Renewable Energies and Energy Efficiency – Six Years of Experience with an Interdisciplinary Master Program

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Abstract

In April 2005, Kassel University launched the new MSc-program "Renewable Energies and Energy Efficiency" (www.energie.uni-kassel.de). There was a consensus that problems related to energy supply and consumption can only be solved by interdisciplinary cooperation. Therefore, five faculties (mechanical, electrical, civil and agricultural engineering as well as architecture) are directly involved in the program. Also the target group of students should hold quite different BSc degrees. This caused special challenges for the curriculum. Furthermore, students should be able to start the program in summer as well as in winter term. The paper discusses issues which have be considered and decided when planning a course program in renewable energies.

1. Introduction

Kassel University is a midsize German university with about 20.000 students and 320 professors. The structure consists of currently 12 faculties. A large number of professors with special fields in renewable energies and energy efficiency were and are active in different faculties at Kassel University. In total more than a dozen chairs teach and research in the fields of

- wind energy
- small hydro power
- PV and electrical energy supply
- grid integration of renewable electricity
- solar heating and cooling
- building physics
- technical services
- industrial energy efficiency
- renewable process heat
- waste engineering
- biomass utilization
- renewable energies for agricultural applications

and furthermore

- thermodynamics and refrigeration technology
- turbo machinery
- high voltage engineering
- building industry
- sanitary environmental engineering

Thus, an interdisciplinary course program in renewable energies and energy efficiency was started, which opened up for the first students in April 2005 (Vajen et al. 2004). Intense discussions lead to decisions about the structure and alignment of the program. Some of the issues are discussed in the following, taking more than six years of practical experience in consideration. The development of the program is based on the regulations and traditions of continental European university programs. This means i.e. an MSc program with three or four terms and a separation of courses and thesis, which has to be prepared at the end of the program. Not all issues discussed in the following might therefore be transferable to other regions.

2. Renewable Energies: Undergraduate and/or Graduate Programs?

This first decision to be made is whether one aims at an undergraduate or a graduate course program or even both. This can be looked at from the student's and from the university's point of view.

It is difficult to foresee what the labor market necessitates in the next 30 years. It is obvious or at least very likely, that the demand will grow rapidly for staff highly qualified in renewable energies. But what means "highly qualified"? Unfortunately, a comprehensive investigation of likely developments in this specific labor market is missing, but probably the optimal qualification for most of the jobs is to be specialist in a specific technology and have furthermore a broad knowledge of energy technology in general and renewable energies in particular. The following arguments have to be considered thoroughly before coming to a decision about BSc and/or MSc programs.

A BSc in renewable energies is especially useful for those students who do not aim at a master degree when they start their studies, but want to get a job in the field of renewable energies. As long as traditional engineering curricula of mechanical or electrical engineering do not contain significant shares of new energy technologies, a BSc in renewable energies is the fastest way to enter the specific fields. The curriculum should contain, if possible, a general education about renewables and a specialization through some elective courses and the BSc-thesis.

An MSc in renewable energies is ideal for those students who hold already a general BSc degree in technical or natural science and intend to specialize further towards renewable energies. These students have already another broad qualification and can therefore enter a wide field of general jobs, fitting even to their primal education if the renewable labor market does not develop as (fast as) expected. Another target group are people who work e.g. in industry already for several years, but find themselves now in a professional "blind alley" and need an additional timely qualification.

A BSc plus an MSc in renewable energies is easier to implement compared to an MSc with broad access alone, as one can assume that all students have more or less the same basic knowledge. In this case, the MSc program should be more specific and focus on one or maximal two renewable technologies. But two academic degrees in renewable energies might also be an overkill, miss the demand and be a bit more risky for the students due to their narrow specialization.

From the university's point of view, the target group of students for an MSc which is based on a BSc in renewable energies are just the own graduates, whereas the target group for an MSc based on a general technical degree is much broader. Taking this all into account, three alternatives remain:

1) A "stand-alone" BSc-program, which was not seen to be appropriate for a university
2) A broad BSc-program in renewables, combined with several particular MSc-programs in specific renewable technologies
3) An MSc-program with broad access of student's qualification and a specialization through elective courses and the thesis.

Kassel University decided to implement the third alternative. This fitted furthermore best to the extant structure with several chairs in different fields of renewable energies and energy efficiency. Furthermore, the program is then especially attractive for students from other universities, which reduces potential trouble with colleagues who fear a competition for students.

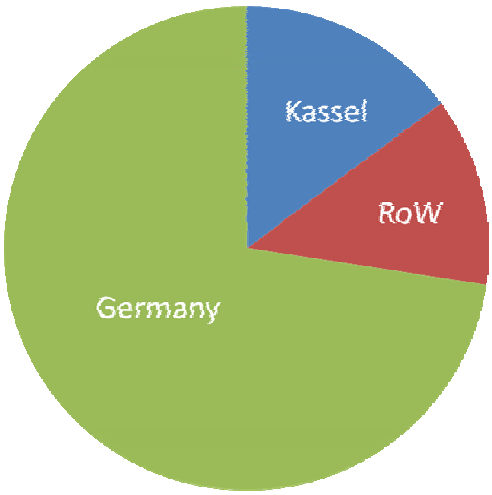

Fig. 1: Regional distribution of the first degree of students 2005-2011 in the master program "Renewable Energies and Energy Efficiency" at Kassel University.

3. Arrangement of the MSc-curriculum

BSc programs can start only once a year, as high school education ends usually once a year in the same season within a country. The season where students graduate is however more or less uniformly distributed. This is caused by delays in the study program of individual students, but (at least in Germany) also due to parallel existence of BSc degrees which last 6 or 7 terms. Thus, the program for MSc-degrees should also start twice a year to avoid long waiting periods for the students. In this case, students start courses in different terms in different order. This demands a particular arrangement of the curriculum, as the staff is limited and the same courses can usually not be offered twice a year. Basic and/or mandatory courses might therefore be split e.g. in a "thermal" and an "electrical" term. As another constraint, basic lectures to a topic should be scheduled in the same semester as continuative lectures as specified in table 1.

Tab. 1: Possible distribution of the curriculum with the aim to study two basic terms in both orders. Biomass might be sorted in both semesters, depending on the main area (e.g. biochemistry or electricity production and grid integration). A general problem is the allocation of thermodynamics and heat transfer, as this field is helpful as a basis of fluid mechanics and biomass as well.

"thermal" term

- Thermodynamics and heat transfer
- Solar thermal technology
- Building physics and technical services
- Geothermal technology

"electrical" term

- Electrical and control engineering
- Photovoltaics
- Fluid mechanics, wind and hydro
- Biomass

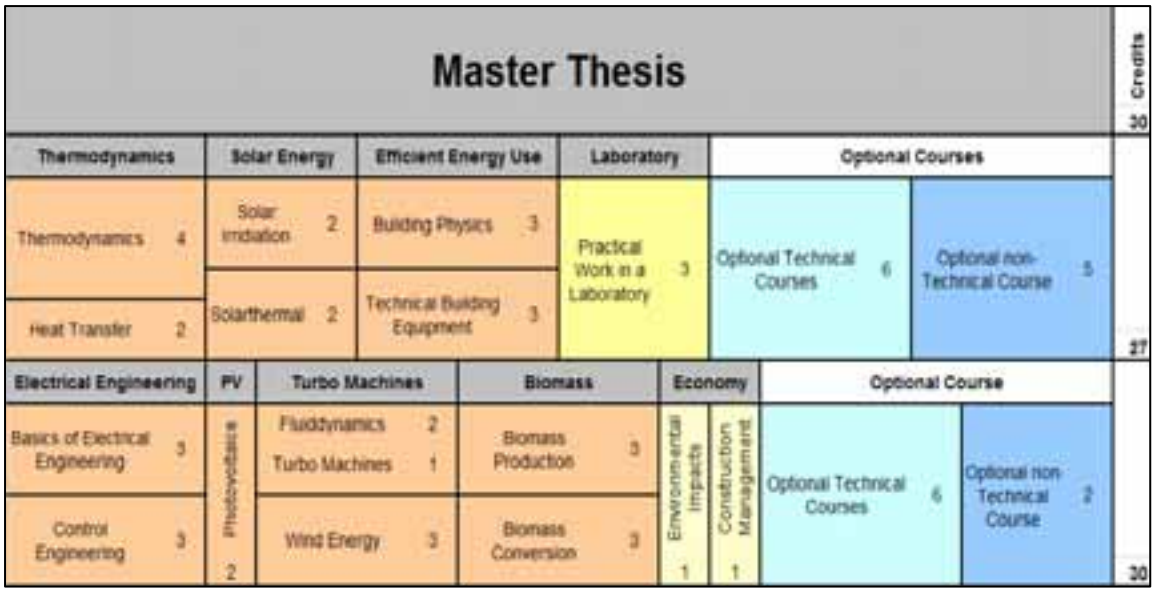

Fig. 2: Curriculum of the MSc-program "Renewable Energies and Energy Efficiency" at Kassel University. Courses marked grey are compulsory. Students can enroll for the program either in the winter or in the summer term. One (European) credit represents an average work load for the students of 30 hrs.

It is for sure easier to arrange the curriculum for only one start of the master program per year. It has to be discussed properly whether the necessary rearrangement for a second start is possible with reasonable effort. The students give a positive feed-back on joint classes of 1st and 2nd term students, as this supports networking between them.

4. Multidisciplinarity and individual course schemes

The master program described is basically open for all students with a technical or natural scientific BSc, cf. fig. 3. More than half of the students hold a previous degree in mechanical and electrical engineering. Agricultural engineers had a reasonable share in the early stage of the program, but they enroll only in single cases meanwhile. Most of the natural scientists are physicists. "Others" encompasses mainly industrial engineers, who are accounted for 50% as "others" and for 50% as their technical specialization, mostly mechanical and electrical engineering. The multidisciplinarity reflects the fact, that skills from several disciplines are necessary for the implementation of renewable energy systems. For the installation of a PV system one needs e.g. experience regarding the constraints of electrical installations, but also about building integration and the statics of the building. Utilization of biomass demands skills in agriculture and biochemistry, but also in mechanical and electrical engineering. The students realize that they have quite different backgrounds with regards to contents, but also that the experience of their fellow students from neighboring disciplines can help them to solve their problems. They learn fast to help each other and an orientation towards teamwork is strongly supported. The multidisciplinarity is a positive characteristic of the master program, and although most of the students chose at the end a subject for their MSc thesis which is thematically quite close to their first education, they give an enthusiastic feedback about multidisciplinary program, this means both, the multidisciplinarity of the teaching staff as well as of the students themselves.

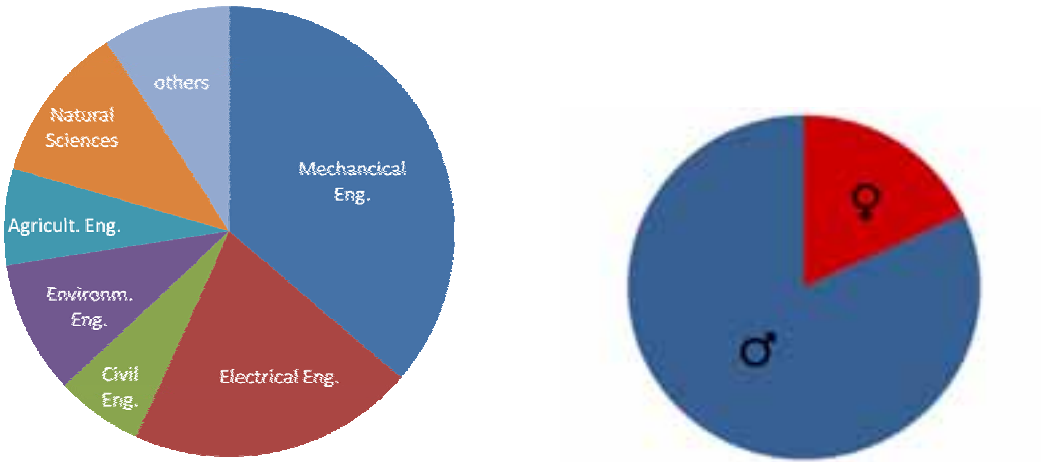

Fig. 3: Academic origin (left) and sex (right) of students in the master program "Renewable Energies and Energy Efficiency" at Kassel University since 2005. The average share of female students in technical MSc programs in Germany is around 5 %. In total 40 students can enroll each term, the number of applicants is much higher.

As the students' orgins are quite different disciplines, their previous knowledge is quite different as well. Those who hold a BSc in Mechanical Engineering have usually successfully completed a course in thermodynamics, whereas electrical and civil engineers usually did not. Mandatory courses like thermodynamic, heat transfer, fluid dynamics and electrical and control engineering lead to a comparable basic knowledge of all students who can then follow the same special technical courses. To avoid unnecessary repetitions, a scheme of individual course guidance measures has been developed. Students have to undergo a mandatory advisory service with a professor of their choice. Students are advised which compulsory courses of the program are not necessary to be passed by the students once again due to their BSc study program, elective courses can be signed up for instead. Furthermore, a study plan is developed in advance for the entire program and agreed on with a professor. The plan can later be changed, but the compulsion of the compilation forces the students to structure their course program properly in advance. It makes furthermore sure that the chosen course program is coherent with the examination regulations.

5. Arrangement of the curriculum

All courses are grouped as basic (thermodynamic etc.), technical (solar technology etc.), non technical (environmental issues etc.) or laboratories. The students have to collect credits from all groups within given constraints. So, a multitude of courses offered at the university can be used also for the MSc renewable energy and energy efficiency.

About 50% of the program consists of mandatory courses, the rest is elective. A list of about 100 unrestricted approved courses is published and updated each term. Most of these courses are also used in other (engineering) degree programs. Upon request, the students may choose additional courses offered in other disciplines of the university. E.g., a course in marine biology might be helpful for a student who aims at a specialization in offshore windmills, for a PV-specialist it will usually not be useful. In average, the students collect about 20% more credits than needed, because the abundance of interesting courses motivates them to register for more than required. At the end, each student finishes the program with a very individual course scheme, based on his previous degree as well as on his aptitudes. Nevertheless, the level of difficulty is comparable.

6. Drawbacks and limitations of multidisciplinarity in MSc education

Teachers have to be sure of the same basic or technical knowledge of the students when planning the content of a course. This causes usually no problems within a given consecutive program, but it cannot be assumed if students with plenty of different degrees enroll for an MSc program. Additional basic courses are necessary to ensure a common level e.g. in thermodynamics or control theory. Here, courses can often not be taken from an existing BSc program, as the didactic of BSc and MSc teaching is different, especially, if the BSc courses are scheduled in early semesters of their original programs. The demanded additional courses on MSc-level may therefore require additional teaching capacity. Furthermore, the necessary individual course schemes for each student cause a lot of additional effort for consultation of the students. Last but not least, there is a high administrative effort to combine teaching modules from different faculties with different traditions and administrative rules, at least within the given structure of German universities. Additional staff

is needed to coordinate the program and to ensure that things run smoothly. Nevertheless, experience has shown that all these problems can be solved, but the additional effort has to be considered.

But which graduates can be bound together in an engineering-orientated MSc program? In the experience of the authors, no problems arise if graduates of mechanical or electrical engineering and physics are mixed. Also the integration of civil, environmental or industrial engineers is usually no problem. Architects and agricultural engineers show normally a lack of mathematical background, their integration in an engineering-orientated program is often difficult and limited to particularly motivated students. The integration of graduates from non-technical faculties like economy or law has not been considered at Kassel University yet and would probably fail.

A fair selection of the students is another problem related with multidisciplinary MSc programs. The program is very attractive, and the number of applicants exceeds by far the places at university. But as the students come from quite different universities and disciplines with different cultures of grading, the final grade cannot be used as only criterion for the admission. Therefore, the effort is high for a fair selection, which furthermore has to be in accordance with administrative laws.

7. Prerequisites and transferability

Whereas general engineering courses like control engineering etc. can sometimes be used from other programs, teaching staff for courses with at least 100 additional (European) credits is necessary for a "copy" of the described program. This includes basis mandatory technical courses as well as sufficient broad range of courses which offer specializations in the different technologies. Translated to conditions at German universities (8 contact hours/week), at least four specialized professors are necessary who should be able to work more or less exclusively for the MSc program. It might be difficult to generate these resources in many cases due to limited budgets, if the respective specialized teaching staff is not already existent at a university.

8. International student exchange

Globalization and labor market expect more and more education or working experience of graduates in foreign countries. Also the students are interested in new challenges abroad. But the possibilities for an international exchange of students are limited especially for MSc programs in renewable energies. The curricula of such programs are not that standardized compared to e.g. mechanical engineering or physics, and they last only two or maximal three reading periods. If the students should not miss compulsory courses, one needs a partner university with a very similar arrangement of the curriculum. And a suitable foreign partner university is very difficult to identify. An international data base with programs in renewable energies would help to overcome these problems and would make an education in renewable energies even more attractive for students.

9. SolarCampus – a multidisciplinary project course

The interdisciplinary project-based student course *solarcampus* was brought up at Kassel University in 2005. Main objective of this course is to put students into realistic situations and processes, that are similar to those appearing in the graduates' future work and which can't be taught in the context of lectures and seminars.

In the first phase, photovoltaic systems with a total power of 67 kW_p were installed on roofs of different buildings of the university with the help of more than 100 external investors and without any costs for the university itself. In the second phase, which was started in 2007, students work out concepts for improving the energy performance of the university's building stock. Simplified, *solarcampus* operates like a firm of consultant engineers. Client of this "company" is the university. Main objective is to give students enrolled in the course programme "renewable energies and energy efficiency" the opportunity to practice their specific knowledge learned in lectures. So they can develop both, technical experience and soft skills for interdisciplinary teamwork, as both are mandatory in their future working life.

The course is extraordinary successful. The students realize the demands for interdisciplinary knowledge (different technical disciplines, financial, administrative, …) of a project, and identified already plenty of very economic energy saving measures. More details can be found in (Vajen et al.2010).

10. Summary and outlook

The conversion of the energy supply systems demand new ways of tertiary education with progressive profiles of the graduates in almost all countries. A multidisciplinary MSc program on renewable energies and energy efficiency has been developed at Kassel University. The multidisciplinarity demands the

implementation of additional courses and student advisory services. At least four relevant professors should be employed to start such an MSc program. Furthermore, the administrative effort to operate the program is comparably high, thus additional staff for the coordination is required. Since the program is very attractive for students, the high number of applicants require restricted admission for the places at university. The feedback of the professors and students on the program is almost entirely positive, but the organization of student exchanges especially for MSc students is one of the major problems to be solved internationally.

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