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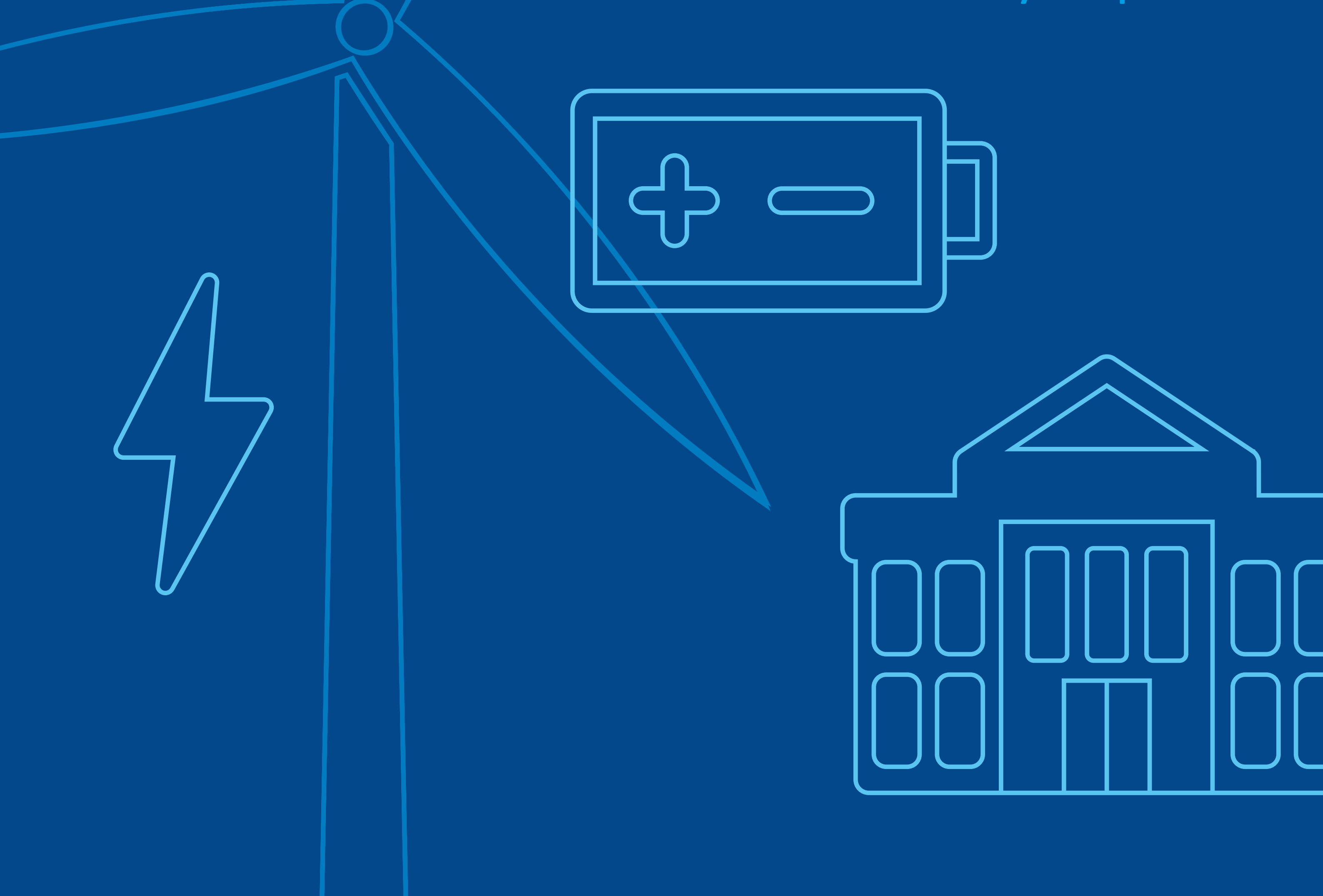
UNIVERSITIES IN THE SET-PLAN

Energy Research and Education at European Universities

The UNI-SET Universities Survey Report



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The UNI-SET Universities Survey Report

UNIVERSITIES IN THE SET-PLAN

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1 Introduction

1.1 Background

Energy Research, Innovation and Competitiveness is a Energy Union policy priority. As the European Commission explains, "Research and Innovation (R&I) must be at the very heart of the Energy Union. If Europe's Energy Union is to be world number one in renewable energies, it must lead the next generation of renewable technologies and storage solutions".[1]

This development changes the nature of the European Strategic Energy Technology Plan (SET-Plan), Europe's prime instrument for aligning EU policy with national research policy in this area since 2007, making it a major tool for implementing the Energy Union.[2]

Universities in the SET Plan (UNI-SET) is a 3-year project supported by the 7th Research Framework Programme and coordinated by the European University Association (EUA) in cooperation with KU Leuven, which represented the universities in InnoEnergy.[3] The project aimed to "mobilise the research, education and innovation capacities of European universities" to better contribute to addressing the challenge of creating a sustainable, affordable and secure energy system for society. It also sought to facilitate the creation of multidisciplinary collaborations between European universities to advance knowledge and address Energy Union and SET Plan objectives. UNI-SET structured higher education support and input for the SET-Plan and Energy Union objectives as a Coordination and Support Action.

To address energy sector needs in terms of education and research, the European Commission previously published the SET-Plan Education and Training Roadmap[4] and the SET-Plan Integrated Roadmap[5]. EUA helped draft these documents on behalf of its membership through the European Platform of Universities in Energy Research & Education (EUA-EPUE). Subsequently, UNI-SET and EUA-EPUE contributed to the SET-Plan Key Action Consultations and several SET-Plan Temporary Working Groups.[6]

1 COM(2015)080, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0080&from=EN
2 COM(2015)6317 final, available at: https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v8_0.pdf
3 The Third Parties to the project are: Karlsruhe Institute of Technology (KIT), Royal Institute of Technology (KTH), Grenoble INP, UPC BarcelonaTech, and Jagiellonian University.
4 https://setis.ec.europa.eu/setis-output/education-training-roadmap
5 https://setis.ec.europa.eu/set-plan-process/integrated-roadmap-and-action-plan
6 https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan

1.2 Objectives of the Universities Survey

UNI-SET conducted the Universities Survey to gather information about energy research and education at Europe's universities. It sought to identify and gather key information on university research and education programmes at master's and doctorate level in all areas of knowledge related to energy as a first step towards mobilising universities under the SET-Plan. It surveyed programmes covering the entire spectrum of academic fields, from 'hard sciences' to social sciences, arts and humanities as these graduates and researchers can help us move towards a low-carbon society using the skills acquired through their studies, research and other university activities.

The survey followed a previous exercise launched in 2010 by EUA that aimed to provide the first empirical basis for university input to the SET-Plan process. It also laid the foundation for the creation of the EUA-EPUE platform.

Besides analytical interest, the survey was designed to enable the development of free online, interactive, thematic maps giving an overview of the European university landscape in the field of energy. The data will also provide the insights to identify multidisciplinary educational and research gaps and opportunities and to develop recommendations for European energy research, innovation and higher education policy.

Together with the UNI-SET Employers Survey 2017, collecting employers' views on energy education and training in Europe, this report is part of the main UNI-SET deliverables providing empirical evidence about the state of energy research and education at Europe's universities.

Project Consortium

2 Survey Design and Implementation

2.1 Survey Design

The questionnaire was designed between September 2014 and 7th April 2015. The draft process used previous experience from a survey conducted by EUA-EPUE as the basis for the UNI-SET Universities Survey.

The questionnaire went through several rounds of development. This included consulting the material and knowledge available at EUA[7] and internationally validated manuals like the OECD Frascati and Oslo manuals as recognised practices for measuring different dimensions of research, innovation and education activities at national or organisational level. The questionnaire was tested, validated and refined at every major development phase.

Staff and funding indicators are based on existing OECD definitions, e.g. for funding models and research staff. The decision to use available and accepted indicators was taken in order to minimise the work for those surveyed, as they could be expected to be experienced in answering similar questions in other national or international surveys.

Existing classification systems such as the ISCED Fields of Education and Training 2013,[8] the UNESCO Standard Nomenclature for Science and Technology[9] and the EU SET-Plan Areas, were used for similar reasons.

Research applications, projects and publications are often classified for statistical or bibliometric purposes using the UNESCO Standard Nomenclature for Science and Technology. In parallel, educational programmes including master's programmes, are usually classified by Fields of Education and Training. Thus, university staff can be expected to be familiar with the classification systems used. The SET-Plan areas were used as the project takes place in the context of the SET-Plan and because they provide a comprehensive classification for research activities in the field of clean energy technology and services.

The questionnaire was tested and validated over a period of six months through:

a. Internal review and discussions between EUA-EPUE staff and the Chair of the EUA-EPUE Platform
b. Discussions within the Project Management Group (PMG)[10]
c. A pre-test involving members of the Third Party Consortium[11]
d. Discussions and pre-tests involving members of the Steering Committee[12]

7 In particular the aforementioned EUA-EPUE survey and the EUA Trends questionnaires.
8 http://eqe.ge/res/docs/228085e.pdf
9 http://unesdoc.unesco.org/images/0008/000829/082946eb.pdf
10 The project staff of EUA and KU Leuven are represented in the PMG.
11 The Third Party Consortium consists of five universities: Grenoble INP (France), Jagiellonian University (Poland), Karlsruhe Institute of Technology (Germany), Royal Institute of Technology KTH (Sweden) and UPC BarcelonaTech (Spain).
12 http://uni-set.eu/index.php/project/steering

The objective of the different testing phases, in particular of PMG and Steering Committee dialogue, was to ensure the maximum reliability, validity and relevance of the data collected, i.e. to ensure that the questionnaire would allow respondents to describe their institutions and programmes in a way that reflects the institutional realities and practices at European universities.

2.2 Survey Structure

The final questionnaire is structured into five main sections of varying length (see Figure 1 below). The full questionnaire can be downloaded from the UNI-SET Universities Survey website.[13]

- **Part 1** contains information about the university itself, e.g. the size of the student body, staff numbers, network membership, funding levels and, importantly, questions regarding specific energy initiatives that are of (strategic) relevance to the university.
- **Part 2** asks questions about master's programmes, e.g. student population, cooperation with other organisations, Fields of Education and Training, SET-Plan areas and whether they are dual/joint degrees.
- **Part 3** addresses Research Topics and Doctoral Programmes, specifically, and analogous to Part 2, inquires about research staffing and collaboration with other organisations. UNESCO Standard Nomenclature for Science and Technology was used to classify research topics, SET-Plan Areas, and adjacent/integrated doctoral schemes.
- **Part 4** identifies development stage activities at participating universities through questions about the type and stage of the activities. The classification systems used in Parts 2 and 3 are used here too. Finally, this section asks about the sources of funding and partners sought for the respective activities.[14]
- **Part 5** concludes the questionnaire with feedback questions about the questionnaire itself – and asks respondents to agree with the disclosure policy for inclusion in the maps.

→ Participate
Register at any time on:
http://universities.uni-set.eu

Figure 1
Questionnaire overview

1. University Profile	2. Master Programmes	3. Research Topics & Doctoral Education	4. Plans for new programmes & activities	End of Survey
• Contact • Address • Size and networks • Budget • Energy focus	• Overview • Cooperation • Joint degrees • Fields of education and training • SET-Plan areas • Upgrades	• Overview • Cooperation • Fields of science and technology • SET-Plan areas • Upgrades • Doctoral schemes	• Overview • Fields of education and training • Fields of science and technology • SET-Plan areas • Cooperation & Funding	• Review • Disclosure policy • Submission

13 http://universities.uni-set.eu
14 The response rate to this part of the survey prevented inclusion of the findings in this report.

2.3 Data Collection and Sample

The UNI-SET Universities Survey was carried out in recurring phases. This method was deemed appropriate for several reasons: respondents can work towards defined deadlines in a structured and focussed manner, the data collection and analysis timeline could be aligned with other project activities such as Energy Clustering Events, and marketing to encourage participation could be concentrated over a certain period. So far, 4 survey waves have been conducted since the April 2015 launch. At the time of writing this document in November 2017, 231 universities had signed up to the survey. All of results in this report are based on the input received before the end of the 2nd wave, i.e. before 15th December 2015.

From the full or partial responses received from 202 universities before December 2015, 864 individual research topics, including 451 with associated doctoral programmes, were identified. In total, these topics represent 9,833.28 full-time equivalent (FTE) research staff and 6,286.57 doctoral candidates (FTE). The survey also identified 579 master's programmes with a total of 36,903 master's-level students.

The difference between the total number of registrations and the number of 131 universities appearing in the Atlas can be explained by three factors:

a. Failure to respond, i.e. universities who signed up to answer the questionnaire then failed to provide a response
b. Failure to provide an answer in a relevant field resulting in quality control, i.e. universities that did not provide any information about Fields of Education and Training, the SET-Plan Areas or where master's programme websites were not displayed in the Atlas,
c. Non-agreement with publication: a number of universities requested to not to be displayed in the Atlas even though responses would have been of sufficient quality to be published.

3 Findings

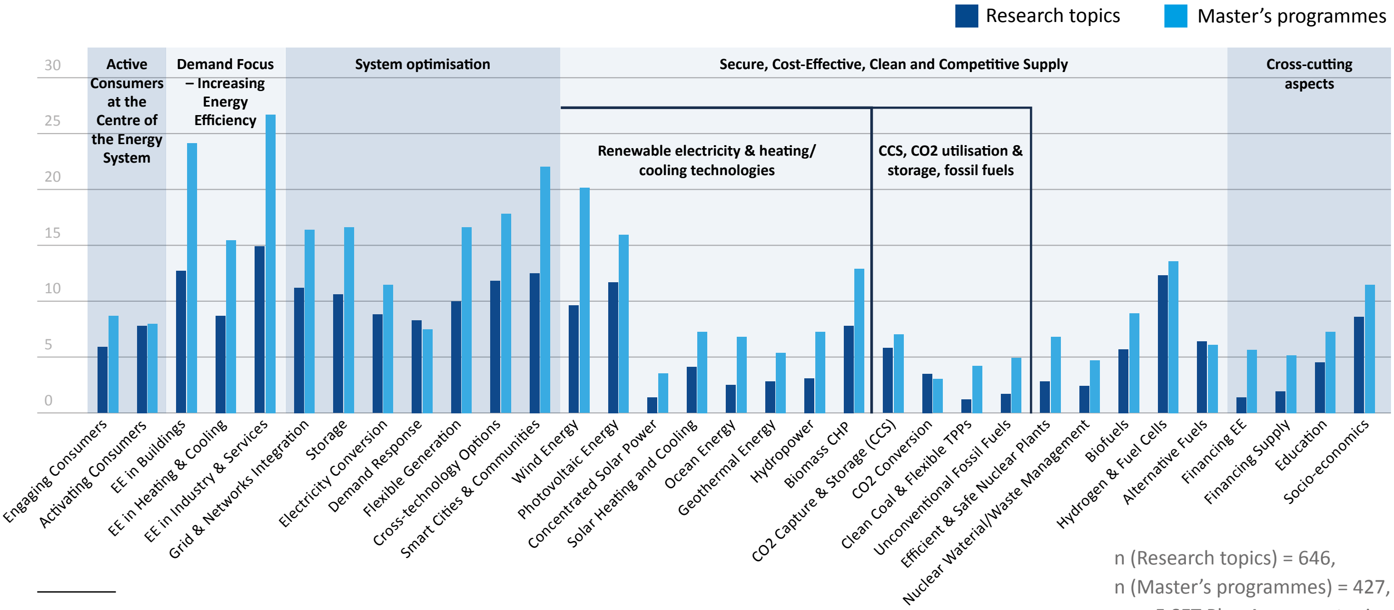
3.1 SET-Plan Areas

One of the survey's main objectives was to identify the scope of university activities in priority areas of the SET-Plan in order to meet the objective of mobilising universities under the SET-Plan. Each master's programme and research topic was therefore assigned up to five different SET-Plan areas.

The classification is based on the categorisation used in European Commission document *Towards an Integrated Roadmap: Research and Innovation Challenges and Needs of the EU Energy System.*[15] The SET-Plan areas were selected as they provide a comprehensive classification of research activities in the field of sustainable energy. Two further classification systems were used in the survey be able to accommodate any programmes that did not fit into SET-Plan areas (for example, some universities reported activities relating to the oil and gas sector).

Figure 2 below shows the outcome of these questions. The chart displays how SET-Plan Areas are covered by master's programmes (light blue) and research topics (dark blue). The

Figure 2
SET-Plan activities overview (%)



n (Research topics) = 646,
n (Master's programmes) = 427,
max 5 SET-Plan Areas per topic

15 https://setis.ec.europa.eu/system/files/Towards%20an%20Integrated%20Roadmap_0.pdf

percentages indicate the share of programmes/topics within the sample for the respective SET-Plan Area. Individual programmes can be counted multiple times under several SET-Plan Areas, which is why some percentage totals are above 100%.

Broadly similar patterns are visible for research topics and master's programmes in all SET-Plan areas. Master's programmes show higher percentages in most fields. The average number of SET-Plan areas in a master's programme is 3.5, while the average SET-Plan areas per research topic is 2.9. This could reflect master's programmes' broader orientation than research topics.

In some areas (e.g. under *Active Consumers, Electricity Conversion, Hydrogen and Fuel Cells,* and others), there are little to no gaps between the percentages achieved by research topics and master's programmes. This pattern is only reversed in *Alternative Fuels, Demand Response* and *CO2 Conversion,* where slightly higher research activity is reported.

Overall, the percentages range from 20-25% in energy efficiency-related fields to less than 5% in areas such as *Concentrated Solar Power, CO2 Conversion* or *Clean Coal*. Research into the financial aspects of clean energy technology is only present in 1-2% of research topics.

3.2 Multidisciplinarity

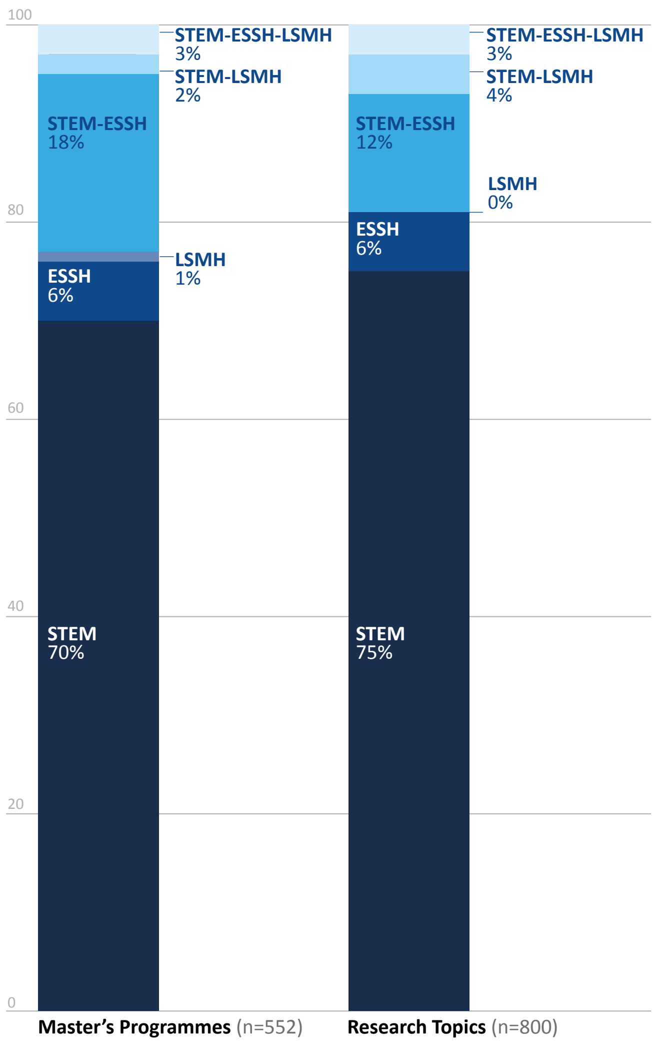
One goal of this mapping was to identify the level of multidisciplinarity of master's programmes and research activities. In order to allow for a basic typology of multidisciplinarity, a question about "broad fields of knowledge" was introduced. It was included, slightly tailored, for each master's programme and research topic.

> *Question*: Which **broad fields of knowledge** are covered by the contents of the programme / activities of the research topic?
> **STEM** (Science, technology, engineering, mathematics);
> **ESSH** (Economics, Social sciences and Humanities);
> **LSMH** (Life science, medicine, health)

The responses are displayed in Figure 3. Based on the multiple-choice answers to the question, 7 different answer types were possible. The charts display the shares of these types across all master's programmes or research topics.

The figures highlight that both master's programmes (70%) and research topics (75%) are highly concentrated on STEM fields. ESSH areas account for the second-highest monodisciplinary area at 6% of each programme type. Multidisciplinary studies are most prevalent in the combination of STEM and ESSH with 18% of master's programmes and 12% of research topics combining both fields. Activities consisting of or being conducted in combination with LSMH have only a marginal presence in this sample. Master's programmes or research topics combining all three broad fields of knowledge represent 3% of both samples.

Figure 3
Broad fields of knowledge (Master's Programmes and research topics) (%)



Master's programmes appear to be more multi-disciplinary, displaying higher numbers of cross-disciplinary activities than research topics. This may reflect a trend of educational programmes covering broader areas than research activities.

A further look into the individual fields represented by the broad categories of STEM, ESSH and LSMH is provided in subsequent sections.

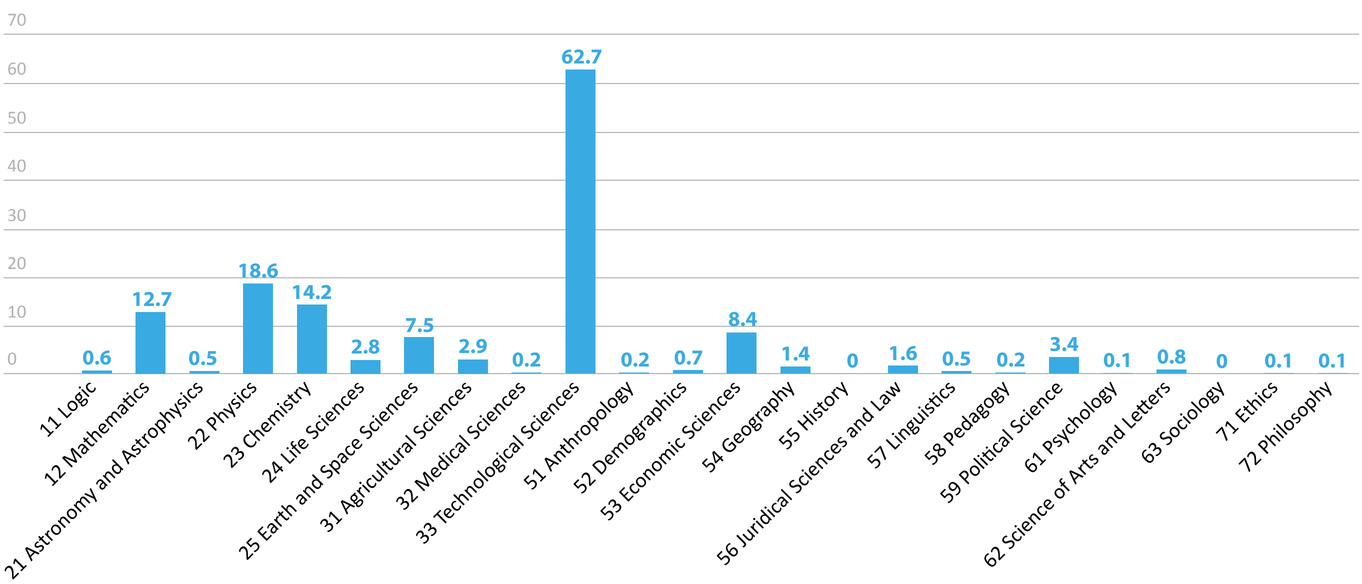
3.3 Fields of Science and Technology

While the SET-Plan areas provide an overview of the fields of application in the energy system, the UNESCO Fields of Science and Technology make it possible to gather information about the disciplinary orientation of research topics.[16] A total of 656 research topics provided answers about their disciplinary focus.

As highlighted below in Figure 4, most research topics are anchored in technological sciences, physics, chemistry and mathematics. Economic sciences and political science are in the minority in ESSH disciplines at 8.4% and 3.4% respectively, reflecting the pattern reported in Section 3.2 Multidisciplinarity. This includes multidisciplinary projects such as technological projects with an ESSH component. Only 1.6% of topics include research in *Juridical Sciences* and *Law*. The distribution suggests that research at the universities surveyed is strongly oriented towards STEM fields and that there is more room for cooperation between STEM and ESSH researchers.

Technological Sciences can be further broken down into sub-disciplines, as shown in Figure 5. This figure demonstrates that the major fields in engineering sciences are: electrical engineering, power technology and environmental engineering. This suggests a strong focus on research related to electrical energy systems and technologies. Instrumentation technology, materials research, mechanical engineering and chemical engineering are other notable disciplines.

Figure 4
Fields of Science and Technology in research topics
(%)



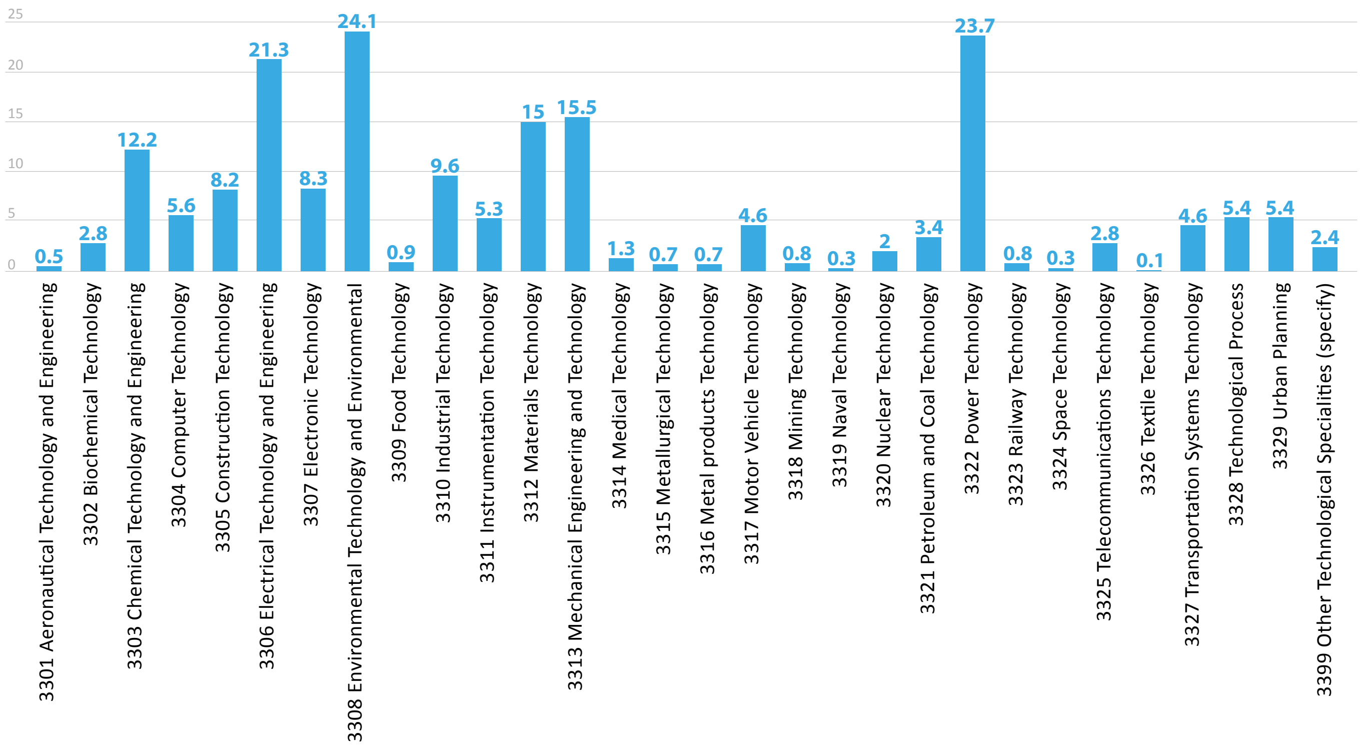
16 http://skos.um.es/unesco6

Three main findings can be derived from Figures 4 and 5. First is the clear emphasis on STEM research, second the concentration on electrical and power engineering and thirdly, Figure 5 also reveals a notable variety of different research foci within the STEM areas.

Figure 5

Fields of Science and Technology-technological Sciences in research topics

(%)



3.4 Fields of Education and Training

Each master's programme was assigned several SET-Plan areas, as well as the Fields of Education and Training covered by each programme under the International Standard Classification of Education (ISCED-F 2013).[17] In total, 447 programmes answered this question. A programme may be counted in several fields as they were allowed to list up to 8 fields.

The pattern in Figure 6 is broadly similar to results in other items. Programmes are highly concentrated on engineering and 'hard sciences'. Nevertheless, master's programmes include a higher share of social and behavioural sciences or business and administration than research topics. master's programmes seem to be broader than research topics, as noted in Section 3.2 Multidisciplinarity.

The *71 Engineering and Engineering Trades* Field from Figure 6 is further broken down into individual subjects in Figure 7 below. Perhaps unsurprisingly, Electricity and Energy is the main field, covered by 61.5% of programmes. Nevertheless, a number of different but related fields such as *Environmental Protection* and *Electronics* feature highly in the master's programmes surveyed and are addressed in 31.8% and 21.9% of cases, respectively.

Figure 6
Fields of Education and Training in master's programmes
Share of programmes (%)

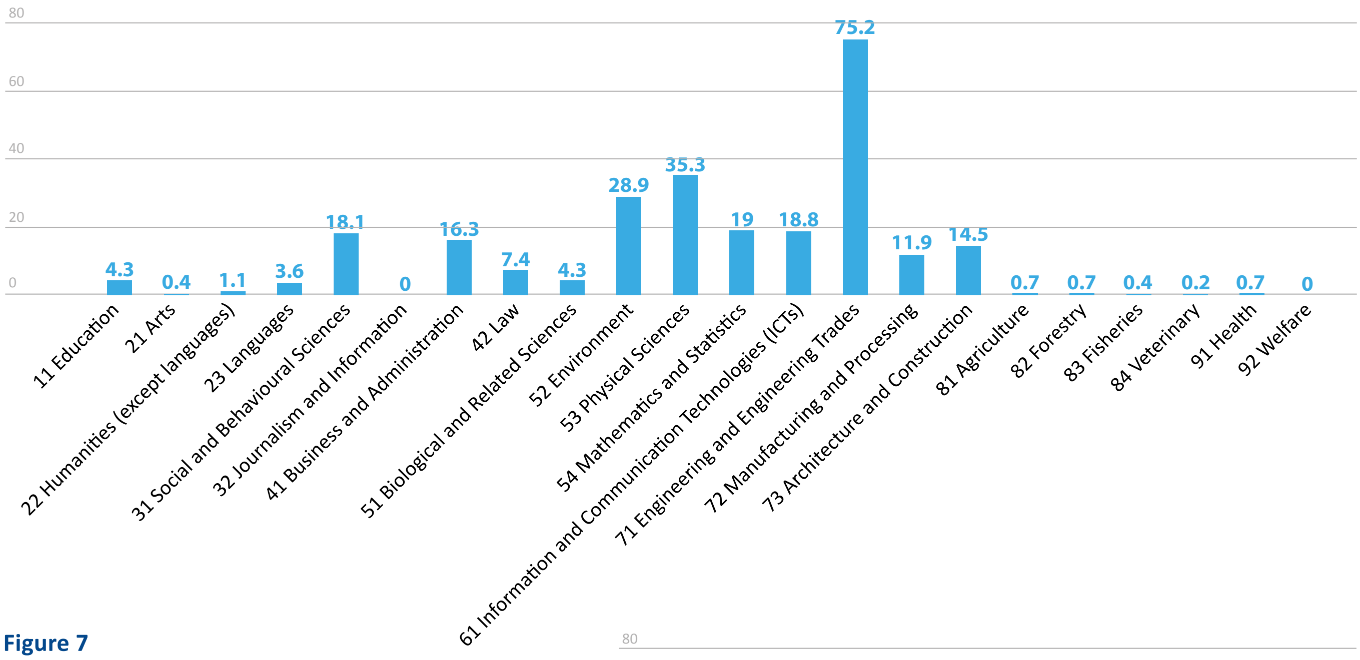
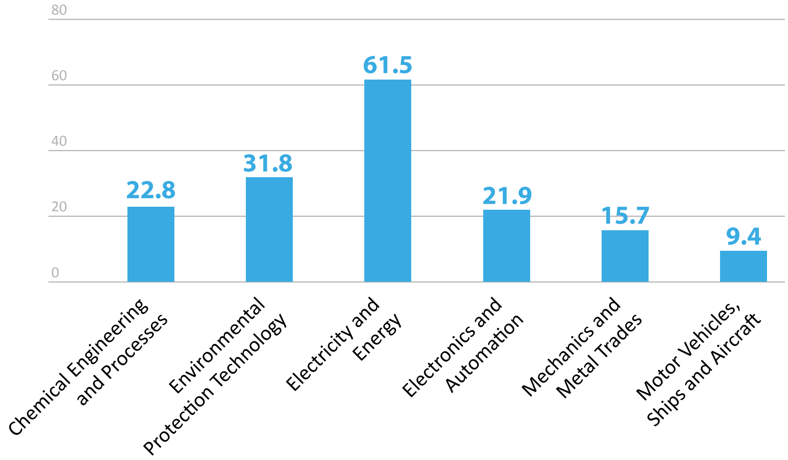


Figure 7
Engineering and Engineering trades in master's programmes
Share of programmes (%)



17 http://www.uis.unesco.org/Education/Documents/isced-fields-of-education-training-2013.pdf

3.5 Master's Programmes: Students and Structure

Several different measures were used to gather information about the evolution of student populations, ECTS per programme, the use of English as a teaching language and graduate employment. Attention was also paid to the total number of students per programme, annual student intake, the ratio of international students and the gender ratio. The findings are shown in Figures 8A-D below.

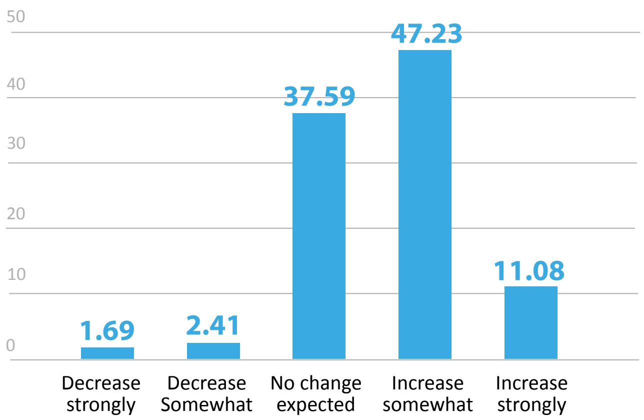
Generally, most respondents expect increases in enrolment or stagnant numbers. There is a strong trend for 2-year programmes. Only 15% are 60 ECTS master's programmes. 25% report a 90 ECTS credit load. In terms of English language instruction, the sample is almost evenly split between programmes taught mainly in local languages (43%) and those mainly taught in English (46%). Most graduates are in employment 1 year after graduation, although the quality and type of employment is unknown.

Figures 8A-D

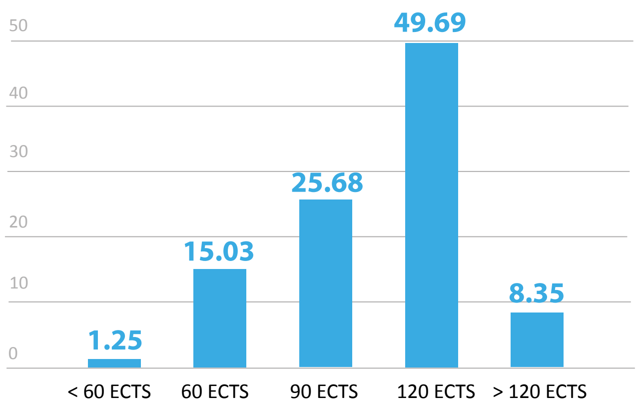
Master's programme data

Share of programmes (%)

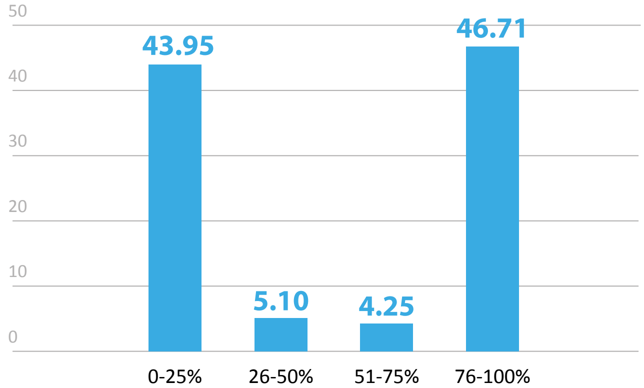
How do you expect the number of students to evolve in the next five years? (n=445)



Total number of ECTS credits for the programme? (n=479)



Percentage of the programme (e.g. in ECTS) conducted in English? (n=471)



Graduate in employment one year after their graduation? (n=307)

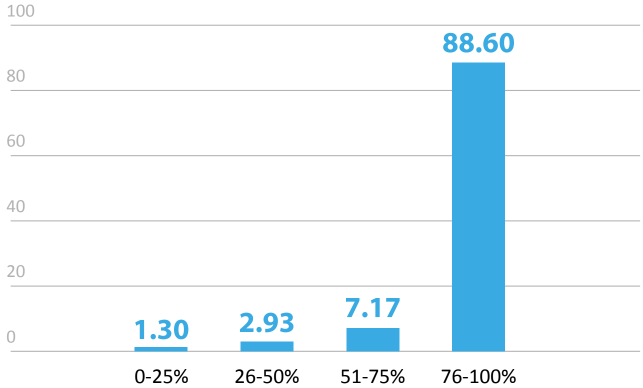


Table 1 shows that on average, the master's programmes surveyed accept 35.6 new students each academic year and had an average of 79.7 students enrolled on each programme at the time of the survey. The ratio of international students was 26.3% and 30.6% were women. In total, 15,852 new students are accepted annually and a total of 36,903 students are enrolled in the surveyed programmes.

Table 1
Student population statistics

Measure	N (valid responses)	Sum	Mean
Student intake	445	15,852	35.6
Total student number currently enrolled in the programme	463	36,903	79.7
Percentage of international students	422	-	26.3%
Percentage of female students	428	-	30.6%

3.6 Research Topics: Staff and Output

Statistics about staff and research output were collected for each research topic. Table 2 shows the various indicators used. Research topics have an average staff of 13.3 professors or senior researchers and include an average of 11 PhD researchers. The numbers of both administrative and support staff are lower at 5 per research topic.

Research output data was collected for the 2011-2014. In this time, 621 research topics reported an average of 156 peer-reviewed publications, amounting to a total of 97,000. Other publications were less prevalent with an average of 35.5 publications over the same period, amounting to a total of 16,771. Both figures demonstrate a focus on research publications and also show that other means of publishing research findings are used. The figures reveal that each member of research staff produced an average of 1.97 publications annually in this period.

Pilot tests (as defined in the survey) are less common, with 2.7 pilots per research topic between 2011 and 2014.

Table 2
Research topic statistics

Measure	N (valid responses)	Sum	Mean
Professors, faculty, post-docs, researchers (FTE)	741	9,833.3	13.3
Doctoral candidates (FTE)	570	6,286.6	11.0
Administrative staff FTE)	488	2,435.6	5.0
Peer-review publications between 2011-2014	621	97,044	156.3
Other publications between 2011-2014	472	16,771	35.5
Pilot tests between 2011-2014	267	717	2.70

3.7 University Strategy and Budget

The first part of the survey contained several questions on the general importance of energy for the respondents' institutional strategy. The questions also asked about expected changes to research budgets and funding for energy research.

Figure 9 shows how 136 universities answered the question of how relevant they consider energy as a field of strategic importance. Given the survey focus, an overwhelming majority deemed this either *Very important* or *Quite important.*

The next two figures show the answers to 2 budget-related questions. Figure 10 shows expectations regarding changes in the overall budget allocated to energy research and Figure 11 shows the most relevant, anticipated, sources of funding.

Most respondents expect there to be an increase in the budget for energy-related research in the coming years (Figure 10), less than 2% foresee a slight decrease. Only 10% anticipate a stagnating budget.

Respondents predict that national (40%) and European (37%) funding programmes will be their main sources of funding (Figure 11). Only a minority of 12% see private funding (from industry) as their most important source of finance in the coming years. This highlights the importance of the availability of public funding for university research, as well as the importance of European funds for the higher education sector.

Figure 9
Energy research and strategic decision-making
How relevant do you consider the broad field of energy research and education for strategic decisions at your university?
(%) n=136

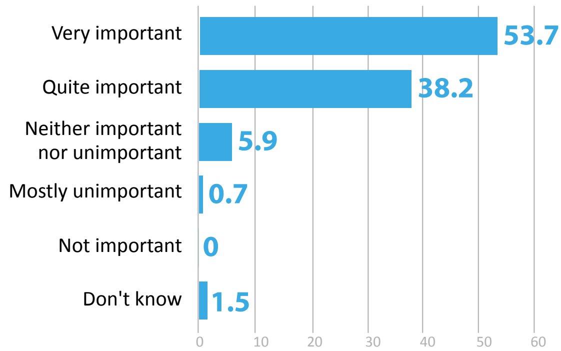


Figure 10
Energy research budget
How do you expect your energy-related research budget to develop within the next five years?
(%) n=119

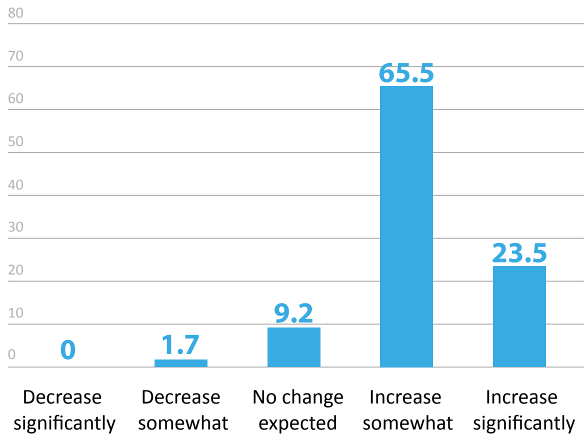
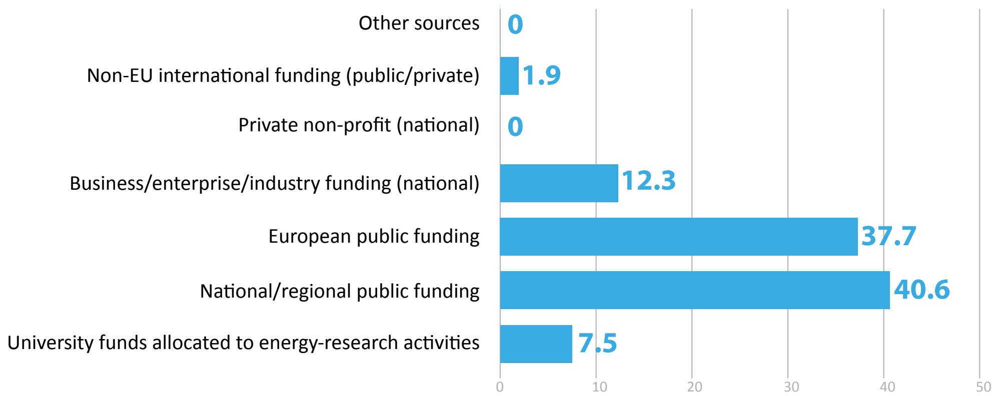


Figure 11
Funding sources
In your opinion, what will be the most important sources of funding for energy research in the next five years (2016-2020)?
(%, first choice)
n=106



3.8 Doctoral Education

The survey achieved 201 responses from across the continent in 2015. It collected data about 864 individual research topics. Of these, 412 had a doctoral programme (defined as being recognised at institutional level). Information about doctoral training was associated with individual research topics and respondents were generally the principal investigators working on these topics.

3.8.1 Structure of Doctoral Education

Where there was a formal doctoral training component connected to their research topic, only 18.1% of respondents stated that this was an individual supervision programme, probably indicating that they are following a traditional apprenticeship model (see Table 3 below). The others were embedded in doctoral schools or structured programmes. PhD candidates therefore either fall outside institutional doctoral education structures, as in one half of the 864 research topics (which is more likely), or the role of the structures does not imply formal recognition of the training programmes as related to the research topics.

Even where there is no formal recognition of the doctoral programme, doctoral candidates may still be covered by institutional rules on admission, supervision, professional development or similar areas. As we know very little about internal accreditation for doctoral programmes, the data does not offer any simple conclusions, but it does raise interesting questions about how far PhD candidates are actually integrated into institutional structures.

The survey data also reveals that the average number of publications produced under a formal doctoral programme, is roughly twice that of programmes without a formally recognised doctoral component. This suggests that the formal component is helpful to the productive integration of doctoral education into research activities.

How is the doctoral scheme organised?
Choose as appropriate (max. 3)

- Graduate or Doctoral school* (GD)
- Structured programme** (SP)
- Individual supervision*** (IS)

* Graduate/doctoral schools: Organisational structures that include Doctoral and sometimes Master students, organised around a particular discipline, research theme or a cross-disciplinary research area and possibly focused on creating a research group/network. It may provide administrative, development and transferable skills development support, organises admission, courses and seminars, and takes responsibility for quality assurance.

** A doctoral scheme with (often partly) predefined curricula with contents/courses that students need to fulfil in order to graduate. It is not integrated in a specific organisational structure responsible for the programme.

*** No specific doctoral programmes offered, but individual supervision by Doctorate research scientific supervisors.

3.8.2 Internationalisation

The share of international (EU and non-EU) doctoral candidates is roughly equivalent to the OECD average, with about 1 in 4 students coming from abroad (see Figure 12A). However, this is unevenly spread between the respondents. A third of the respondents had no international doctoral students, while a fifth had over 50% from other countries. The sample is therefore more or less evenly divided between programmes with very few and programmes with considerable numbers of international PhD students.

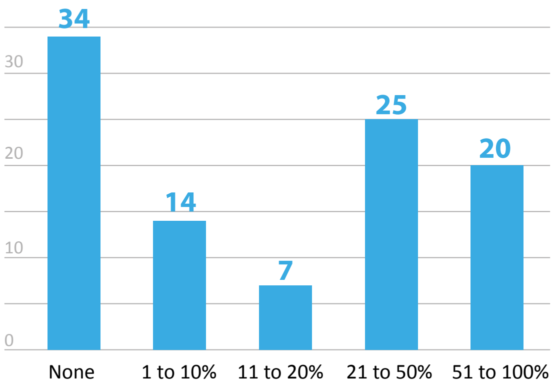
Looking at language as an internationalisation indicator (Figure 12B), doctoral education in the field of energy is largely split between programmes that use English almost exclusively and those that use their local language (when this is not English). A minority use both English and other languages.

Table 3
Structure of doctoral education

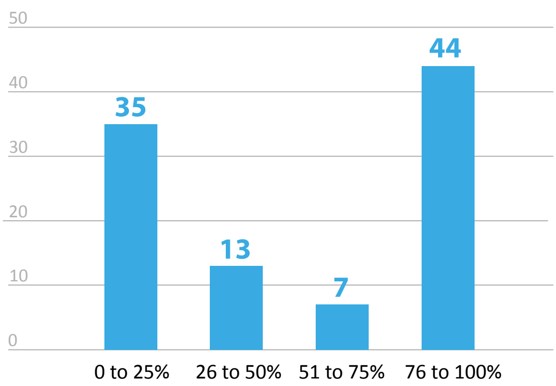
	GD	SP	IS	GP + SP	GP + IS	SP + IS	GD + SP + IS	Total
Absolute	107	38	66	3	15	45	90	**364**
Percentage	29.4	10.4	18.1	0.8	4.1	12.46	24.7	**100**

Figure 12A-B
Internationalisation of doctoral education
Share of doctoral schemes (%)

Share of international doctoral candidates



Use of English (%) throughout the contents of the doctoral track (if course-based) (n=282)

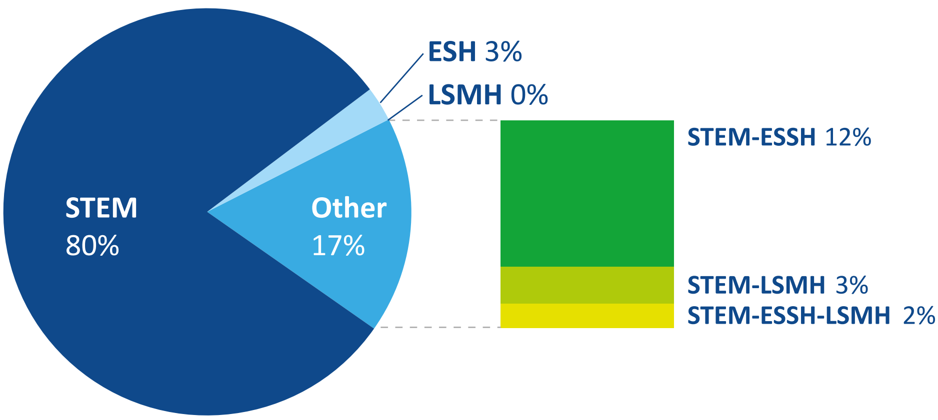


3.8.3 Multidisciplinarity

As mentioned above, energy should invite multidisciplinary research due to the complexity of the issue. We asked institutions to indicate the "broad fields of knowledge" addressed by each individual research topic: STEM (Science, Technology, Engineering and Mathematics), ESSH (Economics, Social Science and Humanities), LSMH (Life Science, Medicine and Health) or combinations of these fields. The results are shown in Figure 13. STEM fields dominate the graph with 80% of doctoral programmes. The same dominance is shown in research topics.

This suggests that genuine cross-field interdisciplinary doctoral education is still a rarity, but that when it does happen, it combines science with social sciences. It is worth highlighting that the number of multidisciplinary doctoral topics is slightly lower than the overall figures for all research topics (see Section 3.2). Doctoral research appears to be more specialised and disciplinary. This could be due to expectations that young researchers will specialise in a single discipline rather than engage in research that crosses disciplinary boundaries.

Figure 13
Multidisciplinarity in doctoral education



3.9 University-Business Cooperation

The UNI-SET data yield insights into different aspects of University-Business Cooperation across 864 research topics and 579 master's programmes in the field of energy. This provides a unique overview of how universities work with different types of partners (businesses, academic institutions, Research and Technology Organisations (RTOs), and other partners).

Respondents were asked to identify the type of partners involved in an activity for both research topics and master's programmes. They were given the following options to choose from: *academic partners* (universities, universities of applied sciences etc.), *industry partners* (companies, company research laboratories, consultancies, etc.), *research and technology organisations* (public or private research and technology organisations), and *other partners* (e.g. ministries, municipal, regional, national or European agencies, NGOs, etc). They were also asked to specify the number of partners.

There was a further question about the type of partnership and mutual activities. For research topics, the potential forms of cooperation were: *research* (project/topic involving partners who conduct research as a part of a project/topic), *access to research infrastructure* (partners offering access to research facilities/infrastructure for research staff and/or the institution giving partners access to research infrastructure) and *hosting doctoral candidates* (offering PhD candidates temporary or permanent positions to allow them to conduct research or write a dissertation at a partner institution).

To allow readers to compare UBC in research with UBC in education, a similar question was included in the questionnaire addressing individual master's programmes. It was adapted slightly to account for differences between cooperation in education and research. Respondents could select from the following options for academic partners: *Education - double or joint degree* (the programme is a double or a joint degree offered in cooperation with other academic institutions) or *Education – other* (regular education activities are provided to programme students, e.g. lectures or other courses, lab facilities and/or dedicating time to students, site visits or other activities. The options available for non-academic partners were as follows: *Education* (regular education activities are provided to programme students, e.g. lectures or other courses, lab facilities and/or dedicating time to students, site visits or other activities) and *Internship/Thesis placements* (the industry partner regularly offers internships for students or allows them to write a thesis at the partner company/organisation).

The questions only covers formal cooperation. This means that ad-hoc or informal exchanges are not reflected in the survey. This also suggests that the level of UBC is higher than reported in most figures, as a 'dark figure' of non-formal collaboration can be assumed.

3.9.1 Overview

Several observations can be made from the data collected about research topics and UBC (Figure 14). First, clear majorities of research topics are implemented in collaboration with research partners (e.g. project partners) from HEIs (>60%) or industry (>56%), almost half with RTOs (>44%) and a quarter with other partners (23%).

The data also reveals that access to other partners' research infrastructure (or vice versa) is common in an eighth to a third of research topics (12-35% of topics), depending on the type of partners.

Researcher mobility is also part of research topics, in particular where academic partners are involved. However, 20% of research topics do not include formal schemes for extramural mobility of PhD candidates to partner organisations.

Energy-related master's programmes offer industry placements in 44% of recorded cases (Figure 15). Placements with RTOs are less common but still widespread with a third to a quarter of master's programmes cooperating with RTOs. Educational cooperation, for example in the form of visiting industry lecturers, is common in 30% of master's programmes. RTOs and Other partners also engage in educational cooperation in 23% or 13% of cases, respectively.

Cooperation with academic partners is less prevalent than in research topics. However, almost a third (28%) of programmes benefit from educational cooperation with other HEIs.

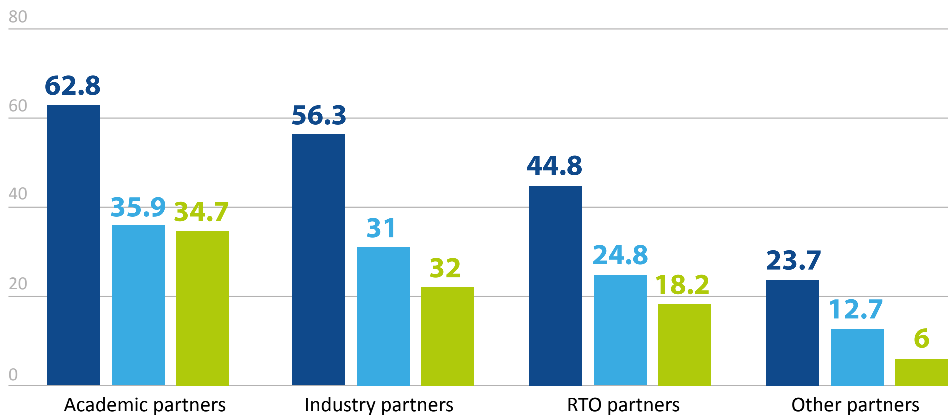


Figure 14
UBC in research
(%)

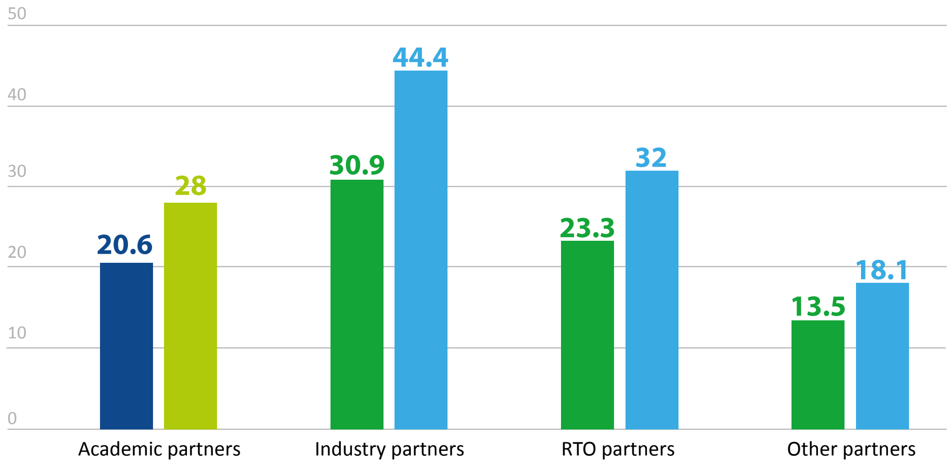


Figure 15
UBC in master's programmes
(%)

3.9.2 UBC in the Fields the SET-Plan

The far-reaching scope of the survey and the number of responses from different European countries gave an interesting insight into the data. How do patterns of collaboration vary between countries and SET-Plan areas? Is UBC more prevalent in some areas of technology than others? Some preliminary answers are obtained by linking the type of research partner with SET-Plan areas and university locations.

Table 4 below shows the average number of partners in each partner type. It is worth nothing that, on average, research topics have more industry than academic partners. Partnerships with RTOs or Other partners are less than half as common with 3.43 to 3.75 partners respectively per research topic.

Table 4
UBC overview

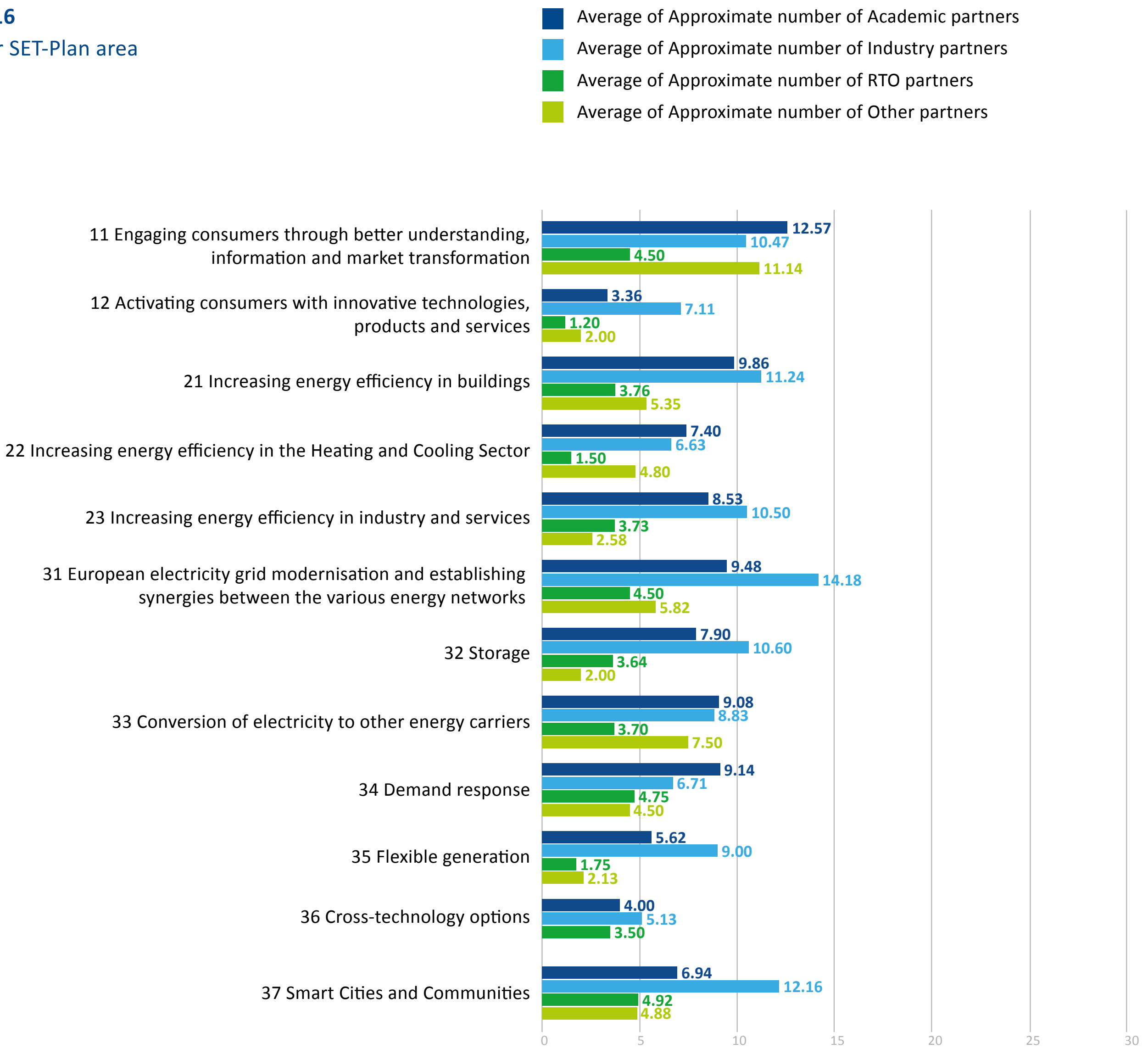
Average Approximate Number of Academic Partners	Average Approximate Number of Industry Partners	Average Approximate Number of RTO partners	Average Approximate Number of Other Partners
8.20	8.86	3.43	3.75

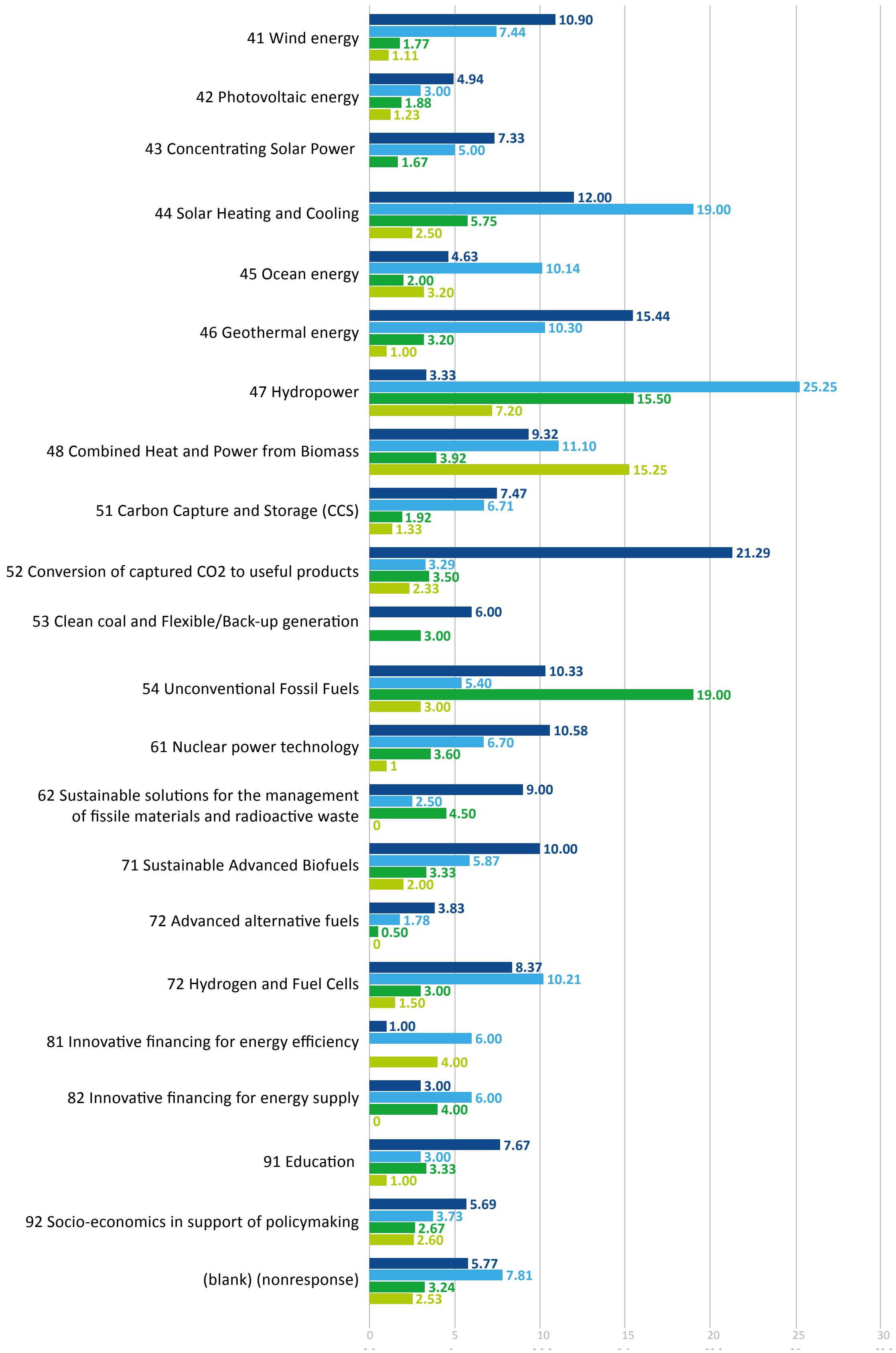
Figure 16 shows the SET-Plan areas on the x-axis and the average number of partners per research topic, broken down into partner types, on the y-axis. It is difficult to pinpoint clear UBC patterns, however some SET-Plan areas show notable deviations from the average number of partners.

Fields 51 *Conversion of Captured CO2 to Useful Products* and 54 *Unconventional Fossil Fuels* are an example of this. The former displays far beyond average levels of academic partnerships, and far below average levels of industry partnerships. The latter shows higher RTO than academic and industry partnerships. Here, the cooperation pattern could be an indication of the stage of industrial development of a technology, with a lack of industry partners pointing to technologies that have not yet reached market readiness or are not sufficiently attractive for industrial R&D.

Cooperations with Other partners occur three and four times more than the overall average in Field 48 *Combined Heat and Power from Biomass* and Field 11 *Engaging Consumers Through Better Understanding respectively.* The sector structure extends beyond traditional R&D actors (e.g. public authorities, consumer and citizen's organisations), which could explain the patterns reported in Figure 16.

Figure 16
UBC per SET-Plan area





41 Wind energy
10.90
7.44
1.77
1.11
42 Photovoltaic energy
4.94
3.00
1.88
1.23
43 Concentrating Solar Power
7.33
5.00
1.67
44 Solar Heating and Cooling
12.00
19.00
5.75
2.50
45 Ocean energy
4.63
10.14
2.00
3.20
46 Geothermal energy
15.44
10.30
3.20
1.00
47 Hydropower
3.33
25.25
15.50
7.20
48 Combined Heat and Power from Biomass
9.32
11.10
3.92
15.25
51 Carbon Capture and Storage (CCS)
7.47
6.71
1.92
1.33
52 Conversion of captured CO2 to useful products
21.29
3.29
3.50
2.33
53 Clean coal and Flexible/Back-up generation
6.00
3.00
54 Unconventional Fossil Fuels
10.33
5.40
19.00
3.00
61 Nuclear power technology
10.58
6.70
3.60
1
62 Sustainable solutions for the management of fissile materials and radioactive waste
9.00
2.50
4.50
0
71 Sustainable Advanced Biofuels
10.00
5.87
3.33
2.00
72 Advanced alternative fuels
3.83
1.78
0.50
0
72 Hydrogen and Fuel Cells
8.37
10.21
3.00
1.50
81 Innovative financing for energy efficiency
1.00
6.00
4.00
82 Innovative financing for energy supply
3.00
6.00
4.00
0
91 Education
7.67
3.00
3.33
1.00
92 Socio-economics in support of policymaking
5.69
3.73
2.67
2.60
(blank) (nonresponse)
5.77
7.81
3.24
2.53
0
5
10
15
20
25
30

3.9.3 UBC per Country

Similar observations can be made in relation to university locations. Do UBC levels for example differ per country? UNI-SET data offers a unique opportunity to find preliminary answers to this question by examining the landscape in the energy and related sub-sectors. Table 5 shows a selection of countries that reported over 10 research topics.

Indeed the data suggests a wide range of industry interactions based on HEI location. The table highlights national differences in levels of University-Business Cooperation. This divide is particularly obvious in (although not limited to) Southern and Eastern European countries, in terms of the average numbers of partners across all partner types. High interaction is reported in a group of mostly Northern European countries: Austria, Denmark, Finland, Ireland, the Netherlands and the United Kingdom. France, Germany, Belgium Norway and Spain form a group close to the average.

Deviation from the average appears lower for *RTO partners* and *Other partners* than for *Academic partners* and *Industry partners.* Given the national differences noted, support for establishing partnerships, UBC and promoting a cultural shift towards more interaction with external partners could increase the capacity for innovation and impact of university research in some countries.

Table 5
UBC per country

Country	Average Approximate Number of Academic Partners	Average Approximate Number of Industry Partners	Average Approximate Number of RTO Partners	Average Approximate Number of Other Partners	N topics*
Austria	20	7.5	5	10	14
Belgium	6.24	8.48	2.53	1.67	55
Czech Republic	3.07	5	2.89	1	19
Denmark	14.78	17.3	3.48	8.68	51
Finland	13.42	19.24	3.95	3.89	28
France	8	7.87	4.29	3.1	77
Germany	5.49	6.49	2.58	2.5	112
Ireland	20.78	12.11	6.8	4.4	26
Italy	4.76	4.73	2.6	1.54	89
Netherlands	11.75	14.67	5	4.5	14
Norway	6.49	6.81	3.46	1.3	41
Poland	3	3.8	1.28	0.68	64
Portugal	3.33	6	3	4	20
Romania	2	1.6	2.13	0.89	12
Spain	8.71	7.58	2.93	2	108
United Kingdom	21.04	17.91	4.48	7.82	63
Total	**9.55**	**9.19**	**3.52**	**3.62**	**793**

Another angle for exploring the data is to compare UBC collaboration between countries and SET-Plan areas. The question is whether UBC depends on the national or sector environment, i.e. whether the UBC structure is more dependent on a national or sector-based innovation system.

Table 6 shows a selection of countries and the average number of partners in the energy efficiency sector. The top row shows the average number of partners for all institutions across Europe. Additional national averages were calculated for the Energy Efficiency sector in a selection of five countries. In the next step, a simple calculation of the difference between the national sector average and a) the European sector average, as well as b) the overall national average for all sectors was performed.

In all five countries sampled, the average number of *Academic, RTO* and *Other partners* in energy efficiency is closer to the overall national average than to the European average in the energy efficiency sector. This could indicate that the structure of extramural cooperation is highly dependent on the national innovation system.

However, in three cases (Belgium, Germany, Spain) industrial partnerships stray from this pattern. Here, the average number of industrial partners is closer to the average number of partners in the field of energy efficiency than to the national average. This suggests that cooperation patterns in the energy efficiency sector in these three countries differ from the normal national cooperation pattern. In all three countries, university-industry cooperation is higher than the respective country average. This phenomenon might be caused by different sector policies or priorities, which could be subject to further research.

Table 6
UBC in Energy Efficiency

Row Labels	Average Academic Partners	Average Industry Partners	Average RTO Partners	Average Other Partners
EE sector average (all countries)	9.9	11.2	3.8	5.4
Belgium (EE average)	3.0	10.5	2.0	N/A
Difference from sector average	-6.9	-0.7	-1.8	N/A
Difference from national average	-3.2	2.0	-0.5	N/A
France (EE average)	5.2	5.2	2.7	1.5
Difference from sector average	-4.6	-4.6	-7.1	-8.4
Difference from national average	-2.8	-2.6	-1.6	-1.6
Germany (EE average)	2.9	8.9	2.0	2.0
Difference from sector average	-7.0	-1.0	-7.9	-7.9
Difference from national average	-2.6	2.4	-0.6	-0.5
Italy (EE average)	2.6	4.4	1.8	1.5
Difference from sector average	-7.3	-5.5	-8.1	-8.4
Difference from national average	-2.2	-0.3	-0.9	0.0
Spain (EE average)	3.0	11.3	1.0	1.7
Difference from sector average	-6.9	1.5	-8.9	-8.2
Difference from national average	-5.7	3.8	-1.9	-0.3

4 Summary and Main Themes

The UNI-SET Universities Survey charts a thriving landscape of research activities and educational programmes in Europe. Universities are active in all areas of the SET-Plan and therefore contribute to a wide range of clean energy solutions and technologies. They contribute to advancing knowledge and teaching students and professionals to tackle the energy challenge.

Yet, the data also shows that multidisciplinary research spanning different fields of knowledge, is still more of an exception than the rule. Energy research and education is rooted in STEM disciplines and other areas such as SSH or LSMH are only a marginal part of the research topics and master's Programmes surveyed. Given the socio-technical nature of energy transition, universities and stakeholders need to work more closely together to make multidisciplinary research and education more attractive and more visible. Other dimensions, such as the connection between digitisation and energy transition opportunities could also warrant stronger action given its political prominence.

Dissecting the data collected on student bodies and master's programmes reveals other notable findings. Almost a quarter of students are international students, meaning that they study abroad or enter a full degree programme in another country. English is widely used in teaching, preparing students for European and international positions and cooperation. The gender ratio shows that, on average, thirty percent of students are women.

The inclusion of over 6,000, often international, PhD candidates in the projects surveyed illustrates the capacity to conduct research and advance scientific knowledge to serve society. Research topics are more productive where PhD students are involved. The main university output is still scientific publications – both peer-reviewed and others. The survey also shows that new, structured approaches to doctoral education are widespread in the field of energy.

University-Business Cooperation is normal in the field of energy. Both master's programmes and research topics are strongly connected to industry partners or other government and social institutions. This shows the need for instruments that support collaborative research and education throughout Europe.

The universities surveyed also emphasise the importance of energy research for their institutional strategies. They embrace the societal challenge of energy and use their own means and resources to provide answers and offer learning opportunities to train the next generation of researchers and professionals for the energy sector. This is reflected in the expectation that energy-related research budgets will soar. European public funding, such as that awarded through the Framework Programmes for Research and Innovation, is seen as a major source of research financing, alongside national funding. Although it varies per country, this also demonstrates the need for European programmes that help universities conduct excellent, multidisciplinary or interdisciplinary research together with other European partners.

In sum, the survey shows many positive signs about the direction of energy research and education at European universities. They are keen to be involved and to put their resources to good use, contributing to resolving a great challenge for European society.

5 Outlook and Future Actions

Mapping the university landscape in energy research and education was one UNI-SET building block. Another work package addressed the needs of energy sector employers and their expectations of university graduates. The results of this activity, which included 6 workshops across Europe and a survey reaching over 120 EU companies, show that expectations of higher education programmes are shifting.[18]

Being able to work in or lead multidisciplinary teams will be a crucial skill for energy professionals. The digitisation of the energy system will also require workers and professionals who know how to use up-to-date ICT tools such as big data analysis, machine learning or artificial intelligence, to name only the most obvious. Knowledge of the regulatory and legal environment will also be needed to develop business models and create and operate profitable companies. Policy makers will also need to understand the intricacies of a decentralised energy system and the new, central role of consumers.

The results of the UNI-SET Universities Survey show that many universities across Europe already offer well-designed, future-oriented teaching programmes. Yet, it also highlights that more can be done in some areas such as ICT, law or business. The large-scale transformation of the current energy system in Europe, including its societal and technological components, requires a workforce that is able to plan and execute the transformation. There also needs to be a talent pipeline for appropriately trained scientists to generate new discoveries and breakthrough technologies.

On the research side, cross-fertilisation between the natural sciences, engineering and social sciences needs to be facilitated. This includes a stronger focus on or at least better integration of social sciences and humanities into major European research and education programmes. The role of consumers who will use new technologies or respond to new business models should also be better linked to the often technology-focussed research agenda. Citizens and consumers are at the heart of the energy transition and cannot be neglected by science policy makers.

EUA-EPUE seeks to continue the work begun with the UNI-SET project when it ends in December 2017. The groundwork was laid with the publication of the *Roadmap for European Universities in Energy*[19] in 2016. Considering the main outcomes of the UNI-SET Employers Survey, the project consortium also decided to draft a report on *Energy Transition and the Future of Energy Research, Innovation and Education: An Action Agenda for European Universities* in 2017. This report seeks to spur teaching and learning innovation at universities with programmes addressing the energy challenge. As a transversal challenge for society, energy demands a holistic research and education approach, and EUA-EPUE aims to support its member universities in developing the capacity to deliver it.

More UNI-SET publications

- Roadmap for European Universities in Energy (2016)
- Energy Transition and the Future of Energy Research, Innovation and Education: An Action Agenda for European Universities (2017)
- UNI-SET Employers Survey Report (publication due in 2018)

18 See the forthcoming report on the UNI-SET Employers Survey.

19 http://www.eua.be/Libraries/publications-homepage-list/roadmap-for-european-universities-in-energy

6 Atlas

EUROPEAN **ATLAS** OF UNIVERSITIES IN **ENERGY** RESEARCH & EDUCATION

A major UNI-SET goal was to not just collect and analyse university activities, but also to make them available for everyone to use. The project therefore created the *European Atlas of Universities in Energy Research and Education* to allows people to search and identify master's programmes and opportunities for doctoral training and research activities at participating universities.

Higher education institutions can use this information to pool capacities and build new multidisciplinary and inter-European networks and cooperation. The Atlas allows potential master's and PhD students to find educational and research programmes that are relevant to their professional and research interests.

These maps help energy companies or employers identify research and education opportunities for the continuing education and training of staff, and to identify potential opportunities to offer students relevant work placements, as well as to identify partners engaged in joint R&D projects with universities across Europe.

At the time of writing in November 2017, more than 130 universities from over 30 countries agreed to make their data publicly available. When the UNI-SET project ends, EUA will assume responsibility for the *European Atlas of Universities in Energy Research and Education* and maintain it for the future. Universities and other higher education institutions will be able to add or update information to create a more complete picture of the energy research and education landscape.

The Atlas is available at:
http://atlas.uni-set.eu and http://energy.eua.eu

Why should your university participate?

If your university offers master's and doctorate programmes and performs research in the field of energy, we strongly encourage you to take part, as this is a unique opportunity to:

- Have your energy-related master's, doctoral and research programmes included in up-to-date, interactive online maps
- Attract potential students and researchers
- Identify and be identified by other universities and stakeholders looking for expertise and opportunities to cooperate in research and education
- Identify opportunities to create multidisciplinary teams
- Create a central point of information about your institution's energy-related activities
- Strengthen the voice of Europe's universities in the energy field to attract more funding opportunities and to advocate the role played by universities in tackling the energy challenge
- Be part of an exceptional, strategically important platform for the university sector

Register your university:
http://universities.uni-set.eu

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About UNI-SET

The UNI-SET project supported the participation of universities in the SET-Plan process and in EU energy research and education in general. Coordinated by EUA, in partnership with KU Leuven and the universities in InnoEnergy, it mapped the activities of European universities in the energy field and produced an online, interactive tool that displays Master's, doctoral and research programmes related to the sector.

Additionally, the UNI-SET project surveyed potential energy field employers to gain insight into the current and future demand for professional skills and knowledge in the sector. Moreover, it organised six Energy Clustering Events addressing the key priorities of the SET-Plan and overarching topics. Some of the main outcomes of UNI-SET are:

- the "European Atlas of Universities in Energy Research & Education";
- fifteen SET-Plan input papers;
- the "Roadmap for European Universities in Energy";
- the report "Energy Transition and the Future of Energy Research, Innovation and Education: An Action Agenda for European Universities";
- the report "Energy Research and Education at European Universities - The UNI-SET Universities Survey Report"

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