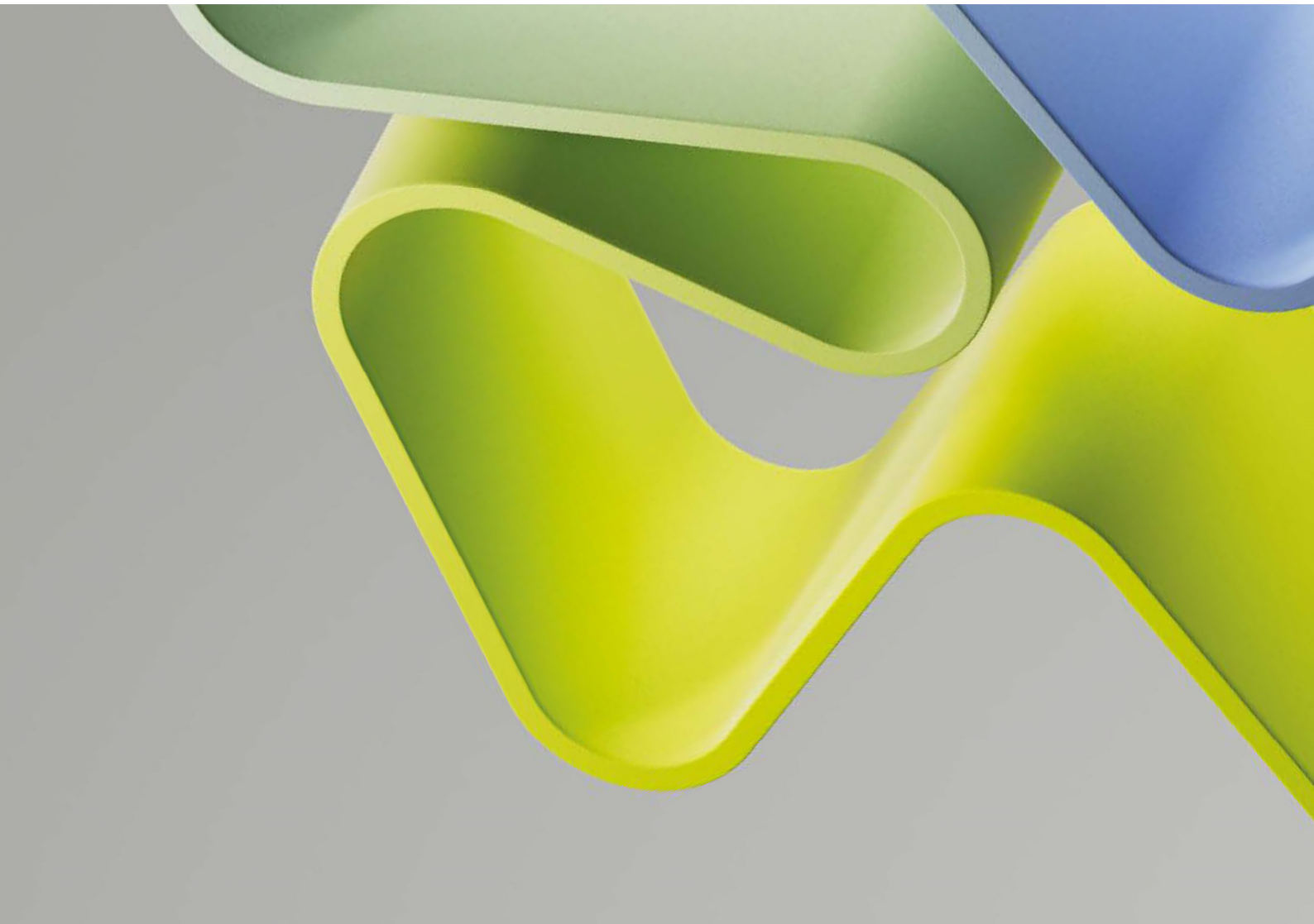
Forskningsrådet

Evaluation of Natural Sciences 2022-2024

Evaluation report
Department of Materials Science and 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**

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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 Materials Science and Engineering – DMSE

The administrative unit

In 2021 DMSE had 158 FTE positions, of which 55% or 87 FTE were dedicated to research. DMSE is a broad materials science and engineering department with five research groups focusing on functional materials, metal production, physical metallurgy, electrochemistry, and materials-related educational research. Educational research group is relatively new and has a focus on research on education and is not subject of this evaluation. DMSE performs research on the manufacture of new and the improvement of existing materials in chemistry, electrochemistry and metallurgy. The department explores the use and recycling of materials and material resources, and reduction of energy consumption and emissions during production and recycling. DMSE performs fundamental and applied research. DMSE's main goals are to develop materials, processes, concepts and components for finding solutions to challenges in energy, the environment, climate and health, and develop knowledge for future generations, and to contribute to the development of industries through research on industrial challenges.

The belonging research groups

DMSE consists of five research groups – Electrochemistry group, Functional Materials and Materials Chemistry group, Physical Metallurgy group, Resources, Energy &Environment group. Educational research group is not subject of this evaluation.

The administrative unit works in relation to the unit's strategies

Concrete measures to reach DMSE's goals include the recruitment of outstanding undergraduates into PhD positions and the creation of an attractive work environment for technical and academic personnel. National and international network building is achieved through strategic research initiatives at a research group level as well as by academic staff sabbaticals, conference attendance and research visits supported by the administrative group. High level academic publication ensures visibility of the results to its main target audience.

The unit works in relation to the belonging sector

DMSE is the only centre of education and basic research in materials science and engineering in Norway. Industries based on materials production and processing are contributing significant amounts of income to the Norwegian society both on individual and structural level. Via education, collaborative applied research and curiosity driven fundamental research in relevant fields, DMSEs educational and research activities are laying the basis for value creation in some of Norway's key industries.

DMSEs study programmes educate students in key aspects of materials science and engineering. By engaging with industrial stakeholders dependent on applying research into their production processes or products in applied research projects, DMSE research is driving sustainable value creation and securing employment in society. As examples, DMSE research (i) is driving the green shift in key companies in the metal production and processing industries, (ii) is strongly contributing to the current built up of a battery industry, and (iii) the increased production of 'green' hydrogen.

Where the unit will be in the future

DMSE strategic vision is to strengthen DMSE position as a knowledge institution in materials science and engineering and systematically improve the quality of all activities. At least two of DMSE academic groups are expected to be internationally leading. DMSE aims to attract best students to their innovative learning environment and creative academic community.

Overall assessment

The Department of Materials Science and Engineering (DMSE) of the NTNU is a well-performing administrative unit. It shows a good performance of all research groups and a high quality of research which is internationally competitive. The unit provides excellent training for PhD students and postdoctoral researchers and high-quality research and publications. The unit has a good research organisation and good levels of external funding.

DMSE has developed a good strategy that is well aligned with the NTNU's strategy and recent international developments in the respective research areas.

The concept of synergy groups for cross-disciplinary research areas strengthens the collaboration within DMSE. Also, good collaborations with industry and research institutions exist, especially internationally. Policies and mechanisms are in place to facilitate new collaborations.

The DMSE brought up some concerns about the reform and potential reduction in size due to planned retirements within the department, which should be considered in the future strategy. The Evaluation Committee recommends further strengthening the high quality of research to keep the high international level.

Reviewing cooperation with the NTNU Department of Chemical Engineering is recommended to strengthen synergies.

The Evaluation Committee considered the points raised by the unit in their Terms-of-Reference document and have commented on those throughout the report where applicable.

Recommendations

The Evaluation Committee recommends maintaining the good performance of the department and the research groups. Good performance is not permanent; therefore, the administrative unit needs to adapt to ever-changing international developments.

The Evaluation Committee recommends maintaining a balanced mix of fundamental research, development of new technologies and international visibility. Fundamental research is important, and resources for funding fundamental research projects should be secured regularly to maintain competence in the relevant fields.

Having and further strengthening strategic national and international networks is highly recommended to maintain and improve research performance.

The plans of hiring industrial professors are encouraged. Still, from its own experience, the Evaluation Committee recommends that the administrative unit is aware of the balance (industrial professors vs other professors) and topics (focus on subjects with potential synergies and contribution to the main research areas). The Evaluation Committee recommends recruiting more junior staff and PhD students to address retirement-related challenges. It is important to ensure gender balance as the unit already does, but reliance on role models needs to be complemented with monitoring of gender balance.

The Evaluation Committee recommends identifying a better-defined strategy to secure funding for infrastructure maintenance and new infrastructure as it is crucial for education and basic research and to reach its targets for research and society.
Careful consideration and implementation of the above points should enable the Administrative Unit to achieve a higher international impact (leading international research) as defined in the Terms of Reference.

1. Strategy, resources, and organisation of research

DMSE has developed a good strategy that has enabled it to achieve international recognition for good quality work and build a strong collaboration with the industry. It addresses research topics for sustainability and further essential topics for the future energy transition.

The administrative unit is an integral part of NTNU and has links, especially to the Department of Engineering and the Department of Physics. It has strong collaborations with industry and international partners. National collaborations are good; there are strong links to the University of Oslo and the University in South-Eastern Norway.

There is a very good level of funding success, which enables research. Notable is the funding from industry and the European Union sources.

Local infrastructure is of high importance to the unit's research. The unit will need to expand, update and maintain the critical infrastructure.

1.1 Research Strategy

The DMSE has developed a clearly defined and good strategy on department level which is well in alignment with the strategy of the Faculty and the University. The implementation of the strategy will greatly depend on DMSE ability to maintain and form strong cooperation with the international research community to ensure research is driven by topical needs and developments and thus can generate new funding options.

The unit is structured in five research groups, of which four were evaluated in this evaluation. DMSE conducts research and teaching in a broad spectrum of topics. The strategic process is anchored in the leader group at the department. All research groups define their own research but have to fit under the broad research strategy of the department. The Electrochemistry group includes research on industrial electrolysis, fuel cells, batteries, corrosion and corrosion protection. The functional materials group covers topics like material synthesis, theory and advances characterization of the materials to industrial processes. The physical metallurgy group conducts research in the field of material and process development with emphasis on light metals and silicon for solar cells. The resource, energy and environment group focus on ferroalloys, silicon and aluminium processing and refining including recycling and industrial emissions. The activities match the strategic goals very well. The synergy groups are a great structure for cross-disciplinary research.

1.2 Organisation of research

The organisation of the department is well-structured with a leadership group including the head of department, research and education deputy chiefs, head of administration, technical leader and group leaders. The department supports e.g., in terms of administration, commercialization, transfer and infrastructure. There exists a very reflective thinking about the strengths and weaknesses of the department.

A remarkable weakness is that there is no funding to maintain the existing critical infrastructure. A strategy is urgently needed to raise the necessary funds. Another threat is the export control regulations, which affect international cooperation in particular.
The unit has overall good balance of number and proportion of professors, PhD students and postdoctoral researchers, with exception of the physical metallurgy group. Master students are involved in third party funded projects, which allows an early involvement in current research topics.

1.3 Research funding

DMSE has a large amount of external funding. The external funding is about 48% of the total budget. A large amount of the external funding comes from the RCN and the EU. The unit hosts one ERC Consolidator grant which signals a very high quality of research. The strategic work of DMSE reflects in the good mixture of funding, which includes funding from industrial partners. Funding with industry could probably be increased given the research areas of the unit. The external funding is very good for performing of research projects, which is also reflected in the overall good performance of the research groups.

The units' successful cooperation is also reflected in its partnership with Research Centres. DMSE is successfully involved in 2 SFI (Centres for Research-based Innovation) and 3 FMEs (Research Centres for Environment-friendly Energy). It also hosts two own SFIs.

1.4 Use of infrastructures

DMSE makes very good use of national and international infrastructures. It hosts the Norwegian Laboratory for Mineral and Materials Characterisation and is partner in the FuelCell, and HydrogenCenter and Norwegian laboratory for silicon solar cell technology. DMSE hosts its own lab infrastructure for all members of the department, which is maintained by highly qualified technical staff. This infrastructure is a good match for department research and helps position DMSE well in the national (and international) landscape. This is very important and should definitely be continued. As modelling is one part of the activity the groups have access to national supercomputers, licences and databases. Furthermore, there is additional access to key equipment with collaborating partners (e.g. SINTEF), which is of high importance. In addition, some groups use other international laboratories, such as synchrotron facilities like SNBL, DESY, BESSY II, etc.

Lack of funding to expand, update and maintain infrastructure is very critical. A good strategy for raising funding is lacking and is needed. Most important critical infrastructure is, for example, electron microscopy and X-ray diffraction facilities.

1.5 National and international collaboration

DMSE is actively supporting and encouraging regional, national and international collaborations. The groups have high quality national and international collaborations, both with academic partners and industry. The groups collaborate with other research groups at NTNU in different departments and with international groups. There are day-to-day collaborations with the NTNU Faculty of Engineering and the University in South-Eastern-Norway. Further collaborations are established with the University of Oslo and the University of Agder.

Important collaboration on many aspects of batteries is established with battery companies and with FFF on technology for metal production with focus on reducing emissions. DMSE is collaborating with important international research institutes like the Max-Planck-Institute in Germany and the Christian Doppler Forschungsgesellschaft in Austria. In addition to the collaborations an extensive international network exists.

1.6 Research staff

In general, the good quality research outputs and the outward-looking orientation of the researchers and managerial staff is testament to a good quality and very well internationally linked research staff.

DMSE shows overall a good composition of staff members (33 FTE professors and associate professors, 15 postdoctoral researchers and 60 PhD students). The unit has a high number of female academics, even on professor level. The leaky pipeline is small (Female PhD Candidates 43% and Female Professors 38%). The department has a good level of Postdocs to support PhD candidates. It has established a good career development of early career researchers and postdoctoral researchers. It is seen as positive, that there are reduced teaching loads for selected early career researchers. There is a need for careful planning of the future size of the unit.

2. Research production, quality and integrity

All four research groups at DMSE are high performing groups. Topics addressed by the groups are of vital importance for the future and thus timely. Overall, the bibliometric data show a good performance of the unit with good impact of the publications demonstrating focus on the quality of the publications.

All research groups produce good quality research. The Electrochemistry group is a key player for electrochemistry and corrosion on a national and international level. The quality of the research is very good. The group maintains strong collaborations with industrial partners and is strongly involved in the international research community. The Functional Materials group also maintains strong collaborations with industry and provides excellent training of PhD students and postdoctoral researchers. The Physical Metallurgy group has a good national presence and some international visibility. The group has a good international engagement mostly through network with international partners. The Resource, Energy & Environment group is a strong group and has strong collaboration with other groups at NTNU, institutes and industry. The research is of internationally high standard.

2.1 Research quality and integrity

Research group: Electrochemistry

The Electrochemistry Group is a key player in Norway in electrochemical research and education and is internationally renowned in several of the active research fields (applied electrochemistry for large scale industrial processes, water electrolysis, corrosion, battery technology). In this rich field of research, the Group publishes high quality papers, linking fundamental science and applications. Indeed, a major strength of this group is that it is able to bridge the gap between fundamental research and the engineering level in various areas of electrochemistry, from batteries to molten salts, aqueous electrolysis, fuel cells. The group has had a long lasting leading international position in localised corrosion and surface treatment of aluminium. This is a strong group, achieving high quality research and advancing technologies that are essential for sustainability of materials and energy, compliant with low carbon emission.

Research group: Functional Materials and Materials Chemistry

The FACET research team is a strong and international group of scientists. Research meets the high international standard in terms of originality and visibility. They are performing extremely well in the education of students and are internationally very well connected. In addition, strong interactions with industrial partners lead to a very good symbiosis between the basic science world and work of higher technological readiness level. Organization of the team seems to be very well thought off, balanced between independence and guidance, and motivating for the researchers. Education and training of young, next generation talents is excellent. The group's contribution to economic, societal

and/or cultural development in Norway and/or internationally is very considerable given what is expected from groups in the same research field. As a small weakness, it is to mention that the range of topics is very wide and collaborations between the members of FACET are sometimes less pronounced than collaborations with other national or international partners, as seen in the cases of the international hiring.

Research group: Physical Metallurgy

The group faces some challenges/threats in renewing experimental infrastructure and recruitment of staff and students. The close collaboration with industry in applied research is somewhat sensitive to industrial activities and market but can also be a strength with new industrial activities. Weaknesses and strengths are rather natural for such academic research, covering applied and experimental research. Stronger activity in EU projects is mentioned which is an opportunity to broaden the application area and network with international academic partners and thus strengthen the ability to attract funding and conduct excellent research. Overall, it is judged based on the documentation that it is an adequate organisational environment, research and publication quality and contribution is excellent and societal contribution in par with what is expected.

Research group: Resources, Energy &Environment

This is a strong group with a high output of publication and PhD, capability to attract competitive funding and access to unique research infrastructure. The field of research is highly important, not the least with the emphasis on carbon neutrality and resource efficiency, thus a field of high importance. Recruitment of students is a potential threat which may also impact in the longer-term recruitment of professorial staff. Overall, it is judged based on the documentation that it is a very strong organisational environment, research and publication quality and contribution is excellent and societal contribution on a par with what is expected.

2.2. Open Science

DMSE has open-science strategies which are forced by the NTNU's open science policy. NTNU Open (a platform) is available for archiving all articles. This implicates a high open access rate and results in a high impact for Norwegian and international research. This focus absolutely has to be maintained to be able to secure funding and international recognition.

3. Diversity and equality

At NTNU a policy for Gender and Diversity exists and DMSE has implemented diversity and equality in its strategy. DMSE shows a good awareness of gender balance and equality. Measures that are implemented include, for example, work environment surveys to reveal positive and negative factors at work. Surveys lead to measures to preserve positive and change negative factors. Social activities are arranged to create meeting arenas. Whistleblowing routines are in place via ombudspersons at different levels. Hiring processes follow NTNU standards based with the goal to hire the best qualified candidate. For permanent positions, representatives from Trade Unions are included in the committees. For all positions, the equal opportunity ombudsperson must approve a candidate. Implicit biases are difficult to exclude but are tackled through raising awareness.

The number of female researchers appears to be very similar in an international comparison. The leaky pipeline is quite small (Female PhD Candidates 43% and Female Professors 38%).

4. Relevance to institutional and sectorial purposes

The impact of the DMSE is high, as it is the only centre of education and basic research in material science and engineering in Norway. Research and education are very related to Norway's key industries like metal production and processing industries, battery industry and production of green hydrogen. DMSE maintains close collaborations with industrial partners (e.g., in large network projects). The strong focus on industrial cooperation is also reflected in innovation projects for the Industrial Sector.

A very interesting measure was the hiring of an innovation manager for three years to enhance innovation. Additionally, there are funds to generate innovation from research results from NTNU.

The list of successful commercialisation projects provided by the unit demonstrates success, but there was no indication of commercial income. It is praiseworthy to mention that start-ups have emerged from some of the results, patents are being exploited through licenses and products are being sold.

Research-based education for PhD and master students is a central pillar of the unit. Master students are involved in research projects via thesis, project work and summer jobs. Overall DMSE provides a high standard for PhD and Master students.

5. Relevance to society

DMSE has a good track record of relevance to society. Its research is on more sustainable materials production, replacement of toxic materials, increased recycling, as well as energy conversion and storage. It has strong activities towards implementing the green shift in key industrial sectors in Norway. The department's research is a key driver towards several UN sustainable development goals. The unit's strategy fits well in the Norwegian long-term plan for research and higher education. The strategy shifts towards future challenges of climate and the green transition which seeks to give the unit continued societal relevance. Although with some weaknesses and sometimes missing the link between research and wider relevance, overall, the impact cases demonstrated by DMSE illustrate the above claims on the relevance of DMSE research to society.

A short statement about the sustainability of their own research, e.g., on reducing emissions at the institute or their research, would complete the topic.

Comments to impact case 1

Impact Case 1 is not written very clear as it seems that the Ferroally Industry's Research Association (FFF) is an association, from which DMSE has gained funding for several projects. To the reviewers understanding DMSE is mainly involved in FFF and especially in FFF projects. The main goal of FFF is to further develop environments and activities that recruit and train professionals, preferably at PhD level, and who can solve research tasks of vital importance to the industry as a whole. 70 PhDs have been educated in FFF-projects, and in addition to financing the industry is also supporting the individual PhD students by participation in advisory committees, co-authoring papers, and taking the role as future users of their findings. Two examples regarding environmental standards and process-related Health, Environment and Safety (HES) work are the Promiljø project (2006-2010) and the FUME project (2009-2014). Promiljø has the objective to reduce environmental impact of ferroalloy

plants whereas the FUME project focused on the internal plant environment by development of competence in the area of “fugitive” emissions of materials (gas, dust/particles etc.) to the internal and external environments as well as low and high temperature energy losses from the Norwegian ferroalloys industry. The impact case would be clearer if the impact of the projects were better emphasized and the definition of FFF was not explained in the summary.

Comments to impact case 2

This impact case represents work at DMSE to develop a new metal continuous screw extrusion (MCSE) method over the last 15 years. The innovative idea is to go from granular material to a finished product in one continuous operation, without remelting. Recycling of metal scrap, imposes a large reduction in energy consumption (90% compared to remelting) and limited material waste. Closed-loop recycling of end-of-life high-power transmission lines by MCSE has shown great potential, with engagement from the industry. 18 master and three PhD students have been dedicated to different aspects of the technology and the apparatus itself as well as exploring the potential applications of the screw extruder to make new materials and examine the properties of these materials. This is a good example of timely research and a second generation of the screw extender is already available at NTNU. Research is still on going. The direct link between the specific cited impact on industry or policy is not clear and should be improved.

Comments to impact case 3

This impact case shows research on fundamental properties of electrode reactions having impact on key parameters such as the current efficiency for metal deposition and kinetics for evolution of chlorine and oxygen on alternative anodes during electrowinning of zinc, nickel, copper and cobalt from aqueous electrolytes. Factors affecting energy consumption, energy efficiency and carbon footprint in industrial electrowinning processes have been emphasised in several projects. It shows an interesting topic, but the impact remains unclear. In particular, several publications were listed. It's important to show the impact on industry or policy.

List of administrative unit´s research groups

Institution	Administrative Unit	Research Groups
Norwegian University of Science and Technology	Department of Materials Science and Engineering	Electrochemistry
		Functional Materials and Materials Chemistry
		Physical Metallurgy
		Resources, Energy &Environment

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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