The Research Council of Norway

Evaluation of Mathematics, ICT and Technology 2023-2024

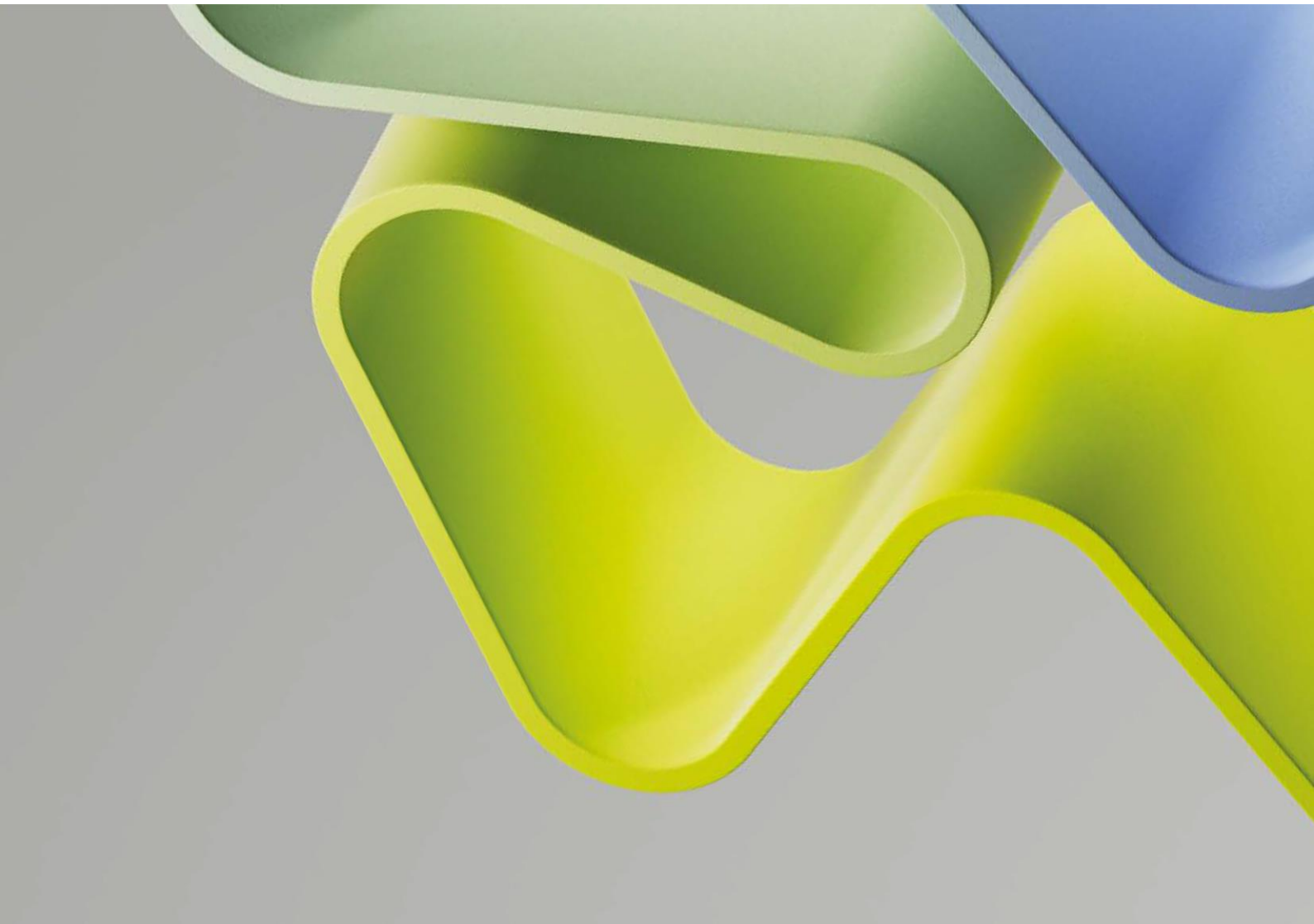
Evaluation Report for Administrative Unit

Administrative **Unit: Department of Electronic Systems (IES)**

Institution: **Norwegian University of Science and Technology (NTNU)**

Evaluation Committee Higher Education Institutions 2

December 2024



Contents

Statement from Evaluation Committee Higher Education Institutions 2 1
Description of the Administrative Unit 2
Overall Assessment 4
Recommendations 4
1. Strategy, Resources, and Organisation of Research 5
1.1 Research Strategy 6
1.2 Organisation of Research 6
1.3 Research Funding 7
1.4 Research Infrastructures 8
1.5 National and international collaboration 8
1.6 Research staff 9
1.7 Open Science 9
2. Research production, quality and integrity 10
3. Diversity and equality 12
4. Relevance to institutional and sectorial purposes 13
5. Relevance to society 14
5.1 Impact cases 14
Methods and limitations 16
List of administrative unit's research groups 17
Terms of Reference (ToR) for the administrative unit 18
Appendices 20

Statement from Evaluation Committee Higher Education Institutions 2

The members of this Evaluation Committee have evaluated the following administrative units at the higher education institutions within Mathematics, ICT and Technology 2023-2024 and has submitted a report for each administrative unit:

- Department of Computer Technology and Computational Engineering (IDBI), UiT The Arctic University of Norway
- Department of Automation and Process Engineering (IAP), UiT the Arctic University of Norway
- Department of Electronic Systems (IES), Norwegian University of Science and Technology (NTNU)
- Department of ICT and Natural Sciences, Norwegian University of Science and Technology (NTNU)
- Department of Information Security and Communication Technology (IIK), Norwegian University of Science and Technology (NTNU)
- Department of Engineering Cybernetics (DeptCybernetic), Norwegian University of Science and Technology (NTNU)
- Department of Information Systems (IIS), University of Agder (UiA)
- Department of Computer Science, Oslo Metropolitan University (OsloMet)
- Faculty of Science and Technology (REALTEK), Norwegian University of Life Sciences (NMBU)
- Department of Science and Industry Systems (IRI), University of South-Eastern Norway (USN)
- School of Economics, Innovation and Technology (SEIT), Kristiania University College

The conclusions and recommendations in this report are based on information from the administrative units (self-assessment), digital meetings with representatives from the administrative units, bibliometric analysis and personnel statistics from the Nordic Institute for Studies of Innovation, Research, and Education (NIFU) and Statistics Norway (SSB), and selected data from the National survey for academic staff in Norwegian higher education and the National student survey (NOKUT). The digital interviews took place in the autumn 2024.

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

The Evaluation Committee consisted of the following members:

Professor Jan Canbäck Ljungberg
University of Gothenburg

Professor Bo Wahlberg (Chair)
KTH

Professor Nancy Pouloudi
Athens Univ. of Economics and Business

Professor Alessandra Costanzo
University of Bologna

Professor Torsten Braun
Universität Bern

Professor Stefan Wermter
University of Hamburg

Description of the Administrative Unit

The Department of Electronic Systems (IES) is part of the Norwegian University of Science and Technology (NTNU). IES's research focus can be described as "Digitalisation On The Edge", meaning they perform research activities enabling the transition from the physical world to the digital world, from sensing to processing and including data sharing. The department has a non-hierarchical structure with 31 professors, 15 associate professors, five researchers, four post-docs and 30 PhD students. Of these, 45 people hold temporary positions (mostly the PhD students), and around 19% are women.

The IES is arranged into five official groups (Acoustics, Circuit and Radio, Nanoelectronics and Photonics, Signal Processing, Smart Wireless Systems) and one mixed group for research and didactics in engineering education. Most research activities are coordinated/developed by the groups. Cross-group initiatives are encouraged and are increasing. Each research group has a group leader for effective inter-/intra-group management, and meetings between leads and the department head represent a crucial tool for strategy development and implementation.

IES is aligned with the NTNU and IE Faculty's research visions and has been active in the NTNU's strategic areas (Energy, Ocean, Health, and Sustainability), in the NTNU enabling technologies (Digital and Nano), and in the IE faculty strategic areas (Internet of Things, Small Satellites, Energy Efficient Computing Systems, and Digital Twins). IES extensively cooperates with prestigious foreign universities for research projects and research exchange. The unit has several collaborative research projects with local and international partners from the private and public sectors. With respect to research infrastructure, IES is involved in a cross-disciplinary clean-room, they have access to the Sigma2 national e-infrastructure and to EU and US synchrotron facilities, and they also have their own laboratories for molecular beam evaporation and, for example applications in autonomous ferries.

IES strategy aims at a good balance between academic-oriented and industrial-oriented research and innovation. This goal is pursued via strategic areas grouped in "enabling technologies" and "needs-driven activities": the former including nanoscale-component technology, energy-efficient electronics, communication systems, artificial intelligence & machine learning, smart sensors, speech technology, augmented/virtual reality, acoustics; the latter including medical technology, small satellites & autonomous vehicles, Internet of Things, art & technology, ocean & energy & the environment. The unit secures research funding at the national and international levels. At the national level, the department is involved in three centres for research-based innovation and programme-funded research projects. At the international level, the unit mostly receives funding in relation to Research & Innovation Actions and to FET-OPEN. With respect to innovation and commercialisation of their own research, IES enables this through a dedicated Innovation Manager (a member of the leadership team), and through seminars and courses aimed at staff and students.

As it relates to the wider sectoral impacts, IES is the main responsible party in Norway for research and education in electronic engineering, which is reflected in the master program "Electronic System Design and Innovation" and the PhD program "Electronics and Telecommunications", where teaching is directly affected by research activities. Students have several opportunities to become familiar and take part in research activities of different groups both during regular courses and in the development of the thesis. Furthermore, IES scientific staff are involved in providing advice to Norwegian administration on various aspects related to digitalisation. IES is mostly responsible for the supply of engineers and scientists with the required expertise to expand and renew Norwegian industry to meet "The

Green Shift", e.g. in energy-efficient electronics, nanotechnology, machine learning and artificial intelligence.

IES plans to meet the following research objectives: (i) increase the research activities, (ii) prioritise strategic areas, (iii) strengthen collaboration with private and public sectors, (iv) increase the number of high- quality scientific publications, (v) establish good routines for the implementation of research projects, (vi) develop the PhD program according to the faculty plan for future PhD education, and (vii) optimise the teaching portfolio in order to secure sufficient research time to the scientific staff.

Overall Assessment

The Department of Electronic Systems is a large department, where several research areas have established themselves, and certainly presents a multi-disciplinary format which is exploited by most of the research groups. IES is able to put together research projects with wider outcomes and deliverables.

Their research strategy is generally well-organised and effectively managed, with a clear articulation across various forms and levels. It encompasses both fundamental (basic) research and applied research in strategic sectors of national interest. The strategy is primarily supported by national funding sources, including both public and private sectors, with some projects also benefiting from international funding, particularly from the European Union. However, there are some areas that require attention. One of the main challenges arises from the broad scope of research activities undertaken by IES, which can sometimes complicate coordination and the optimal use of available resources. The diversity and scale of the research initiatives, coupled with the need to navigate both national and international funding mechanisms, can create challenges in aligning efforts and maximising the impact of the resources available. Ensuring more streamlined coordination and a clearer alignment between different funding sources, both national and international, would enhance the efficiency and effectiveness of the research strategy. For example, certain research groups, such as AK, may face specific challenges due to the unique characteristics of their discipline. To support these groups, targeted actions are necessary to ensure they are adequately equipped to overcome these challenges.

It is crucial for IES to further support the recruitment and development of young talent and to create more opportunities for their involvement in high-impact projects. For some groups the Administrative Unit should implement actions to facilitate attraction not only of more external funding, but also of more young PhDs.

The average scientific production is good, with several publications in peer-reviewed Journals and at international conferences but an increase in the overall visibility should be carried out which will increase the IES societal impact. Technology transfer activities with external entities and industries are limited and the Administrative Unit could implement more action in this direction. IES follows NTNU initiatives regarding the protection of diversity and inclusiveness and has clear policies regarding the prevention and management of unpleasant cases such as discrimination and sexual harassment.

The impact cases presented demonstrate that the Administrative Unit contains several areas in which it can produce excellent results that have and will have an impact on society.

The Terms of Reference for the administrative unit is attached to the report.

Recommendations

These recommendations aim to support IAP in enhancing its research capabilities, fostering collaborations, and aligning its structure to achieve long-term success.

The main recommendations from the Evaluation Committee to the Department of Electronic Systems (IES) are to:

1. **Improve the Research Strategy:**
    - Implement actions in support groups, such as the AK, that are facing more challenges due to the characteristics of their discipline different from the other groups.

- Strengthen research collaborations between the different departmental groups by making them more structured and less spread
- Take measures to increment the number of young professors and researchers
- Ensure uniform growth among the groups.
- Consider strategies to modify the balance between teaching time and research time to increase the research impact

2. **Consider the Industry R&D opportunities:**
   - Continue leveraging local conditions to strengthen strategic planning.
   - Implement a systematic procedure at departmental level to increase the promotion of research activities towards potential interested industries
3. **Define a Unified Strategy Across Research Groups:**
   - Establish a common research strategy that fosters interdisciplinary collaboration and aligns diverse groups toward shared goals. enhancing both the collective output and visibility of the institution.
   - For underperforming or less visible groups, take targeted actions to improve their scientific impact, such as attracting internationally renowned scholars, accessing to advanced facilities.
4. **Enhance International Visibility:**
   - Develop a comprehensive community engagement strategy to enhance international collaborations.
   - Actively pursue involvement in International and European funding opportunities, to expand the projects portfolio.
5. **Expand and Improve PhD Education:**
   - Increase the number of PhD students to achieve a larger critical mass, considering the number of the Department staff.
   - Try to reach a target of at least two PhD students per research-active professor.
6. **Strengthen Collaboration:**
   - Develop a proactive strategy to further expand the collaborative project portfolio.
   - Increase efforts to establish partnerships within and beyond the university.
7. **Improve Leadership:**
   - Create a strategy and process for promoting associate and assistant professors to full professor positions.
   - Consider inviting external professors to foster the weak groups activities and visibility

These recommendations aim to support IES in enhancing its research capabilities, fostering collaborations, and aligning its structure to achieve long-term success.

1. Strategy, Resources, and Organisation of Research

The IES research strategy aligns with NTNU's strategic areas in Energy, Ocean, Health, Sustainability, and primarily focuses on digitalisation through electronic systems. The approach is balanced with respect to academic and industrial research themes. The strategic plan is well organised, with emphasis on allowing faculty more research time alongside teaching responsibilities. Cross-group initiatives are well organised for both the research and the education aspects and supported by the Administrative Unit for preparing project proposal. Effort to be further enlarged is to include different IES groups. Enough funding sources are available, most of which come from national grants. There is a good number of international entities involved, though not uniformly distributed over the different groups. IES also fosters collaboration with key national partners, helping to stay aligned with societal needs and strategic developments. The Evaluation Committee offers a positive overall assessment of IES's research strategy, emphasising the need for a structured

research framework to support both staff and students in such a large department. While most research groups were positively evaluated, performance varies significantly, ranging from outstanding to fair.

1.1 Research Strategy

The IES research strategy aligns well NTNU strategic areas in the field of Energy, Ocean, Health, and Sustainability, and enabling technologies areas, mainly Digital and Nano, and with the IE faculty strategic area of Internet of Things, where it plays a coordination role. The overall research focus is on digitalisation using electronic systems with a balance between academically oriented and industrially oriented research. The strategic research plan is annually updated and relevant controls on the research plan, intensity and active collaborations are verified by analysing research activities with respect to their focusing on strategic areas. However, the research strategy should obtain better results in terms of number of publications per research group and number of PhDs, with attention to allow academics to have sufficient time for research with respect to teaching. IES has five distinct groups and for each one has hired a group leader for more effective management of the research activities.

Overall, the Evaluation Committee has a positive evaluation of the research strategy adopted by IES, which, being a large department with a significant number of professors, has the need to provide a structured research organisation to its staff and to its students. Researchers and students really need such a structured research organisation. Most of the research groups' evaluation reports are positive but the range in performance is large, going from outstanding evaluations to fair ones.

Recommendations to the administrative unit.

The Evaluation Committee recommends that IES put more effort into supporting groups that are less effectively achieving the department's objectives, possibly by implementing a transversal synergy between the different groups so that those largely satisfying the department's research strategy can support those facing more critical challenges.

The Evaluation Committee recognises the importance of taking actions to address the unique challenges faced by the AK group, which is dedicated to research that differs significantly from that of other groups.

The Evaluation Committee recommends implementing new actions to enhance the enrolment of young researchers into the SWS group.

The Evaluation Committee suggests putting in place actions to increase the international visibility of the department and to ensure that each research group is attractive not only for national funding but also for international opportunities.

1.2 Organisation of Research

IES is organised into five official groups: Acoustics, Circuit and Radio, Nanoelectronics and Photonics, Signal Processing, and Smart Wireless Systems, with most research activities coordinated and developed by these groups. Cross-group initiatives are encouraged and are on the rise. A mixed group focuses on research and education in engineering. The administrative staff support the research staff in preparing project proposals and encourage the inclusion of different IES groups, when possible. It provides a panel-level review of proposals before they are submitted.

It is worth noting the choice of configuring the laboratories as shared facilities owned by the department, designed to enhance research capabilities and to facilitate cross-initiatives among research groups while promoting efficiency. Each lab is overseen by a professor or associate professor responsible for strategic development.

PhD Students are deeply involved in the research activities and are considered crucial actors in IES's research activities. However, the ratio between enrolled PhD students and professors is below the potential of the entire Administrative Unit and needs to be improved even more since in IES attention is paid to ensure a correct time balance between teaching and research for the professors and the supervisors. IES tries to arrange seminars by the different research groups to disseminate the main innovations over the entire department with the goal of increasing the cross-collaboration among the groups. However, the effectiveness of these activities indicates there is room for improvement, as the number of PhD students remains below the desired level.

Recommendations to the administrative unit.

The Evaluation Committee recommends actions to encourage young students to be enrolled in IES PhD program.

The Evaluation Committee recommends actions to share the research results and to promote their further dissemination with the goal of increasing the Administrative Unit's visibility and thus its attractiveness also at the international level.

The Evaluation Committee recommends analysing the topics and correcting them, when possible, to improve the interdisciplinary aspects to mitigate the internal collaborations clashing.

1.3 Research Funding

The self-assessment report states that the unit receives national grants, mainly from RCN (80%), and the rest from competitive sources such as industry grants. This allows the Administrative Unit to ensure a good level of research activities, comparable to other international institutions.

External National funding primarily comes from industries and external International fundings mainly come from the European Union, but their amount is around 20% of the National grant value. Industry collaborations are quite strong but may be further enhanced by implementing a systematic procedure to increase the promotion of research activities towards potential interested industries. External funding capabilities are not uniform over the research groups. For some research groups, the administrative unit has been very successful in applying for external grants. The administrative unit offers good support for fundraising, which however, as mentioned above, is used very well by some groups and to a lesser extent by others. Overall, industry collaborations seem to be strong but the Administrative Unit's capacity to attract external funding probably is not exploited fully yet to better align IES to internationally excellent universities of similar dimensions.

Recommendations to administrative unit.

The Evaluation Committee recommends developing strategies to increase research activities involving international partners and funding, especially for those groups that still demonstrate weakness in this respect.

The Evaluation Committee recommends that the administrative unit pursue an ongoing analysis of the capacity of individual groups to conduct both basic and applied research activities and to search for new research funds opportunities that will enable them to maintain and increase the level of staff involved and of infrastructure, acquired and to be acquired.

1.4 Research Infrastructures

The administrative unit is actively involved in the NORFAB (Norwegian Micro- and Nanofabrication Facility), a key national infrastructure focused on the development of advanced nano-devices. Through this collaboration, the unit contributes to cutting-edge research in nano-fabrication technologies, positioning itself as an important player within the national scientific landscape. Additionally, the unit has played a pivotal role in the establishment of the NTNU Nanolab, strengthening its presence in the field of nanotechnology However, it is important to note that IES currently does not have direct participation in any international infrastructures. While this limits its engagement in certain global collaborations, IES does benefit from access to High-Performance Computing (HPC) infrastructures, which enables the unit to conduct complex simulations, data analysis, and modeling required for advanced research projects. This access to computational power is crucial for the research activities conducted within IES, particularly in areas where large datasets and computational resources are essential. In terms of physical resources, the equipment available for carrying out IES research projects is generally adequate and well-organised, providing a solid foundation for high-quality research. The unit boasts a range of laboratory equipment, ensuring that researchers have access to the tools necessary for testing. Moreover, the labs within IES are staffed with technicians, which is critical for maintaining the high standards of research and ensuring the longevity and functionality of the equipment. However, a challenge that remains is the uneven distribution of laboratory activities across the various research groups within IES. While some groups actively engage with the available facilities, other groups make more limited use of them. This suggests that the scale of laboratory activity within IES may not entirely match the research needs of the entire administrative unit. It is crucial for IES to address this imbalance and ensure that all research groups have equal access to and make optimal use of the laboratories and equipment. This might involve better coordination and planning, as well as ensuring that all groups have the support they need to fully integrate laboratory activities into their research agendas.

Recommendations to administrative unit.

- The Evaluation Committee recommends encouraging all the groups to increase their participation in national infrastructures.
- The Evaluation Committee recommends a more uniform exploitation across the research groups of the available infrastructures, encouraging those groups whose research activities need to be enhanced.

1.5 National and international collaboration

International cooperation is a priority in NTNU's 2022–2025 strategy, focusing on leveraging EU funding, forming strategic global partnerships, recruiting top researchers, and promoting student and staff mobility.

At the administrative unit IES, collaboration with partners from private and public sectors is frequent in developing research projects. IES collaborates with 10 national institutions, in particular several Centres for Research-based Innovation such as: the SFI AutoShip and the SFI Centre for Innovative Ultrasound Solutions and coordinates the SFI Centre for Geophysical Forecasting. The most frequent national and international Academic partners include University of Oslo, University of Tromsø, SINTEF, Simula, KTH Royal Institute of Technology, Aalto University, University of Naples "Federico II", and companies include Nordic Semiconductor, Equinor, Kongsberg, Telenor, Telia. IES promotes also collaboration with national relevant partners which is important for keeping awareness of the national societal needs and strategic developments. These collaborations are quite significant and

provide an added value for the administrative unit but can be increased to obtain a better balance between public funding and external sources.

The bibliometric analysis from NIFU shows that, after a relevant growth up to 2020, the scientific production at IES has suffered in the post-COVID period. The relative citation indicators are fair and not constant over time. At both the Administrative Unit level and research group level an action should be taken to better align the bibliometric results of such a large unit to those of similar ones at the international level.

Recommendations to administrative unit.

- The Evaluation Committee recommends putting more effort into the dissemination aspects of its research activities especially addressing peer-reviewed, well-known journals.
- The Evaluation Committee recommends putting more effort in their dissemination and publication activities to increase the visibility of the research groups.

1.6 Research staff

The unit has a good research staff organisation with low hierarchy rules for recruitment policy. IES still shows a significant underrepresentation of women in its permanent staff, especially the junior positions, and is working to meet the gender balance requirements and to remove the view of the department as consisting of male-dominated disciplines. The ratio between Professors (Associate and Full) and PhD students is low and the Administrative Unit should work to increase it. The Staff has some international members which denotes a good level of internationalisation and visibility in international contexts

Recommendations to the administrative unit.

- The Evaluation Committee recommends that the department should develop a strategy to increase the PhD positions with respect to permanent staff and should work to obtain a larger uniformity among the research groups.
- The Evaluation Committee recommends that the department should put up metrics for gender balance and may initiate faculty positions only for women. It would also be good to set up an internal diversity, inclusion and gender balance group.

1.7 Open Science

From the self-assessment report of IES it can be deduced that research outputs at NTNU IES are published according to NTNU's "Policy for Open Science,". IES research activities and publications should be strongly focused in the ICT area, but given the widespread distribution of the research groups this not fully respected. Indeed, the research group ‘ Acoustics’ focused on various types of acoustics, including environmental and musical, is more bordering on ICT. Others are more pertinent like; Circuits and Radio Systems: focused on digital, analogue, and radio systems.; Nanoelectronics and Photonics: focused on nanoscale materials and photonic devices; Signal Processing: focused on statistical processing and machine learning, Smart Wireless Systems: focused on IoT and wireless communication systems.

Publications are available at the NTU data base in their final version. 50% of the publications of IES are Open Science and data management plans support FAIR principles. IES work with the legal office at NTNU to make sure that consortia agreements are signed in agreement with NTNU regulations for projects involving external partners.

The bibliometric analysis from NIFU indicates that IES's scientific production has decreased post-COVID after significant growth until 2020. Citation metrics are weak, suggesting a need

for improved international research promotion, although collaboration with esteemed European universities is robust but requires actions to be more effective in disseminating the results.

NTNU's open science policy mandates that research results and data should be made publicly available when legally and practically possible. However, open access may not always be appropriate due to issues like sensitive data, copyright restrictions, or commercial agreements. NTNU encourages sharing underlying data, methods, algorithms, and code where feasible.

There are no specific examples of open science reported in the self-assessment report.

Recommendations to the administrative unit.

The Evaluation Committee recommends implementing a more structured set of actions to promote open science, such as creating a platform at the Administrative Unit level where the groups; staff meet to periodically share the data and tools.

2. Research production, quality and integrity

IES follows NTNU and IE Faculty guidelines on research integrity. The research leaders regularly meet to discuss these guidelines and potential risks of violations. PhD students are required to incorporate ethical considerations into their research plans and complete a course on research ethics as part of their training.

IES covers a wide range of ICT areas:

- **Acoustics Group**: Research focuses on room acoustics, environmental acoustics, underwater acoustics, geophysics, musical acoustics, and bio-acoustics.
- **Circuits and Radio Systems Group:** Engages in digital and embedded systems, analogue and mixed-signal technologies, and radio systems.
- **Nanoelectronics and Photonics Group**: Explores nanoscale materials and photonic devices, with applications in information technology, biomedical innovations, and environmental solutions.
- **Signal Processing Group**: Specialises in statistical signal processing, machine learning, and communication theory.
- **Smart Wireless Systems Group**: Research focus on IoT and wireless communication systems, including channel modelling and physical layer development, emphasising safe and reliable wireless communication.

Research group Electronic Systems Education (ESE) overall assessment

ESE has been active for 10 years. It has a strong focus on development of especially the EISys study program and a lesser focus on engineering education research. ESE is actively aligned with the recommendations and principles from NTNU's strategic educational development project Technology Education of the Future. The recommendations from this project are well in line with current research findings about student learning and is therefore a good source for not only development activities but also research activities. The group conducts some research in elementary and secondary education relevant to electronic systems. This seems like an add-on, but with a potential to strengthen research in e.g. motivation for studying electronic systems and thereby increase the societal contribution. The publication from the group is of mixed quality. One is published in a good journal, one in a mid-level journal and three at a rather low-level conference. The publications have between 0 and 5 citations, a fairly low number. The research quality could be increased by a stronger focus

on research methodology. ESE has been able to attract more and more external funding, from 0% in 2018 to more than 40% in 2022.ESE has a strong focus on students and their learning, thereby making impact within the student cohort at NTNU. We cannot see how students (or the broader society) are involved in the research process. ESE is active in relevant European and international Research and Development networks. The group is not a formal research group in a department (level 4 unit). It is difficult to evaluate the organisation of the group based on the self-evaluation.

Research group Smart Wireless Systems (SWS) overall assessment

The main research areas of SWS are the Internet of Things, MIMO communications, and wireless-powered communication. The SWS group does not fully exploit the potential of those topics for high-quality research and project funding. The focus of SWS seems to be on teaching with only a few low-quality research activities, which produce low impact publications. International collaboration exists, but not on a technical and scientific level. External funding is low. Some student research activities with limited practical and societal impact have been performed. International activities are mainly in events, conferences and visits but these do not cover significant research activities. There are good training plans and opportunities for educating students at various levels, also in collaboration with other national partners. Contacts with local industries exist but have more potential to be exploited for joint research and funding activities.

Research group Nanoelectronics and Photonics (NF) overall assessment

NF group at NTNU is a team with an excellent track record in scientific publications, grant income, innovation, and enterprise. It defines and pursues strategic directions in their activities, successfully exploiting their expertise and facilities available. Its scientific profile, which includes both electronics and photonics, puts the group into a strong position to explore technologies of complete optoelectronic systems. Indeed, this approach is pursued through the group activities, both in education and in research, effectively utilising the existing synergies. The group priorities, such as quantum technologies, biomedical sensors, and energy efficient components, are well aligned with the one of the most topical areas currently pursued internationally. The access to the state-of-the-art facilities in terms of fabrication, characterisation and computing provides a robust base underpinning research and innovation. Strong and competent leadership of the group is evident.

Research group Signal Processing Group (SI) overall assessment

This is a well-established and experienced group, which follows clear goals and objectives in line with those at institutional level. It appropriately uses benchmarks (defined as “ambitions”) to measure success and demonstrates good practice in managing the operations expected in an academic environment of the size and quality of NTNU. The group has built solid expertise in heavily populated national and international areas of interest and is well funded from sources on both scales. The publication strategy is well thought and successful, placing its best outputs at the highest level globally. The group appears to see its main challenges to be in national and international recruitment (at highest and lowest level) and funding (fundamental vs application-oriented expertise and skills). The group sees these in a positive light, identifying opportunities to build a more up to-date and flexible research profile, while retaining and developing further areas currently under demand (e.g. AI). This is matched by ambition to re-design the study programmes in which it is involved, in resonance with the research directions – current and in the predictable future. The group is confident of the match between what it can offer and potential future calls by national and international funding agencies. Appropriate attention is given to the natural evolution of research

taxonomy and how that should be complied with in search for potential industrial partners. The group is strongly visible nationally and internationally, as evidenced by collaboration and co-authorship in the submitted lists of projects and publications.

Research group Circuit and Radio Systems group (KR) overall assessment

The strengths of the KR team are active involvement in national research projects, creating high quality talents for industry (especially companies like Nordic Semiconductor), high quality publications, internal collaboration with different disciplines, involvement in large centres by providing expertise within the disciplines covered in the research group. There is a good span of research within the group at different Technology Readiness Levels (TRLs), which makes the group's activity matched with different calls in national and international level. The group is internationally also competitive and creates high quality output which is of high importance for the relevant community. The main weaknesses of the team are low involvement in EU projects, no significant project as the coordinator especially the international projects, lack of junior and motivated professors within the field of chip design especially considering the EU Chips Joint Undertaking (Chips JU) program, lack of enough publication per VIP per year especially higher impact journals in Nature portfolio, or the Institute of Electrical and Electronics Engineers Journal of Solid-State Circuits (IEEE JSSC), IEEE Transactions on Circuits and Systems I (TCAS I), or similar channels. The group is internationally strong but not among the strongest although they have potential to be more active by feeding more resources into the team and hiring motivated young researchers with potential to attract prestigious grants like European Research Council (ERC) or similar.

Research group Acoustics group (AK) overall assessment

Strengths and weaknesses: The group's specific strength is its deep scientific expertise and excellent international reputation in acoustics. Its challenge is to contribute to a large variety of adjacent sciences in Electrical Engineering, Civil Engineering, Geosciences, Industrial Engineering, etc., in spite of its limited resources. Overall performance: The Acoustics Group managed very well to integrate all specific needs, and it can be expected that this can be maintained with recruitment of qualified and best matching leadership in future. Specific goals, however, are hard to find in the self-assessment. The organisation of strategic planning can be surely improved. National and international context: The Acoustics Group cooperates with centres of research excellence as well as more broadly with universities and research institutes in Norway. International academic collaborations include several high-ranked universities in Sweden, Finland, Denmark, France, Germany, Italy, Portugal, Japan, UK, Canada, and USA. Acoustics also contributes to collaborations with Oil and gas industries in Norway, Italy, UK and USA. The group's international perspective is supported by professors taking sabbaticals with renowned partners abroad.

3. Diversity and equality

IES is committed to protect staff from discrimination and promote diversity actively also by conducting interviews every other year with individuals about the work environment. Attention is put on the wellbeing of PhD students considering also their relationships with their supervisors. The management and the research group leaders play an active part in assuring zero-tolerance for bullying, mobbing, or any form of harassment. Coordination with the administrative staff at the faculty is exploited. The self-assessment provides a link to four documents spanning gender equality and diversity: IES uses them as a reference and plans to improve its performance in these fields. These documents are offered by NTNU to all departments and include specific projects on how to implement changes to promote a better

gender balance. IES has demonstrated to put in actions several activities but is probably among the departments of NTNU that need implement further actions to increase the impact of inclusion.

Concerning the staff, IES operates in male-dominated disciplines, but many good actions and initiatives are set to attract female students and employees. What has been presented is a good initial step to be continued in the next years at both the staff and students' levels.

Furthermore, there is a good distribution, that can be improved in terms of the age distribution and internationality of the staff. NTNU also offers classes for learning Norwegian, but it is not clear if IES promotes these classes.

4. Relevance to institutional and sectorial purposes

IES is a leading institution in Norway responsible for research and education in electronic engineering, playing a central role in shaping the field both nationally and internationally. The unit runs two key academic programs: the Master's program in Electronic System Design and Innovation and the PhD program in Electronics and Telecommunications. These programs are robust academic structures that effectively merge research with high-quality teaching, providing students with both theoretical knowledge and practical experience in the rapidly evolving field of electronics and related topics. The Master's program is designed to offer a comprehensive education in electronic system design, innovation, and advanced technologies. Students may know about the latest research developments and innovations in areas such as microelectronics, embedded systems, and communication technologies. This approach ensures that graduates are well-prepared for careers in both academia and industry. The PhD program in Electronics and Telecommunications similarly emphasises research excellence, fostering a deep understanding of the field's foundational principles while pushing the boundaries of knowledge in specialised areas such as wireless communication, signal processing, and network technologies.

IES places a strong emphasis on keeping its educational programs aligned with current research trends and the evolving needs of the industry. A key strength of the unit is its regular revision of master's courses, ensuring that course content reflects the latest research outcomes and the ongoing academic interests of the faculty. This practice allows IES to provide students with high-level education that is directly informed by the latest advancements in the field. Moreover, it serves as an important link between teaching and research, encouraging students to engage with the cutting-edge research being conducted within the department.

Additionally, the continuous revision of courses helps ensure that the programs remain competitive and relevant in the ever-changing field of electronics and telecommunications. This dynamic approach is particularly valuable in a discipline that is so rapidly evolving, where staying on top of emerging technologies and innovations is crucial.

To further promote research engagement among students, IES organises periodic seminars throughout the academic year. These seminars provide students with regular opportunities to learn about ongoing research activities within IES and the broader academic community. The seminars also serve to highlight the work of the entire research staff, promoting the visibility of faculty members and encouraging interaction between students and researchers. These events are an important aspect of IES's educational philosophy, as they help bridge the gap between research and teaching.

In addition to these seminars, IES actively encourages students to participate in research projects, providing them with hands-on experience in real-world applications of electronic system design and telecommunications.

Overall, IES's commitment to merging high-quality teaching with research creates a dynamic academic environment that is beneficial for students. The integration of research into the educational experience not only enhances the quality of the programs but also should play a critical role in attracting students to engage in research activities and pursue advanced degrees, including PhDs. However, in this respect the ratio between PhD students and professors may be increased.

Recommendations to the administrative unit.

- Increase the number of PhD students to achieve a larger critical mass
- Try to reach a target of at least two PhD students per research-active professor

5. Relevance to society

IES has developed a large and diverse research portfolio, designed not only to meet the Long-term plan for research and higher education but also to contribute to the broader societal goals In line with Norway's strategic vision for the future, IES's research and education activities aim to empower students at both the Master's and PhD levels, equipping them with the skills and knowledge needed to drive innovation in critical sectors such as ICT and related topics.

This research and educational portfolio is structured to support national priorities, particularly in sectors central to Norway's future economic and societal development such as maritime and space, including communications and medical applications. These sectors have broad implications, from ensuring safer and more efficient transportation systems to advancing healthcare and space exploration aiming to foster an ecosystem of research that drives technological and societal progress. IES pursues basic research but also applied one in collaboration with local industries.

The research strategy at IES is also built on activities aligned with the UN Sustainable Development Goals (SDGs).

The impact cases presented span a very broad range of research fields some more linked to emerging technologies, for which significant basic research activity is still necessary, others instead linked to more specific local and territorial needs, which again demonstrate that the Administrative Unit is composed of group with very different characteristics. This can make in some cases both collaboration and the identification of well-focused and targeted strategic choices difficult and challenging.

5.1 Impact cases

Comments to impact case 1: Epitaxial III-V nanowires on graphene for UV-disinfection

In 2005, NTNU began basic research work on III-V semiconductor nanowires for optoelectronic device applications. In March 2010 NTNU discovered how semiconductor nanowires can be epitaxially synthesised on graphene and the research was further co-financed. In 2019 the first nanowire UV-LED was published by NTNU. Collaboration with the spin-off company CrayoNano has been established and many further projects have obtained fundings.

This case study demonstrates the full path from basic research to product commercial exploitation and took place thank to the combination of highly qualified researchers and of the NTNU lab facilities. It has shown a significant success for both the innovative research theme and the transfer research into innovative businesses. A large number of patent families, 15 has been also generated.

Comments to impact case 2: Home of the trolls/"Troll i ord"

This case was motivated by innovating Cultural & adventure tourism schemes and was started by the basic research in Multimedia Signal Processing, focused on Audio visual compression. These algorithms were shared with the Centre of Excellence at the IE faculty where they were exploited for multimedia experiences and Quality of Experience (QoE) and further designed and tested for reaching the goals of Immersive Media Experiences (IMX). IMX was exploited in the framework of the "Home of the Trolls" where the technology-driven Story telling was implemented. Subsequently it was applied in other cultural contexts and the Troll I ord was developed and were commercialised.

This case demonstrates a useful exploitation of advanced signal processing techniques for everyday use and its commercialisation for cultural heritages.

Comments to impact case 3: Autonomous ferries

This impact case is dedicated to the projects of two autonomous ferries "milliAmpere1" and "milliAmpere2", launched in 2017 and 2020, respectively. This activity has been intensively pursued by many research centres and in particular IES researchers decided to collaborate with the NTNU Department of Engineering Cybernetics and Department of Marine Technology. These prototype ferries were then extensively adopted by many PhD students to implement and test sensors of various kind and technologies for multi-disciplinary activities. "milliAmpere2" conducted the world's first trial operation of an autonomous passenger ferry in September 2022. In June 2023 the first commercial autonomous ferry "Estelle" entered regular traffic in Stockholm using Zeabuz. Both the ferries and the developed Shore Control Lab are still a unique lab facility welcoming a large number of PhD and master's students.

This case demonstrates a successful implementation of multi-disciplinary collaboration and can be considered a good example of how to enrich research results by allowing the experiments of a large number of young scientists.

Comments to impact case 4: Constant envelope spreading for satellite communications

This case aligns well with the worldwide research theme dedicated to innovative design of waveforms for efficient and high-capacity hearth to- satellites communication. In this field NTNU has collaborated with several research entities including ESA and private companies and has contributed to the design of a new waveform that is now included in the ITU recommendations. Some measurable performance indexes should have been added.

This use case, very specific with respect to the others, has the significant impact of enhancing energy efficiency and loss reduction for equipment in VHF.

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 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 (only for HEIs)

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 groups' evaluation reports, and the interview. The Administrative Unit had the opportunity to fact-check this summary. The Administrative Unit approved the summary without adjustments.

Limitations

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

List of administrative unit's research groups

Institution	Administrative Unit	Research Groups
Norwegian University of Science and Technology (NTNU)	Department of Electronic Systems (IES)	Electronic Systems Education (ESE)
		Signal Processing Group (SI)
		Smart Wireless Systems (SWS)
		Circuit and Radio Systems group (KR)
		Nanoelectronics and Photonics (NF)
		Acoustics group (AK)

Terms of Reference (ToR) for the administrative unit

The board of the Faculty of Information Technology and Electrical Engineering at the Norwegian University of Science and Technology mandates the evaluation committee appointed by the Research Council of Norway (RCN) to assess the Department of Electronic Systems (IES) based on the following Terms of Reference.

Assessment

You are asked to assess the organisation, quality and diversity of research conducted by the Department of Electronic Systems as well as its relevance to institutional and sectoral purposes, and to society at large. You should do so by judging the unit's performance based on the following five assessment criteria (a. to e.). Be sure to take current international trends and developments in science and society into account in your analysis.

a) Strategy, resources and organisation

b) Research production, quality and integrity

c) Diversity and equality

d) Relevance to institutional and sectoral purposes

e) Relevance to society

For a description of these criteria, see Chapter 2 of the mathematics, ICT and technology evaluation protocol. Please provide a written assessment for each of the five criteria. Please also provide recommendations for improvement. We ask you to pay special attention to the following 4 aspects in your assessment:

1. NTNU has a national role as the major university for technology education and research, and the Department of Electronic Systems has major responsibility in covering a broad range of research topics within electronic systems and related disciplines.

2. The department aims at good balance between academic-oriented research and industrial-oriented research.

3. The department aims at good balance between internal collaboration (within the department) and external collaboration (both inside and outside of NTNU).

4. The department aims at governance and support for activities with impact on society, including innovation and technology transfer.

In addition, we would like your report to provide a qualitative assessment of the Department of Electronic Systems as a whole in relation to its strategic targets. The committee assesses the strategy that the administrative unit intends to pursue in the years ahead and the extent to which it will be capable of meeting its targets for research and society during this period based on available resources and competence. The committee is also invited to make recommendations concerning these two subjects.

Documentation

The necessary documentation will be made available by the mathematics, ICT and technology secretariat at Technopolis Group.

The documents will include the following:

- a report on research personnel and publications within mathematics, ICT and technology commissioned by RCN
- a self-assessment based on a template provided by the mathematics, ICT and technology secretariat

Interviews with representatives from the evaluated units

Interviews with the Department of Electronic Systems will be organised by the evaluation secretariat. Such interviews can be organised as a site visit, in another specified location in Norway or as a video conference.

Statement on impartiality and confidence

The assessment should be carried out in accordance with the Regulations on Impartiality and Confidence in the Research Council of Norway. A statement on the impartiality of the committee members has been recorded by the RCN as a part of the appointment process. The impartiality and confidence of committee and panel members should be confirmed when evaluation data from the Department of Electronic Systems are made available to the committee and the panels, and before any assessments are made based on these data. The RCN should be notified if questions concerning impartiality and confidence are raised by committee members during the evaluation process.

Assessment report

We ask you to report your findings in an assessment report drawn up in accordance with a format specified by the mathematics, ICT and technology secretariat. The committee may suggest adjustments to this format at its first meeting. A draft report should be sent to the Department of Electronic Systems and RCN. The Department of Electronic Systems should be allowed to check the report for factual inaccuracies; if such inaccuracies are found, they should be reported to the mathematics, ICT and technology secretariat within the deadline given by the secretariat. After the committee has made the amendments judged necessary, a corrected version of the assessment report should be sent to the board of the Faculty of Information Technology and Electrical Engineering and the RCN no later than two weeks after all feedback on inaccuracies has been received from the Department of Electronic Systems.

Appendices

1. Description of the evaluation of EVALMIT
2. Invitation letter to the administrative unit including address list
3. Evaluation protocol
4. Template of self-assessment for administrative unit (short-version)

The Research Council of Norway

Norges forskningsråd
Besøksadresse: Drammensveien 288
Postboks 564
1327 Lysaker

Telefon: 22 03 70 00

post@forskningsradet.no
www.forskningsradet.no

Publikasjonen kan lastes ned fra
www.forskningsradet.no/publikasjoner

Design: [design]
Foto/ill. omslagsside: [fotokreditt]

ISBN 978-82-12-04153-0 (pdf)