Expert report, panel 6

KTH's Research Assessment Exercise (RAE) 2021

Panel chair:
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Introduction

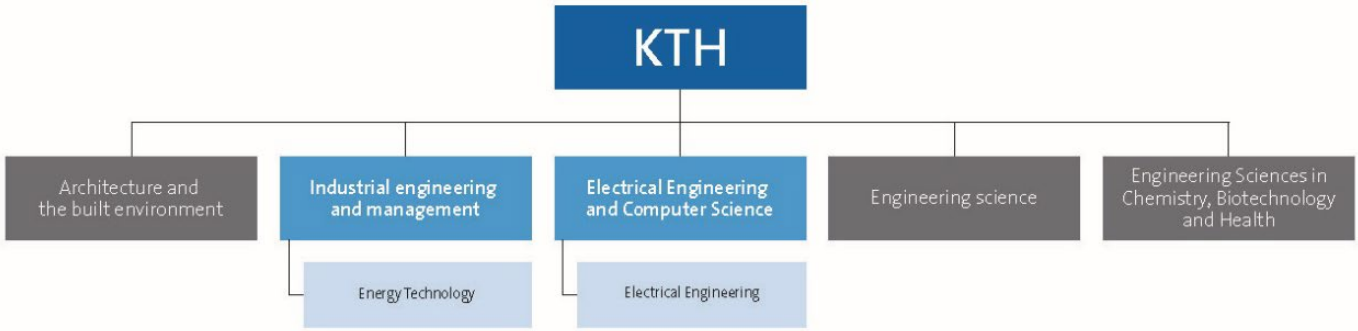
This expert panel report is part of the Research Assessment Exercise (RAE) 2021 at KTH Royal Institute of Technology. The report is based on the self-evaluation on panel 6 and aims to provide recommendations and feedback to the involved departments and KTH.

Expert panellists:

- Prof. Luisa F. Cabeza, University of Lleida, Spain, chair
- Prof. Tomás Gómez, Comillas Pontifical University, Spain
- Prof. Tulika Mitra, National University of Singapore, Singapore
- Prof. Farhad Rachidi, EPFL, Switzerland
- Prof. emer. Kevin Bennett, University of Cape Town, South Africa
- Prof. Henrik Bindslev, University of Southern Denmark, Denmark
- Prof. Elena A. Lomonova, Eindhoven University of Technology, Netherlands
- Prof. Lis Navner, University of Twente, Netherlands

Panel 6

Coordinator: Prof. Gunnar Malm, KTH Royal Institute of Technology
Vice-coordinators: Associate Prof. Staffan Norrga and Prof. Viktoria Martin, KTH Royal Institute of Technology



Part A: Summary of the whole panel

1. Strengths, weaknesses, and recommendations

General strengths of the Energy and Electrical engineering panel:

- Research is of very high standard and highly relevant
- Excellent and top-level research track-record of the staff members
- Excellent laboratory infrastructure, being unique in some aspects
- The research areas covered are comprehensive
- The projects presented by young researchers were impressive, with fresh ideas and promising funding
- A large part of funding is obtained from agencies and industry through national programs
- In general, strong links with industry
- Excellent packages for the junior faculty staff

General weaknesses of the Energy and Electrical engineering panel:

- In some areas, the research is fragmented and, therefore, does not show clear potential of having impact
- In some areas, there are limited basic-research activities
- Relatively low number of junior faculty
- There is no career path for researchers other than becoming docents
- There is limited EU funding
- The number of PhDs per research staff is low and has been decreasing in the last few years
- Too much pressure on the faculty members to ensure external funding
- Very little evidence of collaboration among the different research groups within the divisions and among divisions

General recommendations:

- A more strategic vision and roadmap (5-10 years) promoting collaboration around larger flagship projects is recommended
- This strategy should also ensure greater collaboration between divisions, between the two departments, but also with other departments at KTH
- A strategy to align and coordinate fundamental and applied cross-disciplinary research, beyond the immediate need of the local industry, is desirable to maintain, advance and expand their core expertise and enable the departments and its individuals to build up and extend their scientific reputation

- The complementary nature of expertise has the potential for strong cross-layer research in many areas, that is essential for the future and should be better exploited
- New positions should be decoupled from teaching needs. Research needs should also allow to open tenure-track new positions
- Although most young researchers appreciate their independence in the research, some more guidance from senior researchers may help them
- Definition of a strategic plan to address the issue of low number of PhD students
- Revision of PhD program requirements to reduce the course loads. There is also a problem that the course loads differ and there is a need to both equalise the course loading and give serious consideration to an overall reduction in course loads.
- Increasing EU funding participation by identifying internal administrative and financial barriers

2. Feedback on the formulated visions and strategies

The visions and strategies presented were found to not be clear enough, this is why one of the recommendations listed above is to develop a more strategic vision and roadmap for promoting larger flagship projects and to coordinate fundamental and applied cross-disciplinary research. This would clearly benefit KTH, since it would enable to build up and extend their scientific reputation and to open new research areas.

3. Ideas and recommendations for essential steps

Some of these are already listed in the recommendations, but could be prioritize as:

1. Develop a strong strategic vision, both for each department and for the full panel research topic
2. Identify one strong flagship project where internal collaboration could be strengthened
3. Identify a funding agency that could fund totally or partially such flagship project (i.e., ERC or other national calls)

4. Potential links and synergies

The two departments evaluated have the potential of developing strong links and synergies that need to be explored in detail. The self-evaluation report already highlights this fact.

Other links are with the Computer Science department, Intelligence Systems department, Physics department and the Chemistry department, amongst others, not evaluated in this panel but with clear potential to develop synergies or to strengthen those already established.

5. Recommendations for strengthening the departments and their future potential

Other recommendations listed above and needed to strengthen the departments are:

- Recover the number of PhD students working in the departments about three years ago
- Increase guidance of young researchers from their seniors without loosening independence in research
- Revision of PhD program requirements to reduce the course loads

6. Recommendations applicable to the whole of KTH

Other recommendations listed above that are more related to the whole of KTH are:

- Decoupling new academic positions from teaching needs
- Increasing EU funding participation by identifying internal administrative and financial barriers

Part B: Report for each department

Department of Electrical Engineering

Major findings

1. Strengths and weaknesses of the department

General strengths of the Energy and Electrical engineering panel:

- Research is of very high standard and highly relevant
- Excellent and top-level research track-record of the staff members
- Excellent laboratory infrastructure, being unique in some aspects
- The research areas covered are comprehensive
- The projects presented by young researchers were impressive, with fresh ideas and promising funding
- A large part of funding is obtained from agencies and industry through national programs
- In general, strong links with industry
- Excellent packages for the junior faculty staff

Additional strengths of this department:

- In particular, the research on fusion energy is highly valuable to the European integrated research programme
- KTH fusion energy researchers have taken up new topics and reached high standing and are taking leading roles in these new fields
- EES division has close collaboration with part of the Computer Science department as well as the Physics department

General weaknesses of the Energy and Electrical engineering panel:

- In some areas, the research is fragmented and sub-critical
- In some areas, there are limited basic research activities
- Relatively low number of junior faculty
- There is no career path for researchers other than becoming docents
- There is limited EU funding
- The number of PhDs per research staff is low and has been decreasing in the last few years
- Too much pressure on the faculty members to ensure external funding
- Very little evidence of collaboration among the different research groups within the divisions and among divisions

Additional weaknesses of this department:

- Department is dominated by senior (50+) and male faculty
- The number of publications per research staff has significantly decreased in the evaluation period, probably because of a decreasing number of PhD students

2. Relevant and forward-looking objectives

Individually, each of the research topics with the department are forward-looking, but there seems to be no clear common goals or roadmaps to go for more challenging issues, that would require collaboration between divisions and departments at KTH.

3. International community engagement

KTH is very well integrated within the European fusion research programme. KTH researchers also take leading roles in the integrated European fusion programme.

There is also international collaboration in other divisions, with involvement in such programmes as ESA and H2020.

4. Future potential of the department

The engagement of KTH in the fusion programme with the ensuing domain knowledge and network could be exploited by KTH to open opportunities for engagement for other groups at KTH with fields closer to industry and relevant to fusion.

The complementary nature of the EES and EME expertise has the potential for strong cross-layer research in electronics and electromagnetic system design, that is essential for the future.

The department has the potential to explore new ideas and topics, but its big dependence on industry funding hinders the potential for basic research and new ideas.

5. Recommendations

General recommendations:

- A more strategic vision and roadmap (5-10 years) promoting collaboration around larger flagship projects is recommended
- This strategy should also ensure greater collaboration between divisions, between the two departments, but also with other departments at KTH
- A strategy to align and coordinate fundamental and applied cross-disciplinary research, beyond the immediate need of the local industry, is desirable to maintain, advance and expand their core expertise and enable the departments and its individuals to build up and extend their scientific reputation
- The complementary nature of expertise has the potential for strong cross-layer research in many areas, that is essential for the future and should be better exploited
- New positions should be decoupled from teaching needs. Research needs should also allow to open tenure-track new positions
- Although most young researchers appreciate their independence in the research, some more guidance from senior researchers may help them

- Definition of a strategic plan to address the issue of low number of PhD students
- Revision of PhD program requirements to reduce the course loads
- Increasing EU funding participation by identifying internal administrative and financial barriers

Additional recommendations for this department:

- In the area of fusion, the domain knowledge should be used to strengthen Swedish industrial base in a future fusion industry

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

The research questions are related to changes in the technological paradigm, and policy shifts and changes in societal needs or trends. Digitalisation will ensure that electronics and embedded systems grow in importance. Finally, fusion interest and space technologies are of big importance.

The central research questions answer very well to the on-going research in the department, and it is integrated within its 5 divisions:

- Division of Electronics and Embedded Systems (EES)
- Division of Electromagnetic Engineering (EME)
- Division of Electric Power and Energy Systems (EPE)
- Division of Fusion Plasma Physics (FPP)
- Division of Space and Plasma Physics (SPP)

b. Contributions to the advancement of state of the art within the research fields of the department

The research carried out by the department has a clear contribution to the advancement of the state of the art, which is summarized and presented for each of its divisions:

- Division of Electronics and Embedded Systems (EES)
    - Silicon-carbide integrated circuits for high temperature and harsh environment applications, including space.
    - Nano-electronics.
    - Custom hardware for high-performance computing.
    - Hardware and cyber security (research topic in expansion today).
    - Systematic design of embedded systems software (ForSyDe platform).
- Division of Electromagnetic Engineering (EME)
    - Antenna and electromagnetic compatibility research.
    - Aperture antennas, including lenses and leaky-wave antennas.
    - Methods with potential applications to diagnostics of devices and components in the electrical power grid.
    - Smart grids, including societal aspects such as user concern on data privacy.
    - Maintenance and performance of the power system.

- Division of Electric Power and Energy Systems (EPE)
    - Model and control strategies of power systems with high renewable penetration, including wind farms, hybrid grids, etc.
    - Experimental aging of large, prismatic lithium-ion cells.
    - Modular multilevel converters.
- Division of Fusion Plasma Physics (FPP)
    - Reactor components (such as ITER wall).
    - Understanding of the high-confinement mode pedestal in tokamaks.
    - Magnetohydrodynamic mode control.
    - Development of a new generation of quantitative tools for modelling ion cyclotron resonance frequency (ICRF) heating.
- Division of Space and Plasma Physics (SPP)
    - Development of experimental instruments on major international space missions (e.g. NASA and ESA)
    - Responsibility for the Scandinavian Cluster Data Center, contributing to the production of ESA Cluster EFW instrument dataset.
    - Understanding of formation mechanisms of different types of polar arcs, such as bending arc formation due to dayside reconnection, and their statistical dependence on different solar wind conditions

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

In the period of evaluation (data of 2012-2018), the department has published 3750 documents. 25% are either IEEE journals or IEEE sponsored conferences. 10% of the publications are in physics, mainly in AIP journals.

The total number of publications has decreased. The number of peer reviewed papers decreased from an average of 120 papers/year in the period 2012-2015, to around 75 papers in 2019. The decrease in peer reviewed conference papers has decreased even more, from an average close to 150/year in the period 2012-2015, to around 55 in 2019. Since the decrease of PhD students has also decreased, the number of paper per capita has not shown such change.

The quality of the publications is presented with the impact factor for the publications and for the journals where the papers are published. This impact has been constant in the time of evaluation.

The department shows a clear engagement with international cooperation. This can be seen by its research activities and by the quantity of publications with co-authors from other countries (this last metric has increased in the period of evaluation).

d. Follow-up from previous evaluations

The self-evaluation report shows the answer to previous evaluation recommendations:

- Increase in international mobility, which has increased both for junior and senior staff.
- Increasing external recruitment in tenure track positions, which has been balanced in the period of evaluation between internal and external candidates.
- Ensure funding for technical support staff. Some divisions were able to do it, considering that the cost is charged directly to the research projects.
- Extending the experimental work in some research areas.
- Improvement of organization, leadership, and long-term strategies, done in some of the divisions.
- Good establishment of the fusion field in the European roadmap in a 10-year timescale.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

Most of the department funding is external, coming from research agency funding and from governmental funding to KTH for research and doctoral studies. The department is very successful in attracting external funding, but this also means that its research is heavily dependent on the calls and industry needs (KTH has strong industrial contacts with such companies as Saab and Ericsson). This has resulted in a relatively limited activity in basic research compared to applied research (only about 24% of funding is obtained from the VR (Science Council)).

Also, the need to get co-funding for most research projects or PhD salaries means that the internal money from KTH is used for such actions in detriment of investing in new ideas or more basic research.

The department does not show clear strategies for the future funding.

Due to the national funding system, funding is mainly sought for 1-PhD projects which makes the maintenance/growth of chosen research directions challenging both with respect to momentum and continuity.

b. Academic culture

The academic culture is very good, researchers and professors are committed to their research and to the institution. The individual groups are generally led by an academic in a tenured or tenure track position, with a number of researchers, post-docs, PhD students, and technical staff.

c. Current faculty situation and composition of the research team(s)

This department has an inversed pyramidal structure, with more professors than young researchers and young assistant professors; moreover, a large fraction of the professors are older than 50 years.

The number of PhD students has decreased during the period of evaluation, but the department does not seem to have any strategy to change this trend.

d. Recruitment strategies

The recruitment strategy is clearly set for KTH, being open to attract the best candidates. Any candidate that applies for an OPEN faculty position at KTH needs to demonstrate research and teaching skills.

Nevertheless, it is recommended that young researchers be made aware of this strategy and what they should focus on to get a tenure-track position (i.e., publishing more peer-reviewed papers or getting their own funding to gain managerial experience or teaching, or all the preceding in a suitable balance).

e. Infrastructure and facilities

The department has excellent infrastructure to carry out its needed research. The different laboratories available are:

- Electrum laboratory

- Sustainable power laboratory
- Infrastructure of the division of electromagnetic engineering
- Infrastructures of the divisions of space and fusion plasma physics

Electrum is operated within Myfab (Swedish research infrastructure for micro- and nanofabrication) and a significant part of the funding comes from users. External users pay according to a full cost model, which makes the lab costs quite high and some potential users end up going elsewhere. As one of the KTH Research Infrastructures, Electrum receives a small contribution from KTH, but the departmental research relies on the financing of their own technicians and equipment. Likewise, for the other laboratories, the department has to raise all the funding needed to extend, maintain, and update the equipment as well as the salaries for the technicians without any basic funding coming from KTH.

At the moment there is a lack of good funding programs for large equipment. Therefore, investments are mainly in personnel and small equipment/updates.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

The department shows links with the UN Sustainable Development Goals (SDGs):

- SDG 7: Affordable and clean energy
- SDG 4: Quality education

But the department does not present a clear strategy and goals for the next 5-10 years.

b. Congruence with university-level goals

The department shows clear alignment with KTH goals:

- An integrated KTH, with a very open atmosphere for students, but with gender balance being a pending target.
- A more sustainable KTH, contributing clearly to the energy transition.
- An open KTH, with the main weakness in life-long learning.
- An increasingly digitalised KTH, for example with the work in collaboration with the computer science department.
- While KTH does have a diverse faculty, participates in EU projects, and attracts international students, there is scope for strengthening these aspects in some divisions.
- An equal-opportunities KTH, again, with low number of female academic, researchers, and students.

c. Leadership structure and collegial structure

Boundary conditions for research, staff and educational development are set at the department level, and much of the actual decisions and implementation is done within a collegial structure at the respective divisions. In addition to the division level collegial structure, the department also benefits from having four members on the EECS school level faculty assembly.

d. Strategies for achieving high quality

The strategies listed by the department are:

- Regular follow-up.
- Publication strategy.

The strategy in this department is based on identified KPIs, but there is no clear strategy on research topics and interests.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

Since professors (assistant, associate, and full) and researchers (with docent competence) are responsible for teaching in the department and there is a clear interaction between research and teaching.

The department has teaching responsibilities in different BSc level degrees and is responsible for others, with the teaching based at fundamental level. But most teaching of the department is on MSc level, based on applied science.

The advanced master courses are a natural bridge to the master thesis degree projects, which commonly are performed in connection with industry R&D projects or on-going research projects at some research groups. PhD students are commonly involved as teaching assistants in courses at BSc and MSc levels and their cutting-edge knowledge from research can significantly contribute to teaching.

The research within the department is to a high degree connected with PhD thesis projects; pure research projects without the involvement of PhD students are less common. Specific third cycle courses are provided for PhD students with dedicated advanced content. There are more than 100 PhD courses at EE with a defined course plan and about 15 of these are actually offered each semester.

Moreover, to foster creativity, the department hosts two workshop environments for student activities, the mentor-space in Kista campus and the creative electrical engineering CrEE-lab.

The department participates in the student rocket project Rexus/Bexus programme, organised by the German Aerospace Centre (DLR) and the Swedish National Space Board (SNSB), in collaboration with the European Space Agency (ESA).

The continuity of research projects and associated equipment usage is often dependent on the older PhDs passing their knowledge on to younger PhDs.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

The department has a high societal and industry impact. The impact to society is a long-term contribution to the global energy landscape, with its contribution to the energy transition.

Stakeholders such as the Swedish Energy Agency, power grid utilities, and industry are identified, and there is a clear interaction among them.

Fusion energy is a valuable contribution to the European integrated research program.

Finally, the department is engaged to different networks to increase its impact to society.

b. Research dissemination beyond academia

The department organises different outreach activities, such as seminars, appearance in media (i.e., radio and newspapers), and has a webpage that disseminates its activity.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

As stated before, the department has identified links with two SDGs, SDG 7 and SDG 4. Links with other SDGs are presented, highlighting also SDG 1, SDG 3, SDG 9, and SDG 13.

d. Plans and structure for increased impact

The plans to increase the direct societal impact to society are:

- Better connection with high-school students.
- Discussions with House of Science, Tom Tits, and Tekniska Museet.
- Participation in technical magazines and other daily news forums.

The self-evaluation report did not highlight entrepreneurial activities, such as number of patents or spin-offs, even though they exist. It seems that there are not explicit incentive mechanisms for the impact activity conducted at the department.

6. Recommendations for strengthening the department and its future potential

<u>General recommendations:</u>

- A more strategic vision and roadmap (5-10 years) promoting collaboration around larger flagship projects is recommended
- This strategy should also ensure larger collaboration between divisions, between the two departments, but also with other departments at KTH

- A strategy to align and coordinate fundamental and applied cross-disciplinary research, beyond the immediate need of the local industry, is desirable to maintain, advance and expand their core expertise and enable the departments and its individuals to build up and extend their scientific reputation

- The complementary nature of expertise has the potential for strong cross-layer research in many areas, that is essential for the future and should be further exploited

- New positions should be decoupled from teaching needs. Research needs should also allow to open tenure-track new positions

- Although most young researchers appreciate their independence in the research, some more guidance from senior researchers may help them

- Definition of a strategic plan to address the issue of low number of PhD students

- Revision of PhD program requirements to reduce the course loads

- Increasing EU funding participation by identifying internal administrative and financial barriers

- Reinforce institutional support to platforms (such as Energy and Digital Futures) and specific centers or labs (such as Electrum lab, sustainable power lab, KTH live-in lab) to enable visibility and impact of the research

Additional recommendations for this department:

- In the area of fusion, the domain knowledge should be used to strengthen Swedish industrial base in a future fusion industry

- Design research impact metrics and develop a plan to increase visibility and impact of the research

7. Final remarks

All the needed material was in the self-evaluation report or was given available during the evaluation week.

Overall, KTH is an impressive university with many excellent researchers and research projects. Many of the concerns with respect to the future research environment relate directly to the funding system that nevertheless has been adequate in providing enough small projects to satisfy the immediate needs of the researchers (but this does not motivate proposals for, for example, EU funding of larger initiatives). In addition, the restrictions on the hiring of personnel (e.g., support staff can only be offered 2-year contracts) makes it challenging to secure good technicians. It is also not possible to stay at KTH after starting a spin-off which can be problematic for such initiatives.

Department of Energy Technology

Major findings

1. Strengths and weaknesses of the department

General strengths of the Energy and Electrical engineering panel:

- Research is of very high standard and highly relevant
- Excellent and top-level research track-record of the staff members
- Excellent laboratory infrastructure, being unique in some aspects
- The research areas covered are comprehensive
- The projects presented by young researchers were impressive, with fresh ideas and promising funding
- A large part of funding is obtained from agencies and industry through national programs
- In general, strong links with industry
- Excellent packages for the Junior faculty staff

Additional strengths of this department

- The research areas covered by the three divisions are well structured and complementary between each other
- Developed modelling tools with the uniqueness of being open-source software, that have big impact
- Projects with strong impact on sustainable development and with focus on developing countries
- Very international teams
- Good balance among seniors and young researchers

General weaknesses of the Energy and Electrical engineering panel

- In some areas, the research is fragmented and sub-critical
- In some areas, there are limited basic research activities
- Relatively low number of junior faculty
- There is no career path for researchers other than becoming docents There is limited EU funding
- The number of PhDs per research staff is low and has been decreasing in the last few years

- Too much pressure on the faculty members because they need to secure funding for the lab technicians
- Very little evidence of collaboration among the different research groups within the divisions and among divisions

Additional weaknesses of this department

- Funding in turbomachinery is changing
- The business model for the available open-source software is not clear
- Weak visibility at national level in terms of sustainability work

2. Relevant and forward-looking objectives

The research interest areas may be too many for the number of staff.

3. International community engagement

Strong international collaborations.

4. Future potential of the department

The department has the potential to open new ideas and topics, but their big dependence on industry funding hinders the potential for basic research and new ideas.

The complementary nature of the department expertise has the potential for strong cross-layer research in many areas, that is essential for the future and should be exploited.

5. Recommendations

General recommendations

- A more strategic vision and roadmap (5-10 years) promoting collaboration around larger flagship projects is recommended
- This strategy should also ensure larger collaboration between divisions, between the two departments, but also with other departments at KTH
- A strategy to align and coordinate fundamental and applied cross-disciplinary research, beyond the immediate need of the local industry, is desirable to maintain, advance and expand their core expertise and enable the departments and its individuals to build up and extend their scientific reputation
- The complementary nature of expertise has the potential for strong cross-layer research in many areas, that is essential for the future and should be further exploited
- New positions should be decoupled from teaching needs. Research needs should also allow to open tenure-track new positions as an opportunity to open research in new directions
- Although most young researchers appreciate their independence in the research, some more guidance from senior researchers may help them

- Definition of a strategic plan to address the issue of low number of PhD students
- Revision of PhD program requirements to reduce the course loads
- Increasing EU funding participation by identifying internal administrative and financial barriers

Additional recommendations for this department

- There is a need to ensure long-term business models for the open-source modelling tools available in the department
- There is some effort in digitalization, but more can be done
- The division of Heat and Power Technology should consider if using a catchier name would help in attracting students
- The Heat and Power Technology division should consider identifying a reduced academic portfolio and cover their portfolio more densely

Specific issues

1. Research profile and quality

a. Central research questions and themes, and main research activities

This department has the viewpoint of working from a system perspective, which ensures collaboration between its divisions; this is encouraged via bi-yearly strategy workshops. Its main aim is to contribute to the sustainable transition for the energy sector.

The department is divided in three divisions:

- Applied Thermodynamics and Refrigeration, focussed on energy transformations in the built environment.
- Energy Systems, with a broad system perspective to investigate energy technologies and innovation with policies for sustainable development.
- Heat and Power Technology, which works on the analysis and design of critical components and systems for harnessing renewable energy in providing sustainable electricity, heat, cooling, water, and other energy services to buildings and systems.

The research themes are usually followed by groups, with a group leader (researcher, Assist. Prof., Assoc. Prof., or Prof.).

b. Contributions to the advancement of state of the art within the research fields of the department

The research at the Department of Energy Technology is ranging from applied research related to the development of components and systems of equipment in the energy system, to techno-economical modelling of the possible scenarios for future energy systems of countries and regions. There is limited basic research carried out within the department.

The advancement of the state of the art can be summarized as:

- How to speed up the adoption of low emission technologies with policy, innovation, and business models.
- How to integrate large shares of renewable energy in supply and transport.
- How energy systems affect, and are affected by other sectors and topics? (e.g., physical connection climate, land, water; across scales – households, cities, regions, nations; circular economy and inequalities).
- How will artificial intelligence and cyber security affect future energy systems, and potentially aid the transformation towards sustainability?
- How to use models with a high spatial and temporal resolution for understanding energy systems?

c. Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

All scientific publications are aimed to reach the most influential international audiences in the specific field. It is the aim of the department to publish in the most highly rated international journals. PhD students are encouraged to publish papers, usually after participating in international conferences.

In the period of evaluation with data available (2012-2019), the department published between 37 and 63 journal papers annually, and between 20 and 40 peer reviewed conference papers annually. The number of publications appear to be steady in the period of evaluation.

The publication impact and journal impact are also stable in the period of evaluation, with an average of around 5 citations per article.

The self-evaluation report states that the number to top 10% researchers are well above the world average, showing good international attention.

The number of publications with international partners as co-authors has increased from around 60% in 2012, to around 75% in 2019. The department's research collaborations are to a high degree an outcome of their funded project collaborations. Both international programs such as the EU Horizon2020 and national programs through the Swedish Energy Agency require consortia collaboration for project funding, being the main sources of funding for the department.

d. Follow-up from previous evaluations

In the last evaluation, RAE 2012, different areas of improvement were identified and have been addressed as follows:

- Researchers' mobility being low. Mobility has increased since 2012, in particular, the number of incoming students and researchers has increased.

- Department more focussed on education than on academic research. The self-assessment report states that this has not improved due to the high teaching load of the academic staff.

- Lack of good branding of the energy research. Many impactful research activities are being carried out, but there is no real coordination from KTH or from the Energy platform to highlight this.

2. Viability and research environment

a. Internal and external funding; current status and strategies for the future

The main funding is external. During the period of evaluation (2013-2020), 70% of funding was from external sources, namely research grants and industry. The main sources of external funding are the Swedish Energy Agency and the European Commission, followed by FORMAS Research Council on Sustainable Development, Vinnova Sweden Innovation Agency, and United Nations FAO. The dependence on external funding means that research depends also on political decisions. This is why steam and gas turbine technology have received less funding, while renewable energy related research has received more. This is very apparent for the Swedish Energy Agency and the European Commission and less for the other funding agencies. Also, the need to get co-funding for most research projects or

PhD salaries means that the internal money from KTH is used for such actions in detriment of investing in new ideas or more basic research.

The department does not present clear strategies for the future funding.

b. Academic culture

Research is organised in research groups, with senior researchers and younger researchers supervising PhD students. There is interaction between groups at different levels. The involvement of industry in most projects and the international projects ensure that researchers and PhD students have the possibility of knowledge transfer and networking. Also, the participation in international conferences is encouraged. Similarly, MSc students are an integral part of research activities. Recently, EGI organises monthly seminars to provide career guidance and interaction among researchers. The self-evaluation report highlights that the researchers see a lot of room for improvement in the academic culture.

c. Current faculty situation and composition of the research team(s)

In 2021, the department had 7 professors (1 female), 8 associate professors, and 3 assistant professors. Four academics are older than 60 years, meaning that replacement might be needed within the next few years. But there is no clear strategy on how this substitution will be carried out.

The department also has 24 researchers (7 females) and 5 post-docs (2 females). The career of these personnel strongly depend on funding availability.

d. Recruitment strategies

The recruitment strategies are two-fold. One strategy for PhD, post-docs, and researchers, which are usually funded by specific project financing with very specific qualifications, and another for academics going to the tenure-track system well established by KTH.

e. Infrastructure and facilities

The infrastructure at the department is, in general, very extensive. There is a clear challenge in maintaining it, both from the point of view of equipment and from the point of view of technician availability.

3. Strategies and organisation

a. Goals for development 5–10 years ahead

The department lists several goals for the next 5-10 years period, which includes:

- To continue developing world leading research in different topics.
- To get 3 new tenure track faculty members in the next 5 years, and another 4 at the end of the 10 years period.

- To develop big internal projects to increase the interaction with other departments in topics such as big data/AI, use of live-in lab, new energy system demonstrators, energy research linked to the transport sector, and energy storage.

- To have a sustainable number of publications and funding per year.

b. Congruence with university-level goals

The department shows clear alignment with KTH goals:

- Leading Education, Leading Research, Leading Collaboration, with closed intertwined education, research and collaboration.

- An integrated KTH, with a very open atmosphere for students, but with gender balance being a pending target.

- A visible KTH, in areas such as energy system analysis.

- An equal opportunities KTH, an open KTH and a KTH in a global world.

- A KTH for a more digitalized world and a KTH for a more sustainable world.

c. Leadership structure and collegial structure

The department follows the structure given by KTH. There are many responsibilities at department level, with the underneath organization (divisions and research groups). Although the school is above the department, there is still a lot of managerial work at department level.

d. Strategies for achieving high quality

The department organizes the quality by work processes, research output, and outreach activities. The department has created new check-points (key performance indicators, KPIs), on top of those given by KTH:

- Quality issues studied by the management team (bibliometric data and publication, funding, recruitment and reach-out to other internal and external stakeholders).

- Division meetings once a month.

- PhD students mid-term seminar.

- PhD students need at least 4 publications to include in their thesis, and at least two should be published in high quality journals.

Identified opportunities are:

- Recruitment of assistant professors and not higher ranks, to attract worldwide talent and better gender balance.

- Open access publications in high impact journals.

- Assessment of new ways of increasing PhD education.
- Finding better ways to impact society.

4. Interaction between research and teaching

a. Interaction between research and teaching at all three levels (B.Sc., M.Sc., Ph.D.) of education

Teaching and research at the department are strongly interconnected and complement each other. This is reflected by work duties of staff at the department, which are typically a mix of research and teaching responsibilities. Faculty following the tenure track are required to actively seek funding for new research ideas where they supervise PhD students and manage research projects, and they act as examiners of courses at the graduate and undergraduate levels. Research staff typically devote 20% to teaching duties such as lecturing within courses, serving as course leaders, and handling supervision for BSc and MSc students. In addition, the department has three lecturers ('adjunkter') amongst its staff members; they are fully devoted to teaching although they all have advanced research degrees (licentiate or PhD). Employed PhD students can be asked to spend up to 20% of their time on departmental duties (without special agreements), which predominantly comprise of teaching duties.

At undergraduate level, teaching goes from fundamental topics to more applied science. At graduate level, students have more contact with research, where for example they work with the software OSeMOSYS.

Moreover, the master theses are another good opportunity of interaction between research and teaching. PhD students are also involved in MSc thesis supervision.

Connecting teaching to research during the graduate and undergraduate studies prepares the students for the research tasks in the degree projects, making the supervisors' job less demanding and more interesting in terms of having more time to focus on research methodology and results.

Finally, the department offers PhD level courses. Some PhD courses belong to the Erasmus Mundus joint PhD program Environomical Pathways for Sustainable Energy Services and have been offered to internal and external students.

The department also organises research seminar with the objective of achieving active participation of students, who present their research results to other PhD and MSc students.

5. Impact and engagement in society

a. Relevance, scale, and impact of the department's current engagement with society and industry

The department carries out applied research related to the ongoing energy transition. The transition needs changes in the power generation and for heating purposes. Access to clean energy for all is one of the key aspects of the department research. The research at the department is supporting the transition in many different ways and is directed both towards more general questions of interest for planners and policymakers, and towards development of new technology which, in shorter or longer perspectives is of importance to different parts of the industry.

Several projects at the department are based on open-source software developed at the department, related to evaluation of different options for expanding the energy infrastructure in developing

countries, or how to use the existing resources in terms of land, energy and water considering the climate challenges. Other projects have been related to policies and technology for urban mass transport systems. Renewable energy sources have also been a research topic in the department, as well as energy storage.

The department has a lot of links with the industry, showing a very high impact to it. Global impact on energy policies is achieved through collaborations, among others, with the International Energy Agency, United Nations, and World Bank. Outreach to society is not as clear, and there are areas where a higher impact to the Swedish society could be reached (i.e., sustainability for countries in transition).

b. Research dissemination beyond academia

Most outreach of the department is done in relation with industry. But the department also is engaged in working groups such as IIR, IEA, and ISES. The department also participates in newsletters directed towards specific technical fields of interest and has participated in media outreach.

c. Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

The departments had identified clear alignment with the SDGs. Those with higher impact in the department are SDG 7 and SDG 13 (Affordable and clean energy and Climate action), followed by SDG 9, SDG 12, SDG8, SDG 6, AND SDG 11.

d. Plans and structure for increased impact

The department is making a coordinated effort on enhancing the creation, capturing, and communicating the societal impact of all its research activities.

The plans to increase this impact include an impact case collection in a systematic way, including it as an important criterion in the hiring process, including more digitalisation in the departments research, and growing towards more interdisciplinary and trans-disciplinary research. To achieve this last goal, the department should increase the collaboration with other KTH departments (for instance computer science or materials science).

The self-evaluation report did not highlight entrepreneurial activities, such as number of patents or spin-offs, even though they exist.

6. Recommendations for strengthening the department and its future potential

<u>General recommendations:</u>

- A more strategic vision and roadmap (5-10 years) promoting collaboration around larger flagship projects is recommended
- This strategy should also ensure larger collaboration between divisions, between the two departments, but also with other departments at KTH

- A strategy to align and coordinate fundamental and applied cross-disciplinary research, beyond the immediate need of the local industry, is desirable to maintain, advance and expand their core expertise and enable the departments and its individuals to build up and extend their scientific reputation

- The complementary nature of expertise has the potential for strong cross-layer research in many areas, that is essential for the future and should be further exploited

- New positions should be decoupled from teaching needs. Research needs should also allow to open tenure-track new positions

- Although most young researchers appreciate their independence in the research, some more guidance from senior researchers may help them

- Definition of a strategic plan to address the issue of low number of PhD students

- Revision of PhD program requirements to reduce the course loads

- Increasing EU funding participation by identifying internal administrative and financial barriers

- Reinforce institutional support to platforms (such as Energy and Digital Futures) and specific centers or labs (such as Electrum lab, sustainable power lab, KTH live-in lab) to enable visibility and impact of the research

<u>Additional recommendations for this department:</u>

- There is a need to ensure long-term business models for the open-source modelling tools available in the department

- There is some effort in digitalization, but more can be done

- The division of Heat and Power Technology should consider if using a catchier name would help in attracting students

- The Heat and Power Technology division should consider identifying a reduced academic portfolio and cover their portfolio more densely

7. Final remarks

All the needed material was in the self-evaluation report or was given available during the evaluation week.

Overall, KTH is an impressive university with many excellent researchers and research projects. Many of the concerns with respect to the future research environment relate directly to the funding system that nevertheless has been adequate in providing enough small projects to satisfy the immediate needs of the researchers (but this does not motivate proposals for, for example, EU funding of larger initiatives). In addition, the restrictions on the hiring of personnel (e.g., support staff can only be offered 2-year contracts) makes it challenging to secure good technicians. It is also not possible to stay at KTH after starting a spin-off which can be problematic for such initiatives.