

Report by the  
2021 Evaluation Committee  
of PhD Programmes  
at Faculty of Information Technology and  
Electrical Engineering  
in NTNU

15 December 2021

## Introduction

In Summer 2021, The Faculty of Information Technology and Electrical Engineering (IE) of the Norwegian University of Science and Technology (NTNU) nominated an international expert team to evaluate the quality and relevance of its six PhD programmes. According to the Quality system of NTNU and IE, the educational programmes need be regularly evaluated. This evaluation of the PhD programmes is the second one, after the first evaluation performed in 2016.

The appointed 2021 evaluation committee (EC) is the following:

- **Ari Sihvola**, Aalto-yliopisto, Finland (leader of EC)
- **Göran Andersson**, Eidgenössische Technische Hochschule Zürich (ETHZ), Switzerland
- **Mogens Blanke**, Danmarks Tekniske Universitet (DTU), Denmark
- **Kyrre Glette**, Universitetet i Oslo, Norway
- **Alessandra Micheletti**, Università degli Studi di Milano, Italy
- **Jochen Schiller**, Freie Universität Berlin, Germany

The mandate given to the evaluation committee asked to provide a critical assessment of the strengths and weaknesses of the Faculty's research education, and to provide recommendations for improvements. In particular, the mandate defined three focal dimensions: learning environment (are the PhD-candidates part of an active high-quality research and learning environment?), relevance (is the research education relevant and up to date according to international practice and for addressing societal and scientific needs and challenges?), and organisation (are the organisation and management of the research education appropriate and efficient with clear roles and responsibilities?).

The IE faculty offers the following PhD programmes:

- computer science
- electric power engineering
- electronics and telecommunication
- engineering cybernetics
- information security and communication technology
- mathematical sciences

The PhD programmes are run by the departments in the faculty: the departments and their faculty arrange the courses for the PhD candidates and the candidates have their working contract with the department. There are seven departments in the faculty:

- Computer Science (Institutt for datateknologi og informatikk, IDI)
- Electric Power Engineering (Institutt for elkraftteknikk, IEL)
- Electronic Systems (Institutt for elektroniske systemer, IES)
- Engineering Cybernetics (Institutt for teknisk kybernetikk, ITK)
- Information Security and Communication Technology (Institutt for informasjonsikkerhet og kommunikasjonsteknologi, IIK)
- Mathematical Sciences (Institutt for matematiske fag, IMF)
- ICT and Natural Science (Institutt for IKT og realfag, IIR)

The members of the evaluation committee were provided in October 2021 with several documents to prepare themselves to the research education at IE: research profiles and self-evaluations of all seven departments and the faculty, statistics and quantitative data of the research and education

over the past five years, and additional background material connected to doctoral education and administration.

The evaluation committee visited NTNU in Trondheim for three days (16–18 November 2021). This intensive site visit started with a plenary session with Professor Ingelin Steinsland (Vice Dean for research at the IE Faculty) where the mandate of the committee was analysed and agreed on. The main body of the visit consisted of interviews with representatives of all the seven departments and six PhD programmes. Each departmental interview was composed of three parts: first the leadership and other key persons of the department (2–8 people) presented the state of the PhD education and discussed with the committee (60 minutes), then a selected group of supervisors (4–8 people) were interviewed (30 minutes), and finally a group of PhD candidates (4–8 people) came to talk and share their views with the committee (30 minutes). The interviews were followed by EC's internal meetings. Throughout the visit, adviser Harald Lenschow provided practical and useful help.

During the site visit, the evaluation committee interviewed altogether 100 people who have a role in the PhD education at the faculty.

## Observations on the present status and recommendations

The overall impression on the state and potential of the doctoral education in the IE Faculty of NTNU was very positive. The research groups in the departments are active and the research ambitions are high, which forms a very fruitful environment for PhD candidates to work effectively towards the doctoral degree. The departments seem to align much of their research with the strategic focus areas of the University and Faculty, which is naturally connected to the fact that research projects often are truly multidisciplinary. Employment prospects of graduated PhD's are bright, at least outside academia.

The administrative processes that guide the progress towards the completion of the degree are documented according to the quality system of the university and IE Faculty and written out on different websites and the PhD handbook. It is understandable that in a large organization consisting of seven departments, a uniform set of processes may not necessarily apply to every unit. The departments in the IE Faculty have very different historical roots, and the culture and ways of conducting the supervision of PhD candidates is also variable. This is not a problem, as long as the common standards and principles of NTNU are followed, and all students are treated on equal basis.

It is worth noting that the present evaluation takes place only five years after the previous one in 2016. To judge the report and act on recommendations takes time in a large Faculty like IE. Hence our committee may have been observing a dynamic state of the situation in PhD education in which old ways of working are being transformed into new ones, which makes it difficult to judge the smoothness of the processes. The evaluation committee, however, considered it very positive that the IE Faculty had taken the 2016 evaluation seriously, and several actions had been successfully implemented.

In the following, we describe our findings and opinions based on the observations that we have gathered from the documentation and our interviews during the site visit. The report is structured such that first we discuss overall findings on the level of the whole IE Faculty, followed by detailed reports on the six programmes and the seven departments. The analyses follow roughly the three main focus directions (learning environment, relevance, organisation) given in the mandate.

## Faculty of Information Technology and Electrical Engineering

### Learning environment:

Perhaps the most important environment in which a PhD candidate spends the three to four years of doctoral studies is formed by the research group: supervisor (possibly co-supervisor), researchers and postdocs working on the same project, and fellow PhD candidates. It is obvious that the size of the group of people around a single student may vary from group to group and from department to department. It was anyway very reassuring to learn from the self-evaluation reports of the departments and statistics of the faculty that around 90% of the students were satisfied with the collaboration with the supervisor. However, while in the interviews with the evaluation committee, clearly most of the students were satisfied with the relation with the supervisor, we unfortunately also encountered anecdotal evidence of lack of supervision in individual cases.

Some of the programmes host students that are working in other campuses (in particular the programmes in Computer Science and Engineering Cybernetics, hosted mainly under the IIR department in Ålesund, but also in the Gjøvik campus). The geographical distance is large to Trondheim where the courses are mostly offered and where the administration and fellow PhD candidates of the program are located, and this inevitably causes problems. Of course, during the 2020–2021 pandemic, by force, new instruments have been adopted and effectively used to keep communication through digital channels. However, onsite coursework has true advantages. While in the interview we sensed the happy community spirit of students in Ålesund, they had experienced difficulties in planning their coursework concerning courses from other campuses. This was due to the fact that the practical information about courses on official websites were not up-to-date.

**Recommendation:** *The EC recommends the IE Faculty to establish procedures that ensure annual updating of the course database and other essential information for PhD candidates.*

The exposure of the PhD candidates to the international scientific community is absolutely essential. Departments within IE have indeed been working to secure possibilities for the students to become connected outside Norway. (Of course, the past two years have been difficult in this respect.) The programmes participate in some international educational networks. Depending on department, there exists funding for the students to join international conferences and workshops to present their research results, and naturally all candidates are encouraged and required to publish their results in international peer-reviewed journals or conferences of serious technical and scientific reputation. In some interviews we observed that students had such strong and safe home-feelings in Trondheim, having studied there also for the earlier degrees, that it might make an obstacle for the student to actively apply to an exchange or post-doctoral position abroad.

During the interviews, we did not encounter students being active in international technical and scientific organizations (IEEE (Institute of Electrical and Electronics Engineers) or similar). To enter such activities would require that the supervisors and the group members around the student would be already involved and encourage him/her to join as a student member. This may be a national characteristic in the Norwegian electrical engineering landscape; for example, while the IEEE Section websites of Sweden, Denmark, and Finland are up-to-date with events in the Fall of 2021, the Norway Section website has most recent information dated May 2017.

The already existing quality of PhD supervision appears to be good, and needs to be sustained and supported. In the opinion of the evaluation committee, the supervision and collaboration in the

faculty works very well. One observation was, however, that the interaction of the student with the co-supervisor was rarely mentioned. If this is a true picture, something could be done towards truly involving the co-supervisors as active advisors, in particular in cases where the main supervisor has many supervisees.

**Recommendation:** *Review supervision structures, including the role of co-supervisors and division of responsibilities in general. Strengthen the concept of a co-supervisor as supporter of the PhD giving additional insight and maybe also different viewpoints and approaches.*

The EC feels strongly that the midway evaluation is a very effective instrument to secure the progress of the student's work. This forces the candidate to collect the results of the past 18 months, face them him/herself and present them to a committee. It is also essential that in this external committee, people not in the supervisory group can interact with the student, and exchange views without the presence of the supervisory team. The EC learned that the practices and guidelines of running the midway evaluation varied between departments and programmes. Since this instrument is very essential, the experiences and internal guidelines of different programmes and departments should be shared. The departments could learn very much from each other in this respect.

**Recommendation:** *Review the procedures of the midway evaluation, including following up and modifying the initial research plan, and taking into account best practices across the programmes. Harmonise the process of the midway evaluation taking the existing best practices into account. Furthermore, the department should automatically notify the supervisor in due time to guarantee a timely evaluation. Ensure documentation and administrative support is available to support and supervise the execution. Additionally, more frequent or different types of checkpoints could also be considered, as a measure keep the research on track. Such annual evaluations could be redefined to be leaner for candidates and supervisors.*

## Relevance:

The PhD candidates' thesis works are usually connected to research projects within the departments. One of the measures of relevance is that the research activities are aligned and connected with the strategic goals of the university and IE Faculty. This is mostly the case, for example concerning NTNU research areas energy and sustainability. Multi-disciplinarity is characteristic to most of the projects, which is an excellent way to prepare the students into working life outside the university.

Most of the PhD graduates (perhaps more than 80%) find their future careers outside academia: in industrial companies, research institutions, public sector, startups, as entrepreneurs, etc. The students have very good employment prospects and many have secured their job contracts already before defending their thesis. This is often made possible by the fact that the thesis is done in collaboration with industry, and short-term internships in companies are offered during the study time.

There seem to be few problems for the IE PhD graduates to secure jobs after completion, but since candidates continue to positions outside academia, it is important to prepare the candidates for other career paths than solely academic ones. One good initiative from the IE faculty on this is the inclusion of the transferrable skills courses which can give credits in the educational part. Some programmes offer a career seminar towards the end of the study, and the IE faculty has taken a good initiative with the "industry seminar". However, an integrated focus on career development seems to be less present, as expressed from the motivation of candidates and supervisors, and from

what can be seen of information on this on web pages. A stronger focus on career development, perhaps through a structured career development programme, could be beneficial. This could also have potential long-term benefits in terms of industry valuing the PhD degree more, and making the PhD studies more attractive for especially local candidates.

On the other hand, the three-years (including 30 credit points of coursework) is rather short to grow up into a solid academic researcher. Hence a post-doctoral period or two are necessary to become eligible to apply for an assistant professor position at a national or international university. The evaluation committee found that the number of postdocs working in the departments is low compared to several international universities.

The course portfolios are in a state of change in some departments (for example, the IES department has reduced the number of their course palette from 31 to 10 courses, also in the Computer Science programme, the Computer Science programme has reduced the number of courses, resulting in stronger “core” courses aligned with the five research groups, and the IIK department already aligned the courses with research groups putting emphasis on method-based courses). It may be too early to estimate the effect of such changes but indeed this action has the advantage of collecting more students into a given course. This creates interconnection between the students and mutual learning. The courses become broader in their contents and they need to be useful for a wider range of students. In the interview, the EC encountered also opinions that too generic courses are not appealing, or are even a waste of time, in particular if the student wishes to optimise her/his use of time and tries to fill the credit point requirement with courses of a narrow topic that is better tuned to the needs of the thesis.

Topical courses with some flexibility in scope were appreciated by students and supervisors. They are reported to be adaptable to the changes in research scope that takes place in several Departments and thereby feasible to bend towards new directions of research that Departments wish to pursue, and able to support PhD candidates in these new areas with knowledge that they need.

The coursework load for a PhD student is 30 credits (corresponding to six months of work). As a result of the 2016 evaluation, a requirement was implemented that in this package 5–15 credits have to be so-called transferable skills courses (research ethics, didactics, project leadership, communication, innovation). In particular, the course on ethics (IDT8000: Research ethics) is a compulsory course for every PhD candidate, starting from 2019. This transition seems not to have proceeded smoothly. The course on ethics received mixed opinions, both from the students’ and the supervisors’ side. It is hard to disagree that ethics in general and research ethics in particular is very essential in the education of PhD candidates. However, voices were heard that at least one of the earlier editions of the course was pedagogically inadequate and badly organised (grades have not been given even after two semesters). Furthermore, concerning the project management course, it was not clear to PhD candidates we interviewed that this course was aimed at how to manage their PhD study. Expecting knowledge about industrial project management, some PhD candidates said that this course did not meet their expectations. The course description could be revisited and changed, or the course could be extended to include some of the elements of industrial project management.

**Recommendation:** *The requirement on 5–15 credits of transferable skills courses should be maintained. These courses, both regard to contents, realization, and examination, should be carefully scrutinised and monitored so that they really give the knowledge and skills that are intended. Feedback from the PhD students is important in this process.*

Having course loads of only 2.5 or 7.5 ECTS forces PhD candidates to attend three of the 2.5 credits courses. The Faculty and Departments could consider whether introducing some 5 ECTS courses could make the course selection more flexible for PhD candidates, and give a larger spread of the knowledge the PhD candidates will acquire.

### Organisation:

Organizing the PhD education in a faculty with a scientific staff of 350 people and close to 500 PhD candidates requires formalised processes and effective administration. Guidelines and process descriptions on different levels (department, programme, faculty, university) have to be consistent with each other. There are plenty of documentation available about the various committees and their mandates within different stages of doctoral education.

The doctoral programmes belong to the IE Faculty, which secures a certain degree of uniformity in the processes. The grassroots level of the life of a doctoral candidate happens in the departmental level (courses are run by the staff of the departments, and research work is performed in the research groups under the supervision of a professor in the department). The seven departments and numerous groups have all a different history and tradition in educating PhDs which means that the general principles of the higher level in the university have to be applied and perhaps modified at the floor level. Even the terminology changes: in the self-evaluation documents of the programmes/departments, the use of language is freer than in the more formal documents of the faculty. This is understandable and it does not cause problems as long as all actors are aware of the principles and the hard rules.

**Recommendation:** *IE Faculty might wish to ensure management and administrative resources to make information updated and uniform.*

The research committee at faculty level comes with strong formal powers (concerning admission of students to the PhD programmes and approval of changes in curricula and supervision, overseeing the best practices within research education, and presenting recommendations of research-related issues to decision-making bodies). After the 2016 evaluation, an action was implemented to re-establish programme councils for each programme. Such PhD programme boards have other duties than the faculty-level research committee, but one observation of the EC committee was that the boards, if they exist, act according to different modes in different programmes. In the self-evaluations of the departments, nothing was mentioned about PhD programme boards (except references to “research board” (IDI department) and “committee of research and education of researchers” (IMF department)).

The recruitment of new PhD candidates has to be given sufficient attention. This was emphasised also in the 2016 evaluation report. During the interviews, we heard complaints that the process as it is now is quite bureaucratic. On the other hand, it needs to be strict and transparent because the accepted candidates become employees of a department with duties and rights for three years. However, some interviews reflected frustration over the time delays that cannot be overcome in the formal process. Funding time scales often are faster than the hiring system can follow.

In addition to this, several of the programmes reported a challenge in recruiting local candidates, as they are often picked up by industry as early as in the fourth year of their MSc studies. It is hard for the PhD programmes to compete with industry when candidates cannot know if they will be offered a PhD position before the end of their fifth year. The departments are aware of this situation and try

to improve on it. Some have offered an “integrated PhD” where candidates can be sure of funding at an earlier stage and found the scheme to work well.

**Recommendation:** *Continue the effort on recruitment of new PhD candidates. Consider if some parts of the process could be streamlined further and delays be made more predictable. Additionally, strengthen the long-term effort on recruiting local candidates, through the “integrated PhD” or similar schemes.*

It was not unexpected to learn about the concerns of the low number of female students, which is a consequence of few women applying. This is a problem recognised globally within electrical engineering and computer science.

**Recommendation:** *Make use of role models to attract more female students to the PhD studies, e.g., by organizing workshops, seminars or other activities addressed to MSc students, run by female senior scientists and PhD students. Additionally, specific PhD positions dedicated to female students may be offered and advertised to the students of the last two years of the master and also outside NTNU. To improve the gender balance is a long-term project that requires perseverance and different means might apply to the different PhD programmes and departments, but still joint actions on faculty level should be considered.*

Regarding on-boarding of the new PhD candidates into the programmes and the departments, EC was delighted to learn about several efforts to welcome the newcomers. On the faculty level, an introduction seminar is arranged for the PhD candidates. In departments, it is important that social events are organised where all new students can meet senior fellow students and the staff. But very important is also on-boarding into the research work and working towards a clear vision about the thesis topic. This admission application package contains the early research plan which often includes a preliminary list of articles to be written for the thesis, including their titles and short contents. This should be understood in a way that the research plan is flexible to revisions in details. However, EC learned that in many cases this research plan is not a living document. It may have been submitted in the early phases of the doctoral studies but never again revisited, not even by the candidate her/himself.

**Recommendation:** *Make use of the best practice already existing in some departments (e.g., IIK) to consider the research plan as a living document that is updated on a regular basis, adjusted to the current developments, and discussed in the regular meetings with the (co-)supervisor.*

The procedure of exiting the system through the PhD thesis defence should also be clear. There are many steps in this off-boarding process that require attention. The details of the publishing and printing of the final thesis need contacts with the library and other parts of the administration. Other type of paperwork is also necessary which in the earlier times was taken care by a quick consultation with a knowledgeable secretary but which (for the sake of a working quality system) should be transparently documented.

**Recommendation:** *The IE Faculty could ensure clear guidelines including procedures for on-boarding, mid-term evaluations and off-boarding. This could be done in the form of Faculty web pages that could provide a one point of contact information about PhD studies and administrative matters.*

The quality of the doctoral thesis will be evaluated by the external assessment committee before and after the thesis defence, and ultimately by the Faculty research committee. Before this, the step to be taken when the thesis manuscript can be taken for pre-examination is determined by the supervisory team along with the PhD candidate. At this point quantitative aspects appear. In article-



based theses, the number of publications that form the core of the thesis is very visible in the explicit appearance of the thesis. The evaluation committee learned that there was a great variation between the expectations from the different supervisors and the formal requirements of the faculty. While the IE Faculty guidelines say *“the doctoral thesis is expected to be based on at least one peer-reviewed publication, with the candidate as the main author, in a recognized journal relevant for the academic topic of the thesis”*, the EC felt that some supervisors have their own norms in this respect: three or four publications are required for the thesis. In some theses, many more publications appear, even up to 10 (see, for example, the thesis of A.A. Vatanjou, 2019:362). The EC understands that it is not possible to define normative metrics in this question: publishing traditions differ between technical fields, publication forums have different standards and reputation, and the contribution of the candidate in publications with several co-authors may vary. However, implicit expectations on the quantity of required publications that may vary across the groups and the faculty may lead to students ending up in unequal positions.

**Recommendation:** *Try to avoid that the expectations about the package of publications in the thesis diverges within the faculty and different departments. We suggest open communication between supervisors within a department and across PhD programmes about the implicit requirements about the scientific output in the doctoral thesis. Relaxing unrealistic expectations will also help avoid delays in completion of the doctoral degree in nominal time.*

**In conclusion**, the EC has the overall impression that the state and potential of the doctoral education in the IE Faculty is very high, but still varies in quality between the departments. However, the best practices in place in the different departments show, that “somewhere” in the faculty the knowledge about excellent processes is available, but somehow this knowledge did not percolate through all structures.

**General meta-recommendation:** *Try to learn from the best practices of other departments (e.g., sharing the guidelines for the midway evaluation of IK department, considering the research plan as living document, offering integrated/industrial PhDs etc.) to further harmonise the processes.*

## PhD Program in Computer Science (PHCOS)

The PhD programme in Computer Science and Informatics is managed by the Department of Computer Science (IDI), and comprises 113, 32, and 8 PhD candidates from the campuses in Trondheim, Gjøvik, and Ålesund, respectively. There are five organizational research groups at the department: Applied Information Technology, Computing, Data and Artificial Intelligence, Information Systems and Software Engineering, and Norwegian Colour and Visual Computing Laboratory (IDI Gjøvik), making IDI a diverse department in both research topics and methods. However, research is also less formally organised into smaller and more specialised sub-groups. PhD candidates belong formally to one of the five research groups, and also informally to the smaller research groups. The PhD candidates have an administrative contact point at the department.

### Learning environment

**Local academic environment:** The PhD candidates with their supervisors all belong to a local research group, and have the opportunity to attend group meetings and seminars. These groups consist of multiple PhDs, postdocs, and permanent staff, bringing some diversity in the local academic environment. In addition, candidates take part of a larger social and learning environment in their organizational research groups and the rest of IDI, taking courses with multiple other PhD students, and joining department-wide seminars for PhDs. Some candidates reported on lack of office space in the department (Trondheim), making the work situation somewhat unpredictable.

**Multi-campus:** The candidates are mostly in two big groups: Trondheim (113 candidates) and Gjøvik (32 candidates). Students in Ålesund have a requirement for staying one year at one of the other locations to have sufficient contact with a larger academic environment. The programme management did not report on big issues with the multi-campus situation; after an initial run-in period the setup has been running well for about three years. When talking to the PhD candidates, they seemed mostly satisfied with the solution. Although the Ålesund campus was the smallest, they were in close contact with their supervisors and had a good local community.

**Internationalization:** Candidates have the opportunity to join one of the leading international conferences early in the project, without having a paper ready yet, to get a kickstart on international networking. They are also encouraged to go on research stays with groups outside of Norway.

**Requirements and completion on time:** As with several of the other programmes, many of the candidates have to implement artifacts (software or hardware) and with the 2.5 years available for the research part of the study there is little time to finish actual research work. This is combined with sometimes too high expectations of what a thesis should contain in actual publication output. At IDI the research communities are very diverse, and while it is hard to find common standards in number of publications and similar, there seems to be diverse impressions among supervisors and candidates about the requirements. Numbers show that there are many active candidates who are long beyond the scheduled completion time, and the PhD committee are working on measures to improve completion times.

**Supervision:** There seems to be some imbalance between supervisors on how much time they have available for each PhD candidate, being either a result of a large variation in number of candidates supervised, or other workloads. On the other hand, many seemed to not actively use their co-supervisors, for various reasons.

**In summary**, the Computer Science programme has a good and diverse learning environment. The computer science programme should also focus on the recommendations on supervision structures and midway evaluation, found in the general report.

## Relevance

**Courses:** The programme has recently restructured the course portfolio, resulting in fewer courses, with more students taking each course. Each of the five groups has a core course which multiple PhD students take. This seems like a good strategy to identify the scientific profile of the groups, to ensure quality of the offered courses, and not least to improve the learning environment as the candidates will meet fellow PhD candidates while taking the courses. Some mentioned that it would be nice to have the option to take a course on research statistics. In addition to this, transferrable skills courses are offered by the IE faculty. Some of these courses are very new, and the experiences have been somewhat mixed so far, but more time should be given to evaluate them. In particular, some courses have been reported to be too much work compared to the stated credits, while others have had very little work. While some students have found some of the transferrable skills courses very relevant, others report it as a “waste of time”.

**Career development:** As about 80% of PhD candidates continue to jobs outside academia, it is important to prepare the candidates for other career paths than solely academic ones. One good initiative from the IE faculty on this is the inclusion of the transferrable skills courses which can give credits in the educational part. IDI also offers a career seminar towards the end of the study. However, an integrated focus on career development seems to be less present, as expressed from the motivation of candidates and supervisors, and from what can be seen of information on this on web pages.

**Recruitment:** The CS PhD programme, like several of the other evaluated programmes, struggle with recruiting internal candidates or on a national level. Potential internal candidates are recruited by industry early in their MSc studies. IDI has had an instrument called “integrated PhD” which allowed to recruit students and have them start in the final year of their studies, with guaranteed funding. While computer scientists are very much in demand in the industry, it seems to be less clear what relevance a PhD education has for industry, especially in Norway. The IE faculty has taken some good initiatives in this direction, with the “industry seminar”.

**In summary**, the programme has undergone a promising restructuring of the course portfolio, which may need some time to settle in and be fine-tuned. The programme could, in collaboration with the faculty, continue and expand the long-term work on career development. This could have the effect of strengthening the relevance and attractiveness of the PhD candidates’ skills for industry and other sectors, and in the long term also making it more attractive for local candidates to take a PhD. One should also continue to keep a strong focus on recruitment and continue successful schemes like the “integrated PhD”.

## Organisation

**Administration:** The students have access to an administrative contact person (100% position) in addition to the PhD committee. Given that the department has a large number of candidates, it is essential to have a dedicated person to help with practical issues.

**Support procedures:** Procedures are in place for onboarding, start-up, midway evaluation, and completion. However, while much initial work is spent on the research plan and submission of this, the plan is in many cases not followed up much, even for the midway evaluation. Procedures for the midway evaluation seemed to be a bit unclear, at least there did not seem to be information about this on the web pages, and there seemed to be somewhat different practices in the execution.

**In summary,** the programme seems to be well organised, but could also benefit from the recommendations in the general report about learning from best practices across the programmes and making information clearly available and updated. This is especially relevant due to the multi-campus situation.

## PhD Programme in Electric Power Engineering (PHELKT)

The PhD programme in Electric Power Engineering is run by the Department of Electric Power Engineering (IEL) that was established at NTNU in 1910. The department covers all important fields relevant for modern power systems and is the leading academic institution in Norway and it ranks high internationally, and in selected areas its research is on the forefront. The department is involved in a number of BSc and MSc programmes, the major one being Energy & Environment, which is a five-year program initiated in 1997. This is a joint program with the Energy & Process department of mechanical engineering. A new program in “Electrification and Digitalization” was started in 2021.

The department is organised in five research areas: Electric market and Energy Planning, Power System Operation and Analysis, Power Electronic Systems and Components, High Voltage Technology, and Electrical Machines and Electromagnetism. Academic staff: 11 Professors, 15 Associate Professors, 5 Adjunct Professors, 9 PostDocs, and 56 Doctoral Students. (These numbers are from the information dated 10.09.2021, at the interviews it was informed that the number of doctoral students had increased to around 75, November 2021.) All the PhD students and supervisors in the program are located at the campus in Trondheim.

### Learning Environment

The department and its research groups have good national and international networks involving both academic and industrial partners, and these partners offer students excellent opportunities for research stays – under normal non-pandemic conditions. The close links to SINTEF Energy have been valuable for the department over the years and are still important. Several co-supervisors and adjunct professors come from SINTEF Energy and junior researchers are recruited as PhD students. In general, the doctoral students were content with supervision and co-supervision. The program has equal numbers of domestic and foreign students. A desire to increase the fraction of domestic students was expressed and a number of actions have been taken and tried, e.g., organisation of “Energy-Days”. However, the possibility to offer an integrated MSc-PhD program has not been pursued. This vehicle has turned out to be effective for the recruitment in other PhD programmes.

**Recommendation 1:** *To make the program more attractive to NTNU students an integrated MSc-PhD program should more often be offered to talented students at an early stage. Experiences from other PhD programmes show that this can be an effective means to increase the number of domestic students.*

### Relevance

Electric power engineering is one of the oldest disciplines at NTNU and it has continuously been modernised to meet new societal, industrial and environmental needs. Also, new enabling technologies and analytical tools from other disciplines have been introduced to keep the research up-to-date and internationally competitive. This is also reflected in that PhDs graduated from the program are attractive on the job market, both for academia and the industry. The new challenge for the electric power system is to incorporate large amounts of weather dependent and fluctuating energy sources, i.e. wind power and photo voltaic (PV), together with new types of loads, e.g., electrical vehicles. They cope with this new situation a ubiquitous use of ICT, often referred to as

digitalization, on all levels of the power system is foreseen. NTNU is doing a lot of research in this field, but it should be more clearly reflected in the PhD program. This could also be a means to attract students with majors in other field than power engineering.

**Recommendation 2:** *While NTNU is very active in “Electrification and Digitalization” in the research, this is not prominent in the PhD program. It is suggested that digitalization be included as a salient component in the PhD program to make it more fit for future demands and to attract students from other specializations.*

## Organisation

The formal parts of the PhD program, i.e., writing of research plans, midway evaluations, etc., is very well organised and clear rules regarding responsibilities are implemented. The research plans, which are continuously updated due to new results, were regarded as important supporting documents both by the doctoral students and the supervisors. Clear rules on required publications for the PhD thesis have been applied. Sufficient funds to support conference and workshop participation are available. Lack of qualified support for advanced experimental work in some cases has delayed some doctoral students, particularly in high voltage engineering. A remedy would be to hire more PostDocs, especially in groups with advanced experimental research.

**Recommendation 3:** *It was noted that the number of PostDocs was quite low for a department of this size. More PostDocs would give doctoral students more informal supervision and also be beneficial for those doing experimental work.*

## PhD Programme in Electronics and Telecommunications (PHET)

The PhD programme in Electronics and Telecommunications is managed by the Department of Electronic Systems (IES: Institutt for elektroniske systemer). The IES department has a long history with roots back to the origins of the Norwegian Institute of Technology 111 years ago. Its spectrum of research reflects the broad range of research domains in electrical engineering: from wireless radio, circuits and systems, remote sensing, signal processing, acoustics, to modern photonics and nanotechnology.

The department is fairly large: in addition to 46 full-time tenured faculty members, there are 7 adjunct positions, 15 post-doctoral researchers and around 30 technical and administrative employees. The population of PhD candidates has been slightly increasing during recent years and is presently at a healthy level of 75 students. The department seems to be well-run and organised. A strong connection of the activities of the department to the industry provides project funding with which most of the PhD candidates are financed; however, also internal funding is provided to PhD projects that are not necessarily application-oriented. To increase the number of in-house PhD students, two scholarships are available for the Master students who excel best in their fourth-year studies.

### Learning environment

The PhD students in the program of electronics and telecommunications are working in the IES department, located in the Trondheim and Gjøvik campuses. However, neither in the interviews nor in the self-evaluation report, challenges caused by the multicampus character of NTNU were mentioned.

The department expressed the concern with difficulties in recruiting internal (NTNU) students into the PhD program. Since PhD students often assist in bachelor and master level teaching operations, it is understandable that foreign students not yet fluent in Norwegian are not as effective for this purpose as local ones. Efforts should be made to speed up the integration of foreign students into the Norwegian society and Trondheim environment.

Another concern is the small number of female PhD students in the program. This problem seems to be universal, as in many other countries the share of women students in electrical engineering programmes is often below 20%. The leadership of the IES department is clearly aware of this situation and working to improve it. Hiring a new female adjunct professor has been a good step towards this direction.

**Recommendation 1:** *Continue with the efforts to make the program more attractive to female students. For example, ask previous women graduates (who preferable have been successful in their career) to come to speak at recruiting events for NTNU's master-level students.*

### Relevance

The activities of the IES department are clearly aligned with the strategic visions of NTNU and of the IE faculty. The Strategic Research Area on Internet of Things (IoT) of the faculty is coordinated by the IES department. Most of the students work with projects where sustainability is a key aspect.

As to the employment prospects of PhD candidates in the program, there is no doubt that the education in the Program in electronics and telecommunications offered by the IES department is relevant. Practically all the PhD graduates find employment, mostly outside academia.

The department has been revising the palette of courses offered to the PhD program, reducing the number of courses from 31 to 10. This has the advantage of involving more students in each course which makes it easier for them to interconnect and learn from each other. Likewise, the scope of the courses becomes broader as they need to appeal for a wider range of students. On the other hand, some students may find the reduction of the number of courses problematic, especially if he/she is looking for a course with a narrow topic that would be tailored to the needs of the thesis.

## Organization

The largest component in the workload towards the PhD degree in the doctoral program is with the thesis (2.5 years out of the 3-year net amount of time). While the department is responsible for offering courses for the student to satisfy the credit requirement, the PhD candidates work within the research groups under the supervision of a professor. In addition, a co-supervisor is appointed to each student. However, the style, structure, and intensity of the supervision process may be very different in different groups, due to varying tradition and culture. The requirements for the quantity and quality of publications in the PhD thesis are often different from supervisor to supervisor. It was therefore positive to learn about common procedures at the department level to take care of the progress of the PhD students, like on-boarding efforts to guarantee a safe welcome and a speedy starting point into research to new PhD candidates. Likewise, the midway evaluations (mid-term discussions) are held with participation from the leadership of the department. Furthermore, the final meeting with the candidate before her/his graduation is conducted in a similar manner.

**Recommendation 2:** *Compared to other departments, publication activity in IES has not been very high in the past years. The present efforts of the leadership to increase high-quality publication output from the research are welcome and should be continued.*

**Recommendation 3:** *In some cases, supervisors seem to expect a rather large publication output from their doctoral students, sometimes into an extent that to deliver the results within three years becomes unrealistic. Communication across the groups in the department should be ongoing and clear enough so that deviations in the expectations among the supervisors stay acceptable.*

**Recommendation 4:** *The Department apparently receives funding based on the number of PhD graduates in the program. It could be considered that those groups whose doctoral students graduate in nominal time be partly rewarded from this money.*



## PhD Programme in Engineering Cybernetics (PHTK)

The ITK department (Engineering Cybernetics) has 120 active PhD candidates, of which 100 are still employed. The faculty consist of 17 professors and 13 associate professors. 12 adjunct professors participate as co-supervisors where this is relevant. The ITK department has made an extensive expansion of their area over the past few years, extending their scope to cross disciplinary topics and applications that are essential for highly automated systems today and in the future. These make use of methods and sensors (machine learning and vision to mention two) and to application areas that are essential for Norwegian industry and Society. The ITK department is located in Trondheim.

### Learning environment

The PhD-candidates at ITK are part of an active high-quality research and learning environment. Most of the candidates are funded by large and medium-sized research projects funded jointly by Research Council and Industry. The candidates have very good conditions for development of top-notch theory and high-quality validation of results.

#### **Participation by PhD candidates in the academic environment.**

Candidates interact closely with others in smaller groups and interact closely with their supervisors. Several candidates reported close interaction with both main and co-supervisors.

#### **Active participation in the international scientific community.**

Several but not all candidates have close contacts with the international community. International orientation should remain in focus for all PhD candidates.

#### **PhD supervision.**

Regularity of supervisor meetings with candidates vary from weekly to monthly meetings, but contact with most supervisors is much more frequent since many supervisors and candidates work closely together on joint publications and on other research milestones.

The learning environment at PHTK is very good.

### Relevance of courses

The research topics for PhD candidates are relevant and up to date according to international practice and they address societal and scientific needs and challenges. The topics covered by the course portfolio has, however, not quite kept up with the recent expansions made at the ITK Department.

#### **Preparation for future career.**

The mixture of theory and methodology development plus the implementation and validation of results that are included for most if not all PhD candidates from ITK, is a valuable mixture preparing candidates very well for their future career. 80% of candidates get jobs in industry and most of non-native candidates remain in Norway after their graduation.

### **Course portfolio.**

The course portfolio consists of 8 courses that are given regularly. Candidates and supervisors see a need to supplement this list with more "topics" style courses to better support the envelope of topics for candidates working in the newly added areas of interest of ITK.

**Recommendation 1:** *Expand the scope of courses to better cover the necessary background knowledge needed by the recently added areas of research. "Topics" style courses were mentioned as being particularly attractive for the PhD candidates.*

## Organisation

### **Research education - roles and responsibility.**

Courses exist in the course catalog with erroneous information about when (which semester) a course is given and about who is course responsible. Interviews reported that responsibility for updating is assigned to the former lecturer of a course. Apparently, this does not function.

PhD candidates report satisfaction with the latest versions of Transferable Knowledge courses.

### **Processes for renewal, development, and quality of programme.**

Several PhD candidates and supervisors we interviewed wish better support of the new areas that have been included in the focus for ITK in recent years. Two topics courses 8108 and 8111 offer some flexibility in the scope from year to year. This type of courses are on the wish list of the PhD candidates.

The transferable skills courses at IE level have 2.5 ECTS as credits. Trimming some courses to 5 ECTS would give better flexibility in study plans and scope for the individual candidates, and ensure a scope fitted better to candidates pursuing research in the areas of recently extended focus.

## Ensuring quality for individual candidates

### **Recruitment and onboarding.**

ITK recruits about 50% native candidates, which is the highest seen at the IE Faculty. International candidates are screened by an external recruitment company.

### **Underway: Midway evaluation / annual reporting.**

Most midway evaluations are carried out before two years of the study. ITK expressed that annual evaluations are being considered.

### **Completion: Duration, outboarding, awarding, extension, and termination.**

PhD candidates reported that they have a need for an updated web page with list of points of contacts for administrative matters and clear instructions about procedures.

**Recommendation 2:** *Ensure that PhD course information is updated and correct at all times. Consider whether the module structure could become more flexible by introducing new courses as 5 ECTS credits.*

## PhD Programme in Information Security and Communication Technology (PHISCT)

The PhD programme in Information Security and Communication Technology (PHISCT) is run by the Department of Information Security and Communication Technology (Institutt for Informasjonssikkerhet og kommunikasjonsteknologi, IIK), which will provide at least one principal supervisor for any candidate in the program. The department was formed in 2016 as a merger of the Department of Telematics at NTNU and the Information Security Section. Researchers are based both, at the campus Trondheim and Gjøvik and conduct research and education in key areas of cyber and information security, communication networks and networked services. After reorganization in 2021 the department has a matrix structure comprising four disciplines (Information Security, Communication Technology, Cryptology, and Human, Organizational, and Societal Aspects) with research organised in seven research groups that form the basis for PhD education (Applied Cryptography Laboratory, Critical Infrastructure Security and Resilience, e-Health and Welfare, Network Research, Norwegian Biometrics Laboratory, System Security, Privacy and Data Protection).

### Learning environment

The research activity in the department is organised into the above mentioned 7 research groups, some of which are quite numerous and established since a long time (in terms of permanent staff, PhD candidates, and postdocs). All research groups have a good set of international collaborations and strong networks with industry. Furthermore, the department is currently in a process of revising the course portfolio in order to take not only the merger but also the newly offered transferable skills of the faculty into account.

**Recommendation 1:** *While the course revision is an ongoing process, the department should really emphasise that PhD candidates can take their courses as early as possible (e.g., “critical thinking”) in order to benefit from them. Furthermore, some deadlines/start of courses (e.g., Norwegian) should be better aligned to allow students the participation from the very beginning.*

**Recommendation 2:** *While in general PhD students seem to be content with their supervisors, the role of the co-supervisors seems to contain a (too) large spectrum from non-visible to co-working in a lab. The department should take care about the (negative) outliers to stronger support the concept of a co-supervisor as supporter of the PhD giving additional insight and maybe also different viewpoints and approaches.*

### Relevance

Considering the demand in industry, but also authorities in the field of information security and communication technology, it does not come as a surprise that all graduates of the PhD program have excellent employment prospects. However, this is also true for BSc and MSc students due to the tremendous growth rates in industry. Although there is no real wage benefit when it comes to having a PhD, the department still has a continuous flow of very good candidates due to additional efforts, such as integrated PhDs or industrial PhDs. Furthermore, strong and manifold networks to industry make the PhD education more attractive for many as more than 80% of graduating PhDs go to industry anyway.

## Organisation

Overall, the department is well structured, has clear rules for PhD education and enough grants to not only send students abroad but also to cover potential gaps in contracts. Furthermore, the department actively engages in the currently problematic recruitment of excellent candidates by, e.g., offering integrated PhD programmes (5 years) to excellent Master students. Additionally, an industrial PhD scheme allows for PhD candidates working in industry and, thus increasing the attractiveness further. The internal organization of all necessary steps seem to be good (e.g., automatic push for midway evaluations) plus a separate position is available to take care of all PhD relevant issues.

**Recommendation 3:** *While all necessary procedures seem to be established it remains often unclear to the students what the status is and how long things will take. Thus, make all procedures visible (e.g., Wiki) including rough time estimations about how long which procedure typically takes (e.g., 6 weeks from submission of research plan to approval).*

**Recommendation 4:** *Many best practices do exist in the department when it comes, e.g., to the approval for research from an ethics board or to get special licenses. However, it seems that not everybody is fully aware of these best practices. Thus, it is recommended to collect all best practices and make them available to everybody, in particular the newcomers to speed-up the start-up phase of the PhD.*

## PhD Programme in Mathematics (PHMA)

The PhD programme in Mathematics is run by the Department of Mathematical Sciences (IMF). The department counts

- 84 full time staff positions
- 11 adjunct positions
- 13 technical/administrative positions
- 76 doctoral students
- 23 postdocs

The personnel are entirely located in the Trondheim campus.

### Learning environment

The research activity in the department is organised into 6 research groups, some of which are quite large and established since a long time (in terms of permanent staff, PhD candidates, and postdocs), others are relatively new and/or small. All research groups have a good set of international collaborations to which the PhD candidates are fruitfully exposed. A research line that is very active is related with didactics of Mathematics, which attracts mainly Norwegian speaking PhD students, being aimed to train local teachers from primary to high schools.

A weakness under this item is a limited ability of some supervisors to promote the development of soft and interdisciplinary skills in the students.

**Recommendation 1:** *Make mandatory the attendance of the training courses for supervisors offered by the Faculty.*

### Relevance

The Ph.D. course portfolio is based on 18 specialised courses within advanced mathematical and statistical subjects. In addition, some reading courses are regularly offered in which the students can design a curriculum based on their own research interest and activities. Some students also choose some courses offered in other PhD programmes of the Faculty. The supervisors are very committed to the research of their students, thus are following the progresses of the candidates on a regular basis, usually scheduling weekly meetings. Each supervisor is following usually 1-2 candidates.

Almost all the PhD students have teaching duties in the BSc and MSc courses of the Faculty. This helps the PhD students to improve their ability to communicate mathematics to non-experts and to work in an interdisciplinary environment.

Over 90% of the PhD candidates leave the academic world after the PhD. The industrial world in particular is quite interested in hiring mathematicians with a postgraduate training.

A weakness under this item is a limited awareness of the students of the skills requested by the industrial world to a mathematician.

**Recommendation 2:** *Organise more frequently (e.g. yearly) workshops and meetings with industry, in which the specific skills needed for a mathematician to work in a non-academic environment are highlighted and discussed, in order to increase the awareness of supervisors on the requests of the non-academic world.*

## Organisation

PhD candidates are mainly recruited from NTNU's master students (about 66 %) in mathematics and statistics. All the candidates are assigned a supervisor, a co-supervisor, with supervising duties and often complementary competences, and a mentor, that is a senior PhD student or a postdoc who could help the new PhD student with practical questions as well as professional ones. The PhD candidates are encouraged to present their research in international congresses, and to spend a period of research abroad. Midway evaluation and the final defence of the theses are very well organised, by a specific PhD committee of the Department of Mathematical Sciences, which includes also administrative dedicated personnel.

The main identified weaknesses in this item are the lack of female students and of international students. The request of teaching in Norwegian language can be problematic for foreign students, and may disincentivise the recruitment of international students.

**Recommendation 3:** *Make use of role models to attract more female students to the PhD studies, e.g. by organizing workshops, seminars or activities addressed to MSc students, run by female senior scientists.*

**Recommendation 4:** *Offer specific positions dedicated to female students and advertise this possibility to the students of the last two years of the master.*

**Recommendation 5:** *Involve foreign students in teaching only at the MSc level, where usually the courses are offered in English.*

## IIR Department (ICT and Natural Sciences)

- associated with the PhD Programmes in Engineering Cybernetics (PHTK) and Computer Science (PHCOS)

The environment of doctoral studies within the IIR Department (Institutt for IKT og realfag) is fairly young, and it has a different history compared to the rest of the PhD education in the Faculty of Information Technology and Electrical Engineering (IE). It was only in 2016 that Høgskolen i Ålesund was merged with NTNU where the present IIR became a department of the IE faculty. The activities are located in the campus of Ålesund, however with a vibrant connection to the main location of NTNU in Trondheim.

PhD students at IIR whose working contract is within the IIR Department are enrolled in two of the PhD programmes under the Faculty of Information Technology and Electrical Engineering: Engineering Cybernetics (PHTK) and Computer Science (PHCOS). This is a natural way of connecting to the doctoral education matrix of the IE Faculty, because the two main research groups in IIR are the Cyber-Physical Systems Lab and the Sustainable Digital Transformation Group.

### Learning environment

There does not exist a history and tradition of PhD education in the IIR Department. There are presently 14 PhD candidates working for their degrees. The first thesis defense will happen in 2022. And since the number of new PhD candidates is increasing, we can expect a healthy growth towards a solid base of doctoral education in Ålesund. There are 5 full professors, several adjunct and associate professors, and additional research staff forming the learning environment at the Ålesund campus. The advantage of a small campus community is that the students, supervisors, and the administrative personnel are located close to each other, the offices even at the same corridor. The interviews with the supervisors and doctoral students confirmed this feeling. The student community keeps a close contact, for example through the formal PhD forum. On the other hand, the physical distance to other campuses (Trondheim and Gjøvik) requires efforts to keep up with the formal requirements of the doctoral programme, as the bulk of the courses offered are organised in Trondheim. It is positive that in each PhD candidate's supervisory team there is at least one external co-supervisor from the other campuses.

### Relevance

The course portfolio is provided and developed by the two PhD programmes hosted by the ITK and IDI departments, and comments on the relevance are given in connection of the evaluation sections on these departments. As to the importance of the two research focus areas in the IIR department (cyber-physical systems and sustainable digital transformation), there is no doubt that a PhD educated in either of these domains has been exposed to truly relevant questions and problems to be solved in the future, both on the national societal level and globally. United Nations' Sustainable Development Goals have been incorporated into the educational visions and objectives of the IIR department.

## Organization

The PhD candidates in the IIR department follow the requirements of the two PhD programmes in IE Faculty, fully alike the students having their working contracts in the departments hosting the two PhD programmes (ITK and IDI). This looks very good from the point of view of a quality system; however, actual practice causes extra efforts and difficulties for students to access seminars and courses from Ålesund. During the interview sessions, our Evaluation Committee noticed that students felt that the information that they extracted from the official information channels (curriculum lists, course website data) were sometimes outdated: teachers had changed, courses were not given as planned, etc. While for main-campus students the planning of studies can be flexible because there exists a large palette of courses offered on-site, Ålesund students need to plan much further ahead, and accurate and up-to-date information is essential.

On-boarding of PhD students into Norway and into becoming an employee in the department works fairly well, judging from the interviews with the people involved. Also, the midway evaluations of the PhD candidates seem to be taken care with sufficient efforts, which is of course partly understandable due to the rather small number of students. The supervisory teams and the administrative office have ample time to arrange the evaluation meeting.

**Recommendation 1:** *The visions of the IIR department include a rapid increase the volume of PhD candidates. This may lead to disruption of the togetherness and intimate student community in Ålesund. It is important to plan this growth carefully to keep up the good spirit of the existing PhD Forum.*

**Recommendation 2:** *For the benefit of the IIR PhD candidates taking the coursework in other campuses, it is essential for their course planning that the information offered on official NTNU and IE Faculty websites be up-to-date.*