

Scientific Audit Report



2017

Self-Assessment 2011-2016



combining scientific excellence with commercial relevance

Preface

We proudly present the 2017 Wetsus Scientific Audit report and the accompanying self-assessment report.

The audit has been performed by a committee of four world-wide renowned scientists who have assessed Wetsus on four aspects: Research quality, Relevance to Society, Viability and Network Value. The first three criteria were judged according the so-called SEP protocol, which is generally used for Dutch universities. The assessment of the network value is specific for Wetsus as the network is a unique defining aspect of Wetsus.

The judgment of the committee is based on a site visit that took place in July 2017 and a self-assessment report written by Wetsus. During the visit, the committee not only spoke with Wetsus staff members and PhD students, but also with various representatives of companies and universities connected to the Wetsus program.

The committee's audit report is integrally presented in the first half of this booklet. In short, Wetsus can be said to perform excellently, as the committee scored Wetsus on all criteria with the highest possible score. To quote the committee:

“Wetsus has achieved a very remarkable goal. Despite its strong focus on industry-relevant projects, the research quality, publications and impact are world-class. At the same time, Wetsus provides the private sector with extremely valuable scientific insight and knowledge that allows it to better compete internationally. The unique set-up of Wetsus at the interface between the universities and industry has created an extremely innovative environment that is of exceptional benefit not only to its industry and academic partners but also to society at large. Wetsus has performed extremely well in all its five major lines of research.”

An important source of information for the committee was the Wetsus 2017 self-assessment report. For that reason the audit report and the self-assessment report are combined in this booklet.

The audit report gives recommendations for further strengthening of the Wetsus innovation system. These recommendations are important tools in our mission to continuously improve the quality and impact of the Wetsus research program and network.

The very positive audit results would not have been possible without the commitment and high quality of the Wetsus scientific and organizational staff, the hard work of many excellent PhD and MSc students and, last but surely not least, the inspiring long term cooperation with the scientists and technologists from the companies and knowhow institutes connected to the Wetsus network. Thank you very much!

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

Wetsus audit 2017

Report by the external assessment committee



Wetsus audit 2017

Report by the external assessment committee

technopolis **|group|** July 2017

Professor Alexander J.B. Zehnder (Chairman)
Professor Jean M.J. Fréchet
Professor Menachem Elimelech
Professor Jürg Keller
Ir. Geert van der Veen (secretary)

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 at 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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1 Introduction

1.1 Background

This report presents the results of the audit of Wetsus, European centre of excellence for sustainable water technology. Wetsus acts as a bridge between companies and research institutes from all over Europe fostering productive cooperation to generate innovations that contribute significantly towards solutions for global water challenges. Wetsus' scientific research program is defined by industry partners from the private and public water sector and is conducted by leading universities.

The audit is commissioned by the Board of Wetsus. The objective of the audit is to reveal and (if applicable) confirm the quality, relevance and viability of Wetsus as a research institute and the value of the Wetsus network as knowledge generation and translation place. The results of this audit are intended for Wetsus partners (universities, companies and/or funding bodies, regional, national and European governments) to enable them to assess their commitment to Wetsus.

The audit is based on the format advised by the VSNU (Association of research universities in the Netherlands). Following this so-called Standard Evaluation Protocol (SEP 2015-2021) makes the outcome comparable to that of Dutch universities and science institutes of NWO & KNAW. The unit's performance is judged on the three SEP assessment criteria as described in Section 2 of the SEP: research quality, relevance to society and viability.

While the conventional VSNU style audit primarily focuses on the science and its societal relevance, this audit includes the evaluation of the added value of the Wetsus network of companies and universities.

1.2 Composition of the Committee, independence, data provided and procedures followed

1.2.1 Composition of the Committee

The audit was performed by an independent external assessment committee, consisting of four internationally renowned water researchers:

- Chairman: Professor Alexander J.B. Zehnder is a Visiting Professor and member of the Board of Trustees of Nanyang Technological University Singapore, founder and director of Triple Z Ltd. (www.triplez.ch), Scientific Director of Water Resources of Alberta Innovates – Energy and Environment Solutions in Edmonton, Canada, and former president of the ETH Board and Professor emeritus of ETH Zurich, Switzerland. He was a member of the previous audit committee.
- Professor Jean M.J. Fréchet is a Professor Emeritus of chemistry and chemical and biological engineering at the University of California, Berkeley and Vice-President for research at King Abdullah University of Science and Technology.
- Professor Menachem Elimelech is the Roberto Goizueta Professor of Chemical and Environmental Engineering at Yale University.
- Professor Jürg Keller is Chief Research Officer of the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) and Deputy Director of the Advanced Water Management Centre at the University of Queensland as well as a Professor in the School of Chemical Engineering.

Short CV's from all assessment committee members are attached in Appendix A.

Ir. Geert van der Veen (Director Technopolis Group The Netherlands) acted as support for the external assessment committee.

1.2.2 Independence

Any existing personal or professional relationships between committee members and programmes under review were reported and discussed in the committee meeting to safeguard an independent assessment of the quality of Wetsus and its research programmes in an unbiased and independent way.

The Committee concluded that there were no close relations or dependencies and that there was no risk in terms of bias or undue influence.

1.2.3 *Data provided to the Committee*

In preparation of the audit the peers received the following information:

- A research performance analysis for Wetsus by CWTS Leiden (Research performance analysis for Wetsus, European Centre of Excellence for Sustainable Water Technology 2010-2014/15, CWTS, Leiden, September 2016).
- An evaluation of Wetsus impact by BBO Leeuwarden (Wetsus 2016 Evaluation report, BBO, Leeuwarden, March 2017).
- A Wetsus self-assessment 2017 for the period 2011-2016 (Wetsus Self-Assessment 2017, Wetsus, Leeuwarden, June 2017).
- Further documentation on Wetsus and the review:
 - Assessment Guidelines
 - Wetsus 2017 Annual Brochure.
 - Wetsus Research Manual, Wetsus, Leeuwarden, July 2016.
 - Wetsus 2017 research projects, Wetsus, Leeuwarden, May 2017.
 - Standard Evaluation Protocol 2015 – 2021, Protocol for Research Assessments in the Netherlands, VSNU/KNAW/NWO, Voorburg, July 2015.
 - Wetsus Vision and Values – what we stand for-, Wetsus, Leeuwarden, June 2015.
 - Brochure ‘Wetsus Watercampus Talent Programme’, Wetsus, Leeuwarden, 2017.
 - Wetsus Innovations and spin-of companies, Examples from the 2004-2015 period, Wetsus, Leeuwarden, 2016.
 - Brochure ‘Wetsus Personal Development Program for PhD students’, Wetsus, Leeuwarden, March 2017.

The documentation included all the information required by the Standard Evaluation Protocol (SEP). The self-evaluation provided by Wetsus was well documented and highly transparent. The assessment in combination with the discussions of the committee with the research leaders, researchers and stakeholders allowed an objective evaluation of Wetsus.

1.2.4 *Procedures followed by the Committee*

The Committee proceeded according to the SEP. The final assessments are based on the documentation provided by the Institute, the key publications and the site visit to Wetsus in Leeuwarden on 10-11 July 2017 (programme in Appendix B).

At the beginning of the site visit, the Committee was briefed by Geert van der Veen of Technopolis about the objectives of the evaluation in general and of the evaluation by the committee in particular. During this meeting, several questions were clarified. The Committee also agreed upon procedural matters and aspects of the assessment.

At the end of the site visit and interviews the Committee discussed the scores and comments and drafted an evaluation text. Draft conclusions were presented to the Wetsus Board.

The report was finalised through email exchanges. The final version was presented to the Institute in July 2017. The reaction of Wetsus was discussed by email by the Committee and led to adjustments of some factual points. The final report was then submitted to Wetsus.

The Committee used the rating system of the Standard Evaluation Protocol (SEP 2015-2021, Appendix D).

For the assessment of the quality of the research, Wetsus was compared at the international level with their peers. Publication and citation records were examined, major achievements were considered and the capacity to attract highly qualified students and collaborators was discussed. For obtaining a view of the relevance for science, elements such as recognition as a knowledge centre, participation in expert groups, editorial boards and professional societies were used.

The relevance of Wetsus in relation to water research was judged at the international and local level. Services and expertise rendered to industry and practical applications of scientific developments served to assess the relevance for society.

The prospects and viability were mainly based on Wetsus vision, relevance, and leadership in the Dutch and European water technology landscape. Special attention was given to the added value of the Wetsus exceptional network of companies and universities and the impact Wetsus has through the research and this network on the economy of the Dutch water and clean technology sector.

2 Role of Wetsus in water research and technology

Increasing water scarcity and water threats are induced by demographic trajectories and/or climate changes. Both population growth and climate change put pressure on water resources. Water scarcity and water induced threats (floods, sea-level rise, droughts, etc.) can be of qualitative and quantitative nature and represent a formidable challenge in developing countries but equally also in the industrialised world. Solutions for these challenges require collaboration across fields of expertise, behavioural changes, and political reforms. Water technology in all its facets is vital to safeguard water sources, for properly managing water and its use, to minimise human and environmental impacts of water-borne pollutants, and is an essential requirement for most societal and policy water measures. Without the support of the appropriate technology, behaviour changes and political reforms come regularly to nothing.

The contribution of water technology to the sustainable use of water is of utmost importance. Water technology in sanitation prevents diseases, is key to obtain clean drinking water, provides water for agricultural production, enables industry productivity through adequate water supply, treats used water to protect the environment and prevents depletion of resources. Because of economic costs and environmental effects, water technology is increasingly moving from end-of-pipe towards integrated solutions that strive towards whole-of-system optimisation.

The economic importance of water cannot be underestimated. Without adequate supply of water at an appropriate quality, most industries would face considerable challenges or could simply not continue to operate. The changing needs of growing cities, the change of water requirements for rural areas (drinking and wastewater treatment), and the fast developing and diversifying industry sector demands highly flexible, efficient and innovative water technology solutions.

Wetsus is playing a very important role as provider of new and adapted technologies to the entire water sector. It bases its work on excellent research in the Dutch universities and close collaboration with industry, the needs of the Dutch and international water sector and the commitment of the Dutch municipalities and utilities to deliver drinking water of highest quality to its people. Wetsus actively bridges the gap between the research knowledge generated locally and globally and the water sector and related industries. There are only a small number of institutions around the world doing similar work and the results of their work are in high demand.

With its well-established model of operation Wetsus is a unique entity to actively enable collaboration between University and Industry, facilitating the creation and transfer of ideas and their translation into economic development.

3 Assessment of Wetsus

3.1 Wetsus strategy and targets

In the eyes of Wetsus, solving the main water issues requires completely new directions leading to breakthrough technologies. Wetsus focuses on developing new processes and technological solutions. Five research areas (sustainable water supply; waste water treatment and reuse; new water sources; reuse and production of components and energy from water; detection of pathogens and micro/nano pollutants) are defined, requiring multidisciplinary research in different disciplines, such as Chemistry and Process Engineering; Membrane Science; Electrochemistry; Solid-Liquid Separation (Crystallisation); Aquatic Physics; Microbiology & Virology; Algal Biology & Zoology.

Within these broad research areas, the research focus is determined by participating companies and organised in themes. Research questions that may lead to a research theme can be proposed by participating companies and are then developed into a project proposal in an iterative process between the companies and interested knowledge institutes. The project proposal is evaluated by an independent Program Council with independent experts from different fields. The final decision is taken by the Wetsus Executive Board, based on strategic fit (chance of delivering breakthrough technology; industry value, scientific quality) and financial feasibility (available budget and financial commitment by companies).

Now, the programme includes 23 themes, supported by 71 companies that have one or more commitments (i.e. multi-year financial contributions of €28.000/y) and involvement of 22 knowledge institutes with a total of 50 professors and their academic groups.

Research targets are defined in generic terms: number and quality of scientific publications, number of spin-off companies and number of (transferred) patents. Industry satisfaction (meaning whether they want to continue their commitment or not) is also an important parameter.

This way of programming and project evaluation with and by Industry has led to a very active and constructive involvement of Industry and University partners with mutual benefits. Universities draw a direct benefit from accessing the network of companies associated with Wetsus. Similarly, Wetsus provides access to a broad array of University expertise to the involved companies.

3.2 Qualitative and quantitative assessment

3.2.1 Research quality

Wetsus has built an impressive research infrastructure with state-of-the-art shared facilities managed by expert staff. Separate PhD-projects are carried out in individual laboratory spaces, which are placed in close proximity to each other in order to favour constructive interactions and expertise sharing.

Wetsus has achieved a very remarkable goal. Despite its strong focus on industry-relevant projects, the research quality, publications and impact are world-class. At the same time, Wetsus provides the private sector with extremely valuable scientific insight and knowledge that allows it to better compete internationally. The unique set-up of Wetsus at the interface between the universities and industry has created an extremely innovative environment that is of exceptional benefit not only to its industry and academic partners but also to society at large. Wetsus has performed extremely well in all its five major lines of research.

Research in **Sustainable Water Supply** spans key areas from the removal of harmful contaminants in drinking water to the preservation of assets such as the water grid and water-processing plants. For example, several projects address the production of safe drinking water, free of viruses and other contaminants such as pharmaceutical residues, through UV disinfection or specially designed germicidal membranes. Projects aimed at the protection of assets include the development of sensing mechanisms to monitor the integrity of water pipelines or the prevention of biofouling in membrane

filtration systems. The work performed by Wetsus in these key areas is uniformly of high quality and great relevance not only to the region and the country but also to the world.

The **Wastewater Treatment and Reuse** area consists of five themes, with some focused on solutions to key challenges or opportunities such as the treatment of "concentrates" or "source separated sanitation", while others are investigating new process technologies for broader applications. The overall quality and novelty of the projects is very high, with clear relevance to industry and/or society needs. The disciplinary coherence of the projects within each theme is generally strong, though in some cases it is unclear what the rationale is behind the 'clustering' of the projects in one theme, particularly in the "advanced water treatment" theme. The cross-project synergies and benefits that can be achieved in such cases may be somewhat limited compared to themes that have stronger disciplinary or application coherence. The collaboration within the themes is highly valued by industry partners as well, particularly where the whole "application value chain" is represented in a theme from component supplier over technology provider to end-user.

The **New Water Sources** area addresses several topics related to desalination, selective separation, and dehydration, using several approaches such as capacitive deionization, multistage electro-dialysis, and selective membranes/materials for specific ion adsorption. The research focuses on two important aspects: achieving high recovery of selected chemicals (e.g., phosphate, sodium) and minimizing the energy of desalination. There is a good balance between applied and fundamental research and the problems investigated provide interesting topics for PhD dissertations, while still being relevant to industry. Overall the research is innovative, of high quality, and of great relevance. The research area may benefit in some cases from performing initial techno-economic analyses for proposed new processes as well as benchmarking against existing processes before construction of expensive laboratory setups begins.

The **Reuse of Components and Production of Energy** area covers a wide range of topics including blue energy production via reverse electro-dialysis (RED), capture of CO₂ for energy recovery, and resource recovery from waste streams. One area of very active research and ambitious pilot testing is the production of electric energy by RED via the mixing of freshwater with seawater, which is particularly relevant for the region. The projects are well integrated with industrial partners and combine applied research with process engineering. Generally, the projects involve novel ideas, at least for the newly initiated projects, and the research is of high quality. Numerous projects in this theme involve electrochemical and bio-electrochemical processes. The theme could benefit from exploring some alternative technologies and benchmarking their results/goals against existing technologies.

The **Sensing of Micro/Nano Pollutants** area has currently only two themes and four projects included. The "sensing" theme is focused mainly on novel physico-chemical measurement approaches that have a high degree of novelty, with significant application potential, but also considerable further development needs. The "genomics-based water quality monitoring" theme is mainly exploiting some of the rapidly developing 'omics' and bioinformatics approaches for water quality applications. The projects are focused on broad-ranging monitoring solutions for microbial or chemical contaminants, which are primarily driven from the application and end-user needs. Therefore, they have a strong strategic fit with the overall water technology focus of Wetsus.

Overall, Wetsus has a unique combination of well-focused industry driven research of very high academic quality. The number of publications from Wetsus is comparable to that of leading, less industry oriented, research institutes in the world, and the publications in all areas are in high impact journals. Remarkably, Wetsus' Mean Normalised Citation Score (MNCS) is 2.13, meaning that Wetsus articles are cited more than twice as often as the average research articles in the fields of science that Wetsus is covering. Moreover, an impressive 31% of Wetsus articles appear in the top 10% of all cited articles in their field.

Therefore, the review committee considers the **research quality** of Wetsus to be **1: The research unit is seen as one of the most influential and effective research groups in the world in its particular field.**

3.2.2 *Relevance to society*

In the first place, Wetsus is a mission-driven organisation, aiming at contributing to breakthrough developments in water treatment technology to help solve global societal threats and challenges.

There is a wide range of global and regional water-related issues and challenges that Wetsus research makes strong contributions to. These cover not only the provision of water with adequate quality to society, but also include environmental and biodiversity protection, the recovery of valuable materials from waste, the reduction of greenhouse gas emissions, the development of energy-efficient water treatment processes and the exploitation of novel sustainable energy sources. These issues are all pervasive and the Wetsus programme is making significant and growing impacts in these areas despite the relatively recent establishment of Wetsus. 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.

The regional economic impact of Wetsus in terms the growth of a water technology knowledge economy in Friesland is very clear. It forms the core of the Water Campus Leeuwarden, and through its activities provides 225-320 full-time jobs for knowledge workers in this brain-drain region of the Netherlands. In the past 10 years, 30 spin-off companies have been created and 20 other companies were attracted to the region.

While Wetsus is clearly a pole of attraction and an economic driver in Friesland, its effect is also felt throughout the Netherlands. Wetsus gives participating companies an additional degree of freedom in their research by providing intensive and highly integrative collaboration opportunities and, in this way, enable companies to explore ideas that they could otherwise simply not pursue by other means. Based on their own feedback, many companies have confirmed that they have already benefited from the research through new or improved technologies (50% of respondents), new products and technologies (35%) and increased turnover (23%). Most remarkably, nearly all companies who responded (96%) expect to benefit from the work of Wetsus in the next 5 years. This highly positive assessment from the survey was also fully confirmed in the discussions with the industry representatives during the on-site visit.

About 170 companies are now financially connected to the Water Campus. The work and activities of Wetsus have further improved the reputation of the Netherlands as a leading centre for water technology. The Wetsus innovation program effectively leads to new products, services and technologies, hence generating an increased turnover and commercial return for Wetsus participants (BBO). Economically a large part of the revenue of the water technology companies is gained abroad. The companies profiting from Wetsus and Watercampus are present in the most important water conferences and exhibitions, like Weftec, Singapore Water Week, Amsterdam International Water Week, IWA congress, etc.

According to the BBO evaluation, investments in water technology lead to diversification of the regional economy, a more knowledge-based regional economy, a greater international orientation of regional SME's, an increase in attractiveness for academic people to come to the city of Leeuwarden and the region, increased reputation and international visibility of Leeuwarden, and an increase in international contacts, cooperation and partnerships. Wetsus itself has become a magnet for the water community at large bringing a sizable number of visitors to Leeuwarden, thus contributing to the local economy. As a consequence, the EC regards Wetsus as a best practice model for smart regional specialisation.

The peer review committee considers the relevance to society of Wetsus to be **1: As a research unit, Wetsus makes an outstanding contribution to society.**

3.2.3 Viability

The management of Wetsus is well organised. Strong leadership from the top-management has built a robust and effective organisation. The past five years have been characterised by strong growth in all areas. The number of participating companies increased, the number of cooperating knowledge institutes increased, the number of researchers increased, leading to increased research output and economic impact. A new building was designed, built and occupied and the professionalization was brought to the next level. With a limited amount of prescriptive procedures and a strong focus on personal responsibility and growth, a professional and pleasantly stimulating research culture was created that drives the research forward in a highly collaborative spirit.

Organisational checks and balances are in place to both generate good quality research as well as useful results for companies. There is also clear support for personal development, shared responsibilities and joint decision making within the organisation that further underpin the strong organisational culture.

The financial system for contributions by companies is simple and effective, avoiding complex administrative procedures and providing a resilient structure to ensure stability of the financial contributions from participating companies. The large number of companies that is participating also gives a very low dependency on one or a few large contributors. The company representatives that the committee spoke to consider their participation to be very valuable and cost-effective.

These industry-sector contributions are multiplied with topsector support from the government, while substantial regional financing (Province of Friesland) helps to provide the base-funding to run the overall operation. The support of the City of Leeuwarden was indispensable for realising the building, which has made a huge contribution to the successful growth and consolidation of Wetsus over the last five years. The mix of funding makes sense in the European context and has brought Friesland to the forefront of water research. Each of the multiple financial inputs is strongly leveraged with other support, which makes for a highly attractive and efficient initiative for all partners involved.

The dependence on government funding is however still the weakest point in the viability. The dependence on an occasionally not entirely secure government funding questions the viability. The upside is that Wetsus has more 'stabilisers' in their system than many comparable organisations. The research returns Wetsus is showing are quite compelling, especially on regional scale. Therefore, continued investments of governments would be well justified, particularly given the significant further growth potential this could unlock across the Leeuwarden Water Campus. Wetsus is directly relevant and valuable for the industry, and is increasingly a key attractiveness factor for companies to settle in the region.

The continuity in staff is good. Wetsus can now pick the best candidates in the world for their PhD position with only 2% of applicants being accepted into the PhD program. It has good scientific and technical support staff and a vast network of university faculty and staff that is strongly connected to Wetsus. Wetsus is now far less dependent on the personal composition of the top-management than 5 years ago. A proactive succession planning strategy for the top-management is nevertheless recommended to ensure the long-term viability of what is clearly an outstanding model of successful industry-academia collaboration.

The peer review committee considers the viability of Wetsus to be **1: The research unit Wetsus is excellently equipped for the future.**

3.3 Quality and organisation

3.3.1 PhD programmes

The Wetsus PhD programme is a core element and a key strength of the unique Wetsus offering to both the industry and academic partners. The Wetsus-developed selection and ongoing development process for their PhD cohort is considered to be exemplary for any PhD program. Wetsus has already such a strong reputation that they can only accept the best candidates (just 2% of all applicants), and they also

provide the students with an extensive range of learning opportunities and experiences to make them highly sought after at the end of their studies.

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.

There is very strong support from the universities and the individual academics involved, as well as the industry partners who also see this as a valuable talent development process for their own future needs. Indeed, 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.

The PhD students are also very positive about their experience in the programme, with extensive professional development opportunities, both through formal training courses at Wetsus and their 'home' universities and informal interactions with industry partners and their peers. Due to the common location in the new building and the range of joint activities, they also strongly identify themselves with the Wetsus PhD programme and are acting as 'ambassadors' for the program. They also value the close social contacts and networking options that the programme offers, in particular the collaboration with industry partners and the exposure to their needs and opportunities.

3.3.2 Research integrity policy

Research integrity is part of the core values of Wetsus. Students get training on conduct of research and ethics and 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.

3.3.3 Network

The 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.

Wetsus not only provides access to an extremely large (and growing) group of universities and professors with diverse skill sets that encourages real interdisciplinary research, but also creates valuable connections with a large body of also diverse and profound (but often also practical) knowledge and skills of other companies. 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. This represents a strong win-win situation. Wetsus also selects and educates talent that provides a very valuable long-term contribution to the expertise and capacity building in the water field.

Indeed, 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.

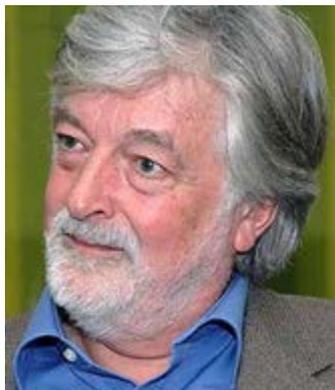
Wetsus in this way is an active facilitator of knowledge transfer that moves research ideas from the phase of invention into innovation and makes the connection between (university) research and industry like no other institute in water technology in the world.

4 Recommendations

Wetsus is a unique institution, not only in the Netherlands but also internationally. Although Wetsus research quality, societal impact and viability are all excellent, the review committee feels that Wetsus needs to focus its attention on a few points to enforce and strengthen its exceptional status for the future. These points, formulated as recommendations, are:

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.

Appendix A Members of the Assessment Committee



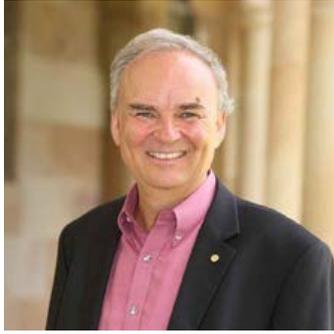
Chairman: Professor **Alexander J.B. Zehnder** is a Visiting Professor and member of the Board of Trustees of, Nanyang Technological University Singapore, founder and director of triple Z Ltd. (www.triplez.ch), Scientific Director of Water Resources of Alberta Innovates – Energy and Environment Solutions in Edmonton, Canada, and former president of the ETH Board and Professor emeritus of ETH Zurich, Switzerland. His work focusses on water policy, the nexus between water, energy and food security, water safety and infrastructures, as well as innovative solutions in industrial water treatment, particularly in the oil and gas industry. He was a member of the previous audit committee.



Professor **Jean M.J. Fréchet** is a Professor Emeritus at the University of California, Berkeley and Vice-President for research at King Abdullah University of Science and Technology. He has authored nearly 900 scientific papers and holds over 70 United States Patents. His research areas include organic synthesis and polymer chemistry applied to nanoscience and nanotechnology with emphasis on the design, fundamental understanding, synthesis, and applications of functional macromolecules. (h=165)



Professor **Menachem Elimelech** is the Roberto Goizueta Professor of Chemical and Environmental Engineering at Yale University. He is the founder and Director of the Environmental Engineering Program at Yale University. His research is in the general area of the water-energy nexus. Specifically, the research in his group involves: (i) membrane-based processes for energy-efficient desalination and wastewater reuse, (ii) sustainable production of water and electricity with engineered osmosis, (iii) environmental applications of nanomaterials, and (iv) water and sanitation in developing countries. (h = 127)



Professor **Jürg Keller** is Chief Research Officer, CRC for Water Sensitive Cities; *and* Deputy Director Research, Advanced Water Management Centre at the University of Queensland and Professor in the School of Chemical Engineering. He has also an Australian Professorial Fellowship from ARC (Australian Research Council). He has over 17 years' experience in water industry research, particularly in biological wastewater treatment, environmental biotechnology, microbial fuel cells and water recycling. While working at the leading edge of research and development in this field, he is also heavily involved in collaborative and consulting projects with industry partners across Australia and New Zealand. He has been director of the AWMC since its inception in 1996. The Centre is one of the leading research centres in this field worldwide with over 60 staff and students investigating innovative ways to improve water management. (h = 76)

Appendix B Site visit programme

Sunday July 9

19.00 – 21.00 **Dinner of the peer review team & science and program director at Post Plaza, Leeuwarden**

Monday July 10

8.30 (2.02) **Welcome and outline of the evaluation** by Alexander Zehnder (chairman) & Geert van der Veen (Technopolis), objectives of the evaluation in general and of the evaluation by the committee in particular.

09.30 (2.02) *Coffee break*

09.45 (2.02) **Presentation & Discussion of Research strategy of the past 5 years and results Wetsus**

Cees Buisman: Mission, objectives, policy, structure, activities, management and financing

of Wetsus (15 min)

Inez Dinkla: Managing network, themes and multidisciplinary staff (10 min)

Bert Hamelers: Performance Analysis (15 min)

11.55 (2.02) Elmar Fuchs: Tour with explanation of facilities (20 min)

12.15 (terrace 3) *Lunch with research management team and business director*

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

Membranes & Electrochemistry

	Theme	Wetsus	University Representative	Company Representative
13:00 (2.02)	CDI AWT CO2-energy Blue Energy	Maarten Biesheuvel Michele Tedesco Michel Saakes	Kitty Nijmeijer Huub Rijnaarts	Peter Aerts Simon Grasman Perry van der Marel
GROUP SWITCH				
13:45 (2.02)	Concentrates Desalination Dehydration	Martijn Wagterveld Henk Miedema	Rob Lammertink Louis de Smet Sascha Kersten	Luciaan Boels Willem van Baak Marco Giuseppin
14:30 (2.02)	Discussion with Company Representatives (2.02)			
15:00 (2.02)	Discussion with University Representatives (2.02)			

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

17.00 (Atrium) *Drinks*

18.00 (2.02) **Committee meets to discuss and conclude Day 1**

19.30 *Dinner at Restaurant De Kleyne Sint Jakob, Leeuwarden with research management team and business director.*

Tuesday July 11

9:00 (2.02) **Discussion with Wetsus staff on specific topics:**

European Collaboration	Roel Meulepas
PhD Recruitment	Heleen Sombekke
Personal Development Program	Bert Hamelers

9.45 (2.02) **Presentation & Discussion of Wetsus strategy/viability for the future:**

General: Cees Buisman
 Finance: Johannes Boonstra
 Quality: Wim Rulkens & Bert Hamelers

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

Biotechnology & Microbiology

	Theme	Wetsus	University Representative	Company Representative
11:15 (2.02)	Resource Recovery	Tom Sleutels	Annemiek ter Heijne	Pieter Hack
	Sulfur	Jan Klok	Gerard Muijzer	Joost Timmerman
GROUP SWITCH				
11:45 (2.02)	Genomic based water quality monitoring	Inez Dinkla	Gert-Jan Euverink	Marije IJszenga
	Source Separated Sanitation	Lucia Hernandez	Heike Schmitt	Cora Uijterlinde
	Virus Control	Sanne van den Hengel	Erik Roesink	Sybrand Metz
12:30 (2.02)	Discussion with Company Representatives (1.02)			

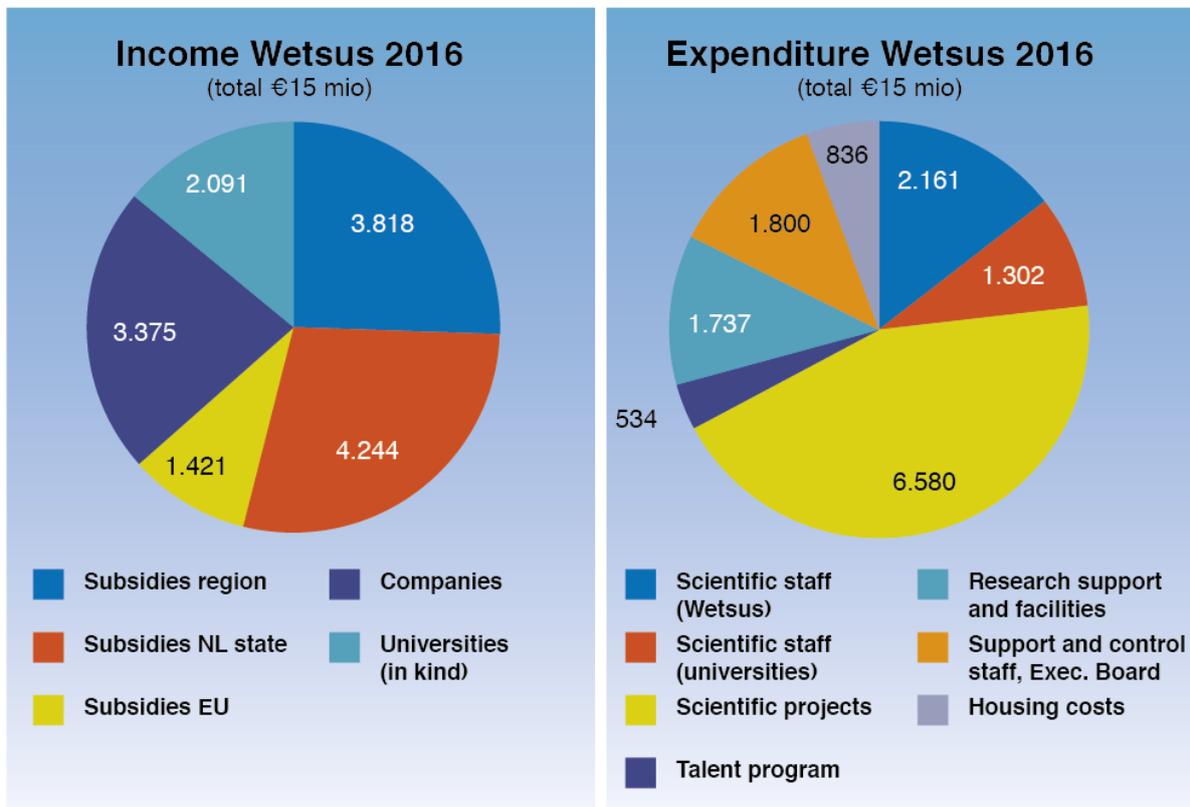
13.00 (terrace 2) *Lunch with scientific staff members & University Representatives*

13.30 (2.02) **Drafting of conclusions 2nd day of evaluation**

15.00 (2.02) **Presentation of conclusion to the board members of Wetsus by the chairman of the evaluation committee**

15.30 (2.02) **Closing**

Appendix C Quantitative data on the research unit's composition and financing, performance indicators



Performance Indicators Wetsus	2011 realized	2012 realized	2013 realized	2014 realized	2015 realized	2016 realized	2016 target
Input							
Program budget (mln €)	13.8	15.7	16	16	14.9	14.1	15.1
Contribution of companies to research programme (mln €)	3.6	3.8	3.6	3.3	3.3	3.3	3.3
Overhead (%)	10	10	10	10	10	10	10
Network							
Number of participating companies	92	95	93	95	105	104	107
Percentage of SME companies (turnover < € 100 mln/y)	55	54	54	56	57	57	50
Percentage of foreign companies	20	20	23	25	24	24	26
Number of participating research chairs	45	46	48	52	54	50	50
Number of public knowledge institutes (participants)	16	18	19	19	21	22	21
Impact, Output and Outcome							
<i>Education</i>							
Number of PhD Students (cumulative)	114	128	145	160	179	197	188
Number of joint degree students	11	21	23	30	36	40	40
Number of MSc thesis students / year	61	80	76	72	79	83	80
Number of talent events	19	19	16	20	25	29	25
<i>Scientific</i>							
Number of scientific papers in international journals (cumulative)	176	234	294	376	425	505	500
Numbers of papers in top 10% citations (cumulative - 1y)		45	67	80	107	120	113
Citation impact (overall)	1.8	2.4	2.8	2.4	1.8	>1.5	>1.5
<i>Valorization/entrepreneurship</i>							
Number of spin-off companies (cumulative)	17	20	24	26	27	30	28
Number of patents (submitted, filed and granted) (cumulative)	53	61	64	67	76	79	79
Number of transferred patents (cumulative)	14	22	22	26	27	28	30

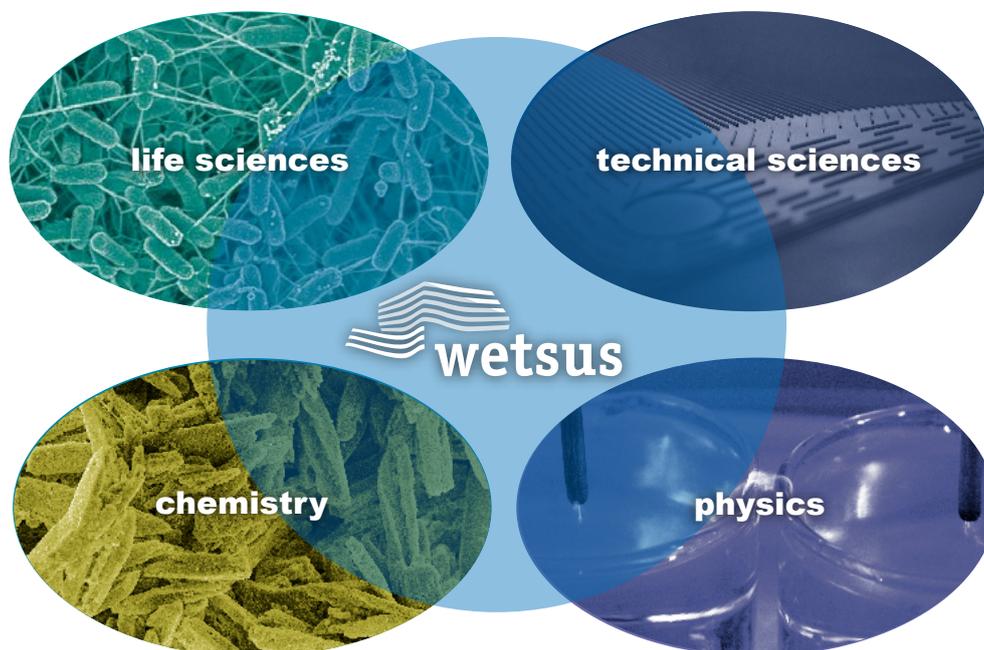
Appendix D Explanation of the categories utilised

Category	Meaning	Research quality	Relevance to society	Viability
1	World leading/ excellent	The research unit has been shown to be one of the few most influential research groups in the world in its particular field.	The research unit makes an outstanding contribution to society.	The research unit is excellently equipped for the future.
2	Very good	The research unit conducts very good, internationally recognised research.	The research unit makes a very good contribution to society.	The research unit is very well equipped for the future.
3	Good	The research unit conducts good research.	The research unit makes a good contribution to society.	The research unit makes responsible strategic decisions and is therefore well equipped for the future.
4	Unsatisfactory	The research unit does not achieve satisfactory results in its field.	The research unit does not make a satisfactory contribution to society.	The research unit is not adequately equipped for the future.

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Wetsus Self-Assessment 2017

2011-2016



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Ministry of Economic Affairs



Ministry of Infrastructure and the Environment



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Introduction

This self-evaluation report is part of the 2017 Wetsus audit. The objective of the Wetsus Audit is to assess the quality, relevance and viability of the research within Wetsus, the value of the Wetsus innovation system and the value of the Wetsus network as knowledge meeting place. The results of the audit are intended for our partners (universities, companies & funding bodies regional, national and European) to enable them to assess their commitment to Wetsus.

The audit is commissioned by the executive board of Wetsus. The audit is based on the format advised by the VSNU (Vereniging van Samenwerkende Nederlandse Universiteiten) and widely used in the Dutch academic setting. This choice makes the outcome well comparable to audits of research groups within Dutch universities and to audits of science institutes of NWO & KNAW.

While the conventional VSNU-style audit primarily focuses on science, this audit will also include a self-assessment of the added value of the Wetsus network of companies and universities, besides describing research, education and valorization. An excellent network is believed to be crucial for science that is both scientifically excellent and commercially relevant.

The audit is performed by an international committee chaired by prof. A.J.B. Zehnder. The committee consists further of prof. J.M.J. Fréchet, prof. M. Elimelech and prof. J. Keller. All are independent (have no relation with Wetsus), authoritative (all are high-ranking scientists) and together constitute an international outlook (Europe/Singapore, Saudi Arabia, US and Australia) with their own vision on water-related issues.

Having an authoritative and independent committee with an international outlook gives Wetsus the possibility to be challenged on its performance, and will yield valuable information and directions for further improvement.

As part of this audit, this self-assessment report is written. This is an important part of the input to the committee enabling them to prepare their site visit.

What is Wetsus

Vision & Mission

Water

Water is a defining component of our blue planet supporting all life forms. Access to sufficient high quality water is required for human and environmental health, but water is also required for many important economic sectors like mining, manufacturing, agriculture and power generation. Access to sufficient water of high quality is under stress as suitable water sources become both depleted and polluted. Water pollution arises often from those same economic activities like cities, mining, agriculture and energy that are heavily depending on water. These sectors not only face water stress but also growing stress from scarcity of other raw materials (e.g. fossil fuels for energy, nutrients for fertilizers).

To accommodate the growing world population with sufficient clean water one can no longer just focus on producing more water but should consider this challenge within the broader framework of growing scarcity of materials (not only water) and energy and its associated pollution.

Breakthrough developments in the field of water treatment technology are required, to help solve global societal threats and challenges, such as:

- Decrease of biodiversity (by waste water discharge, hormone disrupting substances, salination, water depletion)
- Growing shortage of water (water reuse and desalination required)
- Emission of greenhouse gasses, need for sustainable energy and energy efficiency
- Sustainable Development Goals (global water and sanitation availability)
- Growing antibiotic resistance (treatment of water from hospitals & pharmaceutical industry)
- Depletion of raw materials (recycling of metals and minerals from water required)

Wetsus

To meet these grand societal challenges, Wetsus focuses on new **process-technological solutions** that are capable of improving large volumes of impaired water to increasingly higher quality requirements. With the growing complexity of our societal challenges we no longer can rely on currently existing technology but require **completely new directions** leading to **breakthrough** technologies.

Wetsus has defined five main research axes that give direction to where to find the required breakthrough solutions.

1. Sustainable water supply
2. Waste water treatment and reuse
3. New water sources
4. Reuse and production of components and energy from water
5. Detection of pathogens and micro/nano pollutants

To come to results in these five directions, we are mainly active in seven well-defined research domains, or research fields, as summarized in Figure 1. To exemplify this multidisciplinary, in Table 1, seven examples of ongoing research projects are listed.

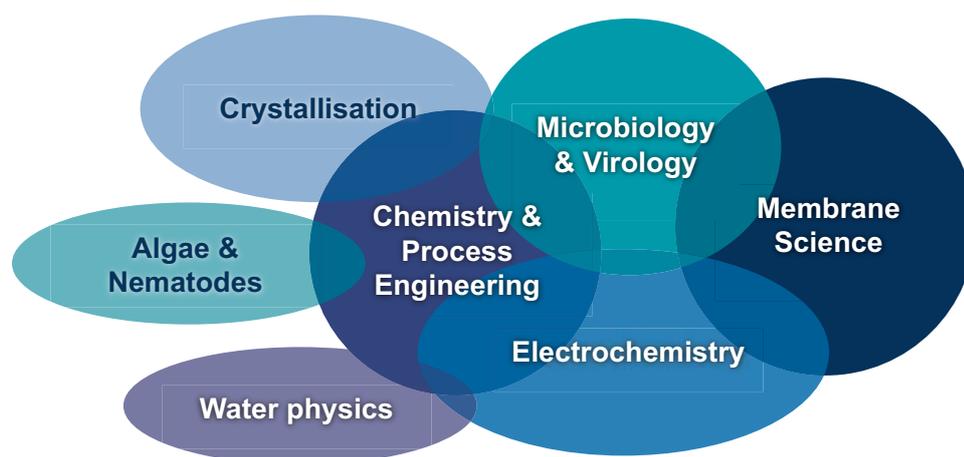


Figure 1. Overview of the main disciplines relevant for water technology. Wetsus research takes place where research disciplines have significant overlap.

Wetsus aims to offer a breeding place for breakthrough processes by bringing together innovative companies and creative scientists to jointly operate a pioneering multidisciplinary research program. The role of the creative scientists is to come up with ideas and to ensure the scientific quality of the research. To bring these innovative breakthrough processes into practice, companies are needed that further develop, produce and distribute these solutions. The role of companies is thus to ensure commercial relevance and to bring the new ideas to real applications.

Not only new solutions are needed, also **new minds** that can develop and bring such solutions further are a necessity. Therefore the core of the research program is a PhD program that brings PhD researchers from various disciplines together in one research laboratory. This gives the PhD researcher a unique possibility to work in a **multidisciplinary environment**. Bringing the PhD researcher outside their own disciplinary group creates a multidisciplinary attitude as they have to rely on each other for support. In addition, the close cooperation with companies creates a unique innovation perspective for the Wetsus PhD researchers. After graduation, the PhD researcher can further develop the new technology either in an existing company or in their own start-up company. The PhD program is thus an important pool of talent for companies that have the ambition to bring the technology to the world. Therefore, next to the development of research skills, a dedicated PhD program is offered to PhD researchers focusing on the required personal growth and “soft” skills.

Table 1. Examples of multidisciplinary research projects at Wetsus

RESEARCH PROJECT	DISCIPLINES INVOLVED
Novel sensor platform for monitoring water composition and biofilm formation	Transmission line technology; polymer chemistry; physical chemistry; microbiology
Characterization of the extracellular polymer matrix of biofilms	Microbiology; polymer chemistry; atomic force microscopy;
Photo-catalysis in a fluidized UV-LED bed	Catalysis; photo chemistry; reactor design; LED technology
Biological phosphate recovery from iron phosphate	Biogeochemistry; microbiology; sewage water treatment; phosphate chemistry
Application of salinity gradient energy systems	Membrane technology, ion transport; modelling; reactor design; physics; biofouling
Robotics and Ultrasound	Signal processing; physics; materials science
Antibiotic Resistance	Molecular tools; microbiology; ecology

Wetsus Network, Research & Organization

Wetsus Organization

Wetsus is a not-for-profit foundation and is managed by its executive board, formed by prof. dr.ir. Cees Buisman and Johannes Boonstra. The participating organizations are represented in the Wetsus supervisory board. This board consists of four members appointed by company participants, four members appointed by knowledge institutes and two independent members, the chair and vice-chair.

Wetsus' international research program is coordinated by program director dr.ir. Bert Hamelers and the multidisciplinary team of Wetsus scientists. **The research is mainly performed by PhD researchers, employed and supervised by the participating international know-how institutes.** These researchers are typically full-time seconded to the Wetsus organization. The PhD researchers work in Wetsus' laboratory in Leeuwarden, where the multidisciplinary team of scientists takes care of their day-to-day supervision. In the Wetsus laboratory, a staff of analysts and technicians ensure the permanent availability of world class research facilities to support 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.

The Wetsus organization has set clear targets summarized as Key Performance Indicators (KPI) that are described in the Wetsus Business Plan. Every year the progress with respect to these indicators is evaluated and published in the yearly report. This makes the functioning of the organization transparent to the Wetsus network members.

Wetsus Network based on Trust

Wetsus can be considered as a know-how and innovation network of companies, universities, research and governmental organizations. Wetsus enables the exchange of ideas, knowledge and opportunities around a multidisciplinary research program aiming at breakthrough solutions for water quality and availability problems by generating scientific knowledge and patents, training of new scientific researchers, and stimulating spin-off companies.

Operating from Leeuwarden, the Wetsus organization facilitates this network and accommodates the associated research program. As the Wetsus organization is part of the network, we will only explicitly refer to either the Wetsus network or the Wetsus organization whenever required by the context.

The research program is the engine of the network. However, to enable an audit congruent with the SEP (Standard Evaluation Protocol) protocol we will separate the network from the program for the sake of the analysis. Please keep in mind that this separation is solely for analytical purposes. In reality, the network and the program constitute a synergistic entity. By implication, some overlap in the analysis will be required and cannot and should not be prevented.

When people or organizations with diverse interests and background meet for the first time and exchange knowledge, new ideas can be expected that can be the foundation of breakthrough technology. In innovation literature this type of network is called a "weak ties network". The network has a lot of weak ties, i.e., ties between partners that are not familiar to each other. Research has shown that such networks are more innovative than networks with strong ties¹. In networks with strong ties, partners know each other well and are close to each other. Networks with weak ties have only the potential of innovation if these ties are trusted. For trust three elements are required, which are: benevolence, reputation, and integrity.

¹ M.S. Granovetter, "The Strength of weak Ties," *American Journal of Sociology*, **78**:1360-1380 (1973).

1. Benevolence – knowledge is only exchanged if there is an atmosphere of goodwill, if there is a propensity to share.
2. 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.
3. 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.

To strengthen this trust we have an organizational framework that stimulates benevolence and integrity. Next to that Wetsus constantly seeks partners with a good reputation, both as knowledge and business partners.

Network partners

The network in 2016 has 104 company members, of which 71 participate in one or more themes, and 33 are platform members. Platform members in Wetsus can join member activities (except theme meetings) and are in general on the lookout for a suitable theme to join. Currently 22 knowledge institutes are associated with Wetsus, with in total 50 professors and their academic groups. All academic groups have a link with one or more themes within Wetsus.

For an overview of the current associated companies and universities and institutes, we refer to the yearly report 2017. An overview of all professors associated to Wetsus is given in Figure 2 on pages 10 and 11.

Theme Structure & IP rules

Theme company participants and universities are connected to one or more research themes. Companies are connected to a theme for at least a 4 year period. Typically a theme has some 4 to 6 companies and 2 to 3 universities connected to it, so cooperation is essential. 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 to the companies in the theme where the IP originates from first. If none of the theme companies is interested, the patent is offered to all other company members of Wetsus. Each theme is centred at a certain (group of) topics for the research program. These topics are defined by the companies and should fall within the framework of the Wetsus research. Below is a list of current research themes, and it is indicated to which one of five research questions they contribute.

Table 2. Overview of all the research themes within the Wetsus network. The color code refers to the five main lines of research of Wetsus, shown at the bottom. Information on the scope and participants of each research theme are given in the yearly report 2017.

1	Priority compounds	12	Desalination
2	Applied water physics	13	Capacitive deionization
3	Smart water grids	14	Dehydration
4	Virus control	15	Blue energy
5	Groundwater technology	16	CO2 energy
6	Biofouling	17	Phosphate recovery
7	Concentrates	18	Algae
8	Advanced water treatment	19	Resource recovery
9	Source separated sanitation	20	Protein from water
10	Natural flocculants	21	Soil
11	Sulfur	22	Sensing
		23	Genomics based water quality monitoring

	Sustainable water supply		Reuse of components and production of energy
	Waste water treatment and reuse		Sensing of micro/nano pollutants
	New water sources		

Network activities & personal contact

The following network activities are yearly organized:

- Wetsus organizes its annual congress (see Table 3) for a target audience of companies, governments, universities and research institutes. One day is devoted to strategic issues in the water sector, and one day to the latest scientific developments in water technology. This activity is also open for non-participants.
- The Wetsus annual internal congress is meant for all participants 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 organizes once a year an international scientific conference together with a scientific organization such as EDS, IAP or EFCE, see Table 4.
- All Wetsus scientists have regular contact with participating companies.



Impression of Wetsus congress held in Leeuwarden City Theatre

Table 3. Overview of the annual Wetsus congress and the central theme of day 1 (each year in October)

YEAR	TITLE	PARTICIPANTS (*)
2011	Cooperation in innovation, a global requirement?	~500
2012	Societal challenges: Call for innovative water technology	~550
2013	Value of Knowledge	~600
2014	From knowledge to business	~600
2015	Talent hubs for innovation	~600
2016	Financing Innovation	~650

(*) Sum of attendances on day 1 and day 2.

Overview of full professors associated with the Wetsus program



prof.dr.ir. R. Akkerman
(UT)
Production Technology



prof.dr. M. Alves
(Univ. Minho, Portugal)
Biological Engineering



prof.dr.ir. M. Bierkens
(Univ. Utrecht)
Physical Geography & Hydrology



prof.dr.ir. R.M. Boom
(WUR)
Food Technology



prof.dr.ir. N. Boon
(Univ. Gent, Belgium)
Microbial Ecology & Technology



prof.dr.ir. C.J.N. Buisman
(WUR)
Biological Recovery & Reuse Technology



prof.dr. A. Cipollina
(Univ. Palermo, Italy)
Chemical Engineering



prof.dr.ir. M. Claessens
(UTwente)
Nanobiophysics



prof.dr. M. Dopson
(Linneaus Univ., Sweden)
Biotechnology & Microbiology



prof.dr. G. Euverink
(RUG)
Biotechnology & Microbiology



prof.dr. A. Friedrich
(RUG)
Medical Microbiology



prof.dr. N. Graham
(Imperial College)
Environmental Engineering



prof.dr.ir. J. van der Gucht
(WUR)
*Physical Chemistry
& Soft Matter*



prof.dr.ing. P.J.M. Havinga
(UT)
Computer Science



prof.dr.ir. D.J.J. Heederik
(Univ. Utrecht)
Epidemiology



prof.dr. K.J. Hellingwerf
(UvA)
Microbiology



prof.dr. J. Huisman
(UvA)
Microbiology



prof.dr.ir. A.J.H. Janssen
(WUR)
Environmental Technology



prof. dr. J. Herek
(UT)
Optical Sciences



prof.dr. M. Kennedy
(TU Delft)
Water Management



prof.dr. S.R.A. Kersten
(UT)
Sustainable Process Technology



prof.dr. J. Kok
(RUG)
Molecular Genetics



prof.dr.ir. R. Lammertink
(UT)
Fluidics & Interfaces



prof.dr.ir. W. Loiskandl
(BOKU Wien, Austria)
Water Management



prof.dr.ir. M.C.M. van Loosdrecht
(TU Delft)
Environmental Biotechnology



prof.dr.ir. W.G.J. van der Meer
(UT)
Membrane Science & Technology



prof.dr.ir. D.J Mevius
(Univ. Utrecht)
Antimicrobial Resistance



prof.dr. F.G. Mugele
(UT)
Physics of Complex Fluids



prof.dr. G. Muyzer
(UvA)
Microbial Systems Ecology



prof.dr. A.J. Murk
(WUR)
Marine Animal Ecology



prof.dr.ir. D.C. Nijmeijer
(TU/e)
*Membrane Materials
and Processes*



prof.dr.ir. I. Nopens
(Univ. Gent, Belgium)
Mathematical Modeling



prof.dr. F. Picchioni
(RUG)
*Product Technology &
Engineering*



prof.dr. A.M. de Roda Husman
(Univ. Utrecht)
Molecular Biology



prof.dr.ir. E. Roesink
(UT)
Membrane Science & Technology



prof.dr.ir. H.M.M. Rijnaarts
(WUR)
Environmental Technology



prof.dr.ir. A.J.M. Stams
(WUR)
Microbiology



prof.dr. P.J. Stuyfzand
(TU Delft)
Chemical Hydrogeology



prof.dr. E. Sudholter
(TU Delft)
Nano-Organic Chemistry



prof.dr.ir. T. Tinga
(UT)
Mathematical Modeling



Figure 2. Overview of full professors associated with the Wetsus program

Table 4. International Scientific Conferences hosted by Wetsus

YEAR	TITLE	PARTICIPANTS	JOINTLY WITH
May 2011	3rd International Microbial Fuel Cell Conference	300	ISMET
Sept 2012	Wetsus-EDS conference on membranes in drinking and industrial water production	150	EDS
May 2014	International Conference on Interfaces against Pollution (IAP)	150	IAP
Sept 2014	Salinity Gradient Conference	50	EU (FP7)
May 2015	IUVA Research Frontiers Conference	100	IUVA
June 2015	7th European SummerSchool on Electrochemical Engineering	130	EFCE
Sept 2015	Young Water Professionals 4th Regional Conference	40	IWA
Feb 2016	EIP Water Conference (*)	700	EIP
Aug 2016	67th Annual Meeting, International Society of Electrochemistry (*,**)	1500	ISE

(*)Wetsus closely involved in organization and scientific program committee. (**) The Hague.

Wetsus Research Program

At the core of the Wetsus 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 3. The PhD program is a continuous flow of PhD projects that are characterized by the 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 there 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.

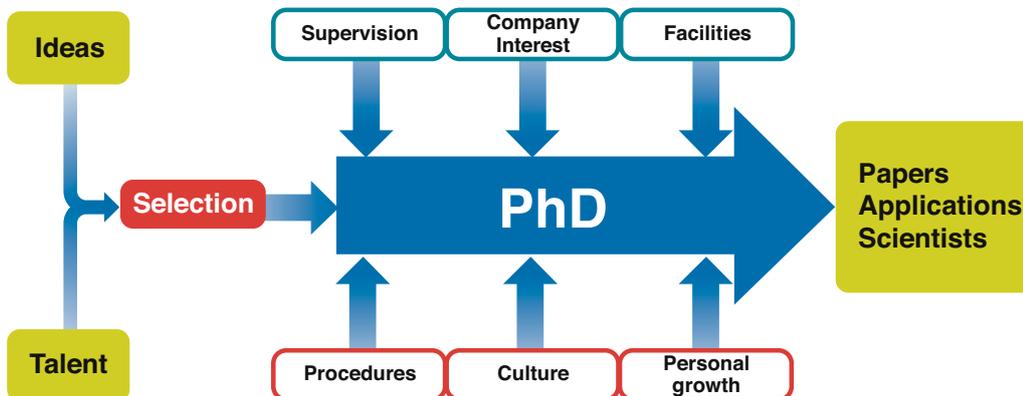


Figure 3. Process flow model of the Wetsus PhD program. On the left, the main inputs in the PhD-program, being ideas and talent, are selected. On the right the main outputs of the program, being trained scientists, scientific papers and technological applications are found. In between, the PhD-program 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 have the final say on which projects are to be supported. Projects need to have a strategic fit with the Wetsus vision, and this fit is assessed by the executive board.

Within the Wetsus innovation strategy three types of projects can be distinguished: Imagination, Optimization and Foundation. Imagination projects aim at realizing technological breakthroughs that potentially may alter the technology landscape. (e.g., early MFC research that promised to make anaerobic digestion obsolete). Optimization projects aim at substantial improvements of existing technology, e.g., a 50% reduction of the energy demand of sea water desalination. Foundation projects aim to explore new science and create insights that support or can lead to new imagination and optimization proposals. Wetsus aims for a research program which promotes imagination projects (target: foundation: 15%; imagination: 50%; optimization: 35%).

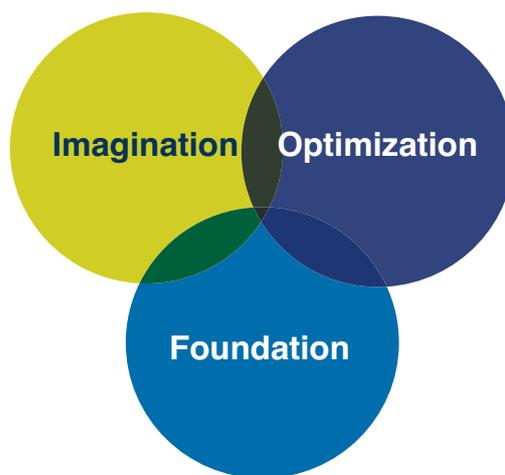


Figure 4. The three types of projects distinguished within the Wetsus innovation strategy.

Project proposals are reviewed by the program council. The program council consists of independent senior researchers that judge the quality of the project proposals. All proposals, independent of the type (Imagination, Optimization, or Foundation), 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. If a proposal is rated to be not according to the expected standards, the proposal requires adjustment. If after the adjustments the proposal still scores insufficient, the proposal will be withdrawn.

The functioning of the Program Council has been re-evaluated recently, and new members have been appointed. The evaluation and the new guidelines are provided 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, in order to stimulate and promote student mobility within the EU countries. Recruitment of almost all research positions is organized in two or three yearly calls with 6-15 positions. Such a call gives more credibility to a Wetsus position, as on average 65 applications are received for every posted open position. This is a 10-fold increase compared to earlier years, reflecting the increased reputation of Wetsus. The candidates go through a four-step procedure, where the first step is an eligibility check by the WaterSeed coordinator, the second an evaluation of CV+motivation letter, the third an oral (skype) interview, and for the fourth step, the so-called Water Challenge, the selected candidates are invited to come to Wetsus. On that day, apart from a job interview, their presentation and communication skills are assessed. During all the steps, both the university and Wetsus participate in the assessment.

In addition, an experienced researcher from the so-called expert committee performs an independent assessment. 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 distance between Wetsus in Leeuwarden and the university. The additional advantage is the possibility of a more multidisciplinary supervision. 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. At the moment about 50 full professors are associated with the Wetsus program. The number of daily supervisors at Wetsus and the coverage of disciplines is increasing every year.

Company involvement

Via theme meetings and contacts outside these meetings, PhD researchers and their supervisor obtain frequent feedback on their work from a company perspective. This additional perspective increases and broadens the relevance of the research. The PhD research is in this way in close contact with the research programs of companies, sometimes PhD researchers are even seconded at companies for some period. This gives rise to new cooperation and results. The number of companies connected to Wetsus increases every year and in 2016, the level of 100 company participants, was surpassed. Companies commit themselves to the program for an initial period of 4 years, followed by a rolling financial commitment with a cancellation period of 3 years. Since the start of Wetsus (2004), about 30 companies have left the program, mainly associated with their decision not to commit to membership for longer than one PhD period (four years). Overall therefore, a total of more than 130 companies have been or are connected for at least four years to the Wetsus research program since 2004.

Facilities

In January 2015, Wetsus moved into its newly constructed building. Because Wetsus was involved in the specification phase of the construction, the building is state-of-the-art with respect to the specific research demands. Wetsus was in need for more space because its research facilities had grown spectacularly in the preceding years. An example is the Separex apparatus that makes it possible to characterize membrane properties under humid supercritical CO₂ conditions. To our knowledge the Wetsus laboratory is the only facility in the Netherlands housing this technology. Another unique aspect of the new Wetsus building is the close proximity of and easy access to a wide array of multidisciplinary facilities, all focused on water technology, and all in one building.

The most important part of the building is the 600 m² technological hall with all the experimental set-ups, where >60 PhD students can perform their research. Twelve specialized enclosed spaces allow working with hazardous gasses like H₂S. State of the art research set-ups are available. A well-equipped workshop is available that is responsible for in-house construction, maintenance and adjustments of the experimental set-ups. For more specialized work, e.g. glass work manufacture, external suppliers are contracted. The technical team overseeing all this counts 9 persons.

In addition, Wetsus has a total of 500 m² laboratory space, which is a substantial enlargement of the space available at the start of Wetsus. This 500 m² is split into several specialized laboratories:

1. Wet-chemical & synthesis laboratory, for materials synthesis and samples preparation.
2. Analytical laboratory, where a huge variety of compounds can be analysed
3. Biology laboratory for virus, microbiology and molecular research.
4. Optical laboratory, constructed in the basement, constructed with a vibration-free floor where the optical equipment (SEM, AFM, Raman, CLSM) is housed next to a laser laboratory for custom-made optical setups.

The analytical team (consisting of a staff of 9 people) is responsible for the operation of all laboratories but is also involved in the development of new analytical methods in close cooperation with Wetsus scientists. The laboratory takes part in a yearly national proficiency test with up to 15 other renowned analysis laboratories. Over the years, the results for Wetsus have always been ranked very good to excellent.

Innovation Ecosystem

In order to stimulate know-how clustering and valorization, it is important that the critical mass of the international research program of Wetsus is embedded in a dedicated innovation ecosystem. Wetsus is located in Leeuwarden, the United Nations Innovating City for water technology and capital of the Dutch province Fryslân. This province is characterized by a relatively high density of independently owned and globally exporting water companies. Together with Water Alliance (www.wateralliance.nl) and the Centre of Expertise Water technology (CEW), Wetsus drives the development of WaterCampus Leeuwarden (www.watercampus.nl).

WaterCampus Leeuwarden is the physical core of the Dutch water technology sector and has the ambition to play a sector uniting role for the rest of Europe as well. WaterCampus stimulates cooperation between (inter)national businesses, knowledge institutes and governments within the water technology sector, in order to create synergy for world class innovation, education and entrepreneurship. This strengthens the global position of the European water technology sector. Additionally, WaterCampus offers a unique research infrastructure, and is a meeting point for scientists and companies from all over Europe.

Wetsus has access to several on-site testing locations (“demonstration sites”) where specific qualities of water are available. Some examples are hospital waste water, sewage water, ground water, drinking water and several process waters. This way, PhD researchers can perform experiments with real waters to improve the practical relevance of their research. For example, the pilot plant located at the Afsluitdijk gives unique opportunity to study salinity gradient energy under real-life conditions. Table 5 summarizes five examples of scientific papers based on research performed at one of the demonstration sites.



The Blue energy pilot plant located on the Afsluitdijk. The pipe passing over the road serves to transport the salty seawater from the Waddensea to the plant.

Table 5. Selected examples of scientific papers based on research performed at one of the Wetsus demonstration sites in period 2010-2014.

D.A. Vermaas, D. Kunteng, M. Saakes, and K. Nijmeijer, “Fouling in reverse electrodialysis under natural conditions,” 2013 *Water Research* 47:1289-1298 (2013)

N.C. Boelee, M. Janssen, H. Temmink, R. Shrestha, C.J.N. Buisman, and R.H. Wijffels, “Nutrient Removal and Biomass Production in an Outdoor Pilot-Scale Phototrophic Biofilm Reactor for Effluent Polishing,” *Applied Biochemistry and Biotechnology* 172:405-422 (2014).

A. Butkovskyi, A.W. Jeremiasse, L. Hernandez Leal, T. van der Zande, H. Rijnaarts, and G. Zeeman, “Electrochemical Conversion of Micropollutants in Gray Water,” *Environ. Sci. Technol.* 48:1893-1901 (2014).

F. Beyer, B.M. Rietman, A. Zwijnenburg, P. van den Brink, J.S. Vrouwenvelder, M. Jarzembowska, J. Laurinonyte, A.J.M. Stams, and C.M. Plugge, "Long-term performance and fouling analysis of full-scale direct nanofiltration (NF) installations treating anoxic groundwater," *J. Membrane Science* 468:339-348 (2014).

L.O. Villacorte, Y. Ekowati, H. Winters, G.L. Amy, J.C. Schippers, and M.D. Kennedy, "Characterisation of transparent exopolymer particles (TEP) produced during algal bloom: a membrane treatment perspective," *Desalination And Water Treatment* 51:1021-1033 (2013).

Appendix D lists all available laboratory and analysis equipment in the Wetsus laboratory.

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.) with a maximum of flexibility. The values of Wetsus are Innovation, Partnership, Joy, Cooperation and Reliability, all described in Table 6. 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 6. The five Wetsus Values, with a brief description.

VALUE	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, IPR and theme structure, to the strictly necessary. This allows for the organizational flexibility needed to achieve innovation. Selection of projects is based on iterative improvements of proposed ideas, as outlined in Figure 5.

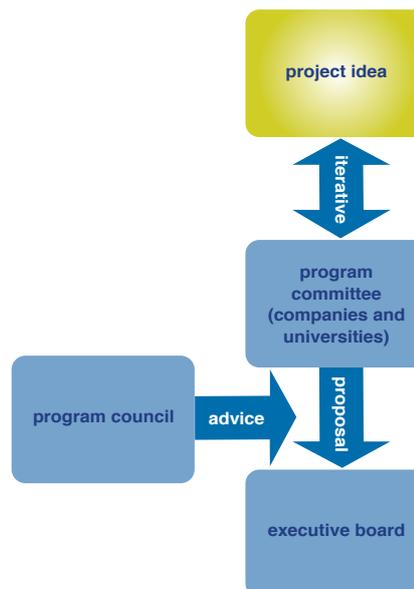


Figure 5. Procedure for idea selection for PhD research

Personal Growth

Personal development is part of the values of Wetsus and is necessary to equip our PhD researchers with the soft skills and competences needed to thrive in the Wetsus network and in their working career after the PhD program. Therefore, a 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”. The training program covers the full PhD research period and is schematically depicted in Figure 6. A leaflet describing the program in more detail is supplied as **additional document**.

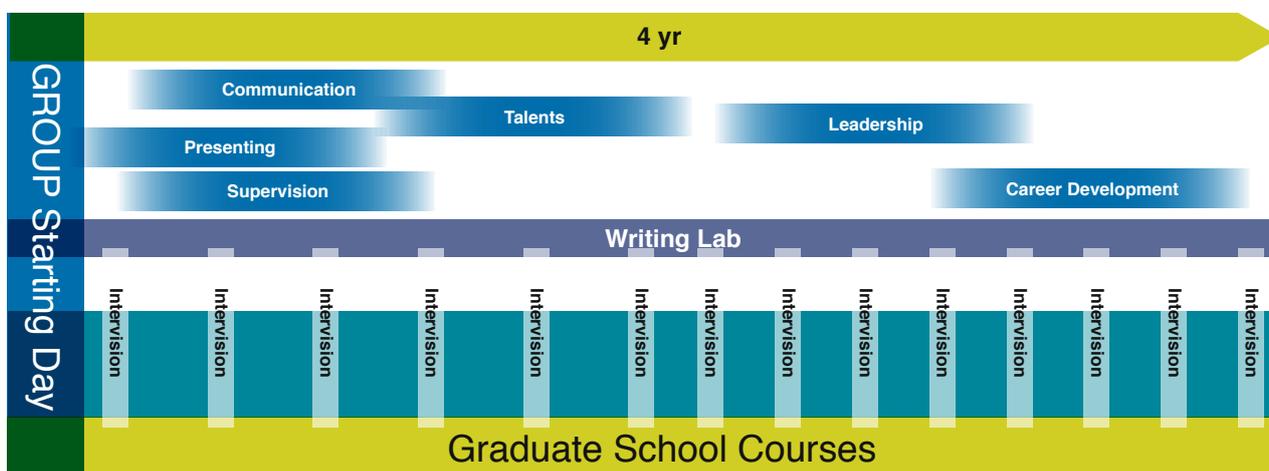


Figure 6. Schematic representation of the PhD personal development program

Jordi Moreno:

“During the talent course, I realized that I’ve got some talents I wasn’t aware. I discovered that in certain occasions I used my stronger talents naturally, and this helps me to solve things out.”

Prashanth Kumar:

“I liked the team work involved with my Wetsus colleagues during these courses. We learned from each other’s experience and built a supportive framework which was very helpful.”

Mithun Chowdhury:

“If I combine all the courses I followed, I have learned several things that can make a high impact in my career. It’s all about knowing your added value to a group, useful techniques for self-development, how to appreciate others opinions, and how to see the same situation from a different angle.”

The program starts with a group of around eight PhD researchers that join the kick-off day of the program. Tools for self-reflection are introduced together with their personal and Wetsus values. The basis of the program is a process of recurring self-reflection in the InterVition group formed at the kick-off day. A writing lab helps students to improve their writing skills and to develop their own style of writing. Dedicated courses have been developed on communication, presenting, supervision, business skills and talents. They all support the self-reflection process. To develop entrepreneurial skills several options are available: the yearly business challenge, the two yearly patent course and/or the lean PhD program (the latter in cooperation with EIT Climate KIC). The program is now well two years under way, and remaining courses on leadership and career development are in progress.

Wetsus employees are stimulated and encouraged to engage and participate in programs for personal growth and coaching. As an example, every year Wetsus organises for its staff a one-day joint activity that serves to foster the personal development at the team level, e.g., a day on talents (2016) and one on scientific quality and how to manage this (2015).

Researchers & Financing

Scientific Staff

Figure 7 shows the number of FTE's related directly to research (staff, post-docs and PhD researchers), technical support (laboratory and workshop) and overhead (board of directors, administration, finance, ICT, HRM and communication) over the last six years (2012-2017). Apart from the number of PhD researchers, the scientific staff and number of post-docs remained fairly constant. The sole reason that the total research staff declined from 99 in 2012 to 77 in 2017 is the decrease of PhD researchers working in laboratories at partner universities outside Leeuwarden ("external PhDs"), almost 30 in 2012 to less than 10 in 2016, whereas the number of PhD researchers located in Leeuwarden ("internal PhDs") stabilized at around 45-52 (Figure 8).

Number of FTE's

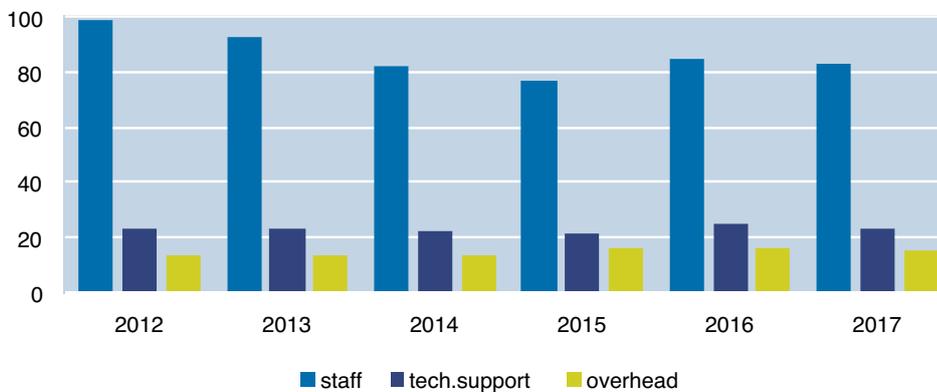


Figure 7. The development over time of the employee composition of Wetsus

One of the recommendations from the previous audit in 2011 was to create more scientific positions in between that of PhD student and Theme Coordinator. Wetsus followed this advice resulting in additional function descriptions such as research post-doc, staff post-doc, senior advisor, program manager and program director. The scientific director (executive board), program director and program managers constitute the research management team. A career line can now be envisioned along the sequence, research post-doc, staff post-doc, theme coordinator, program manager and program director.

Number of PhD researchers



Figure 8. Number of external and internal PhD researchers, including a projection to 2018/19

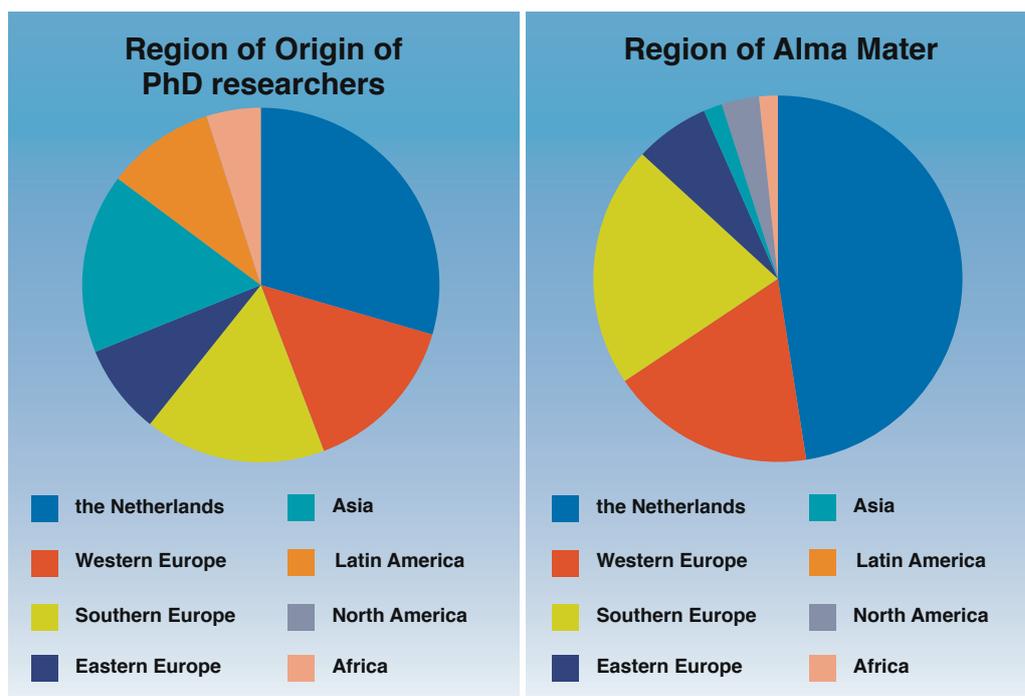
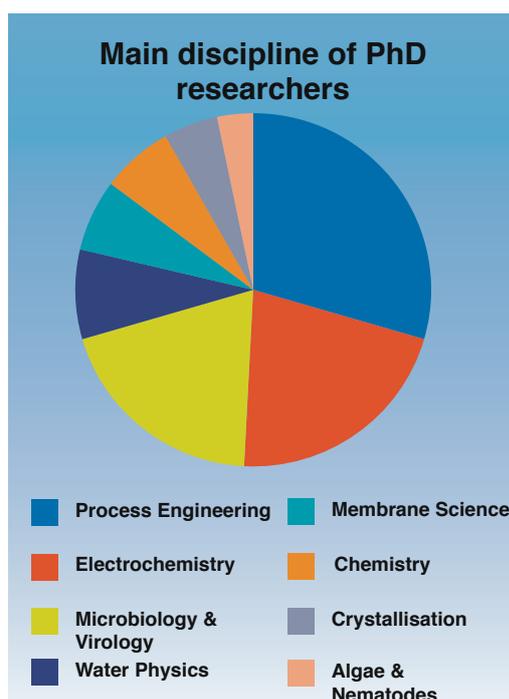


Figure 9. Region of origin and region of the university conferring the MSc degree (Alma Mater) of the PhD researchers currently (1/1/2017) employed at Wetsus.

The majority of the PhD researcher (69%) comes from Europe, the remainder mainly from Asia and South America (Figure 9, left). There are no PhD researchers originating from North America, the reason has not been investigated. It might be that the effort to go abroad does not pay off as North-American universities have a high reputation.

Most PhD researchers graduate from European universities (93%) (Figure 9, right). Most researchers with a non-European origin, come via the Netherlands, Western and South Europe. Internationalization is equally high for all regions, except for Eastern Europe, this lags behind in internationalization. Although no PhD researchers originate from North America, some PhD researchers do come from universities from this region.



The discipline in which PhD researchers are active reflects the multi-disciplinarity of the projects (Figure 10). Process engineering (including environmental), electrochemistry and chemistry are the dominant disciplines. Especially for the field of electrochemistry it is hard to find students with a electrochemistry background, they mostly have an engineering background.

Figure 10. Disciplines within which PhD researchers currently (1/1/2017) at Wetsus are active.

Financing

Figure 11 shows the financing of Wetsus in 2016. The governmental financing comes from the European, national and regional level. The European funding is project-based, while the others are program-based. Participants also contribute, with companies contributing in cash, and knowledge institutes in kind, implying a contribution in the form of PhD research supervision. Wetsus has secured its funding until at least 2021. For the coming years the funding scheme will be more or less comparable to the one of 2016.

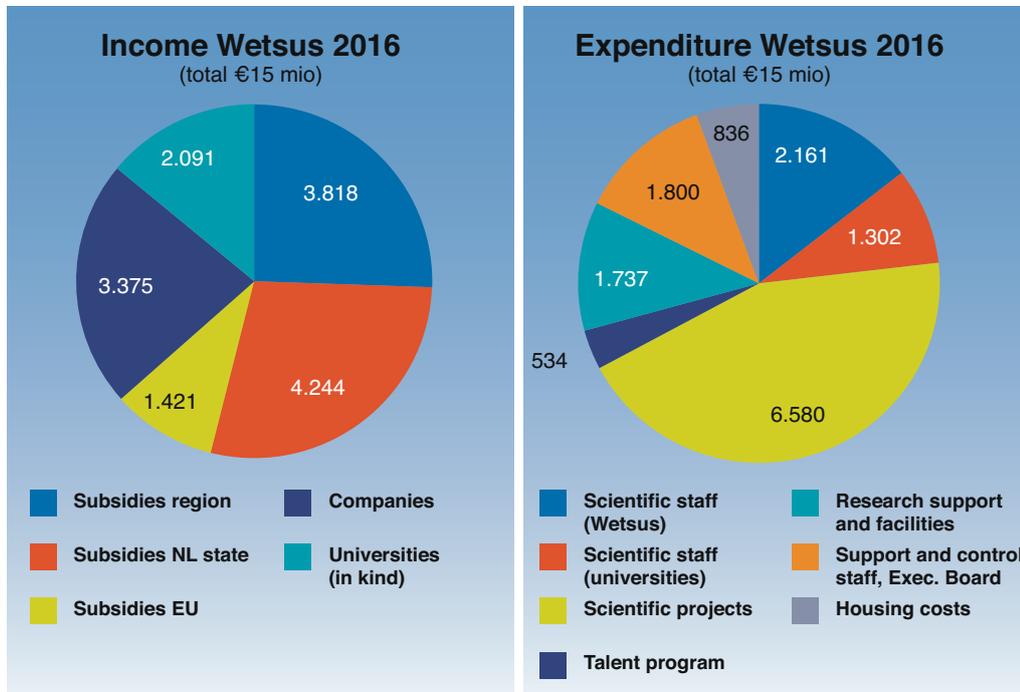


Figure 11. Financial structure of Wetsus for both income and expenditure

The expenditure overview of Figure 11 shows that the **vast majority** of funding goes to research projects (79%), 12% to support and control, 6% to housing, and 4% to the “talent program”. A brief outline of the talent program is provided as **additional document**.

Performance

Specific Targets & Analysis Framework

Wetsus identified a number of specific targets in its business plan as important performance indicator. These performance indicators are subdivided into three broad categories: Input (financial), Network, and Impact. These indicators reflect the main objectives of Wetsus in the field of research, education and valorization. Table 7 (page 24) shows an overview of these performance indicators for the period 2011-2016. This gives valuable insight in the actual performance of Wetsus. These updated overviews are published yearly for participants and stakeholders to assess the performance of Wetsus.

In addition, to make an independent assessment, and to obtain more detailed information, two investigations by independent parties have been performed in the 2011-2016 period (CWTS report). The first investigation assessed the scientific value of the research via a dedicated citation analysis based on papers published in 2010-2014. The (commercial) value of the network for Wetsus partners has been investigated in 2013 and 2016 by questionnaires and interviews (BBo report). The CWTS report and both BBo-reports are included as **additional documents**.

The citation analysis is performed by CWTS (Centre for Science and Technology Studies), Leiden, the Netherlands. CWTS BV is an independent contract research organization that provides high-quality research performance and evaluation studies.

The network analysis is done by BBo, a firm specialized in policy evaluations. BBo is active throughout the Netherlands, with a special focus on the Northern part of the Netherlands. The citation analysis will be referred to as the **CWTS report** and the network analysis as the **BBo report**.

We analyse the performance for three dimensions, the network, the scientific quality and societal relevance. In the VSNU format only the last two are recognized (with viability as third criterion), therefore we will discuss first scientific quality and societal relevance, and finally the network performance. This last dimension, network performance, is essential to be taken into account, as this is a distinguishing characteristic of Wetsus.

For the dimensions scientific quality and societal relevance, performance is analysed according to the subdivision as proposed by the VSNU. First the actual output is described, next the use, and finally how this translates into recognition. For the network performance, Wetsus is benchmarked against similar institutes, based on a survey of BBo.

Scientific Quality

Output

The scientific papers and dissertations (Table 8) are the prime scientific output of Wetsus. In our assessment, a paper qualifies as an official publication if it is included in the Web of Science database. These papers form the basis of the CWTS report and for the relevant Wetsus KPI values.

Table 8. Papers included in the Web of Science (WoS) and PhD dissertations for the period 2011-2016

	2011	2012	2013	2014	2015	2016
Papers in WoS	51	55	53	77	73	83
PhD dissertations	3	4	16	18	11	8

Table 7. Overview of Wetsus Performance Indicators

Performance Indicators Wetsus	2011 realized	2012 realized	2013 realized	2014 realized	2015 realized	2016 realized	2016 target
Input							
Program budget (mln €)	13.8	15.7	16	16	14.9	14.1	15.1
Contribution of companies to research programme (mln €)	3.6	3.8	3.6	3.3	3.3	3.3	3.3
Overhead (%)	10	10	10	10	10	10	10
Network							
Number of participating companies	92	95	93	95	105	104	107
Percentage of SME companies (turnover < € 100 mln/y)	55	54	54	56	57	57	50
Percentage of foreign companies	20	20	23	25	24	24	26
Number of participating research chairs	45	46	48	52	54	50	50
Number of public knowledge institutes (participants)	16	18	19	19	21	22	21
Impact, Output and Outcome							
<i>Education</i>							
Number of PhD Students (cumulative)	114	128	145	160	179	197	188
Number of joint degree students	11	21	23	30	36	40	40
Number of MSc thesis students / year	61	80	76	72	79	83	80
Number of talent events	19	19	16	20	25	29	25
<i>Scientific</i>							
Number of scientific papers in international journals (cumulative)	176	234	294	376	425	505	500
Numbers of papers in top 10% citations (cumulative - 1y)		45	67	80	107	120	113
Citation impact (overall)	1.8	2.4	2.8	2.4	1.8	>1.5	>1.5
<i>Valorization/entrepreneurship</i>							
Number of spin-off companies (cumulative)	17	20	24	26	27	30	28
Number of patents (submitted, filed and granted) (cumulative)	53	61	64	67	76	79	79
Number of transferred patents (cumulative)	14	22	22	26	27	28	30

During a PhD research, there is of course a lag period between the moment of appointing a PhD researcher, and the moment when the first paper is published. In addition, the PhD dissertation and graduation occur about 5 years after the PhD student was employed. This time-lag translates into a fluctuation of the number of papers and dissertations over the years, an effect further enhanced by a strong increase in the number of PhD projects.

Conclusions of CWTS:

“The overall impact was at a very high level”

“The scientific research measured by bibliometric means shows nearly only superlative scores.”

“Wetsus scores are consistently very high over time”

“Wetsus produces very highly visible, (inter)nationally acclaimed scientific research in internationally highly acknowledged journals”

Use

In order to assess the use and impact of Wetsus publications, an extensive citation analysis² has been performed by CWTS for the period from 2010-2014. This period follows up on the previous analysis. The period of analysis ends for papers published in 2014, because the impact of a paper can only be assessed some time after its publication.

Three indicators are of special importance; (i) the MNCS, the average number of normalized citations, showing how often the average Wetsus paper is cited compared to the world average of comparable papers; (ii) MNJS, the average relative impact of the journals in which the Wetsus publications are published; and (iii) PPtop10%, the fraction of the Wetsus papers that belong to the top 10%.

CWTS defines a relative impact to be “very high” when MNCS >1.6. As Table 9 shows, with a score of MNCS=2.13, Wetsus scores by a large margin above this threshold. Thus, the average of the relative impact of all Wetsus publications (MNCS) is more than two times world average. Moreover, Wetsus publishes in high impact journals (MNJS), reflected in a MNJS score of 1.64. Finally, of all Wetsus publications 31% are in the top 10%, which is three times more than world average. Concluding, according to CWTS (p. 20), “the scientific research measured by bibliometric means shows nearly only superlative” scores.

In addition, it must be noted that the Wetsus publication output increased by a factor of five compared to the previous audit period, from 60 to 300 papers. This implies that --given the roughly constant value of MNCS (impact per **paper**)-- our overall impact, our visibility, has dramatically increased since the previous audit.

Table 9. Main bibliometric indicators to gauge scientific use of papers compared to the previous audit period.

	MNCS	MNJS	PP(10%)	number of papers
2010-2014	2.13	1.64	31%	300
2005-2009	2.84	1.78	30%	61

As for the scientific research areas Wetsus is active in, output concentrated around five fields: 1. ‘Engineering, Chemical’; 2. ‘Water Resources’; 3. ‘Environmental Sciences’; 4. ‘Engineering, Environmental’, and 5. ‘Biotechnology & Applied Microbiology’, which together account for more than 50% of the publications. Figure 12 shows the impact of the most important scientific fields of Wetsus research in the period 2010-2014. All our fields, except two small ones (analytical chemistry, applied physics) score very high in impact. This holds for the research fields with a large share of the Wetsus research output, but also for smaller fields.

2 Report CWTS 2011. “Bibliometric study on Wetsus (2005-2009), Leiden, 2011.

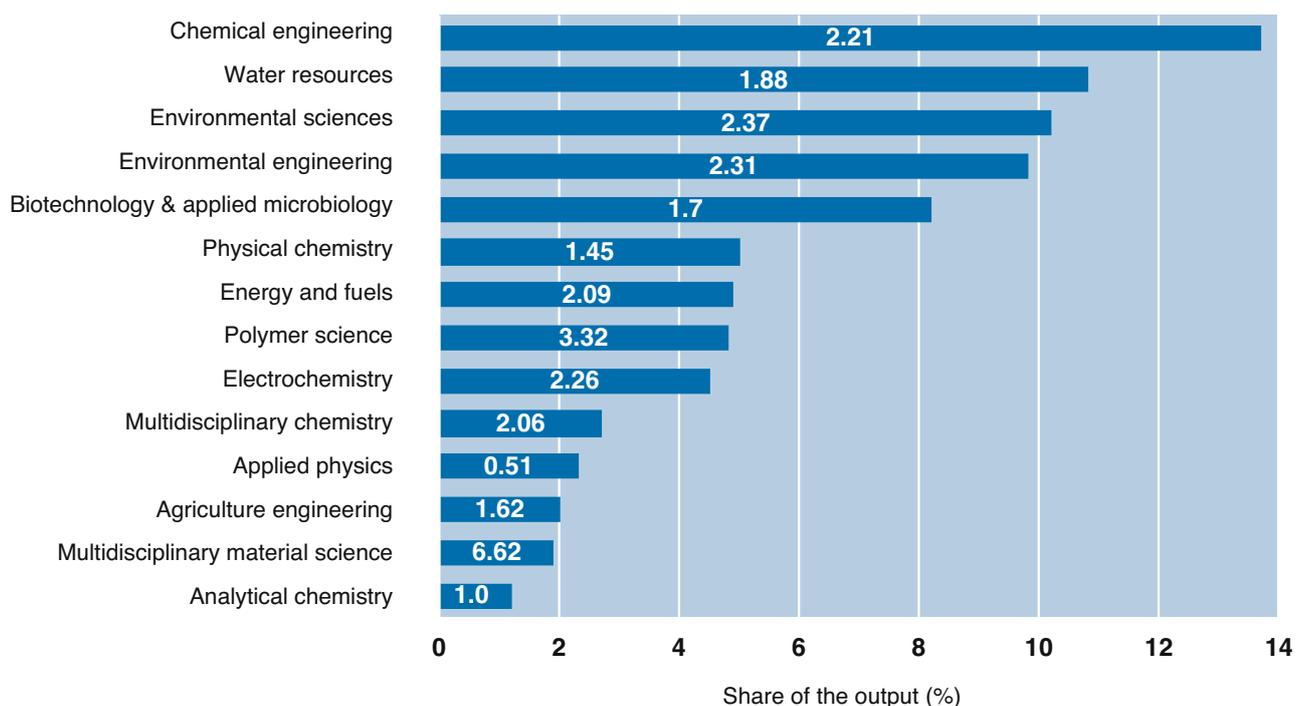


Figure 12. Output and impact per research field for Wetsus in the period 2010-2014, showing the multidisciplinary nature of the Wetsus program

Wetsus is a cooperative institute: almost 93% of all papers are produced in collaboration, notably at the national level. Even though international collaborations result in the highest impact (2.5), ‘remarkably’ (according to CWTS) papers with solely a Wetsus affiliation, or those resulting from a national collaboration, score only slightly lower (2.0). The overall conclusion of CWTS is that all indicators qualify as ‘very high’. Both visibility and impact of the publications are very high, most clearly reflected in the high number of Wetsus papers that classify as a top 10%-publication, and the score of MNCS>2. Both parameters indicate that the (international) scientific community acknowledges and credits the significant contribution of Wetsus research.

Table 10 lists 10 publications from the top10% of Wetsus, including their NCS score. Apart from their remarkable high NCS values, this list nicely demonstrates the variety of topics within the Wetsus research program. The list contains two reviews and eight original research papers. That review papers from Wetsus are cited highly shows that Wetsus is considered an authoritative source of scientific information.

Table 10. List of 10 representative Wetsus top-publications, and their NCS-score

PAPER	NCS
S. Porada, R. Zhao, A. van der Wal, V. Presser, and P.M. Biesheuvel. 2013. Review on the Science and Technology of Water Desalination by Capacitive Deionization. Progress in Materials Science. 58:1388-1422.	26.7
B.A. Wols and C.H.M. Hofman-Caris, 2012. Review of photochemical reaction constants of organic micropollutants required for UV advanced oxidation processes in water. Water Research. 46, :2815-2827.	11.0
S. Salim, R. Bosma, M.H. Vermuë, and R.H. Wijffels. 2011. Harvesting of microalgae by bio-flocculation. J. Applied Phycology 23:849–855.	9.9
P. Kuntke, K.M. Śmiech, H. Bruning, G. Zeeman, M. Saakes, T.H.J.A. Sleutels, H.V.M. Hamelers, and C.J.N. Buisman. 2012. Ammonium recovery and energy production from urine by a microbial fuel cell. Water Research 46:2627-2636.	7.5

H.V.M. Hamelers, O. Schaetzle, J.M. Paz-García, P.M. Biesheuvel, and C.J.N. Buisman. 2014. Harvesting Energy from CO2 Emissions . <i>ES&T Letters</i> 1:31-35.	5.5
D.A. Vermaas, D. Kunteng, M. Saakes, and K. Nijmeijer. 2013. Fouling in reverse electro dialysis under natural conditions . <i>Water Research</i> 47:1289-1298.	4.9
P. van der Marel, A. Zwijnenburg, A.J.B. Kemperman, M. Wessling, H. Temmink, and W.G. van der Meer. 2010. Influence of membrane properties on fouling in submerged membrane bioreactors . <i>J.Membrane Science</i> 348:66-74.	4.8
A.W. Jeremiasse, H.V.M. Hamelers, and C.J.N. Buisman. 2010. Microbial electrolysis cell with a microbial biocathode . <i>Bioelectrochemistry</i> 78:39-43.	4.3
A. ter Heijne, F. Liu, R.D. van der Weijden, J. Weijma, C.J.N. Buisman, and H.V.M. Hamelers. 2010. Copper recovery combined with electricity production in a microbial fuel cell . <i>Environ. Sci. Technol.</i> 44:4376-4381.	4.1
L. Hernández Leal, H. Temmink, G. Zeeman, and C.J.N. Buisman. 2011. Removal of micropollutants from treated grey water via activated carbon and ozonation . <i>Water Research</i> 45:2887-2896.	3.9

Marks of recognition

It is difficult to distinguish between the recognition of a group and that of its members. This distinction is not relevant if a group consists of members that are only member of that group. Being a network organization, this is not the case for Wetsus. Most of the (part-time) scientists have their primary affiliation at their home institution. Therefore here we focus and restrict the marks of recognition to those scientists that spend most of their time at Wetsus, and we only mention grants that are at least partially spent at Wetsus.

For the scientists mainly associated with Wetsus, we distinguish eight marks of recognition, including membership of editorial boards, membership international working groups, European research grants, and awards related to scientific publications. A full overview of scientific marks of recognition is given in Appendix C.

Two scientists with personal grants are presently performing their research at Wetsus. Louis de Smet received an ERC grant in 2016 of which part will be spent at Wetsus as a PhD research project associated with the CDI theme. VENI-fellow Slawomir Porada is presently performing the research at Wetsus. Interestingly, the use of a VENI-fellowship for research in the laboratory of Wetsus, has only recently become possible for the technical sciences program of NWO (The Netherlands Organization for Scientific Research). This agreement of Wetsus with NWO is considered an important recognition by NWO of the scientific significance of Wetsus.

Over the past 6 years, three Wetsus PhD alumni have obtained VENI Grants (Post, ter Heijne, Porada). These are important Dutch science grants in which the top talent gets a personal grant to build further on the scientific work performed during their PhD research. Therefore, the award of this grant to three Wetsus PhD alumni, is a mark of recognition of the quality of the Wetsus research program.

In addition, one scientific mark of recognition is the trust that scientific societies place in Wetsus by co-organizing about each year a scientific conference in Leeuwarden. These conferences have been successful and were very well attended. See Table 3 for an overview of all yearly two-days International Wetsus congresses, and Table 4 for a list all the conferences Wetsus (co)-organized with a scientific society. Wetsus staff members play a crucial scientific role in these conferences as chair or member of the scientific committee, see Table 25 in Appendix C.

Societal Relevance

Output

Patents are filed in consultation with the theme. The theme coordinators, PhD-supervisors and researchers are expected to be alert and identify possible patents in an early stage. This is done

firstly to recover possible value for the companies involved and secondly to prevent any delay in publishing findings. Patents typically count as prime output and the numbers filed in the years 2011-2016 are shown in Table 11.

Table 11. Filed and transferred patents originating from the Wetsus program.

	2011	2012	2013	2014	2015	2016
patents filed	14	8	3	3	9	3
patents transferred	0	8	0	4	1	1

Patents are only filed if one or more companies in the particular research theme show, prior to the filing, a sincere interest in eventually acquiring the patent. This way it is prevented that Wetsus builds up a portfolio of non-transferable patents. There is a substantial delay between filing and granting of a patent, of the cumulative number of 79 patents filed in 2016, 29 were transferred.

Wetsus not only publishes in scientific journals but also in magazines for the public at large. In addition, Wetsus attracts a lot of attention from the local and national news media. Over the years and again in 2017, the largest local newspaper (Leeuwarden Courant) spend six weekends in a row two full pages on Wetsus research. The same newspaper organized in the 2015/2016 winter a well-visited course comprising five presentations of Wetsus research. Table 12 lists the number of articles by and over Wetsus in non-scientific journals.

Table 12. Number of articles by and over Wetsus in non-scientific magazines in the period 2011-2016 shows a constant significant presence of Wetsus in the media.

	2011	2012	2013	2014	2015	2016
Local Newspapers	58	35	42	42	43	45
National Newspapers	9	14	13	7	4	5
Technical Magazines	33	21	17	23	26	31

With articles in e.g. local newspapers Wetsus reaches out to a wider audience. This reaching out is further enhanced by the organisation of open-days at which the public is invited, is offered a tour through all the facilities and can admire demo set-ups of Wetsus research, all explained by expert researchers. Nowadays people have to sign up far ahead, indicating the immense popularity of such open days among the public and the general public's interest in the scientific work performed at Wetsus.

Use

Patents transferred to a company are a first indicator of the use of knowledge developed within the Wetsus network. Given the strong delay build in in the entire procedure of patent filing and granting, the number of patents that are transferred lag behind the number of patents that actually filed. Because the number of patents filed each year is rather variable, see Table 11, we calculated the transfer rate, defined as the cumulative number of patents transferred in year x as fraction of the cumulative number of patents filed in year x-2. This is shown in table 13.

Table 13. Patents transferred and cumulative transfer rate based on research from the Wetsus program in the period 2011-2016

	2011	2012	2013	2014	2015	2016
Patents transferred	0	8	0	4	1	1
Transfer Rate	44%	56%	42%	43%	42%	42%

The transfer rate seems to stabilize just above 40%.

According to the VSNU format, contract research, i.e. money spent by companies on research, is considered as use of knowledge. This also holds for the Wetsus network. The contribution is around 3.3 M euro per year, representing about 25% of the Wetsus research budget (Table 14). After 2013, the government-financing of Wetsus decreased somewhat, followed by a slight decrease in company contributions, maintaining a 25% private contribution ratio.

Table 14. Company contributions to the Wetsus program

	2011	2012	2013	2014	2015	2016
Company contribution (M€)	3.6	3.8	3.6	3.3	3.3	3.3

Spin-off companies (Table 15) is another way in which knowledge is further developed. Spin-off companies in this table are either a direct result of Wetsus knowledge or network. Some of these spin-off companies were started by a Wetsus scientist. Often, spin-offs associate with Wetsus to further develop their idea for a technology.

Table 15. Number of spin-off companies originating from the Wetsus program in the period 2011-2016.

	2011	2012	2013	2014	2015	2016
Spin-off companies	2	3	4	2	1	3

Wetsus knowledge has been absorbed by companies and is used in practice. **Innovation** is a long process, and hard to follow up in a quantitative way. Therefore a list of innovation examples has been identified for the 10 year anniversary of Wetsus in 2014. These examples are extensively described in the Wetsus innovations and spin-off company book (2016) and summarized in Table 16.

Table 16. Examples of scientific results used in society (see book "Wetsus – Innovations and spin-off companies" as accompanying document)

		Transfer via Wetsus member	New spin-off
1	Multi-purpose sensor for water quality, biofilms and corrosion	Vitens	Smart Frequencies
2	Bio-based anti-scalant prevents clogged pipelines	Aquacare	
3	Dutch membranes for Blue Energy	Fuji	Redstack
4	Clean water at an affordable price	ANF	
5	Pure phosphate from wastewater		DeSaH
6	Profitable algae-culture by more efficient use of light	AF+F	
7	Desalinated water of consistent quality		Voltea
8	Biofouling prevention leads to better and cheaper water treatment	WLN	
9	Energy and nutrients from urine	Magneto	
10	Green electricity thanks to Blue Energy	Alliander	Redstack
11	Energy and nutrients from domestic wastewater	Wetterskip Fryslan	DeSaH

		Transfer via Wetsus member	New spin-off
12	Plant-based electricity		Plant-e
13	Metal Membranes for water applications		Metal Membranes
13	Proteins from worms		Tailtec
14	Aquacolor sensor for water quality monitoring		EasyMeasure

An economic evaluation has been performed for the local government by BBo. The impact of the Wetsus program on participant companies active in selling technology products, chemical or projects has been investigated in 2016. The results (Figure 13) show that for many companies the cooperation in Wetsus has led to a positive effect on improving existing technologies (50%), has led to new products (35%) and more water related turnover (23%). Nearly all companies (96%) have a positive lookout toward the future with respect to the impact of the Wetsus program.

Innovations and knowledge from the Wetsus program

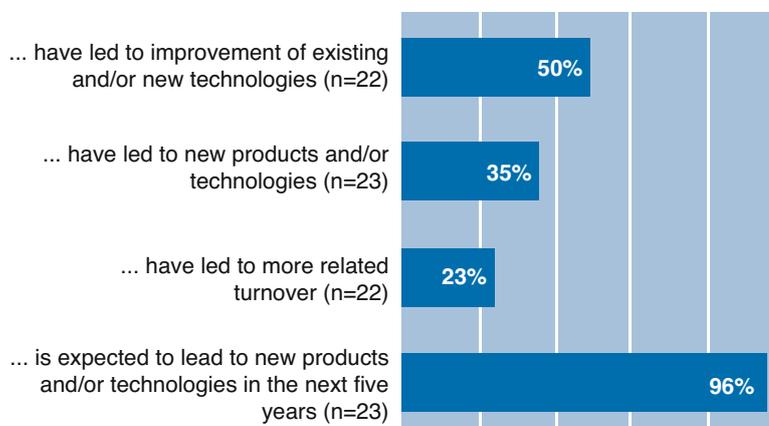


Figure 13. Results of evaluation by BBo investigating the view of participating companies on the contribution of the Wetsus program to their innovation potential.

Another form of use of knowledge is participation in bodies and organizations that advise e.g. the European Commission and European member states. Wetsus is active in the following non-governmental organisations:

- Water supply and sanitation Technology Platform (WssTP), Wetsus coordinates the Resource Recovery Working Group
- European Water Partnership (EWP)
- European Innovation Partnership (EIP) Water, Wetsus coordinates the action group FINNOWATER reaching out the European Investment Bank (EIB) and the European Investment Fund (EIF).
- Joint Programming Initiative (JPI) Water
- European Technology Platform for Sustainable Chemistry (SusChem)
- European technology and Innovation Platform for Ocean Energy (TP Ocean)
- Integrated Network for Energy from Salinity Gradient Power (INES)
- European Sustainable Phosphorous Platform
- European Schoolnet
- European Regions Research & Innovation Network (ERRIN), Wetsus coordinates the Working group Water
- European Institute of Innovation and Technology (EIT) Raw Material, Wetsus is member of the Western CLC Steering Committee
- EIT Climate KIC

Marks of recognition

For the marks of recognition the same holds as already discussed for the scientific quality. We will focus on Wetsus-based employees and spinoffs rooted in technology developed by Wetsus. Compared to the previous audit, there is a clear increase in prestigious marks of recognition, showing the growth of the reputation of Wetsus (Table 17).

Table 17. Public marks of recognition for research from the Wetsus program with societal relevance

Mark of Recognition	Description	Who	When
George Barley Prize	First place (25 k\$) during first stage of USA announced call (10 M\$) to lower the phosphate content in the Everglades waters to ppb levels.	Ir. Leon Korving	2017
Zilveren Zandloper	Award of the Netherlands Biotechnology Association for innovation.	dr.ir. H.V.M. Hamelers	2016
National Icon	Government National Award for technological innovations solving large societal challenges while creating large commercial opportunities.	Redstack (Wetsus spinoff company)	2016
Ridder van de Nederlandse Leeuw	Oldest Dutch Knighthood order for exceptional performance	prof.dr.ir. C.J.N. Buisman	2013
Herman Wijffels Innovation Award	Innovation Award from RABO bank	Aqua Battery (Wetsus spinoff company)	2016
Membership High Level steering group EIP	The European Innovation Platform is the main body advising the EU commission on matters of innovation in the water sector	prof.dr.ir. C.J.N. Buisman	ongoing
Membership ACTI	Netherlands Academy of Technology & Innovation	prof.dr.ir. C.J.N. Buisman	ongoing
TKI board membership	The 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 program board	The program board is responsible for innovation quality of the Dutch water technology program as funded by the government	dr.ir. J. Post	ongoing
Water Campus Board	Water Campus encourages cooperation between businesses, educational institutes and governments. It offers a unique innovation, research and development infrastructure	J. Boonstra	ongoing
KNW board	Royal Dutch Waternetwork, is the prime independent network for the whole water sector including management and technology	J. Boonstra	ongoing

Qualitative Network Benchmarking

The Wetsus network is qualitatively benchmarked via a survey (BBo 2017) on how Wetsus participants assess the Wetsus network compared to other networks they are involved in or have been involved in. The benchmark thus is a measure where Wetsus stands compared to the collective experience of Wetsus participants. An important objective of this enquiry is to determine to what extent the prerequisites for trusted weak ties (goodwill, integrity and reputation) are experienced by participants. Participants could grade the Wetsus performance by using a five-point scale from much lower, via average, to much higher, all compared to their experience with other programs. Figure 14 shows the fraction of participants that grade the performance of Wetsus compared to other programs as higher, or much higher, for the three aspects goodwill, integrity, and innovation reputation.

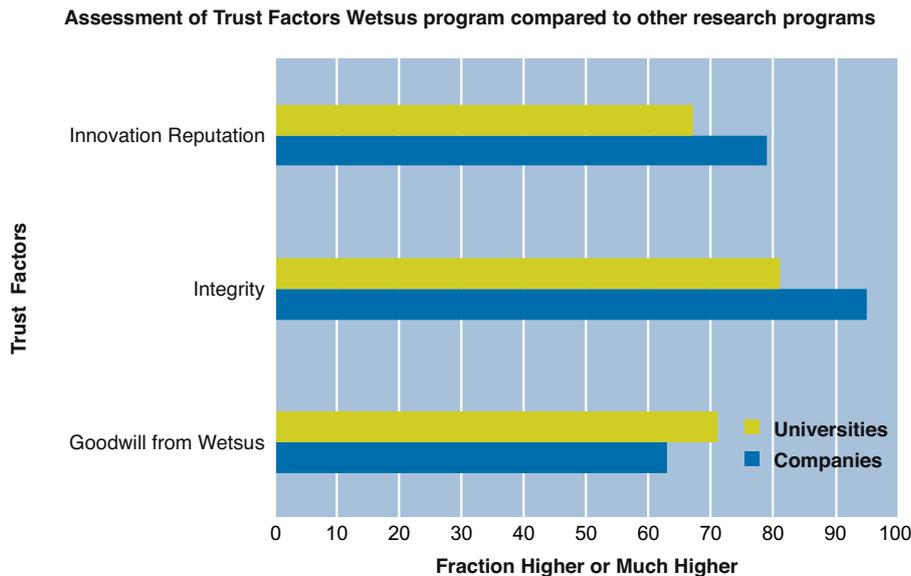


Figure 14. Percentage of respondents in the Wetsus network that evaluate the collaboration with Wetsus as Higher or Much higher, when compared to other network collaborations, as assessed for three main trust factors: Goodwill, Integrity and Innovation Reputation

Participant companies and university departments give high scores on important trust-based aspects of cooperation, such as: goodwill, integrity and reputation. This benchmark study shows that the Wetsus network is much more trust-based than other network programs in which participants participated. This implies that the Wetsus network is a high-trust network. This is certainly a satisfying outcome. However, this study does not give insight into the question how to further improve the network.

Based on the questionnaire and personal interviews the BBo report concludes: “Collaboration with Wetsus is generally judged by participant companies and university departments to be more than good. The overall valuation of Wetsus is continuously on a high level and even slightly increasing compared to earlier evaluations. An interesting observation is that there seems to have been growing a collective culture - a “Wetsus feeling” - among people who are connected to Wetsus. The Wetsus values are recognizable to participant companies and university departments.”

Viability Analysis

The viability analysis gives insight into how well Wetsus is equipped for the future. First results are presented of a SWOT analysis (Strength, Weaknesses, Opportunities, Threats), where the first two categories refer to the internal organisation, and the last two to the external context (environment) of Wetsus. The main strengths of Wetsus have been identified in performance and network analyses. Besides these already identified strengths, weakness of the network, opportunities and threats have been identified. This is done in interviews with participants (BBO report) and with scientific and management staff of Wetsus.

SWOT analysis

Table 19 describes the SWOT analysis. The table is self-explanatory. The SWOT analysis is an important input for the future strategy of Wetsus.

Table 19. Overview of results of Wetsus SWOT analysis based on input from company participants and Wetsus scientific staff.

Internal Organisation	Strengths	Weaknesses
	<p>Multidisciplinarity Trust based network Value based organisation Company involvement Idea driven All elements have been discussed in the section on performance and network analysis. Increased Reputation Due to the quality and relevance of the research, the Wetsus reputation has increased.</p>	<p>Keeping critical mass How to keep critical mass for individual disciplines as a basis for multidisciplinary Loss of inspiration The risk that the need for structure stiffens inspiration. Funding No structural funding arrangement in place.</p>
External Context	Opportunities	Threats
	<p>Demand for sustainable water technology remains high. Access to sufficient water of good quality remains an issue for the coming decades. Expanding European Network especially for funding & companies. Based on our increased reputation, it becomes possible to expand the network in Europe, including funding bodies. Cross sectoral cooperation i.e agriculture, energy & chemistry The trust based Wesus network is well suited to develop cross-sectoral ties that enriches all sectors involved.</p>	<p>Government R&D funding policy Government funding remains crucial to operate the breakthrough idea-driven program of Wetsus. There is little room to increase the already high company contribution for such precompetitive research program. Lower societal trust in science A decreasing societal trust in science will deteriorate the funding willingness of governments. Diverse funding conditions More diversity in funding bodies may lead to more diversity in funding conditions. Without alignment, this threatens the transparency of the cooperation system, the unity between all participants and therefore to the Wetsus innovation system itself.</p>

Strategy

During the first audit period (2004-2010), Wetsus was focused on managing the rapid growth of the network and program in terms of participants, topics, facilities and research projects. During this period a substantial part of the program was performed outside Leeuwarden at the participating knowledge institutes. During the second period which is now under audit, the program has stabilized in size and takes place mainly in Leeuwarden. The focus of this period was on increasing the quality of ideas and talents and subsequent the Wetsus reputation. For this reason, the procedure of the Program Council has been adjusted, the WaterSeed recruitment procedure has been implemented and the PhD development program has started. Also the use and availability of equipment was improved to create unique analytical possibilities.

When looking at the next period, 2017-2022, we foresee that the need for breakthrough sustainable water technology will remain high. Besides, we expect a stronger scientific cooperation with other sectors within our focus of process technology for water and wet processes. This cooperation is needed as the double stress of depletion and pollution is present in several sectors and closer cooperation will give new opportunities around reuse of materials and energy. The theme organization of the research program enables a smooth transition of topics. We have started with two new themes (Soil/CO₂-energy) that explore this model and teach us to refine this strategy.

Even though our network in the Netherlands is still expanding, gradually we see a growth of collaboration with European partners. This shift towards collaborations elsewhere in Europe, with companies, knowledge institutes and regional authorities will increase our impact. Companies and knowledge institutes are already part of the network, regional authorities as funders via the EU will be new.

To keep Wetsus an inspiring place for the employees and participants alike we will remain value-based and keep on investing in personal growth. The composition of the scientific staff needs to remain diverse. In this way it is possible to have a strong team, which can handle diverse conditions. A diverse staff composition also allows to better align people talents with the demand of the different tasks. This gives better results and inspiration.

Finance

Until 2021 the main funding source for Wetsus will be the regional structural fund from the Dutch national government, as shown in Figure 15. Wetsus is redefining its funding structure for the period after 2021. This development points to an important shift in Wetsus funding, in which a diversification of funding sources will take place. This will make Wetsus less dependent on a single funding source but poses a challenge to keep the financial and cooperation rules identical and workable for all participants.

The ambition for the years following 2021 remains to acquire a high level of company funding, not only to finance the program but, even importantly, to secure their commitment to the program. All companies have signed a running commitment contract. This means their membership renews automatically every year. The termination period is three year. The commitment of the companies for the future appears to be quite secure.

From 2021 onwards we want to redefine our financial structure from one fund for all activities into basic funding (probably regionally financed) and program funding (by the national government). This way the funding system of Wetsus will be more comparable with that of other know-how institutes. This will make it easier for Wetsus to comply with the requirements and regulations from funding bodies, since these usually refer to program funding, for instance in relation to the required percentage of company financing.

For the direct basic funding, the regional governments (Province of Friesland, city of Leeuwarden) have signed a letter-of-intent for their financial support for Wetsus in the period 2021 till 2030. We are working together with the local government to complement this regional support with national government support for the program funding.

For the program budget we envision funding from three state departments, namely Education (via NWO), Economical Affairs (via TKI) and Infrastructure and Environment (via Deltaprogram/Circular Economy):

- Recently Wetsus has signed a LOI with NWO (The Netherlands Organisation for Scientific Research) in which NWO and Wetsus run a yearly call of two projects, with an annual contribution from NWO of 0.5 M€. After positive evaluation this could increase to 2 M€ in 2021. The first call was issued at the end of 2016 and we hope to start the first projects in 2017.
- Via the Ministry of Economical Affairs we currently receive a so-called TKI subsidy that rewards 25% of the received company contribution. At this moment this amounts to 0.8 M€/year. It is envisioned that this will be increased to a 40% subsidy on company contribution in 2018, for Wetsus leading to some 1.2 M€/year. This arrangement will continue after 2021.
- From the Ministry of Infrastructure and Environment we used to receive 0.5 M€/year, but this has stopped in 2017. Discussions about prolongation for the years 2017-2021 and the following period are ongoing. Most probable is that we can get a role in the Deltaplan Fresh Water and/or in the national program for Circular Economy.

In conclusion, Wetsus feels confident about its financial viability. Until 2021 all funding is secured. The preparation of the funding scheme for the period after 2021 is well on its way. The financial structure of Wetsus can be improved by introducing direct funding (regional governments) and program funding (national government and companies). Figure 15 illustrates this scenario.

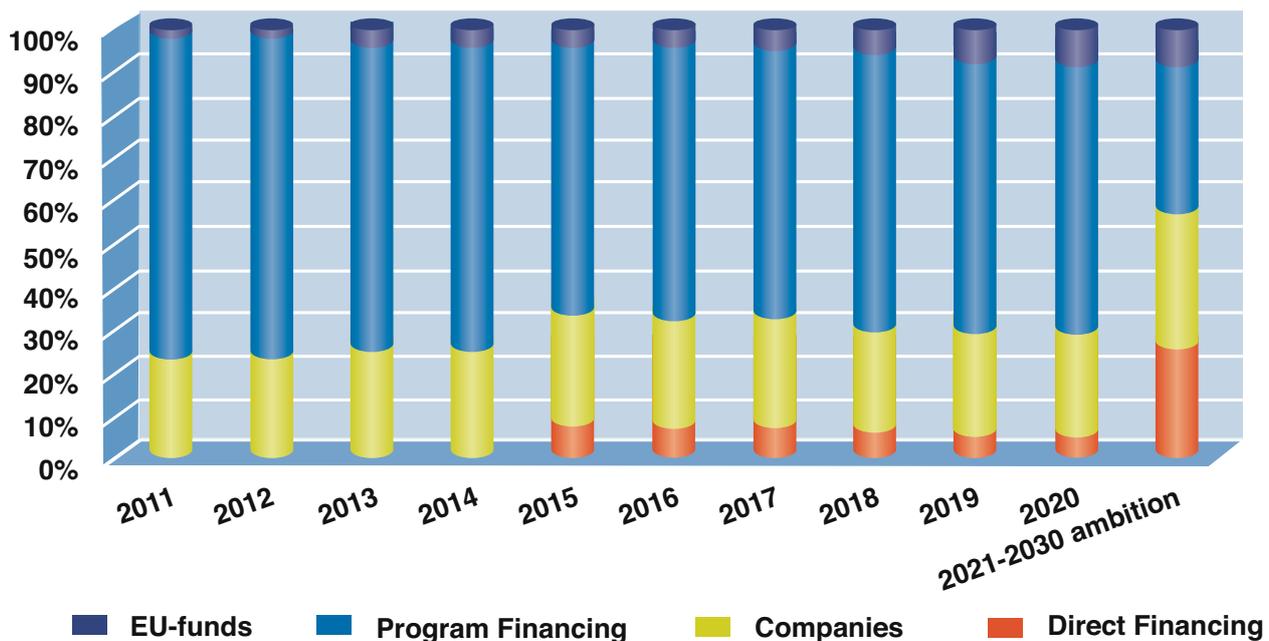


Figure 15. Sources of financial funding of Wetsus in 2011-2020, including outlook for 2021-2030.

Appendices

Appendix A. Composition researchers

	Year 5 (2012)	Year 4 (2013)	Year 3 (2014)	Year 2 (2015)	Year 1 (2016)	Current year (2017)
	FTE	FTE	FTE	FTE	FTE	FTE
Research unit						
Scientific staff	15	14	12	11	13	13
Postdoctoral research fellows	8	9	10	10	12	10
PhD students total	76	70	60	56	60	60
PhD students extern	27	26	15	13	9	8
PhD students intern	49	44	45	43	51	52
Total research staff	99	93	82	77	85	83
Support staff	17	14	17	20	21	19
Total staff	116	107	99	97	106	102

Appendix B. Financing structure

	2011	2012	2013	2014	2015	2016	2017
Research FTEs related to funding	FTE						
Research grants	2	5	6	6	4	15	16
Contract research	93	94	86	76	73	70	67
University in kind contribution	18	19	18	15	14	15	15
<i>Total research FTE</i>	113	118	110	97	91	100	98

Appendix C. Scientific Marks of Recognition

Scientific marks of recognition are summarized in the following tables.

Table 20. Individual research grants

2013: Humboldt Research Fellowship for Postdoctoral Researchers awarded to Wetsus PhD student Dr. S. Porada by the Alexander von Humboldt Foundation - 64,000 €. The AvH Foundation “sponsors exceptionally qualified scientists [...] to target [...] the academic elites of tomorrow [...] to win them over as partners for Germany.”

2016: VENI-award granted to Wetsus postdoctoral researcher Dr. S. Porada. The VENI-award is the most prestigious award in The Netherlands for young researchers with an estimated success rate of 10-15 %. The total award is 250,000 € and funds research costs and personal salary for a total of three years. Research carried out at Wetsus.

2016: ERC Consolidator Grant for Prof.Dr. Louis de Smet (Wageningen UR). Associated scientist with Wetsus. PhD student funded from ERC grant seconded to Wetsus.

Table 21. European Union Grants (FP-7, Horizon2020, EIT, Interreg). Because of the very strict acceptance criteria, leading to an acceptance chance of the order of a few percent only, obtaining EU research grants (awards) can be considered as a strong mark of recognition of scientific and technological excellence. In the period 2011-2016, Wetsus won or participated in a number of EU grants.

Project	Funding Program	Year	Award	
Denewa	Interreg IV A	2011	963 k€	MA
BioelectroMET	FP7	2011	3302 k€	MA
ValuefromUrine	FP7	2012	2912 k€	MA
WaterSEED	H2020	2015	3335 k€	MA
REvivED	H2020	2015	560 k€	*
BAoBaB	H2020	2016	3999 k€	MA
RM@schools	EIT	2016	35 k€	*
Resourcing Water	EIT	2016	200 k€	MA
MEDUWA-Vecht(e)	Interreg V A	2016	302 k€	*
Health-i-care	Interreg V A	2016	379 k€	*

MA: Wetsus is main applicant. In other cases (*) the grant total assigned to Wetsus is stated.

Table 22. Wetsus scientists obtaining academic of research leadership positions outside Wetsus

2016: Wetsus scientist prof.dr. H. Vrouwenvelder becomes Full Professor and Acting Center Director in the Water Desalination and Reuse Center of KAUST University (and leaves Wetsus).

2011: Wetsus Program Director Dr. G.J.W. Euverink becomes full professor at RijksUniversiteit Groningen (and leaves Wetsus; presently chair exam committee Wetsus MSc Water Technology).

2016: Wetsus Scientist Dr.ir. S. Metz becomes director R&D of MetalMembranes b.v. (and leaves Wetsus).

2012: Dr.Ir. Luewton Lemos, Wetsus scientist, becomes professor at NHL, University of Applied Sciences in Leeuwarden, with own research chair (“lectoraat”); parttime employment at Wetsus.

Table 23. Wetsus scientific staff members in membership of editorial boards of scientific journals

2015: Dr. P.M. Biesheuvel starts as member of editorial board of Desalination (impact factor 4.4; ongoing).

2013: Program Director Dr. H.V.M. Hamelers starts as Editor with ACS flagship journal Environmental Science & Technology (impact factor 5.3; ongoing)

Table 24. Review awards and Best Paper Awards Wetsus scientific staff members in

2015: ES&T Letters Best Paper Award for “Harvesting Energy from CO₂ Emissions” (all 5 authors with Wetsus affiliation)

2013: Excellence in Review Award Environmental Science & Technology awarded to Wetsus staff member Dr. P.M. Biesheuvel

Table 25. Scientific international conferences and summerschools organized and hosted by Wetsus including key scientific role for Wetsus staff members

Wetsus Scientist	Role	Participants	Date	Conference title
Hamelers	chair	300	May 2011	3rd International Microbial Fuel Cell Conference
Miedema	chair	150	Sept 2012	Wetsus-EDS conference on membranes in drinking and industrial water production
Hamelers	chair	150	May 2014	International Conference on Interfaces against Pollution (IAP)
Schaetzle	chair	50	Sept 2014	Salinity Gradient Conference
Post	member	100	May 2015	IUVA Research Frontiers Conference
Biesheuvel	chair	130	June 2015	7th European SummerSchool on Electrochemical Engineering
Kuntke	chair	40	Sept 2015	Young Water Professionals 4th Regional Conference
Bijmans	member	700	Feb 2016	EIP Water Conference
Biesheuvel	member/ chair	1500	Aug 2016	67th Annual Meeting of the International Society of Electrochemistry (incl. Symp. 9) (*)

(*) Organized in The Hague. Wetsus member of overall organizing committee, and chair of Symposium 9.

Table 26. Membership of scientific international committees and working groups for Wetsus scientific staff members

Prof.Dr. Buisman permanent member of the scientific committee at the biennial International Society for Microbial Electrochemistry and Technology conferences

Dr. Biesheuvel member of Dutch working party "Electrochemie" of Royal Dutch Society of Chemistry (KNCV); member Intl. Adv. Council of IAP (Interfaces against Pollution) and delegate on behalf of the Dutch Association of Process Technologists in the European Federation of Chemical Engineers (EFCE), working party Electrochemical Engineering.

2014: Dr. Biesheuvel establishes the International working group CDI&E (www.cdi-electrosorption.org) which successfully organizes conferences in Saarbrücken (2015) and Seoul (2017).

Table 27. Overview of Wetsus scientific staff membership of Academic Juries

Dr. Tom Sleutels opponent in PhD defense of mr. Kun Guo at University of Ghent, Belgium (February, 2014).

Dr. Lucia Hernandez acted as the opponent in the PhD defence of Ms. Sanna Jaatinen at Tampere University of Technology (July 1, 2016)

Dr. Biesheuvel member of three-person doctoral committee for Ms. Sofie Haldrup, Aarhus University, Denmark (March 4, 2016)

Dr. Biesheuvel member of three-person doctoral committee for Mr. Christoffer Peder Nielsen, Danish Technical University, Denmark (October 23, 2015)

2015, 2016: Dr. Post chair of jury for Water Innovator of the year

2016: Dr. Hamelers Jury member of Pilots to Innovate

Appendix D. Equipment & Facilities

Analytical equipment

- CLSM (confocal laser scanning microscopy)
- SEM (scanning electron microscopy), EDS (elemental analysis)
- AFM (atomic force microscopy)
- OCT (optical coherence tomography)
- Raman spectrometry
- ICP-OES (elemental analysis), microwave digestion
- IC (ion chromatography)
- LC-MS/MS
- LC-OCD (organic carbon detection)
- UHPLC
- μ -GC (biogases)
- GC-FID
- GC-FPD
- GC-MS/MS
- TOC (carbon analysis)
- UV-VIS spectroscopy
- Particle size analysis, zeta potential
- Surface area and porosity analyzer
- Absorbance/fluorescence/luminescence plate reader
- Gel electrophoresis (DGGE, DNA, protein)
- Microscopy: Brightfield, DIC, fluorescence, phase contrast
- PCR, qPCR
- Quantus (fluorometer for nucleic acids and proteins quantification)
- High-speed camera and image acquisition
- Flow cytometer
- Gain phase analyser, spectrum analyser
- Doppler Echography
- MinIon (DNA sequencer)

Research facilities

- Continuous and batch reactors
- Gas and sewage water distribution network
- Underground water storage tanks
- Safety precaution measurements and systems
- Walk-in fume cupboards
- Flat sheet membrane production
- Biofouling monitors with and without water production
- Multi-channel potentiostats
- Shaking incubators (CO₂/light)
- High-speed cooled centrifuge
- Labopress (molding and pressing)
- Fermentation equipment
- Sonication equipment
- Anaerobic glove box
- Cooling compartments
- High voltage laboratory
- Laser laboratory
- Freeze dryer
- Hot rolling press/calendering machine
- GAP fume cabinets
- Automatic film applicator
- Online process control
- Safety vacuum drying oven
- Tube furnace
- -80 °C freezer
- Ball mill
- Respirometer
- Automated research fume hoods with PLC and SCADA
- 3D printer
- Cutting plotter
- Biobench algae flatpanel reactor systems



