Forskningsrådet

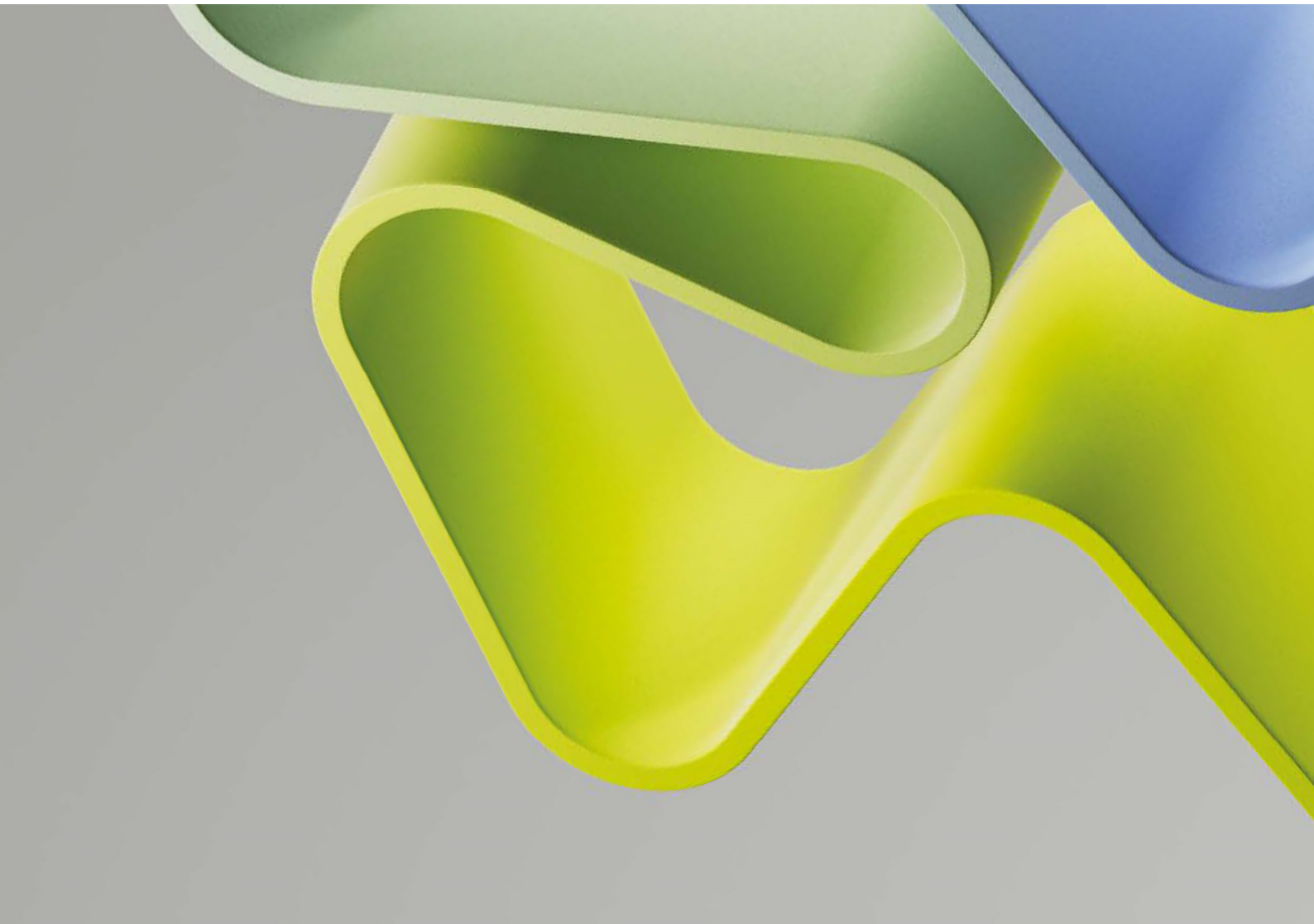
Evaluation of Natural Sciences 2022-2024

Evaluation report

Department of Chemical Engineering

Norwegian University of Science and Technology - Faculty of Science

January 2024



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Statement from Evaluation Committee II

The members of this Evaluation Committee have evaluated the following administrative units at the higher education institutions within natural sciences in 2022-2023 and submitted a report for each administrative unit:

- Department of Chemistry, Norwegian University of Science and Technology
- Department of Physics, Norwegian University of Science and Technology
- Department of Chemical Engineering, Norwegian University of Science and Technology
- Department of Materials Science and Engineering, Norwegian University of Science and Technology
- Department of Geoscience, University of Tromsø
- Department of Chemistry, University of Tromsø
- Department of Physics and Technology, University of Tromsø
- Department of Energy Resources, University of Stavanger
- UNIS – The University Centre in Svalbard

The members of the Evaluation Committee are in collective agreement with the assessments, conclusions and recommendations presented in this report. None of the Evaluation Committee members has declared any conflict of interest.

The Evaluation Committee has consisted of the following members:

Professor **Amelie Hagelauer** (chair)

Technical University of Munich, Germany

Dr. **Eric Deville**

IFP Energies Nouvelles, France

Professor **Christian Ruegg**

Federal Institutes of Technology ETH Zurich, Switzerland

Professor **Guido Mul**

University of Twente, The Netherlands

Professor **Sigridur Suman**

University of Iceland, Iceland

Description of the administrative unit

Norwegian University of Science and Technology - NTNU
Department of Chemical Engineering – IKP

The administrative unit
The unit employs 86,4 FTE research staff out of which 7 are professors, 3 associate professors, 6 researchers, 19 postdocs, 50 PhD students and 1,4 adjunct professors. The unit performs research in a wide variety of research areas including catalysis, colloid and polymer chemistry, environmental engineering and reactor technology and process systems engineering. The work is organised in four research groups.

The belonging research groups
IKP consists of four research groups – Catalysis research group, Process Systems Engineering research group, Reactor Technology and Environmental Engineering research group and Ugelstad lab.

The administrative unit works in relation to the unit's strategies
Research and innovation part of the department strategy is aimed at defining national goals and offer scientific support for the development of energy-efficient and sustainable process technology and in this way, the department contributes to the UN's sustainability goals and the green shift. Department's research disciplines are central in a domestic and international context and best researchers are internationally leading in their fields of expertise.

The strategy is based on three pillars:

- Development of talents and outstanding research groups, with focus on quality improvement throughout our business
- Research in accordance with NTNU's ethical guidelines and UN's Sustainability Development Goals
- IKP's uniqueness and strength within computational and experimentally based knowledge production, as a basis for digitalization of the process industry

The outcome of the research shall benefit society, either through academic publishing, or commercialization. IKP will contribute to innovation by inventions, entrepreneurship activities, and process improvements in close cooperation with industry.

The unit works in relation to the belonging sector
IKP educates master and PhD candidates with competence in sustainable chemical engineering originated from current research efforts, and aligned with the university's initiative for future technology studies. The Department hosts and participates in large long-term publicly funded research centres together with other research institutes (SINTEF) and has collaboration projects with direct funding from industry. The Department educates for industry and has adjunct professors from industry, and internships in industry.

The Department engages in dissemination activities for the general public.

Where the unit will be in the future
According to the IKP strategy for 2018-2025, the mission of the department is to contribute to innovation and development of sustainable solutions that protect the environment and assures sound use of resources, in line with the UN sustainability goals. IKP will be characterized by a generous and inclusive organization culture, with motivated, engaged and competent employees and students. IKP facilitates a health-promoting environment for study and work, characterized by a culture of sharing, quality and dedication to the work. IKP aims to be the first choice for students who wish to study chemical engineering and attracts highly qualified applicants.

Overall assessment

NTNU Department of Chemical Engineering is a large and strong department composed of four research groups with a strong governance structure. Several research groups perform good quality research and have provided impressive impact cases. Overall, the unit has shown very good and resilient performance. The unit performs very well on several dimensions:

- The unit appears most proud of its state-of-the-art research infrastructure, which has been built up over the years, and its collaborative attitude towards using it.
- There is an excellent administrative system for grant applications - including a dedicated officer to guide and help construct excellent proposals (for European Research Council (ERC), for example).
- The unit actively approaches international and local young faculty, and when hired, young faculty is very well embedded in the unit.
- The research groups are robust in terms of staff age distribution and experience.
- The unit makes good use of the mobility of (young) researchers.
- The unit is excellent at setting up collaborations for using national and international infrastructure and exploring funding opportunities.
- The unit is aware of the opportunities and threats presented by artificial intelligence for students and staff in education (evaluation) and research.
- There is an appropriate teaching load for PhD students.
- The unit's scientists and research results have very good international visibility. Visibility is actively pursued by, e.g., the organisation of large conferences.
- A well-appreciated, entrepreneurial spirit is sensed by the Evaluation Committee, both in the interview and through the cases provided.

Overall, the evaluation of the unit is very positive, and the administrative unit is well on track in terms of strategy, resources, and research organisation. Also, the quality and integrity of research activities are top-notch.

The Evaluation Committee considered the points raised by IKP in their Terms-of-Reference document and have commented on many of the issues raised in that document. Comments on the research relevance to sustainable industry are provided in Section 5. Where no comments are provided, this generally reflects a lack of relevant information in the self-assessment to allow the Evaluation Committee to reach a view.

Recommendations

The challenge of the department is to sustain the high level (quantity and quality) of PhD students, now that funding probabilities of proposals are somewhat less likely. There is also a great opportunity to diverge from unsustainable research activities related to the oil and gas industry, and to expand the activities in helping the chemical process industry (in Norway) to become more sustainable, and contribute to other United Nations SDGs. The expressed extension of entrepreneurship is encouraged. Ugelstad appears to be declining in funding, and in particular this group is recommended to change focus to more sustainable chemistry (teaming up with the catalysis group). While for several groups (particle technology, catalysis) internationalisation is in focus, the other groups could enhance their international visibility.

To develop activities in the domain of sustainable chemistry, the administrative unit could be more supportive to other AUs in the faculty, find synergies for example with Material Science and Engineering (electrochemistry) – if not already initiated.

An opportunity to further improve lies in a discussion of publication strategy. The administrative unit should improve particularly the quality of publications but most importantly their impact (citations) to be able to improve the value for the allocated funding.

The Administrative Unit should further encourage staff to consider visiting/guest professorships and generally mobility. Also, the unit is recommended to monitor the impact / result of mobility efforts more strictly/systematically. A somewhat stronger emphasis (for some groups) should be placed on generating societal impact (e.g., contribution to UN SDGs) which is not sufficiently addressed in all units.

1. Strategy, resources, and organisation of research

Summary assessment

The unit operates excellently on the aspect of resources, and the impact cases demonstrate a strong collaborative atmosphere among the different scientific research groups while opportunities exist to further align research strategy of the administrative unit with the UN SDGs. Opportunities also exist to collaborate more intensively with other units within the faculty, such as materials science (in the field of electrochemistry), and chemistry (computational chemistry – suggestion for the PSE group – for example to share computer power).

1.1 Research Strategy

It appears as if the different groups within the administrative unit to some extent develop their own strategy in research and innovation. It is recommended to the unit to discuss these strategies of the groups and better align/identify common ambitions. In particular one could debate if research activities for 'enhanced oil recovery' should be continued. The unit is aware of the importance of strategic discussions, with biweekly meetings organised between team leaders.

1.2 Organisation of research

The unit functions well on an organisational level, and advocates and promotes research and innovation activities well to the Norwegian research ecosystem.

1.3 Research funding

Overall, the administrative unit has been very successful in attracting funding. Several large initiatives/institutes, have been founded and adequately funded in applied engineering sciences across the board – including collaboration with large industries and the institute SINTEF. The funding has been more than adequate for its research activities – given the achieved successes in entrepreneurship, publications in scientific literature, and educating an impressive number of master, PhD students and postdoctoral students.

Based on output of the past, the Evaluation Committee feels acquisition of funds will be, and should be strong in the future – even though the odds of success having proposals granted by RCN appears (too) low.

Some groups have been exceptionally successful in terms of output and recognition, and the Evaluation Committee encourages the unit to have their outstanding scientists apply for individual

grants – such as available of the ERC. The unit has an administrative officer which encourages and or supports young and mid/end career faculty to apply, which is much appreciated.

1.4 Use of infrastructures

Locally, the department is very well equipped with state-of-the-art microscopy and analytical tools. The department has also been instrumental in developing a tool for analysis of the kinetics of catalytic processes – which is now internationally applied by various international catalysis groups. Furthermore, the department has access to clean-room facilities, to make state of the art microfluidic devices, among others. Finally computing facilities are available, supporting the modelling efforts of the Process Systems Engineering activities. Access to international infrastructure is achievable: the department has been successful in achieving beam time at international Synchrotron facilities.

In summary, the department has a very attractive infrastructure for landing industrial and international projects in the future. The Evaluation Committee recommends to pay close attention to maintaining this high-end, state of the art infrastructure 'top notch' and accommodating specialists to have the largest possible output of investments in infrastructure. Finally, the capabilities of the groups in spectroscopy and chromatography (analysing liquid and gas phase processes) are also much appreciated. The unit appears very proud of their research infrastructure – built up over the years, and the collaborative attitude towards using it – including collaborating with the department of physics.

1.5 National and international collaboration

Collaboration is truly more than impressive – with several groups being in the lead for creative and productive international research endeavours. The department has established collaborations with TU Delft– The Netherlands in particles technology – while also connections with institutes in India are in place. The catalysis group has many ongoing collaborations – the department has been involved in several EU funded projects (demonstrating the international recognition), and national collaboration with the SINTEF institute comes naturally.

The catalysis group / department has been instrumental in establishing the organization of the Europacat conference, to be held in 2025. The latter will help to increase the international visibility of the Norwegian research activities in the field of catalysis (engineering). Generally, the department is able to attract young international research stuff to Trondheim. Finally, the collaboration with Norwegian and (international) industry is impressive.

1.6 Research staff

The unit research staff composition (and different research groups) is overall appropriate and the group career development practises consistent with best practices. A good ratio between Professors (11) and Associate Professors (6) as well as researchers/postdocs (24). A very high number of PhD students (58) was present in 2021, showing the strong acquisition potential of the unit.

Mobility opportunities are also considered and present, but seem to be biased towards some groups. It appears the Catalysis group could enhance the number of staff having used mobility opportunities. Also, the unit is recommended to monitor the impact/result of mobility efforts more strictly/systematically. For example, mobility can lead to better research quality, expressed by the number of collaborative

publications, as well as quality in education (training and mentoring). The administrative unit overall has taken adequate actions to fulfil the FAIR-principles.

2. Research production, quality and integrity

Overall, the research quality of the unit is very good in terms of research production, quality and quantity of output (publications) and integrity. Quality is good (although the unit is encouraged to monitor their publication strategy, to increase impact and number of citations). Productivity is very good and the unit contributes to advancing the state of the art in their disciplines (in particular catalysis, process systems engineering and particle technology). Research integrity is very good, in line with international best practises.

2.1 Research quality and integrity

Research Group: Catalysis

This is a large and strong research group.

Strengths:

- In principle they combine industrial relevance (e.g. participation in innovation centres) with high quality science.
- Involved in many international consortia
- Good project portfolio on important and up-to-date topics
- Large output for some of the PIs

Weaknesses:

- No user-oriented outputs are given, so societal impact is difficult to judge
- Clearness of some relevant strategies is currently missing

Research Group: Process Systems Engineering

The research group's organization is aligned well with international process systems engineering groups identified as benchmarks. And this is suitable for carrying out research activities. The group consists of highly qualified and internationally recognized professors overseeing the research strategy and training of PhD and postdocs. Overall, the organizational environment is considered very good in supporting the production of excellent research. Regarding the quality dimension, the research group has performed internationally excellent research in terms of originality, significance, and rigor especially in the area of modelling and plantwide optimization and process control. The group has indeed undertaken a very considerable role in the research process from the formulation of research goals and aims to execution and analysis of research activities to the preparation of the publications. The group's contribution to economic and societal development in Norway and internationally is on similar level with what is expected from groups in the same research field especially with respect to training of highly qualified professionals (MSc, PhDs, etc) and industrial collaboration/dissemination. The relevant industrial stakeholders have been involved considerably in the research process, which is appropriate. Regarding weaknesses the following is noted: (i) there is a clear gender imbalance among the staff, which needs to be addressed and mitigated in the future strategy of the group, (ii) the institutional infrastructure for researching and advancing the wider application range of biotechnology needs more institutional level alignment/synergy between different groups. (iii) The institutional infrastructure concerning computing technologies in the age of artificial intelligence is not explicitly addressed in the group’s strategy.

Research Group: Reactor Technology and Environmental Engineering

Overall, this is one of the largest research groups in the institution and covers many fundamental aspects of the chemical engineering discipline: from reactor technology to thermodynamics, process design, membranes, absorption, crystallization and biorefining. These are important and very relevant for the Norwegian process industry as well as the international community. The group activities are aligned very well with the research goals and the group has an organisational environment that is very strong for supporting the production of excellent research. The quality of research outputs (publications in scientific journals, patents, software codes, etc.) is internationally competitive and considered very good in terms of originality, significance and rigor in some of the areas/fields covered. The group has played a significant role in the research process from the formulation of overarching research goals and methodologies to implementation, execution via research activities to the preparation of the publication. The group's contribution especially in research and training of qualified professionals for process industry is very considerable given what is expected from groups in the same research field. Relevant stakeholders from industry and research community have very considerable involvement especially in collaborative research projects. Regarding weaknesses, the following are noted: (i) The group lacks a unified vision describing different research themes and their synergy/interactions internally within the department and externally with other stakeholders. (ii) The mobility opportunities for young researchers are generically and not very convincingly described.

Research Group: Ugelstad Lab

Strengths:

- Strong position in applied interface science, in particular for petroleum science
- Good contacts with industry
- Solid scientific quality
- Very clear KPIs are identified

Weaknesses:

- A clear overall vision is lacking, and collaboration between PIs seems to be sub-optimal
- The activities of the group appear to be declining, and the project portfolio shrinking, so attention to acquisition is required – focusing on creation of sustainable industrial processes
- Collaborations with other academic groups, at NTNU or internationally, are limited. The lab has a very limited participation in international consortia, e.g. EU
- It is not easy to assess from the document how well the group is doing with respect to the KPIs set at the beginning

2.2. Open Science

The actions towards Open Science and impacts for Norwegian and international research are very good overall. The presented commitment to open sciences is high level.

The AU follows publication policies and principles that require research funded by public grants to be published in compliant Open Access journals or platforms. Other funding schemes are included as appropriate. FAIR principles were communicated from the RCN and the Directorate of higher education. NTNU employs a database depository for open data from all fields and disciplines. Software developed by researchers at Department were made available. e.g., "eT software", PyRETIS, "Thermopack Software", and "PVT calculations". NTNU has strong commitment to open science

demonstrated by efforts in open access software developed there. Open access of publications is based on funded grants, i.e. presumably the grants pay for the APC costs.

3. Diversity and equality

The administrative unit´s actions are appropriate to protect against discrimination. These are among best international practises. The unit aims for robust groups, meaning the unit is aware of age diversity inclusiveness and fair division of tasks in research and education.

4. Relevance to institutional and sectorial purposes

The relevance to institutional and sectorial purposes is generally good. The unit has demonstrated through impact cases and in the different reports a good cohesion and advancement on the different activities (knowledge, commercialisation, infrastructure, collaborations and contribution to high quality education). In some groups, some aspects should be improved (e.g., international collaboration, research commercialisation as well as training and mentoring) but overall the Unit as a whole is performing well.

5. Relevance to society

Four presented impact cases have strong societal impact and are of high quality. The societal impact relates to the environment, health energy, and climate and align well with the Long-term plan presented by NTNU at the faculty level and the UN SDGs. The administrative unit performs research that is highly relevant for sustainable industry, as very well illustrated by some impact cases.

Comments to impact case 1

The first impact case has been provided by the industrial Catalysis Science and Innovation (iCSI) centre. This is a Centre for Research-based Innovation (SFI). The Centre aims to create impact by helping the (Norwegian) chemical process industry to become more competitive and sustainable. In the impact assessment the goals are specified as:

- Establishment of fundamental insights on industrially relevant catalysis
- Education of candidates (MSc, PhD, postdoc.) who move on to realize the green transition

These are very much appreciated goals – and the activities in developing novel catalysts for i) the ethylene oxychlorination reaction and ii) the partial oxidation of methanol to formaldehyde are impressive. These case studies show the large impact of the iCSI in creating sustainable processes and educating an international group of PhD students and PostDocs. The list of publications is state of the art, not only including the premiere Chemical Engineering Journal, but also journals focused on more general and fundamental scientific output (Angewandte Chemie – ACS Catalysis). Interesting to note is that 10 PhD candidates (2 women) and 3 postdoctoral fellows (all women) are or have been affiliated with iCSI at NTNU Department of Chemical Engineering – performing the research activities. Experienced and renown international professors (Hutchings/Iglesia/Beretta) have been associated with the activities – as consultants and providing seminars. People affiliated with the iCSI have been very successful in securing positions in industry and academia – inside or outside Norway.

In summary – these cases form a scientific (publications) and engineering perspective (greening the process industry) – and the contribution to human capital, clearly show the two impact goals

specified above have been reached quite successfully – by strong collaborative efforts with large (petro)chemical companies.

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Comments to impact case 2

The department of Chemical Engineering has also hosted and led the (by the Evaluation Committee appreciated) activity SUBPRO, which is a Centre for Research-based Innovation (SFI) for subsea production and processing. Historically these activities have been focused on making the extraction of fossil resources more sustainable. A strong research activity (12 PhD at IKP) was to better understand how emulsions of water and oil behave, which has been achieved by developing and using advanced microfluidic analysis methods. Activities also include the removal of gases to increase environmental protection - developing treatment methodologies for removal of H_2S from resources. These are again very much appreciated goals; these technologies are highly relevant for partners in relation to the green energy transition, where CO_2 and other harmful gases are captured.

Much appreciated is also that these endeavours and collaborations see a shift towards more renewable technologies. Industrial partners in SUPRO have significantly revised their strategies since the start. Reaching net zero emissions (scope 1-3) in the next decades has become a common ambition of the sector. To reach this challenging goal while remaining profitable requires more efficient processes and new technology. SFI partners have agreed to work towards continuing our collaboration towards a new initiative (SUBPRO-Zero), which extends the current scope of SUBPRO to include carbon-neutral technologies such as Blue Hydrogen and Blue Ammonia. It is encouraged by the Evaluation Committee to continue and expand activities in the domains of renewable energy.

Comments to impact case 3

The third case study is really impressive – showing that the department extends research activities beyond the chemical process industry, and is able to collaborate with local and international colleagues on the development of particle technology – from the lab scale to practical implementation of the technology for (Corona) virus detection applications. “The successful execution of the project not only helped in easing the burden of the pandemic by supplying test kits nationally and internationally, but also led the foundation for the establishment of a research centre and a core facility and the birth of a new start-up company” – showing the capability of the department to be involved in entrepreneurship. This is also evident from the continued collaboration i between the centre (and the department) and Prof. Bjørås’ group at the Department of Clinical and Molecular Medicine, which jointly are running projects on more than 8 mutually co-operating research themes. This research has generated ~9 innovations over the last two years, some of which have been licensed to external companies and some are under evaluation for patenting or being followed up with more research work. Moreover, the scientific data – if not interfering with commercial activities – are published in high impact journals in the field of particle technology.

The societal impact of this endeavour is also evident – providing Corona tests to society. Also, present and future activities between NTNU and TU Delft for nano-plastic detection using gold nanoparticles and use of nanoparticles for biosensing are much appreciated. Finally, although not specifically mentioned by the authors, the centre educates an impressive amount of young people - currently 28 PhDs, Postdocs, Researchers and 15 master students are associated with the centre.

Comments to impact case 4

The fourth case is also really impressive. The department has built an internationally strong reputation with extensive experimental and modelling capabilities within three carbon (CO_2) capture technologies: absorption, membranes, and adsorption – topics which have been addressed by three research teams working on common goals. Among others, skills in computational chemistry, membrane technology and process systems engineering have contributed to the successes of these endeavours – showing a strong collaborative effort within the unit. National funding and European funding – and the associated national (SINTEF) and international partnerships have also contributed to the impressive output of this case. Educational outcomes of the research activities include more than 60 PhD defences. Contributions to the scientific community and literature are also impressive and the sources to corroborate the impact are convincing. The societal impact is again related to the human capital that has been generated, but is also substantiated by the entrepreneurship of this group of researchers – specifically in 2021, Aqualung Carbon Capture AS was established by the scientists of the membrane technology group. In summary – also this case is a good example of the high degree of success the department has achieved – both in educating PhD students, contribution to the scientific community in the field, and society/ the Norwegian economy.

List of administrative unit´s research groups

Institution	Administrative Unit	Research Groups
Norwegian University of Science and Technology	Department of Chemical Engineering	Catalysis
		Process Systems Engineering
		Reactor Technology and Environmental Engineering
		Ugelstad Lab

Methods and limitations

Methods

The evaluation is based on documentary evidence and online interviews with the representatives of Administrative Unit.

The documentary inputs to the evaluation were:

- Evaluation Protocol (see appendix Evaluation Protocol) that guided the process
- Terms of Reference
- Administrative Unit's self-assessment report
- Administrative Unit's impact cases
- Administrative Unit's research groups evaluation reports
- Bibliometric data
- Personnel and funding data
- Data from Norwegian student and teacher surveys

After the documentary review, the Committee held a meeting and discussed an initial assessment against the assessment criteria and defined questions for the interview with the Administrative Unit. The Committee shared the interview questions with the Administrative Unit two weeks before the interview.
Following the documentary review, the Committee interviewed the Administrative Unit in an hour-long virtual meeting to fact-check the Committee's understanding and refine perceptions. The Administrative Unit presented answers to the Committee's questions and addressed other follow-up questions.

After the online interview, the Committee attended the final meeting to review the initial assessment in light of the interview and make any final adjustments.

A one-page summary of the Administrative Unit was developed based on the information from the self-assessment, the research group assessment, and the interview. The Administrative Unit had the opportunity to fact-check this summary. The Administrative Unit approved the summary with minor adjustments.

Limitations

The Committee judged the information received through documentary inputs and the interview with the Administrative Unit sufficient to complete the evaluation.

Appendices (link to website)

1. Description of the evaluation of EVALNAT
2. Invitation to the evaluation including address list
3. Evaluation protocol
4. Self-assessment administrative units
5. Grading scale for research groups

Website: https://www.forskningsradet.no/tall-analyse/evalueringer/fag-tema/naturvitenskap/

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