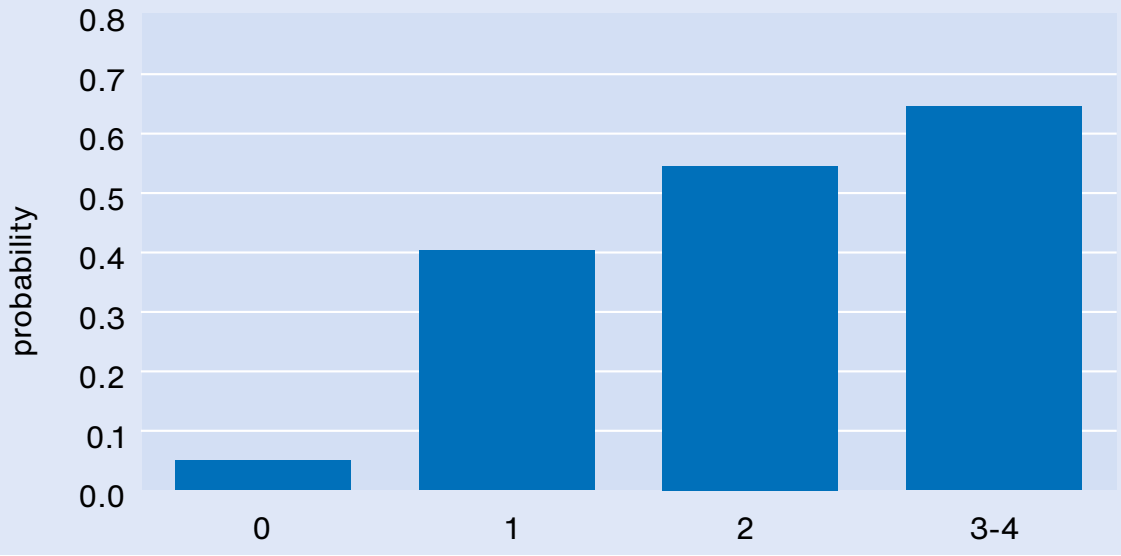



*Figure 22: Patent transfer probability in time for the current audit period. Year 0 means that a patent is already transferred in the year of filing. The years 3 & 4 have been summed because of limited data and serves as a final transfer probability*

## Participants using Wetsus know-how in existing products

The economic impact of the Wetsus program and the innovation community's functioning is extensively investigated beyond KPIs every three years via a questionnaire and interviews. This research is performed by the external economic research organization BBO. The most recent report, for the 2020-2022 period, is supplied as background material.

Figure 23 shows that innovations and knowledge find their way to new and existing products. This result confirms that taking part in the Wetsus program has a clear impact on company innovation and competitiveness.

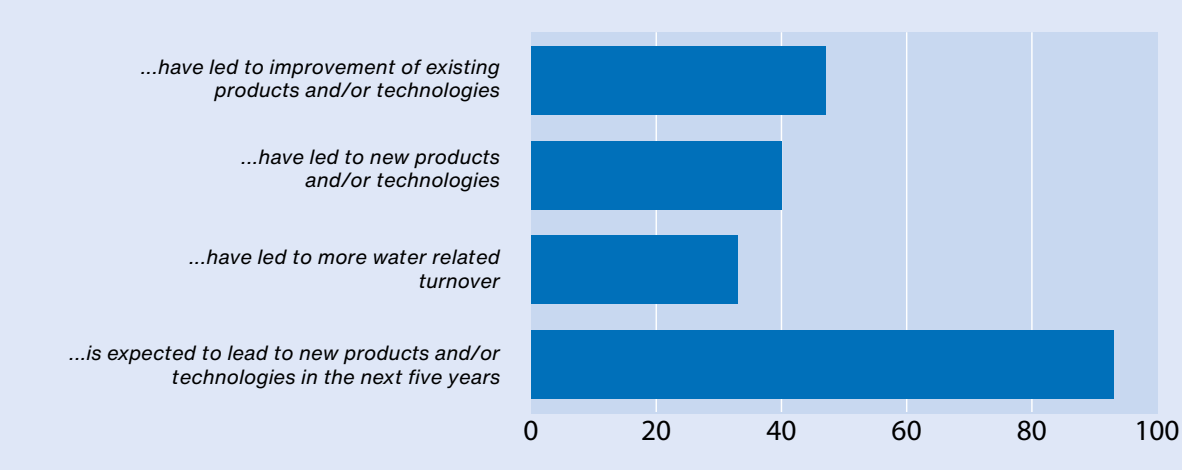



*Figure 23: Innovations and knowledge from the Wetsus program on technological innovation in companies. The x-axis shows the percentage of respondents that agree with the proposition.*

In the Business Plan 2021-2032 the use of knowledge has been introduced as new KPI, as it is a crucial step on the way to societal impact.

Innovation however is hard to catch only in numbers as it is a result of cooperation within the network. This is better understood by studying some case studies. For this reason, Wetsus always selects every 5 years a number of innovations and publishes them as a booklet.

Table 12 list the innovation case studies as collected in the most recent booklet. This booklet is supplied as background information.

*Table 12: Examples of innovation case studies in the audit period. The page number refers to the booklet Wetsus Innovations that is separately made available.*

| Innovation case | Page |
|---|---|
| Recovering phosphate from sludge using magnets | 20 |
| Testing water pipelines using ultrasound | 24 |
| Accurate groundwater flow measurements to efficiently manage water wells | 28 |
| Energy-efficient nitrogen recovery from wastewater | 32 |
| Phosphate recovery from animal manure: closing nutrient cycles and improving soil health | 36 |
| Energy storage with minimal environmental impact 40 | 40 |
| Improved seawater desalination using innovative membranes and smart designs | 44 |
| Smart UV technologies to eliminate micropollutants in drinking water sources | 48 |
| Theoretical models to improve drinking water quality | 52 |
| Rusty granules: the key ingredient for stopping algal blooms by reaching extremely low phosphorus concentrations | 56 |
| Hollow fiber nanofiltration to remove micropollutants from toilet wastewater | 62 |
| Designing aligned pore membranes for resource recovery 66 | 66 |
| Calcium (bi-) carbonate nanoclusters in water: a key to reduce scaling | 70 |
| Removing sodium to save water for crops | 74 |
| Efficient electrochemical recovery and reuse of phosphate in salty waste waters | 78 |

## Innovation Community

The innovation community, as described in Chapter 4, is key in the creation of innovative technology and creating impact with these innovations. All partners have a specific contribution depending on their role. Key for the innovation community are the companies and in particular those developing new products and processes. The KPIs describing the innovation community therefore track the number of businesses associated with Wetsus and how many of them are small and medium sized enterprises (SMEs). Table 13 gives an overview of the realized KPIs.

*Table 13: Realization of KPIs in the area of the innovation community.*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | % Realised |
|---|---|---|---|---|---|---|---|
| Number of participating companies (active) | 105 | 109 | 109 | 105 | 113 | 109 | 102% |
| Number of SME companies in program (turnover < 100 mln €) | 56 | 57 | 57 | 51 | 57 | 57 | 108% |

## Number of participating companies

The number of companies joining Wetsus develops as expected. It should be noted that Wetsus has no growth strategy, expanding the size would put stress on multidisciplinary cooperation, as a too-big organization tends to specialize. Most companies join Wetsus for over ten years. But every year some companies leave, and more new ones join.

## Number of SME companies in program (turnover < 100 mln €)

Small and Medium sized Enterprises (SME) are essential for the network to further develop the technological innovations from the Wetsus research program to the market. Larger companies, in turn, are better equipped for scaling up the developed technology by SMEs in different economic sectors. The number of SMEs is according to Wetsus' expectation and gives a good balance between SMEs and larger entities (Table 13).

## Professors and Principal Investigators participating

The professors and PIs represent the science contribution and multidisciplinarity in the Wetsus network. The numbers are more or less constant. The list of currently active professors and PIs has already been shown in the part of scientific quality.

## Trust and Cooperation

Trust and cooperation are core values of Wetsus. We believe them to be a crucial element for a network to function well. This has been studied in more detail by the economic research organization BBO. Trust and cooperation are crucial for innovation to occur, as collaboration is needed to bring all contributions together, and trust is necessary as innovation always requires upfront investments of the partners involved, not only in financial terms but more important, know-how sharing, experts' time, reputation, and the like.

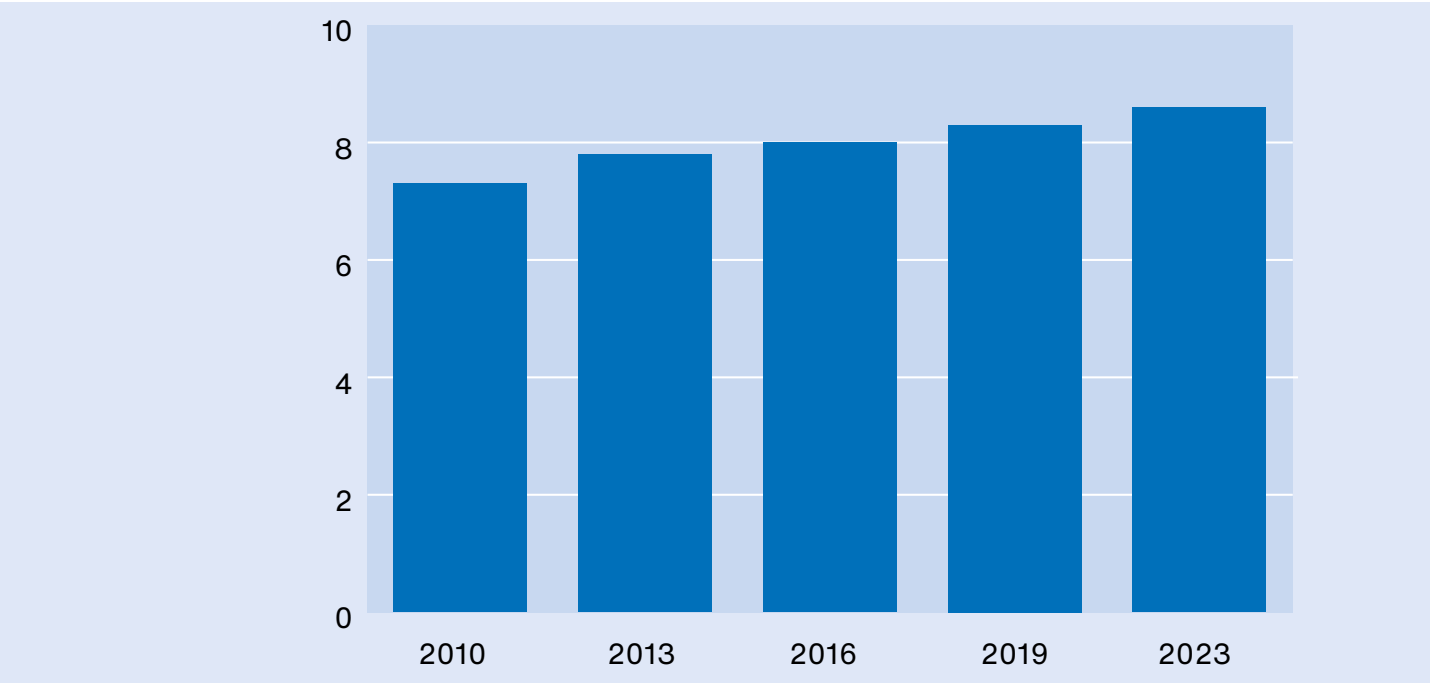



*Figure 24 Development of the assessment by partners of trust and cooperation within Wetsus. Scores are determined as the weighted value of grades from 1 to 10 (with one being worst and ten being best). In the questionnaire, a five-point scale was used. Companies and universities have been summed. In 2010 and 2013 only companies were approached in the survey. Because the results are similar for companies and universities in 2016, 2019, and the 2023 surveys, the results are comparable.*

Figure 24 shows a steady growth of trust and cooperation over time with all partners involved. We explain this growth because increasingly complementary partners are associated with the network over time. Also, within the Wetsus staff, more experience has been building up in facilitating such a network. Finally, satisfied companies renew their membership every 4 years, whereas companies less satisfied end their collaboration with Wetsus. A potential drawback of such a well-aligned network is that fewer innovative ideas are generated, as there is less renewal of the unexplored knowledge and knowledge in the network.

Table 14 shows the BBO report's conclusions, which underline that the Wetsus network operates well.

*Table 14: BBO conclusion on trust and cooperation in Wetsus network*

- For a large part of companies (82%) participation leads to additional contacts outside the Wetsus programme, mostly with companies as well as universities, which illustrates Wetsus' network function.
- For both companies and universities the character of the contacts with Wetsus can on average be viewed as relatively strong ties, meaning a relative high frequency and intensity of contacts.
- The Wetsus network is viewed upon by companies and universities as a high-trust network, meaning a network predominantly based on understanding each other, common vision, discretion, competence and receptivity. In 2023 more companies and universities view the Wetsus network as a high-trust network than before.
- The high trust outcome is competence-based as well as benevolence-based. The numbers are higher than in the 2019 survey (and the 2016 survey), which means that the foundation of the network on competence as well as benevolence trust has become stronger.
- The cooperation within the Wetsus network is in general assessed as above average quality as compared to cooperation in other networks and with other partners, notably on aspects like integrity and reputation.
- Regarding the scientific cooperation a majority of universities (65%) value the supporting technical facilities offered by Wetsus as crucial to the PhD-projects. About half of the universities make use of the supporting technical facilities of Wetsus outside the PhD-project(s).
- The overall benefits derived from the cooperation with Wetsus for the scientific output and reputation of the participating universities is valued as (very) high or even excellent

## Marks of recognition

Table 15 gives an overview of the main marks of recognition in the areas of innovation and leadership roles Wetsus has for the Dutch Water Technology sector, both nationally and European.

*Table 15. Public marks of recognition for the leadership and innovation shown in the field water technology.*

| | | | |
|---|---|---|---|
| International Water Association Award | ViviMag wins in the category "breakthroughs in R&D". | ir. L. Korving | 2022 |
| George Barley Prize | Winner during 2nd and 3rd stage (250.000 $) | Ir. L. Korving | 2017/ 2018 |
| KNW board | Royal Dutch Waternetwork is the prime independent network of the whole water sector including management and technology. | J. Van der Meij M.Sc. | ongoing |
| Membership ACTI | Netherlands Academy of Technology & Innovation | Prof. dr. ir. C.J.N. Buisman | ongoing |
| Advisory Boards of Aquatech, KWR, Blue Tech forum | KWR Water Research Institute, Aquatetch and Blue Tech Forum are all important in shaping the water research agenda. | Prof. dr. ir. C.J.N. Buisman | ongoing |
| TKI Water Technology board member | TKI Water technology is responsible for the policy and distribution of the government innovation funds for water technology | Prof. dr. ir. C.J.N. Buisman | ongoing |

| | | | |
|---|---|---|---|
| TKI Water Technology program board chairman | The program board is responsible for innovation quality of the Dutch water technology program as funded by the government | Dr.ir. Jan Post | ongoing |
| Membership | Member of International Working Group Physics of Membrane Processes | Dr. ir. M. Biesheuvel | ongoing |
| Water Europe Ambassador | Working Group leader resource recovery at Water Europe. | Dr. ir. M. Bijmans | ongoing |

## Future Innovation Leaders

As discussed in our strategy, to train Ph.D. students to become future innovation leaders is essential in our vision for creating impact. The research students support the research of the Ph.D. students and are, in this way, trained in multidisciplinary research. Table 16 shows the realization of the KPIs related to future innovation leaders.

*Table 16: Realization of the KPIs Ph.D. graduates and research students.*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | % Realised |
|---|---|---|---|---|---|---|---|
| Ph.D. Graduates (cumulative) | 7 | 22 | 32 | 44 | 55 | 65 | 85% |
| Research Students (non-PhD) (cumulative) | 97 | 192 | 312 | 372 | 426 | 479 | 99% |

The number of research students is as expected, although fewer could be accommodated during corona. Wetsus is clearly a magnet for (inter) national water technology students, as it is always possible to find good students.

The following analysis focuses on the Ph.D. graduates, as the realization lags expectation. To understand this, we investigated several plausible causes. It might be a result of (i) a low success rate (projects leading to a PhD defence) or (ii) delays because of challenging conditions for the Ph.D. candidates; (iii) or, specifically, corona-related impact. But first, the Ph.D. population will be described in more detail.

### Background Ph.D. candidates

Ph.D. Candidates are at the base of a successful Ph.D. program; therefore, Wetsus takes great care in selecting candidates, via the so-called Waterseed procedure, described in Chapter 4. Figure 25 (panel A) shows that Wetsus attracts talents from over the entire world but with The Netherlands and China as two "leading nationalities," accounting for 15% and 13%, respectively.

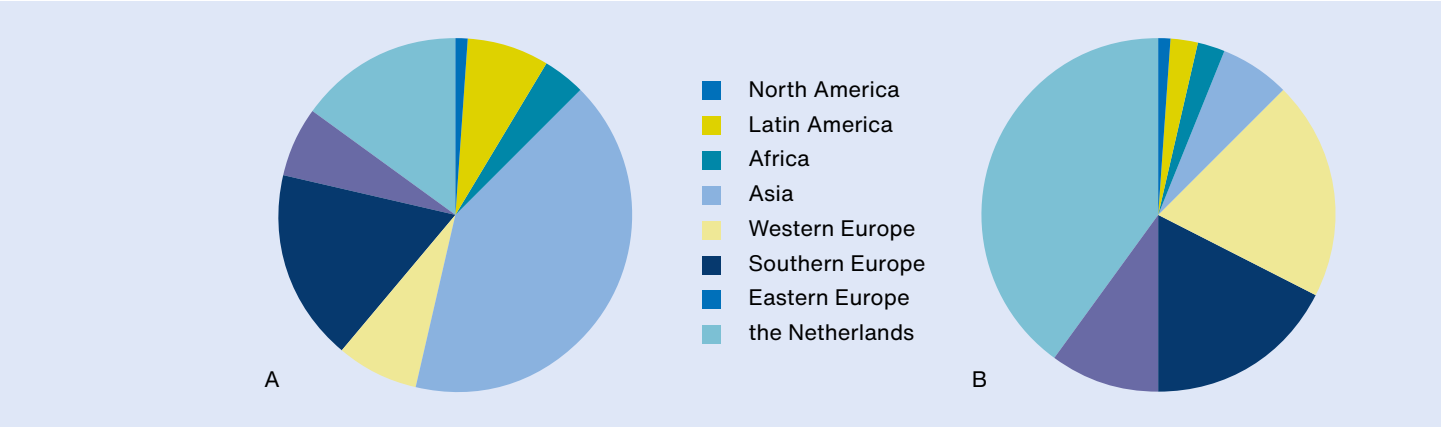



*Figure 25: Background of the Ph.D. students hired in the audit period, the left pie diagram shows their Nationality, while the right pie diagram shows the nationality of their university offering their MSc training, their Alma Mater.*

Compared to Dutch universities, the Ph.D. population is more international as Dutch Universities have a distribution: 50% Dutch, 25% European and 25% rest of the world (RAT). Panel B shows the nationality of the Alma mater where the PhD candidates obtained their master's degree. Most students received their degree at a Dutch or European university (excl.

NL). The difference between panel A and B nicely illustrates the mobility of students in higher Education. As shown in Table 4, the gender balance among the Ph.D. students is on parity, even a slight overrepresentation of female Ph.D. students. This is quite different for the Dutch situation, where in 2021, the percentage F/M is 32% for technology and 42% for life science (RAT).

*Graduation Success Rate*

Based on the data in the Table "Ph.D. candidates" in Appendix C, we can calculate the program's success rate. The success rate is measured as the fraction of Ph.D. candidates that successfully defended their Ph.D. thesis. The success rate is, of course, a function of time. Figure 26 shows the success rate versus time elapsed since the start of the project. Eventually, 7-8 years after the start of the project the success rate stabilizes around a level of 75%-80%. We compared the outcome of the Wetsus program to the data for Dutch Universities and, where possible, with the technical sciences (RAT). It shows that the Wetsus level is slightly higher than the success rates for comparable science areas (72% for technical sciences, 74% for life science and agriculture).

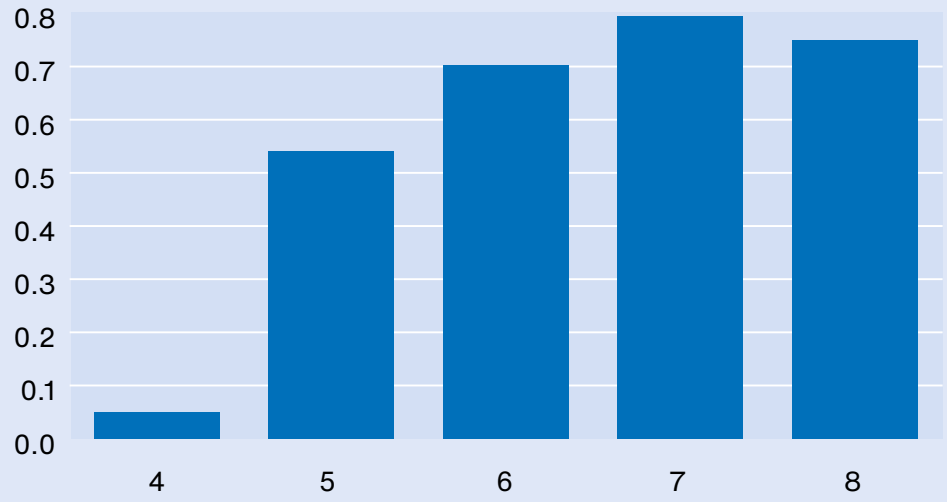



*Figure 26: Cumulative graduation success rate for Wetsus PhDs, as function of time in years since start of the project. The success rates are determined for the cohort 2014-2018. While the succes rate for year 4 can be determined for all cohorts, that for longer periods contain less cohorts, explaining the decrease in success rate going from year 7 to 8.*

## Project Duration

Next to the success rate, the time it takes to achieve graduation is another essential success measure. The graduation duration is defined as the time elapsed between the start of the project and the defence date. This has been studied by the Dutch Statistics Agency (C.B.S.). Figure 27 shows the cumulative distribution of the Wetsus Ph.D. project duration for the cohorts 2014, 2015 & 2016.

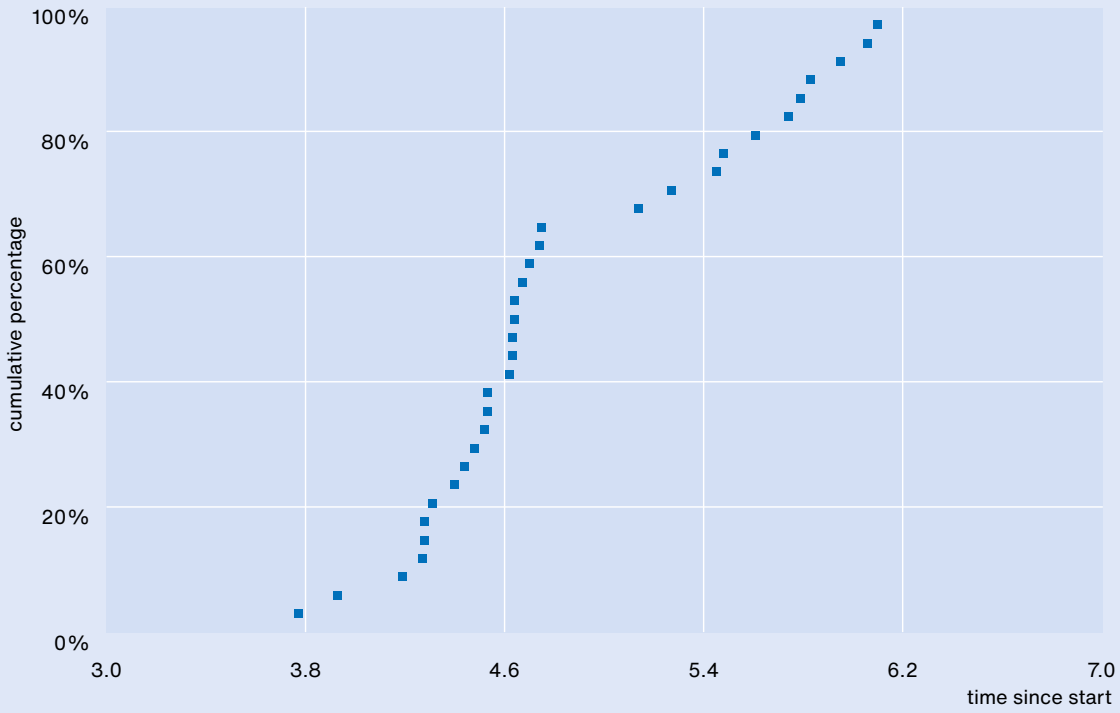



*Figure 27: Graduation period for Wetsus PhDs for the cohorts 2014-2016, the time is expressed as years since start of project. The y-axis shows the fraction graduated. Note this is the faction of the group that will graduate.*

It shows that the distribution is skewed as expected; delays in a project are additive. The median delay is calculated from the moment the contract officially ends and is approximately seven months. There is a strong increase in the graduation period for the "slowest "35%; probably due to candidates starting a paying job. This median delay compares very favourably with the Dutch median value of 12 months (CBS). Note that the delay includes a period of approximately four months needed for thesis approval and organizing the public defence.

## Corona project extension

Due to particular circumstances, personal and/or project-related, the project is sometimes extended beyond the standard four-year period to compensate for lost time. This loss sometimes results from Ph.D. candidates preferring to work part-time or serious illness. Another type of extension is that sometimes, a Ph.D. candidate leaves early in the project as the there is a mismatch between candidate and project. In such case the project is extended, i.e., a new candidate is hired for again 4 years. This is not registered as a new project. Such extensions will lead to an increase in the size of the program as the residence time increases. The average extension can be estimated as the difference between the actual size of the Ph.D. program and what it would have been if all projects would take just four years. Figure 28 shows the delay.

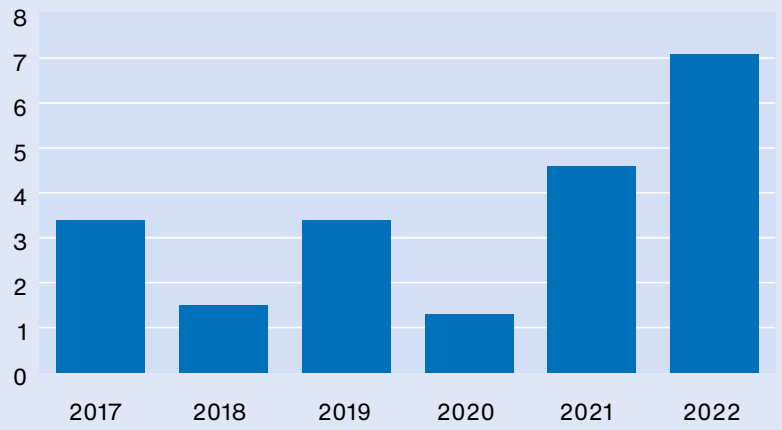



*Figure 28: Project delay ( y-axis in months) for each year, as determined from the expected program size based on inflow*

Over the pre-corona period 2017-2020, the average extension is around 2.4 months. In the years 2021 and 2022 a noticeable increase to almost six months per project occurs. This results from extensions due to COVID that have been paid via universities from special government corona funds. This delay will now start showing up as a temporary dip in the number of yearly graduates. The same trend is observed in the overall data for graduations at Dutch universities.

## Supervision Ratio

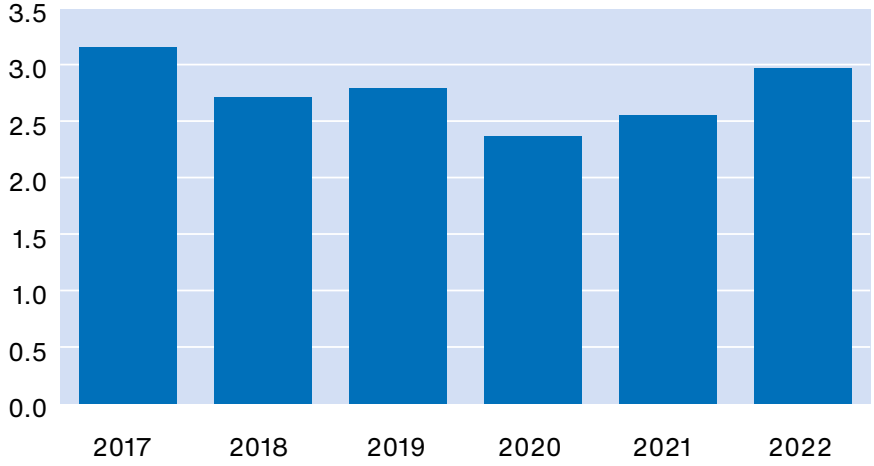



*Figure 29: Ph.D. candidates - science staff ratio over time.*

Figure 29 shows the number of Ph.D. candidates per senior staff member. We see around 2020, a minimum, as the Ph.D. population decreased faster than Science Staff, due to the unclear financial prospect. This ratio is higher than at Dutch technical universities (RAT), however, it should be considered that the Wetsus supervision is additional to the university supervision and intended to facilitate multidisciplinarity and to compensate for the physical distance between the PhD candidate and his/her promotor.

## Personal Development Program and HR

Wetsus has developed a unique on-site development program, that the Ph.D. candidates follow as a half year cohort. In this way, right from the start teams are formed that can support each other through the Ph.D. journey. This is operated on top of the courses from the research schools from the Universities. Figure 30 shows the outline of the program, as developed during the previous audit period, and discussed thoroughly during the last audit.

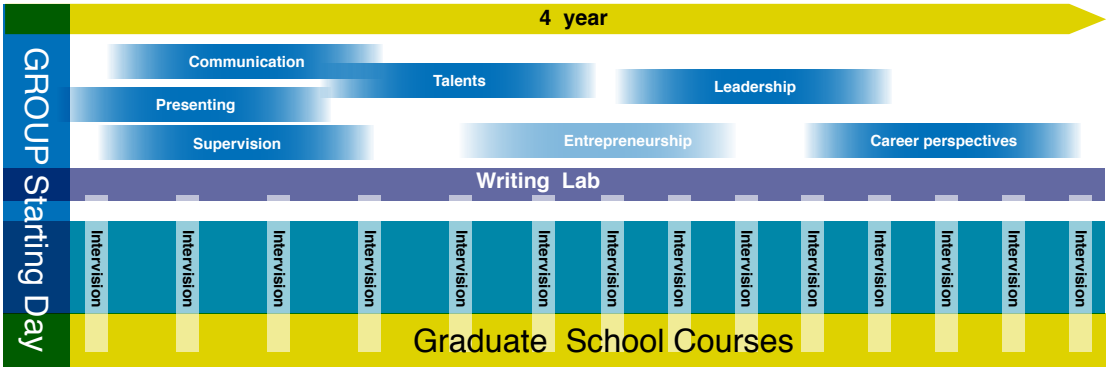



*Figure 30: Structure of the Wetsus personal development program for Ph.D. candidates*

This program is evaluated yearly and has been evaluated in detail by a HR trainee in 2021 as thesis topic for the University of Applied Sciences NHL. This evaluation did not only include Ph.D. candidates but also graduates working at other organizations. The research showed that both current Ph.D. candidates and graduates very much appreciate the program, reflected in a grading of 8.4 on a scale 1-10. The program and skills developed are considered a valuable investment also for the rest of their professional life. A more detailed description will be made available as additional information.

To be an attractive employer, in line with the Wetsus values, Wetsus has applied and got the HR excellence in Research Award from the EU. With this award "The European Commission recognises with the 'HR Excellence in Research Award' the institutions which make progress in aligning their human resources policies to the 40 principles of the Charter & Code, based on a customized action plan/HR strategy. "In this way, Wetsus challenges itself to be and remain a valued employer for researchers.

# 6. Strategy and viability for the next six years

## Introduction

This Chapter investigates how well Wetsus is equipped for the coming six years, i.e. wether, can it be expected that Wetsus will expand its impact in terms of scientific quality, societal impact, and creating value for our partner companies and knowledge institutes alike.

Viability requires that Wetsus is well-aligned with its environment. To investigate this alignment, first a SWOT analysis is performed. This analysis gives insight into the strengths and weaknesses of Wetsus on the one hand and, on the other hand, the opportunities, and threats from the environment.

Next, we will discuss the main (strategic) elements that determine the viability of Wetsus for the coming six years. We will discuss each element, its importance for viability, and how Wetsus manages threats, uses opportunities, and minimizes weaknesses.

We will indicate (if applicable) the extent to which the advice of the previous audit has been followed up for these elements.

## SWOT Analysis

Table 17 shows the SWOT analysis. This analysis results from discussions in/with science staff, the board of directors, and the research management team. The table is self-explanatory and will be used to discuss the Wetsus Viability in the next section.

*Table 17: SWOT analysis of Wetsus*

## Strengths

- **An innovative and impact-oriented research program based on**:
  - High risk-high gain ideas
  - Multidisciplinary cooperation
  - Company Involvement
  - Trust-based network
  - Value-based organization

  All elements described above strengthen each other as described in our strategy. (Chapters 3 and 4). Furthermore, the accomplishments (Chapter 4) show that all elements are well established.
- **Reputation from the regional to the European level**

  Due to the quality and relevance of the research, Wetsus' reputation has been established, giving better access to new ideas, talent, partners, and funding at all levels, from regional to European.
- **Access to Talent at all Levels**

  With internships, Wetsus Academy, and HBO, there is an excellent talent pool for Ph.D. candidates.
- **Proven Valorization Ecosystem at the Watercampus**

  The valorization ecosystem has been shown to bring technological innovation to the market.
- **Strategic Research Infrastructure**

  Funding of infrastructure and projects are combined.

## Weaknesses

- **Keeping critical mass**

  How to keep critical mass for individual disciplines for scientific impact while retaining multidisciplinarity for identifying breakthrough innovations.
- **Loss of inspiration**

  The risk is that the need for structure stiffens inspiration.
- **Location**

  In a more competitive environment for attracting talent, a decentral location is less attractive.

## Opportunities

- **Demand for sustainable water technology keeps growing**

  Access to sufficient water of good quality remains an issue for the coming decades due to rising wealth, population growth, and climate change. Limits to Growth become visible and translate into regulations like the Water Framework Directive and Green Deal.
- **Growing cross-sectoral cooperation, i.e., between agriculture, energy & chemistry**

  The trust-based Wetsus network is well-suited to develop cross-sectoral ties that enrich all sectors.
- **Long-term core funding in place**

  The long-term granting of core funding creates a unique opportunity to foster the development of high-risk/high-gain ideas.

## Threats

- **Lower societal trust in science**

  A decreasing societal trust in science can deteriorate the funding willingness of governments.
- **Decreased government interest in international talent**

  International talent is deemed crucial for developing the Dutch economy; however, there is a serious-minded discussion about reducing the talent flux due to a lack of housing, etc.
- **Shortage of qualified personnel at Wetsus and at Company and University partners of Wetsus**

  Shortage of qualified people will make it harder to innovate and successfully finish projects.

## Wetsus Viability

Here we discuss the main strategic elements that determine the viability of Wetsus. The following aspects will be addressed, Recognition as National Institute, Secured Finance, New Mission & Strategy, Established Wetsus network and organization, Proven Leadership, Experienced Science Staff, New Disciplines, and a new Ph.D. model. If text is underlined, this refers to an aspect of the SWOT analysis, italic is a quote from the advice from the previous audit committee.

### Recognition as National Institute

In 2022, the Dutch government has appointed Wetsus as Institute for Strategically Important Research (Dutch: SBO-instituut) and has granted accompanying funding with that until 2034. This means that Wetsus now formally is part of the Dutch national science landscape and has been recognized as essential part of the Dutch national scientific research infrastructure. As a result of this strategically especially important recognition, Wetsus' access to national funding instruments is increased and eased considerably. So, for Wetsus being an SBO-institute not only is instrumental for the funding of the coming 10 years, but also enables funding for the periods thereafter.

### Secured Finance

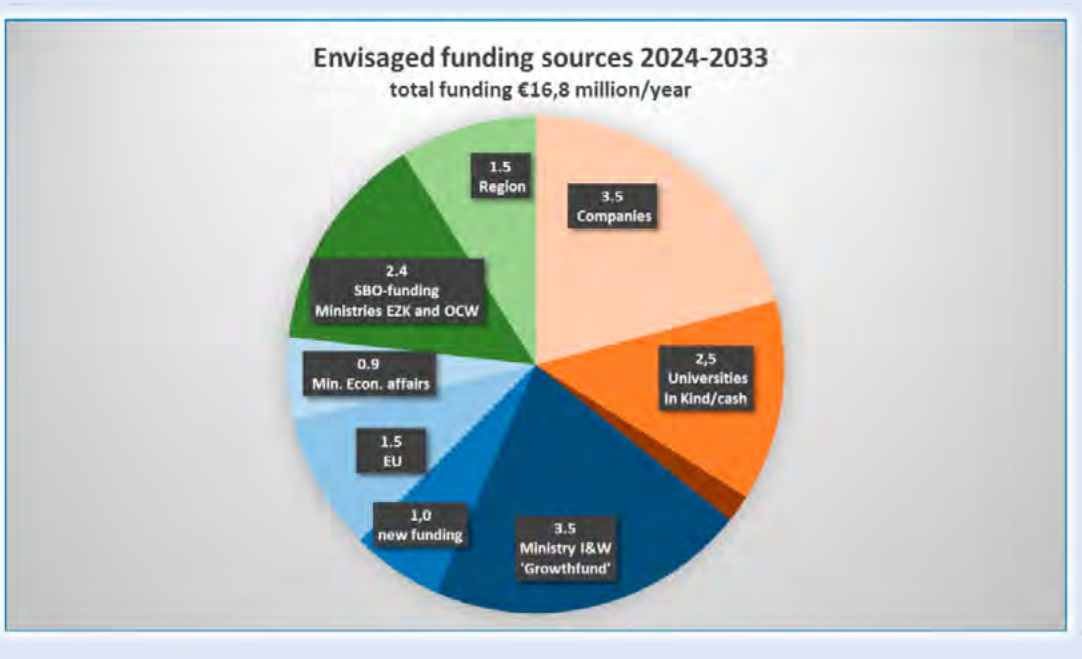



*Figure 31: Wetsus funding sources for the period 2024-2033*

Wetsus has been highly successful in acquiring the necessary long-term funding. Figure 31 shows the funding sources of Wetsus. The green segments indicate the two primary core funding sources, from the regional government and the so-called SBO-funding (Strategically Important Research Institute funding). Both are long-term commitments, from 2023 until 2034. Secured core funding is crucial for a mission-focused organization, as now the leadership and science staff can focus on innovation, without the need to spend significant attention on organizing finance. This long-term core funding makes it possible to look further ahead, commit to long-term obligations (Ph.D. projects, large research investments), and adapt to changing conditions.

With the core financing now well secured, a stable basis exists to keep current and acquire additional company funding (light orange segment) and competitive funding (blue segments) for the program costs. Wetsus is confident of the company's contribution, as this has been long-term contractually committed (the membership of Wetsus is a rolling commitment with three calendar years of notice) by over 100 private and public companies.

Also, for the competitive funding, there is much confidence:

- The Ministry of I&W Growth Fund is a program with a ten-year duration that has been won in a competitive tender. The Growth Fund aims to stimulate competitiveness in the water tech sector at all TRL levels. In this program, Wetsus is responsible for the pre-competitive know-how development, to be organized via the Wetsus innovation system. Wetsus has

successfully led the Growth Fund consortium due to its excellent position in the Dutch Water Technology innovation ecosystem.
- The Ministry of Economic Affairs' contribution is based on specific projects that fit into the Water Agenda of the Top Sector Water. Top Sectors are large economic programs that aim to stimulate a strategic research agenda and schedule for several fields, including water.
- The EU funding is diverse and comes from different programs, as shown in Appendix D, Table 23.
- The new funding category expresses the ambition for Wetsus for the following years, the funding could come from inter-sectoral programs like those of NWO (the Dutch Science Foundation) or other Top Sectors.

Overall, Wetsus has secure funding for the coming ten years; there might be a slight variation in competitive financing (Top Sector, EU funding, new funding), but this can be easily buffered, giving the stable core funding and program funding (Companies & Growth Fund).

The previous committee underlined the need for this secure core funding. *" The review committee is confident that Wetsus will be successful with competitive funding sources. It is critical for Wetsus to maintain the existing balance between public sector, private industry, and competitive funding."*

## New Mission & Strategy

In 2021, Wetsus presented its new Business Plan 2021-2032. This Business Plan 2021-2032 has as its starting point the success of Wetsus as recognized by the previous committee and follows up on their advice *"The review committee fully agrees with this approach and encourages Wetsus to follow the successful path, optimizing some details but keep pursuing the chosen track."*

The ambition of Wetsus is to go beyond recognized success and to enlarge our impact in a changing world. For this, the Business Plan 2021-2032 is constructed starting with a mission. Next the way of working is defined with a three-part strategy, program, impact, and innovation strategy. This approach gives a better understanding of the functioning and results of the Wetsus network.

The strengths of Wetsus are at the basis of a fruitful realization of the mission and strategy.

### *The mission*

The mission describes the raison d'être of Wetsus, it is an appeal and reminder to partners and employees. By having a mission that surpasses the actual activities, there is a yardstick to analyze the activities. In this way, a mission can help to counteract the risk of loss of inspiration. It will be an essential task of the Executive Board and Research Management Team to keep this mission lively in the Wetsus community.

### *The program strategy*

The program strategy describes where and why Wetsus will focus. This is essential to bring coherence by identifying four clear impact areas, our so-called research pillars. These impact areas also invite our partners to join in with innovative ideas. Having clear impact areas helps in keeping critical mass.

By defining impact areas, we follow up on the advice of the previous committee that *"It would be extremely beneficial for Wetsus for its communication to new clients, partners and stakeholders to better connect the themes to some of the key water challenges, or opportunities."* The previous committee also advised to look into the challenge of aging water infrastructure, *"One of the most important challenges for industrialized countries is the control, maintenance, management and renewal of its water infrastructure, such as drinking water supply and wastewater collection and treatment facilities."*. Aspects of aging infrastructure are well served by the current program strategy, e.g., research into pipe inspection.

### *The impact strategy*

We have developed an impact strategy beyond our earlier strategy, which was primarily focused on competitiveness. The impact areas are now leading the technology development, according to our mission; what is needed to create a more sustainable and fair society. Competitiveness is still essential in our strategy but is considered a prerequisite for further technological development and scaling through our partners. With this impact strategy, we are well placed to make full use of the opportunities, both in the rise of demand for water technology and the growing cross-sectoral cooperation.

Following up on the previous committee's recommendations, we added several KPIs to monitor progress in these impact areas. New and adjusted KPI are shown in Table 18. The previous committee advised, *"it is recommended to expand the collection of key success parameters in this field, especially to pay attention to the number of jobs created in spin-offs and collaborating companies. Another valuable success indicator, well-established in economics, is the collation and demonstration of the positions attained by the growing alumni group."*

*Table 18: New and adjusted KPIs in the Business Plan 2021-2032*

| Name | Background |
|---|---|
| Cumulative number of participating companies | With this KPI a distinction can be made between between companies that are actively involved in a specific year and the total number cumulative involved. The former is an existing KPI still included. The new KPI makes it possible to assess the turn-over in the company pool. |
| Trust & Cooperation valued by partners (grading scale 1-10) | This KPI is a measure on how the network is judged compared to comparable initiatives, by the partners involved. High trust and cooperation is a prerequisite for innovation. |
| PhD Graduates (cumulative) | This KPI is shows the number of future innovation leaders, a key element in bringing technology to impact |
| Cumulative Number of PI &professors | Next to professors PI's are added as the ability to be promotor has become open to PI's at Dutch universities |
| Novel/Patented technologies to pilot | More measurable version of earlier impact KPI "novel technologies" |
| Participants using Wetsus know-how in existing products | More measurable version of earlier impact KPI "optimization existing technologies" |

*The Innovation Strategy*

The innovation strategy describes the role of multi-disciplinarity and the partners in achieving breakthrough technology. This focus on innovation makes that Wetsus remains a forerunner in the engineering sciences by incorporating innovations arising from basic sciences, key technologies, and validating sciences. This innovation strategy helps keep critical mass and counteracts the risk of loss of inspiration; while all builds upon the Wetsus' strengths.

The academic network is also a source of inspiration and has been actively involved in writing proposals for funding of multiple Ph.D. e.g., like the Empower project (14 projects) or the so-called long-term program of NWO (>40 PhD. Projects; not granted). In this way the academic network takes part in shaping the Wetsus strategy. This is in line with the advice of the previous committee. *The review committee suggests engaging the academic network more frequently and intensively for strategic discussions, technology innovation and application opportunities, as well as for a broader project selection and development*.

*The Sustainability in the Making Theme*

To strengthen Wetsus' impact, we recently started a new research theme primarily based on social sciences: Sustainability in the Making (title in brochure: Water Innovations Uptake). The title reflects the dynamic character and open process of creating sustainability. This is not a separate research pillar but cuts across all other themes in a matrix model. The new theme will be centered around cases from the other themes in the Wetsus framework. In this way, the social scientists add to the multidisciplinary character of Wetsus' research drawing on the extensive networks. This creates maximum benefits for all partners and other actors involved.

The current strategy of Wetsus represents its best effort to create sustainable breakthrough innovations. Whether these innovations will ultimately contribute to the broad challenges, depends on many other factors. The new theme will help to better understand and improve the Wetsus strategy by analyzing it using state-of-the-art concepts like the responsible innovation framework and sustainability transitions theory. The research will lead to an increased understanding of the broader societal and environmental context and how this influences the ultimate impact of Wetsus' research. Hence, it goes beyond the goals of competitiveness and company involvement. In this way, social sciences together with public companies, end users, technology companies, engineering and natural sciences will develop a framework for analyzing and strengthening the responsible innovation process of Wetsus and its partners.

## Established Wetsus network and organization

The Wetsus network and organization evolved and refined over the years. The accomplishments (Chapter 4) have shown that the organization functions well and the moment is fit for purpose. Wetsus considers the size optimal; large enough to keep critical mass; a larger size could stiffen innovation due to a loss of inspiration due to institutional rules embedded in larger organizations. A larger organization might also lead

to formal or informal disciplinary groups, making multi-disciplinary cooperation more difficult.

The only viable way to grow for Wetsus is to duplicate the Wetsus concept. Wetus is pursuing this line in two directions. Within Europe, investigating possibilities of replicating the Wetsus concept for other fields, especially for widening participation. Outside Europe by helping others to set up a Wetsus branch for sustainable water technology. This route is currently explored with China.

## Proven Leadership

The previous audit committee noted: *"In the interest of Wetsus and the inspiring ecosystem it has created, there is a need to develop a proactive succession plan, jointly with the Wetsus management team, to assure a smooth transition should one of the key persons not be able to fulfil his/her function anymore or leave the organization."* The response of Wetsus has been one of strengthening the leadership base in the research management team. This is done via training (both on the job and via specialized courses), and mentoring.

In this way, a more distributed leadership model is created that is more resilient to personnel changes. Next to that, the Supervisory Board monitors the Executive Board in this respect and makes contingency plans, for instance job descriptions have been formalised and examples of names for successors are collected. It is to be noted that the members of the current Executive Board have indicated that they will stay for the next six years. The only foreseeable change is the retirement of the current Program Director (Bert Hamelers), a successor (Jan Post) is also already appointed.

## Experienced Science staff

A crucial element is an experienced research staff, as they supervise Ph.D. candidates, connect Universities and companies in themes and have an essential role in identifying innovation. A threat to Wetsus and its partners is the general shortage of qualified personnel, as this is the basis for superior performance. For this reason, Wetsus is now more active in developing its scientific staff by offering a dedicated development program for all new post-docs and setting up a mentoring system. This system will lead to a new pool of more mature researchers available to Wetsus and its partners.

## New Disciplines

New disciplines are needed to inspire innovations. As drought resilience becomes a new priority for Wetsus, it has become essential to include soil science and hydrometeorology into the program to develop the new Drought Resilience impact area; for the Sustainability in the Making theme, social science disciplines are needed. Finding experienced people for an institute with no reputation yet in these fields can be hard. Therefore, an important aspect is again to develop own talent within the organization and to join forces with universities in the form of joint positions.

## New Ph.D. model

Wetsus will experiment with enriched Ph.D. training that includes MBA training. The first group starts with 14 Ph.D. candidates. Wetsus has secured a co-funding from the EU to support this training, the so-called Empower project. The Ph.D. projects will be extended by six months, to partly offset the time investment of the student in the additional training. The Business School Nederland (BSN) will be responsible for the training. BSN is a highly reputed Business school.

The objective is to acquire knowledge and hands-on skills to meet current and future organizational and personal challenges within the water sector; to create a sharp vision on the changing future of business and the manager's role in it; to supply a toolkit on strategically managing and implementing change in a digital world and handling finances within an organization at uncertain times. Overall, the program aims for impact innovation leaders, with increased problem-solving abilities, with knowledge of new insights in management and organization.

The training has three phases: the first on learning basic managerial and leadership theory, the second focuses on the practical aspects of management, and the third consists of preparing and defending a thesis. The thesis topic will stem from the Ph.D. project and will be done in the context of a company connected to the theme.

This new model will lead to innovation leaders that are technologically highly skilled and have sufficient business skills to acquire a meaningful leadership role for bringing technology to impact.

In this way, Wetsus will become highly attractive to people with technological and entrepreneurial talents. This counteracts the threat of decreased government interest in international talent, as Wetsus now has a unique offering in the large pool of potential Ph.D. projects. Furthermore, in this way, more talents are attracted that opt for a role in a company. In this way, the lack of qualified personnel at companies is reduced.

The MBA thesis is researched and written at a company. In this way, a new source of inspiration is accessed, reducing the risk of loss of inspiration.

# Appendices

## Appendix A: Data sources

To put the data of Wetsus in context of the Dutch scientific landscape, we compare the findings of Wetsus with those of Dutch universities. The following data sources have been used:

RAT = Rathenau institute is a national institute involved in research and dialogue relating to the societal aspects of science, innovation, and technology. They maintain an extensive database on Dutch research institutes regarding developments around personnel, graduations, and the like.
*www.rathenau.nl/en/science-Figures*

UNL = In Universities of The Netherlands (UNL), Dutch universities work together towards a strong university sector. They maintain another database with interesting information on, among others, open access.
*www.universiteitenvannederland.nl/en_GB/facts-and-Figures.html*

CBS =The national statistical office, Statistics Netherlands (CBS) provides reliable statistical information and data to produce insight into social issues.
*www.cbs.nl/nl-nl/cijfers/detail/83966NED?q=promotie%20duur%20nederlandse%20universiteiten*

# Appendix B: Wetsus KPI Tables Business Plan 2021-2032

*Table 19: Overview of the KPI Targets as defined in the Business Plan*

## Performance Indicators Wetsus 2020-2032

| | cumulative until 2020* | 2020 realized | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Finance and commitment** | | | | | | | | | | | | | | |
| Program Budget (mln €) | | 14.3 | 14.4 | 14.5 | 14.7 | 14.8 | 15.0 | 15.1 | 15.3 | 15.4 | 15.6 | 15.7 | 15.9 | 16.1 |
| Company Contribution (mln €) | | 3.4 | 3.4 | 3.5 | 3.5 | 3.5 | 3.6 | 3.6 | 3.6 | 3.7 | 3.7 | 3.8 | 3.8 | 3.8 |
| **Science Progress** | | | | | | | | | | | | | | |
| Science projects started (PhD/postdoc) (cumulative) | 247 | 6 | 19 | 32 | 45 | 58 | 71 | 84 | 97 | 110 | 123 | 136 | 149 | 162 |
| Papers total (cumulative) | 703 | 66 | 119 | 163 | 200 | 248 | 300 | 352 | 404 | 456 | 508 | 560 | 612 | 664 |
| Citation Impact | very high | very high | very high | very high | very high | very high | very high | very high | very high | very high | very high | very high | very high | very high |
| **Competitiveness** | | | | | | | | | | | | | | |
| Number of spin-off companies (cumulative) | 36 | 2 | 4 | 5 | 7 | 8 | 10 | 11 | 13 | 14 | 16 | 17 | 19 | 20 |
| Number of patents generated (cumulative) | 88 | 2 | 5 | 7 | 10 | 14 | 17 | 20 | 23 | 26 | 29 | 32 | 35 | 38 |
| Number of patents transferred (cumulative) | 37 | 3 | 4 | 6 | 8 | 12 | 14 | 16 | 18 | 20 | 23 | 25 | 27 | 29 |
| Number of SME companies in program (turnover < 100 mln €) | 93 | 51 | 52 | 53 | 54 | 55 | 55 | 56 | 56 | 57 | 57 | 58 | 58 | 59 |
| Novel/Patented Technologies from idea to pilot (cumulative) | 24 | 3 | 4 | 5 | 7 | 10 | 11 | 13 | 14 | 16 | 18 | 20 | 21 | 23 |
| Participants using Wetsus know-how in existing products (%) | | 46 | | | 48 | | | 50 | | | 50 | | | 50 |
| **Innovation Community** | | | | | | | | | | | | | | |
| Number of participating companies (active) | | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 |
| Number of participating companies (cumulative) | 190 | 105 | 111 | 117 | 123 | 129 | 136 | 143 | 150 | 157 | 164 | 171 | 178 | 185 |
| Number of principle investigators and professors (cumulative) | 101 | 53 | 57 | 62 | 66 | 70 | 74 | 79 | 83 | 87 | 92 | 96 | 100 | 104 |
| Trust & Cooperation valued by partners (grading scale 1-10) | | ≥ 8 | | | ≥ 8 | | | ≥ 8 | | | ≥ 8 | | | ≥ 8 |
| **Future Innovation Leaders** | | | | | | | | | | | | | | |
| Ph.D. Graduates (cumulative) | 108 | 12 | 25 | 39 | 53 | 61 | 71 | 84 | 97 | 110 | 123 | 136 | 149 | 162 |
| Joint Degree MSc Students (cumulative ) | 123 | 17 | 37 | 57 | 77 | 97 | 117 | 137 | 157 | 177 | 197 | 217 | 237 | 257 |
| Research Students (non-PhD) (cumulative) | 803 | 60 | 125 | 225 | 325 | 425 | 525 | 625 | 725 | 825 | 925 | 1025 | 1125 | 1225 |

*The cumulative values until 2020 have been realized in the 2004-2019 Wetsus program

# Appendix C: Basic Input data

## Research staff

Table 20 shows the personnel composition in various categories:

Science staff are those scientists that have *next to their research* a substantial role in one or more areas such as: PhD supervision, theme coordination, teaching, EU funding and company acquisition and congress organization.

Post-docs have a primary research focus and are typically responsible for an EU funded project.

Ph.D. -candidates are the major category researchers and have double supervision from University and Wetsus.

Tech and lab support are responsible for good management of the laboratory and the technical facility.

Overhead is the remaining category that is responsible for smooth operation of the organization and includes Finance, HRM, secretarial support, canteen operation, building Maintenace and the like.

*Table 20: Categories personal in full time equivalents, rounded to nearest integer*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| **Science Staff** | 19 | 22 | 24 | 22 | 20 | 19 |
| **Post-Doc** | 7 | 8 | 5 | 5 | 6 | 12 |
| **PhD-Candidates** | 59 | 58 | 67 | 52 | 52 | 58 |
| **Tech/Lab Support** | 17 | 17 | 17 | 15 | 16 | 17 |
| **Overhead** | 18 | 21 | 21 | 17 | 17 | 20 |
| **Total** | 120 | 126 | 134 | 111 | 111 | 125 |

The F/M ratio for various categories is shown in Table 21. Related categories have been merged as the individual categories are too small.

*Table 21: F/M for personnel categories and Wetsus total*

| | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| **Science Staff** | 21% | 20% | 18% | 11% | 15% | 32% |
| **PhD-Candidates** | 44% | 48% | 51% | 56% | 62% | 57% |
| **Tech/Lab Support** | 31% | 39% | 28% | 30% | 32% | 32% |
| **Overhead** | 59% | 66% | 66% | 73% | 63% | 58% |
| **Total** | 39% | 42% | 43% | 44% | 47% | 47% |

## PhD Candidates

Table 22 shows for each cohort of Ph.D. candidates the cumulative number of graduates over time.

*Table 22: Graduation success per cohort*

| starting Year | M | F | | ≤ 4 year | ≤ 5 year | ≤ 6 year | ≤ 7 year | ≤ 8 year | Not yet finished | Discontinued |
|---|---|---|---|---|---|---|---|---|---|---|
| **2014** | 9 | 4 | 13 | 0 | 7 | 7 | 8 | 9 | 3 | 1 |
| **2015** | 6 | 3 | 9 | 1 | 3 | 6 | 6 | 6 | 2 | 1 |
| **2016** | 10 | 10 | 20 | 2 | 14 | 16 | 17 | | 2 | 1 |
| **2017** | 6 | 4 | 10 | 0 | 3 | 4 | | | 4 | 2 |
| **2018** | 7 | 7 | 14 | 0 | 6 | | | | 8 | 0 |
| **total** | 38 | 28 | 66 | 3 | 33 | 33 | 31 | 15 | | |

# Appendix D: Scientific Marks of Recognition

*Table 23: European Grants are a strong mark of recognition of the quality of the Wetsus research program.*

| Project | Funding Program | Year | Award | |
|---|---|---|---|---|
| **RM@Schools2** | EIT | 2017 | 18 k€ | |
| **Electroflex** | EIT | 2017 | 10 k€ | |
| **RM@Schools3** | EIT | 2018 | 102 k€ | |
| **VivaMag** | EIT | 2018 | 721 k€ | MA |
| **SmartVFA** | EIT | 2018 | 50 k€ | MA |
| **NEWBIES** | LIFE | 2018 | 748 k€ | MA |
| **SCALIBUR** | H2020 | 2018 | 789 k€ | |
| **Refarm** | EIT | 2019 | 80 k€ | MA |
| **REPARES** | H2020 | 2018 | 120 k€ | |
| **WaterMining** | H2020 | 2020 | 809 k€ | |
| **RM@Schools4** | EIT | 2021 | 110 k€ | |
| **ConsenCUS** | H2020 | 2021 | 906 k€ | |
| **Agro2Circulair** | H2020 | 2021 | 989 k€ | |
| **RecaP** | H2020 | 2021 | 531 k€ | |
| **AI hubNNL** | REACT EU | 2021 | 102 k€ | |
| **EMPOWER** | H2020 | 2022 | 1709 k€ | MA |
| **Water4All** | HEUR | 2022 | 553 k€ | |
| **H2OforAll** | HEUR | 2022 | 189 k€ | |
| **NINFA** | HEUR | 2022 | 602 k€ | |

*Table 24: Wetsus scientist obtaining academic research position outside Wetsus*

| | |
|---|---|
| **Wetsus Program director** | Prof. dr. ir. H.V.M. (Bert) Hamelers has become special professor Environmental Technology at Wageningen University & Research. |
| **RIVM/Wetsus researcher** | Prof. dr. H. (Heike) Schmitt has been appointed as professor of Antibiotic Resistance in the Water Cycle at Delft University of Technology (TU Delft). |
| **Wetsus researcher** | dr. M. (Michel) Saakes has become lector Water Smart Hydrogen at NHL Stenden University of Applied Sciences in Leeuwarden. |
| **WUR/Wetsus associated researcher** | Prof. dr. ir. L.C.P.M. (Louis) de Smet has become Personal Professor at Wageningen University & Research. A Ph.D. student funded from a VICI grant awarded to de Smet will be seconded to Wetsus. The VICI award is the most prestigous award in the Netherlands for senior scientist. |
| **Wetsus researcher** | Prof. dr. A. (Alan) Werker has been appointed as Adjunct Professor at the University of Queensland, Australia |

*Table 25: Wetsus scientist in editorial boards of scientific journals*

| | | | |
|---|---|---|---|
| **Associate Editor** | Associate Editor of ACS Environmental Science & Technology (Impact factor 11.4) | Prof. dr. ir. H.V.M. Hamelers | 2013-2020 |
| **Member editorial board** | Desalination (Impact factor 7.1) | Dr. ir. P.M. Biesheuvel | ongoing |
| **Member editorial board** | J. Membrane Sci. Lett. (new journal since 2021, no IF yet) | Dr. ir. P.M. Biesheuvel | ongoing |
| **Member of Early Career Editorial Board** | J. Membrane Science (Impact factor 10.5) | Dr. ir. M. Tedesco | ongoing |

*Table 26: Scientific conferences and webinars (co-) organized by Wetsus*

**2017**
- EDS Conference
- IWA Conference on Algal Technologies for wastewater treatment and resource recovery
- STREAM-Wetsus research conference
- Wetsus Congress

**2018**
- European Water Technology Week

**2019**
- Workshop Novel Batteries for Electric Energy Storage
- MMC PHA research workshop
- Workshops Problem of Synthetic nano- and microfibers
- Wetsus Congress

**2020**
- 12th European Symposium on Electrochemical Engineering
- Webinar Bioassays: added value for water quality monitoring

**2021**
- Webinar Artificial Intelligence in water technology
- Webinar AMR in wastewater: determinants and removal
- Webinar Natural nano particles in water: the key to new technologies
- Wetsus Congress

**2022**
- Workshop week Recap
- 5th international symposium on Physics of Membrane processes
- Webinar Applied genomics towards routine use in water monitoring
- European Water Technology Week

*Table 27: Overview of Wetsus scientific staff members participating in Academic Juries abroad.*

| | | |
|---|---|---|
| **Dr. ir. J. Post** | committee member of thePhD exam of Lingshan Ma at Ghent University, Belgium | 2021 |
| **Dr. ir. R. Meulepas** | opponent in PhD defence of Martynas Tichonovas at Kaunas University of Technology, Lithuania | 2018 |
| **Prof. Dr.ir. H.V.M. Hamelers** | examiner of PhD candidate Gaofeng Ni of Linnaeus University, Sweden | 2018 |
| **Prof. dr. A. Werker** | external examiner of PhD committee member of Antoine Brison at EWAG/ETH, Swiss | 2022 |
| **Prof. dr. A. Werker** | external examiner PhD committee member of Anna Burniol-Figols at DTU, Denmark | 2020 |

# Appendix E: Equipment & Facilities

*Table 28: Overview of analytical equipment and research facilities. Technical facilities to make state-of-the-art research set-ups are included in the research facilities.*

## Analytical equipment

- µ-GC (biogases)
- Wateractivity meter
- Absorbance/fluorescence/ luminescence plate reader
- AFM (atomic force microscopy)
- Bead beater (mechanical cell disruption)
- CO2 precision analizers
- CLSM (confocal laser scanning microscopy)
- CPD (critical point dryer for SEM)
- DSC (Differential Scanning Calorimetry)
- Dynamic and monotonic Titration systems
- EA (Elemental Analyzer)
- Flowcytometer (total and targeted cell enumeration)
- FT-IR (composition of solids, liquids)
- GC-FID
- GC-FPD
- GC-MS/MS (with pyrolysis & autosampler station)
- Gel electrophoresis (DGGE, DNA, protein)
- High-speed camera and image acquisition
- IC (ion chromatography of anions, cations & fatty acids)
- ICP-OES (elemental analysis), microwave digestion
- LC-MS/MS
- LC-OCD (organic carbon detection)
- Microscopy: Brightfield, DIC, fluorescence (inverse and upright), phase contrast
- MinIon (mobile long-read sequencing)
- Nanodrop spectrophotometry (nucleic acid quality assessment)
- OCT (optical coherence tomography)
- Particle size analysis (150 – 1500 µm)
- Particle size analysis (50-600 nm), zeta potential
- qPCR (quantitative real-time polymerase chain reaction)
- Quantus (fluorometer for nucleic acids and proteins quantification)
- Raman spectrometer
- Rheometer
- SEM (scanning electron microscopy), EDS (elemental analysis)
- Surface area and porosity analyzer
- TGA (Thermal Gravimetric Analysis)
- Thermocycler for PCR (polymerase chain reaction)
- TOC (carbon analysis)
- UHPLC
- UV-VIS spectroscopy
- Vacuum filtration systems
- Viscosity meter

## Research facilities

- 3D printer
- -80 °C freezer
- Amplicon sequencing
- Anaerobic glove box
- Automated research fume hoods with PLC and SCADA
- Automatic film applicator
- Ball mill
- Biobench algae flatpanel reactor systems
- Biofouling monitors with and without water production
- Biological safety cabinets (HEPA filtered)
- Black water, urine and water storage tanks
- Climate unit/Indoor Plant Growth Room
- CNC mill
- Continuous and batch reactors
- Cooling and heating compartments
- Cutting plotter
- (de)Soldering station
- Doppler echo imaging system
- Fermentation equipment
- Flat sheet membrane production
- Freeze dryer
- Fully equipped electrotechnical station
- Fully equipped optical lab facility
- GAP fume cabinets
- Gas and sewage water distribution network
- High voltage lab
- High-speed cooled centrifuge
- Hot rolling press/calendering machine
- Knife mill
- Labopress (molding and pressing)
- Laboratory eStretching machine / membrane spinning device
- Laboratory information management system (LIMS)
- Laser cutter
- Metagenomics
- ML-II level advanced microscopy lab
- ML-II level microbiology lab
- Multi-channel potentiostats
- Nano-imprinter-coating device
- Nanofiltration system (pilot scale)
- Online process control
- Respirometer
- Safety precaution measurements and systems
- Safety vacuum drying oven
- Shaking incubators (CO2/light)
- Sonication equipment
- Temperature monitoring system for freezers, fridges and stoves
- Transcriptomics (RNA sequencing)
- Tube furnace
- Ultra Turrax homogenizer
- Ultrasonic underwater inspection system
- Walk-in fume cupboards
- Welding equipment for foils and exotic metals
- Whole-genome sequencing

# Executive summary

An international review committee, composed of four eminent engineers and scientists, has evaluated Wetsus following the so-called Standard Evaluation Protocol (SEP 2015-2021) to make the outcome comparable to Dutch universities and science institutes of NWO & KNAW. The audit was commissioned by the Board of Wetsus. The objective of the audit was to evaluate the quality, relevance and viability of Wetsus as a research institute and the value of the Wetsus network for knowledge transfer. The results of this audit are intended for Wetsus partners (universities, companies and funding bodies at a regional, national and European level) to enable them to assess the value of their current investments and future commitments to Wetsus.

***Research quality***: The review committee was impressed by the significant achievements of Wetsus. Its research, publications and impact are world-class. At the same time, Wetsus provides the private sector with extremely useful scientific insight and knowledge that allows it to compete internationally at the highest level. The unique setup of Wetsus at the interface between the universities and industry has created an extremely innovative environment, which is of exceptional benefit to industry, academia and society. **Wetsus, as research unit, is seen by the review committee as one of the most influential and effective research groups in the world in its field**.

***Relevance to society***: There is a wide range of global and regional water-related issues and challenges that Wetsus research makes strong contributions to. These issues are all pervasive and the Wetsus programme is making significant and growing impacts in these areas despite its relatively recent establishment. Wetsus is a pioneer in blue energy research and collaborates with many leading companies for water treatment and other water technologies. At least 40 patents have been filed by Wetsus over the past 5 years with an impressive 42% transfer rate to industry partners, thus confirming the effectiveness of Wetsus in generating industry-relevant solutions and hence making direct contributions towards economic development. About 100 companies are now financially connected to Wetsus. The Wetsus innovation program effectively leads to new products, services and technologies, hence generating an increased turnover and commercial return for Wetsus participants. Wetsus induced investments in water technology are leading to strong regional benefits and impacts that are also felt throughout the Netherlands. The work and activities of Wetsus have further improved the reputation of the Netherlands as a global leading centre for water technology. The European Commission regards Wetsus as a best practice model for smart regional specialisation. **As a research unit, Wetsus makes an outstanding contribution to society.**

***Viability***: The management of Wetsus is well organised. Strong leadership from the top-management has built a robust, effective and efficient organisation. Organisational checks and balances are in place to both generate good quality research as well as useful results for companies. The financial system for contributions by companies is simple and effective and provides a resilient structure to ensure stability of the financial contributions from participating companies. These industry-sector contributions are multiplied with topsector support from the government, while substantial regional financing (Province of Friesland) and the continued support of the City of Leeuwarden help to provide the base-funding to run it all. The mix of funding makes sense in the European context and has brought Friesland to the forefront of water research. The continuity in staff is good. Wetsus has probably worldwide one of the most competitive and detailed PhD selection procedures with only 2% of applicants being accepted into the PhD program. Wetsus has good scientific and technical support staff. In addition, a vast network of university faculty and staff is strongly connected to Wetsus. This increases the resilience of Wetsus and makes the institute overall far less dependent on the personal composition of the top-management than 5 years ago. **The research unit Wetsus is excellently equipped for the future.**

**Research quality, relevance to society and viability were unanimously judged by the committee to each clearly deserve the highest possible score of 1 (one).**

The ***PhD education*** is exemplary. The mixed science/engineering PhD students are not only trained in research and publication processes but also in teamwork and important soft skills, such as presentations, industry engagement, critical reflection of their personal strengths, etc. Several of the PhD graduates from the last few years have found positions in collaborating industry, or academic, partner organisations, or in some of the spin-off companies that have been created from Wetsus projects. Hence the PhD graduates have a very high employability at the end of their studies.

***Research integrity*** is part of the core values of Wetsus. Students get training on conduct and ethics in research. They also learn directly from the strong quality-focused culture of Wetsus. The university research integrity systems are a further safeguard for the already advanced Wetsus system.

The committee also looked of how Wetsus organizes its ***network*** and how it ***connects its partners***. The assessment committee is impressed by the way Wetsus organises the highly integrated and interactive network around them. Both academic and industry partners were very supportive of the network, with universities seeing Wetsus as a valuable extension of their interests, not as a competitor, while companies consider the Wetsus network as a cost-effective platform to engage with key experts and cooperate on strategic or applied research. The culture of Wetsus, the IPR regulations and the way of collaborating closely within the themes creates a culture of high trust that stimulates partners not only to come in and gain knowledge, but also to contribute their own expertise and experiences to get more out of the cooperation. It could be argued that one of the most beneficial impacts of Wetsus is to attract, connect and retain some of the brightest minds to the water industry, which is crucial to the long-term development and prosperity of the sector. Wetsus in this way is an active facilitator of knowledge transfer that moves research ideas from the phase of invention into innovation and makes the connection between (university) research and industry like no other institute in water technology in the world.

The evaluation committee considers Wetsus to be unique, not only in Europe but worldwide. It represents a model research institute on how research and collaboration needs to be organized at the interface between academia, industry and society.

There are a few areas still requiring attention by Wetsus. For these areas, the review committee makes the following recommendations:

1. Both the private sector and the academic community regard Wetsus as a 'pearl' for the Netherlands and beyond. This is not only because of the work that Wetsus members are doing but more so due to the often unconventional and fresh approach that Wetsus has established to drive research and application, with perfect support given to the crucial collaborations needed to achieve success across research, development and application. The review committee fully agrees with this approach and encourages Wetsus to follow the successful path, optimizing some details but keep pursuing the chosen track.
2. A critical size in people, infrastructure and financing is needed to become and remain a successful and efficient innovation hub, like Wetsus. There is still some growth potential for Wetsus. However, it should in no way shrink. Less means, be it from the private sector, competitive funds or public sector (provincial and national support), would put Wetsus innovation potential at serious risk. The review committee is confident that Wetsus will be successful with competitive funding sources. It is critical for Wetsus to maintain the existing balance between public sector, private industry, and competitive funding.
3. Wetsus has been in existence for 15 years by now and the leading team is largely the same as the one that started Wetsus. This is probably one of the key factors of its success. Wetsus has developed a network within the Dutch Universities and the private sector with potential future leaders for Wetsus. In the interest of Wetsus and the inspiring ecosystem it has created, there is a need to develop a proactive succession plan, jointly with the Wetsus management team, to assure a smooth transition should one of the key persons not be able to fulfil his/her function anymore or leave the organization.

4. The academic network of and its commitment to Wetsus is impressive. There is further development potential in this network that Wetsus could tap into even more strongly. The review committee suggests to engage the academic network more frequently and intensively for strategic discussions, technology innovation and application opportunities, as well as for a broader project selection and development.
5. The research themes and the logics to place certain research topics and projects into a theme is not always obvious for the outsider. It would be extremely beneficial for Wetsus for its communication to new clients, partners and stakeholders to better connect the themes to some of the key water challenges, or opportunities. This would increase relevance, distinctiveness and visibility. It would also help to further highlight the important role of Wetsus in the water and environmental technology sector and speak more explicitly to a broader stakeholders group, such as governments and the public at large.
6. One of the most important challenges for industrialized countries is the control, maintenance, management and renewal of its water infrastructure, such as drinking water supply and wastewater collection and treatment facilities. Because of global importance of these issues, the committee recommends to Wetsus to explore these areas as potential new activities.
7. To further demonstrate the value created by Wetsus and to better capture the societal impact and economic benefits on a more systematic basis, it is recommended to expand the collection of key success parameters in this field, especially to pay attention to the number of jobs created in spin-offs and collaborating companies. Another valuable success indicator, well-established in economics, is the collation and demonstration of the positions attained by the growing alumni group.

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