# 24 YEARS RENEWABLE ENERGY MASTER PROGRAMME

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## 1. Abstract

Starting in 1987 with 6 students the *Postgraduate Programme Renewable Energy (PPRE)* has developed to an accredited master program[1] with almost 400 actively networking alumni from more than 80 countries. From originally being a one-year course, it has now developed into a 90-credit, three-term MSc degree course. Fields of study are wind energy, solar electric and solar thermal, energy meteorology, hydropower, storage technology, biomass and economics of Renewable Energy. The Programme aims at engineers and natural scientists. Apart from lecturing, emphasis is put on an eight-week internship in research institutes or companies and intensive hands-on lab courses. Furthermore, we establish contacts to companies, research institutes, consultants and organisations for international development for students within excursions and master thesis. A case study on a real-life project visited by the students allows the comparison of students' research results with the experience of the system's operator.

Long-time and close cooperation with the DAAD provides scholarships for up to 10 students per intake. The Programme is also eligible for other scholarship organisations, e.g. E 8.

Various challenges had to be overcome in the past and up to present such as the inclusion of a multidisciplinary course into an institute of physics; the continuous adaptation of the curriculum to a dramatically developing and differentiating technology; balancing lectures on fundamentals and applied learning contents; adapting lectures to a team of students of multidisciplinary origin; keeping up to date with the requirements of the Bologna process of international education; development of international partnerships with universities and institutes for the sake of improvements on both sides with students' and lecturers' exchange and mobility; supervision of master thesis elaborated abroad and last but not least the day-to-day intercultural communication in the lecture rooms.

The *Postgraduate Programme Renewable Energy* at Carl von Ossietzky Universität Oldenburg has successfully educated and qualified international engineers and scientists who develop a career in Renewable Energy research, consultancy, industry, politics, and international development co-operation. Elements of the curriculum have been transferred to partner universities in several countries. An active, continuously growing internet-based alumni network backed by regular regional alumni meetings supports graduates and new students in their work and studies.

This paper will present 24 years of experience in operation and development of an international master's program on Renewable Energy.

## 2. Introduction

PPRE started as one of the very early master programs focusing on Renewable Energy (RE) in an environment where hydropower contributed in the sub 4% range as the major renewable source to Germany's electricity supply and is now well above 16% with a major contribution of wind, biomass and solar energy

[1] Program (US spelling), will be used while generally speaking of programs, Programme, our spelling within the program's name will be used when speaking of PPRE

(BMU 2010). The figures for Germany reflect a worldwide trend.

Our hypothesis: The demand for qualified personnel in the Renewable Energy (RE) sector will significantly increase worldwide within the next decades. Main driving forces for this development are: global climate change and its economic, ecological and social consequences; increasing costs for extraction of the main conventional energy sources oil and gas, and hence their expected rise in prices and related international conflicts; regionally and socially uneven distribution of energy (exclusion of still 1.4 bio people from access to electricity) and its economic and social consequences.

Parallel to the development of the contribution of RE to worldwide energy supply, both teaching and research in Renewable Energies have differentiated significantly. The number of courses with RE topics has increased enormously. In Germany alone there are currently about 120 master degree programs that are dedicated exclusively to this subject or that deepen RE knowledge in form of a specialization (Lutteroth 2011). In the European context many Master's courses with different specializations (e.g. EUREC) are offered. The thematic specializations range from wind energy, photovoltaics, geothermal energy and the thermal use of solar energy to marine (tidal and wave energy). At the same time, the numbers of applicants and of students grow rapidly. Research, development and training have long since evolved from a niche technology with few students and limited demand in selected areas of society to an influential and sought-after field of research and skills for almost all sectors of society. Renewable Energy generates jobs (BMU 2010)!

## 3. History and Facts PPRE

The PPRE was founded as a reflex on requests from some companies and development organizations during the second half of the Eighties as well as a consequence of internal discussions within the University of Oldenburg, based on multidisciplinary research in RE and student projects with focus on rural energy supply.

Since the beginning of the initial pilot project, external experts have been involved as an advisory panel, who also helped with the outline of the initial one-year M.Sc. curriculum.

The PPRE staff presented their M.Sc. Program on international conferences (Blum, Luther et al. 1988) and joined efforts with researchers and university teachers from more than a dozen countries to create an international community (International Association for Solar Energy Education, IASEE) for the extension of RE education. A newsletter was circulated, and the ISREE (International Symposium on Renewable Energy Education) series started, together with PiSEE (Progress in Solar Energy Education) conference proceedings. This activity later based the working group on education of the ISES. Today, PPRE is active in the DGS[1] Fachausschuss Hochschule[2] (http://www.dgs.de/hochschule.0.html).

As a parallel development, thanks to the support of the DAAD, alumni networking started.

Soon it was recognized that the rapid development of RE technologies required an extension of the M.Sc. Programme to three terms. Through intermediate steps this was finally achieved in 2004 and accredited in 2005 as well as reaccredited in 2010.

Fig. 1 shows the continuous and, in the last years, dramatic increase of applications from 12 applications for the first batch to almost 380 applications for the batch starting in October 2011. Fig. 2 shows the number of participants. We distinguish between participants obtaining a M.Sc., a diploma or dropping out. In total, 349 students have obtained a M.Sc., while 5 students received a diploma and five students dropped out (due to personal reasons) during the Programme. The students' regional origin is depicted in Fig. 3. We have separated Asia into India, China and rest of Asia. Most of our students come from Asia, followed by sub-Saharan Africa and Latin America. An increasing number of students have come from industrialized countries in recent years. Very few students join the Programme from Eastern Europe and GUS. We assume English being

[1] DGS= Deutsche Gesellschaft für Sonnenenergie; German society for solar energy
[2] Fachausschuss Hochschule = expert committee for university education
(both translated by the lead author)

the Programme's language to be a major barrier. Fig. 4 shows a recent statistic of the employment after PPRE studies. The largest amount of students is employed or self-employed in the private sector. 9 out of 84 PPRE alumni are occupied with a PhD. 94% of all our alumni are active in the field of RE.

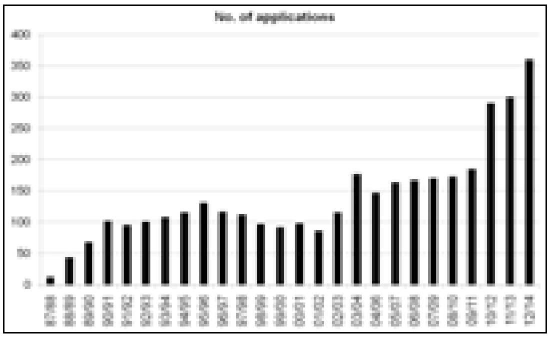

Fig. 1: No. of applications

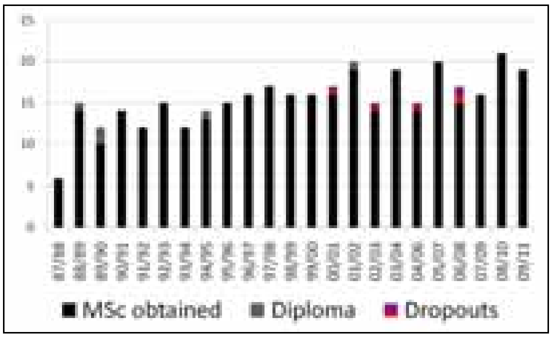


Fig. 2: No. of participants obtaining MSC, Diploma or dropouts.

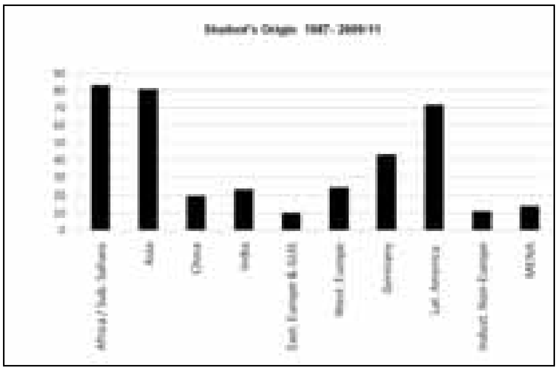

Fig. 3: Student's origin 1987-2009/11

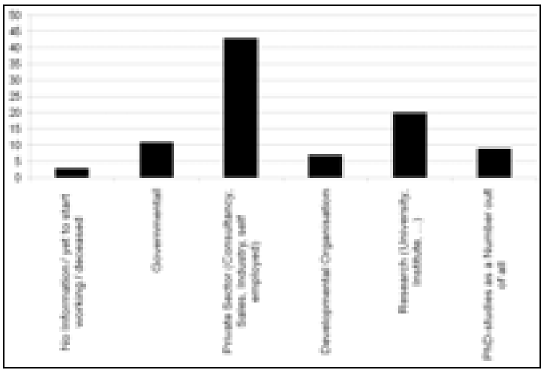

Fig. 4: Employment after graduation (2006-2010)

## 4. Course of Study

The PPRE has developed from a two-semester Programme to a three-semester Programme of 18 months duration and 90 Credit Points. The Programme starts every year in October; the end of the Programme is now in March. The Programme starts with a four-week introduction containing the Intro Lab, an introduction to the university and the town, help with settling the infrastructure such as obligatory insurances, internet access, and a warming up and socializing excursion to sites in the vicinity of Oldenburg relevant to RE. Lectures in six modules of seven Credit Points (CP) each start at the same time as the regular semester at the University of Oldenburg. Units of six modules (see Fig. 5Fig. 5) are shared with *EUREC* students and increasingly with other master students of the University of Oldenburg such as *Sustainability, Economics and Management (SEM)*, *Engineering Physics (EP)*, and *Physics (Phy)*. The interaction of students from developing countries (mostly PPRE), industrialized countries (mostly EUREC) and specifically Germany (mostly SEM, EP, Phy) is of special appeal. Shortly before the scheduled end of the University of Oldenburg winter semester, exams for the first semester are taken.

During the semester break, PPRE students enter a six to eight-week external practical training taking place in international companies, research institutions and with various development organizations (from GIZ to non-governmental organizations) while EUREC students move to their specialization universities.

In April a two-week semester introduction takes place. In the following summer semester, mandatory lectures in seven modules are offered. The Case Study module (see 9. Case Study) is added to the 6 other modules, see Fig. 5. The lecturers of the modules Wind Energy, Solar Energy, Energy Meteorology & Storage Technologies, Energy Systems and Society as well as Case Study offer a specialization lecture which is shared with students from the physics department and the economics department. One specialization (2CP) is compulsory for PPRE students. Some students choose multiple specializations. The specialization allows PPRE students' access to research groups at the University of Oldenburg and it facilitates the inclusion of the multidisciplinary PPRE course into the Institute of Physics.

Within the summer semester, a two-week final excursion takes place. Students visit companies, sites and institutions dealing with Renewable Energy and environmental protection technology. The Intersolar expo in Munich is an integral part of the excursion as well as a hike to an off-grid mountain hut supplied by Renewable Energy (see 9. Case Study). The excursion serves the tactile and the demonstrative approach to learning and offers various opportunities to contact companies for further career development. Each appointment during the final excursion is well documented by student reports in order to recall details in the following career. PPRE's students enjoy a high reputation and are given highest hospitality at the visited companies, who are thanked at this point. Unfortunately, due to the timing of the Intersolar, the excursion is conflicting ongoing lectures of the specialization courses.

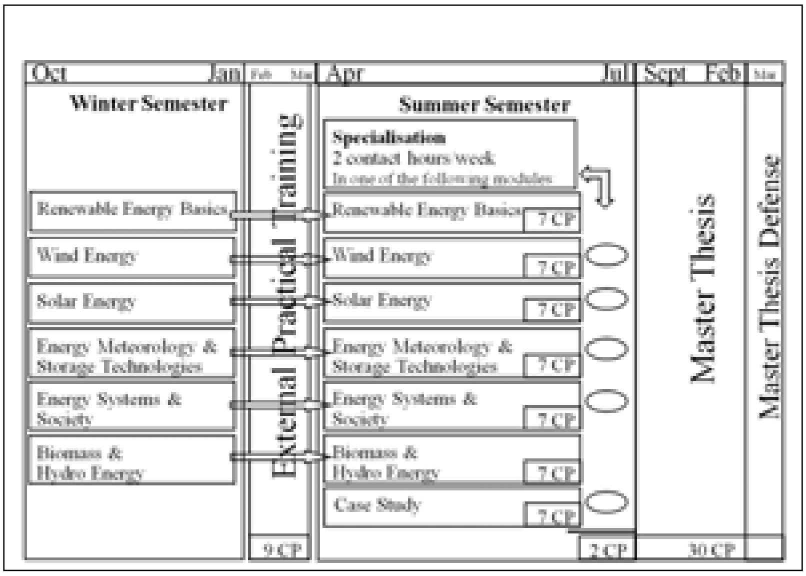


**Fig. 5: Postgraduat Programme Renewable Energy's course of study**

The winter semester focuses on fundamentals of RE while the summer semester rather focuses on applications and systems.

At the end of summer semester, after the exams, students have a short break before they start their six-month Master Thesis project in an acquainted company or institute. Our international network allows projects all over the world. Few students do their project at the University of Oldenburg.

About 80% of our students finalize and defend their Master Thesis in time to receive their M.Sc. certificate during the celebration ceremony at the end of March.

## 5. Alumni Networking

Thanks to the support of the DAAD, alumni networking started from the very beginning of the Programme.

Empirical studies focusing on the career paths of alumni and the very active alumni network, combined with re-invitation visits as well as regional meetings and summer schools, have shown that the majority of our alumni are working in the field of energy technology and RE education and that an increasing number (about one fourth) are pursuing PhD studies, either directly after PPRE or after a few years of further professional experience.

Elements of the alumni network are a yearly newsletter; an alumni space on our website; an e-mail-based internet discussion list (Q&A); regional alumni meetings (DAAD-sponsored); re-invitations of alumni; summer schools (in Oldenburg).

The intensity of the active alumni network helps present students or young graduates with the following activities: finding an internship (external training between $1^{st}$ and $2^{nd}$ semester); finding a thesis project (six-month, in companies and institutions worldwide!); getting advice for very specific questions/topics e.g. during their master thesis; getting job offers.

Senior alumni have reached advanced positions in governments, NGOs, UN and financing organizations , in consultancies and manufacturers of RE, as well as project developers.

Their advice and their input as guest lecturers are very valuable for PPRE.

At present, we are in contact with more than 80% of our alumni.

## 6. International Cooperation

Inspired by contacts found in conferences, supported by the DAAD and GTZ, the Programme has started several co-operations with university departments abroad. In the beginning, agreements were signed with the university in Harare / Zimbabwe (support by GTZ) and Arica / Chile (supported by DAAD). At present, co-operations with the Brazilian universities *Federal University of Amazonas* in Manaus and *Federal Technological University of Paraná* in Curitiba, with Murdoch University in Perth, Australia, with Nelson Mandela Metropolitan University, Port Elizabeth in South Africa, with Institute for Technology in Surabaya, Indonesia and with Imperial College, London, United Kingdom are active.

By developing a coordinated networking structure, we believe to: enable student and staff mobility, leading to an increase of expertise and experience; to develop an international quality assessment; to gain mutual recognition of modules, credits and exams; to develop curricula together; to harmonize courses of studies and to end with full-fledged, independent and complementary master programs.

Up to now, we have established contacts to a wide variety of institutes on a level allowing exchange of students for internships and master thesis projects. There is also a vivid exchange about ideas for the curriculum. However, our efforts to harmonize courses of studies in order to allow students to join lectures at partner universities often fail due to different semester timing. This is obviously valid for exchange of lecturers as well. In short, these co-operations are highly desired although they are characterized by a high workload for the staff of both partner institutions. Still, to a certain degree, an exchange of ideas and materials, even students, is possible without a formal foundation.

Over time, dozens of PPRE students and also a number of foreign students have substantially benefitted from the co-operations described above – obviously, it is essential for a M.Sc. program with a focus on rural energy supply as well as international aspects of RE developments to invest deeply into co-operations with partners overseas.

## 7. Challenges of a Multidisciplinary Program

Students intending to study PPRE come from several dozen countries and multiple fields of engineering and science. Thus, they have made their way through a wide variety of higher education systems and work environments. Their cultural and scientific/technical background may be rather different within the international group and also with respect to German students. This requires special efforts in the beginning of the Master Programme in order to ensure a good start for all students. They have to adapt to a new learning environment, to terms and expressions which are not familiar, to a different working culture and to a university and town where their language competence may need rapid growth (this is helped by intensive German language courses).

On the other hand, after initial problems are overcome, the chance to learn and work in the multi-disciplinary area of Renewable Energy is enhanced by the availability of knowledge from different technical and scientific disciplines. This advantage pays off when the students reach the stage of case study work or other complex, tasks related to real life. For their future professional life, it may also be a benefit to have worked with engineers and scientists with different backgrounds.

Of course, the situation in the student group powers the interest in new topics, and thus the eagerness to learn methods and acquire experience beyond the previously studied fields may lead to a very high workload and even exhaustion. The function of staff and tutors to ease the course of studies for all students thus becomes very important and is only successful with very intensive individual interaction and tutoring throughout the whole study Programme.

## 8. Lab Courses

While venturing through the 24 years of Programme history, experiences and observations shall be shared; our current reflection of the developments prompts the next modifications: as the new discipline of Renewable Energies develops, the Oldenburg course is constantly modified; while new programs come up, often focusing very specifically on single aspects of RE technology, PPRE at present keeps the broad perspective of energy supply, supported by renewable sources, featuring relevant subjects throughout the course. How this focus on the dialog between technical understanding and practical application on the one hand, and the perspective of energy supply and sustainable development on the other hand is achieved shall be narrated in the following. Two few key features of the overall course, the lab courses and the case study, will be described in the next two chapters.

| | Laboratory Work | | |
|---|---|---|---|
| | winter | summer | |
| intro | electrical sensors & multimeters | meteorological sensors / dataloggers | intro |
| funda-mental | light & matter | energy potential & site assessment | fund. |
| | fluids & energy transfer | improved cook stoves | biomass |
| sto-rage | battery or fuel cell | biodigester | |
| technologies | thermal collector | thermosyphon w. storage tank | technologies |
| | PV cell | solar home system | |
| | mini wind turbine | residential WEC | |
| | components | systems | |

**Fig. 6: PPRE's lab courses**

Presently the lab course at PPRE can be depicted as seen in Fig. 6. Since there are two semesters of course work and one for the thesis project the lab courses stretch over the first two semesters. Each semester starts with an Introductory Lab seeking to familiarize the participants with the measurement principles and devices used in the upcoming semester. In each semester, there are six experiments covering major RE topics. In part, the experiments are not labeled in the table by their object of investigation but rather by the fundamental principles they shall supply for the study course.

While the summer Introductory is quite young – about 6 years – the winter Introductory is running since 1996. It was a reaction to the observation that our participants, who mostly came from developing countries at that time, had little to no previous exposure to laboratory work, experimenting, measurement procedures and the like. With a larger share of students from Europe and North America in recent years, we had to realize that experimental practical work in most educational systems is highly underrepresented, and this rather 'playful', investigatory approach of the Introductory serves these participants well. We have ten sets of equipment on which about twenty people can work at a time, typically in teams of two. The arrangement is fairly informal and as all are working at the same problems, spontaneous cross-group discussions occur and reformation of teams is encouraged.

The winter Introductory Lab also aids to make people familiar with our laboratory facilities, our staff and their approaches, a different educational environment, their fellow students, and to merge into this multidisciplinary and multi-cultural group. The summer Introductory still serves well as a warm-up after two months of absence from the Oldenburg labs (internship in companies). And whilst the winter Introductory deals mainly with the fundamentals of electric circuits and the measurement of radiation and temperature, the students get exposed to the full spectrum of meteorological sensors (traditional as well as semiconductor) and various data loggers for remote data acquisition (signal adaption to programming) in the summer.

Determining the Solar Spectrum is the starting point to deal with light generation and absorption, material properties and electron levels. What looks a bit misplaced in a program on Renewable Energies at first shall provide a solid anchorage of mental models for radiative energy transfer in the natural sciences. Through hands-on experimental work, students learn about calibration and measurement errors (which here determine the spectral responsitivity). Similarly, the Centrifugal Pump shall provide re-enforced fundamental knowledge on fluid motion (Bernoulli equation, friction in pipes and valves). On the experimental side, students learn how to establish a characteristic curve – for any device – and become aware of the guiding principles of energy transfer from one domain into another (electric – rotation – fluid – friction – thermal). Besides, centrifugal pumps are a key element in drinking water supply and are central assets of industrial systems, also renewable ones.

Since last year, the students are given a choice either to study the Lead-Acid Battery set or look at an Electrolyzer/Fuel Cell combination for dealing with a storage device – and its troubles. We have not entirely been aware of the fact that it is essential to understand how similar the behavior of such devices is and that one deals with the same underlying principles (charge transfer efficiency, over potentials related to current, inverse current-voltage characteristics for charging compared to discharging resp. electrolysis to oxidation, current density limitations – and a few different ones). We will explore such possibilities further, keeping in mind that this also depends on the tutor available.

In the 'Technology' section of experiments we look at individual devices from the different sectors; typically, the component's characteristics are determined, its dependency on various parameters, and the transfer mechanisms of energy to resp. from it. This features prominently the alternation between generator characteristics and load variation and vice versa, which in turn is a cross-cutting topic of renewables and thus has relevance for all technologies. The three following choices are just meant as examples for the major RE routes: direct radiation usage, thermal and electrical, and indirect solar usage by tapping the resulting fluid motions. At the moment they very much center on the research areas of the Department of Physics at the University of Oldenburg – which are the most widespread applications, at the same time. Over the years each experiment got packed with a number of experimental tweaks and tricks or universal renewable concepts, forming a somewhat solid set.

The Summer Outdoor Lab structure corresponds to the Winter Lab concept, down to the experiments on technologies. We are not dealing with individual components here (single PV cell) but with systems (Solar Home System, consisting of PV panel, charge controller, battery, and various loads). Accordingly, we do not find a storage device experiment in summer but experiments on biomass instead: an assembly of improved wood stoves and two biogas reactors. Along the operation and study of the behavior of the system, analytics of the burning value or material composition are done. We would very much like to strengthen the 'system' aspect of the summer semester, not in terms of experimental setups but on lectures or seminars running in parallel.

This shows the interdependence of the laboratory course with other parts of the Programme. Opposite trends exist, too: The idea of strengthening the insight into biogas, and the large dissemination of biodigesters in Asia, prompted us to establish a three-day workshop once a year (since 2005). We invite field workers who present the technology, but also dissemination schemes, highlight social and political interrelationships, financing, appliances etc. An earlier participant working on a cook stove project in Africa got us the experiment on improved wood stoves set up (and still accompanies it with an afternoon lecture each year).

Additional experimental setups on (micro) hydro power (Pelton turbine, cross-flow), selective surfaces (radiative, convective, and conductive heat transfer), solar desalination by collectors, PV panel investigations, dynamic collector model (with vacuum tube collectors), solar cookers, and other devices were available temporarily. Partly they have been taken out of the Programme because of resource problems, partly one cannot become too specific in such a broadly oriented program, and partly they have been withdrawn to improve the balance between the various technologies and make space for other experiments: a small outdoor wind system, a biogas reactor setup, testing of improved wood stoves – and we would like to add others: a system for drinking water purification (water supply constitutes one of the major global challenges) or a CHP to demonstrate electric versus heat driven operation. Experiments have been shifted between the semesters – there are better wind conditions for the small WEC in winter in Oldenburg, while it is a 'system' experiment and relies on a data logger.

At times, there had been nine experiments during the winter semester and seven during the summer. A major cut occurred when our group joined the EUREC master program in 2004; around the same time we admitted more applicants to PPRE: the number of students soared and we had to accommodate all participants in the laboratory room, provide setups – and time intervals in the weekly schedule. There was also the clear mind-set to increase the profoundness of dealing with the setup as well as the evaluation and discussion of results – a process which is still not resolved to a final point.

Compared to the early beginnings where only a final 1.5-hour oral exam might touch any subject of the entire course, and where maybe one lab experiment was also included, we have introduced pre-experimental interviews ('Antestat' – they seem to be unheard of in most other countries) to secure a minimal proficiency and therefore experimental performance level. At times all lab reports got marked, at others one of each module – we have not reached a fully satisfying procedure yet.

We would like to offer more experimental experience and further subjects to our students, but the laboratory work, demanding a lot of time for evaluation and reporting, already makes up 20% of the workload in the two semesters. We are thinking about finding a mode to offer additionals for the ones specially inclined.

Still, we are seriously missing the experiment on radiation absorption by selective coatings, featuring the various modes of heat transfer. This hampers the student's understanding of thermal devices and systems considerably: the candidates lack the insight of point-wise multiplication of two spectral functions. It has also been the only experiment where vacuum techniques are employed – now applied with device manufacturing of any technology. This demonstrates again that in such a short program each building block typically has to fulfill several purposes – and Fig. 6 is not final.

## 9. Case Study

The module Case Study is featured prominently in the summer semester. It consists of the units case study, final excursion and the specialization "Rural Energy Supply". In the case study unit, multicultural groups of five students design the energy supply system for a stand-alone energy (service) consumer. An economic evaluation of the planned system is a compulsory exercise. A sociocultural treatment of the system is a desired add-on. In the case study unit, the acquired knowledge is transferred to application. Furthermore, team-building and team capability as well as management skills are trained.

Student groups play the role of consultants while the lecturer plays the role of a customer. The consultant is an energy expert and advises the customer, who has little ideas and data on his project. The different student groups are competing for the job and do not interact. In case the "consultant" obviously gets lost in his attempts to solve the problem, the "customer" turns back into the lecturer to aid the students.

The educational objectives of case study are distinguished by hard facts and soft skills which are comprised in Tab. 1.

The case study unit has developed in the past 24 years. The status quo is as follows:

The unit is coached by the lecturer but also by external professionals who give input within a face-to-face lecture. External coaches are ready to answer questions developing subsequently.

Moreover, the case study unit is based on an existing system which is accessible from Oldenburg. Within the final excursion of the Case Study module, the object is visited to enable discussions between the operator and the students. Here students may compare their findings with the real-life situation. Problems not considered by the students arise, potential improvements and drawbacks of their proposal get clear. Technical solutions not considered previously are demonstrated. Stand-alone dwellings in the kW range rarely exist in Germany

**Tab. 1: Educational objectives within case study unit**

| Type of Skill | Educational Objective | Contents |
|---|---|---|
| Hard Skills | Feasibility Studies | Legislative conditions, sociocultural aspects, geographic and climatic constraints, infrastructure (access to building site) |
| | Energy service and demand studies | Domestic hot water, space heating, process heat, chill, cooling, lighting, communication, mechanical power. Load profiles and load management, peak shaving (thermal and electric) |
| | Analysis of renewable sources and backup conventional demand | Bio energy, wind energy, solar energy, hydropower, availability and constraints of conventional fuels |
| | Sizing of renewable and conventional energy supply system | System parameters (loss of load probability, renewable fraction, performance ratio, degree of system utilization, dumped energy), autonomy, sizing of components (generator, storage, controllers, inverters, backup system) |
| | Software | Application of design software for sizing of systems, critical usage of design software |
| | Economic Analysis | Net present value of systems, price per unit energy, |
| Soft Skills | Team work | Intercultural teams, work sharing, reliability, cooperation, discussion, decision making |
| | Project management | Flow chart, milestones, group & member motivation, timekeeping |
| | Presentation and reporting of results | Structure and logic of presentations, presentation techniques, use of resources (audiovisual electronic appliances, blackboard, oral), response to questioning, timekeeping, interaction with audience and presentation, development of written reports |

apart from the Alps in South Germany. Hence, the object of case study is a mountain hut, accessible for private persons only by hike. The visit of the case study object has turned out to be a socializing, adventurous event for the entire group. Personal, lifelong friendships are developed.

The Case Study module also deals with gender aspects. The Global Gender Gap Indicator (Hausmann, Tyson et al. 2010) indicates that gender inequity still exists in elevated positions. In the case study unit, female students are encouraged to play the role of the group's managers. The females have the opportunity to experience and practice leadership while the male students may learn to accept and cooperate with a female manager. Individual, diverse conflicts arise which finally are instructive for all participants involved.

Lessons learned are comprised from the final presentation of 2011 case study managers (Aroeira de Almeida, Braden et al. 2011):

Assessment of the energy demand and load profile is not only the most challenging part but also the subtask with the greatest impact. Thermal demand varied by a factor of 2 and electric demand by a factor of 3 among the groups. Applicable technologies are depending on the site and solutions found were similar for all groups.

Feedback on the different managing experiences from (Aroeira de Almeida, Braden et al. 2011) includes:

Challenging every member of the team while balancing their strengths & weaknesses; working with other managers; the challenge of time management and task management; unifying and respecting different working styles, not expecting too much of oneself and not always being democratic; overcoming unexpected events, separating the private and the professional; importance of identifying your resources.

We have experienced a very high level of motivation among the students during the case study unit. We observe a lack of experience when dealing with energy consumption, system design and balancing of technically feasible solutions with economic constraints. We furthermore observe a dramatic development of these skills within case study.

## 10. Programme Quality

Programme quality is assured by different means and on different levels. PPRE is accredited regularly, students give internet-based, anonymous feedback to the overall Programme and to individual lectures; lecturers and staff give feedback to students by exams and by personal appointments. Every semester, lecturers and staff members meet in a closed session to plan and improve the following semester.

### *Accreditation*

PPRE was first accredited in July 2005 by ZEvA, (http://www.zeva.org/). In March 2010 PPRE was reaccredited by ASIIN e.V. (http://www.asiin-ev.de/pages/de/asiin-e.-v.php). The ASIIN accreditation agency is acting on behalf of the the Conference of German cultural ministers and is implementing its guidelines. EU decisions are translated into national objectives. In addition, the ASIIN is active in a European network of national accreditation agencies in order to exchange experience, further developments, common European approaches, and mutual recognition of national accreditation in joint programs.

ASIIN has proven PPRE to meet European Quality Standards as a Master of Science program, as there are: meeting the quality standards for master programs (ASIIN requirements for accreditation: in-depth expertise, scientific work, development of knowledge transfer); creating transparency to the Programme by developing a students' study book including module handbook, examination rules, study materials; describing the structure, objectives, learning outcomes and the means to achieve the learning outcomes and what the Programme qualifies for besides approval of financial and personnel potential to run this Programme.

Experiences and lessons learned on behalf of the accreditation process are: the communication of the Programme management to individual professors has improved; objectives of the Programme become transparent to students, staff members and all other involved parties; the contribution of professors to the development of the Programme is limited due to their time constraints; a continuous evaluation of the Programme (questionnaire to students and professors) is a major contribution to keep the Programme updated. Accreditation is a time-consuming business which results in higher transparency to all involved parties, forces involved parties to work on concepts and to revise structure and content, highlights the duty of the university to offer the Programme in content and structure in such a way that students are able to achieve the described learning outcomes in the given time.

### *Students' feedback*

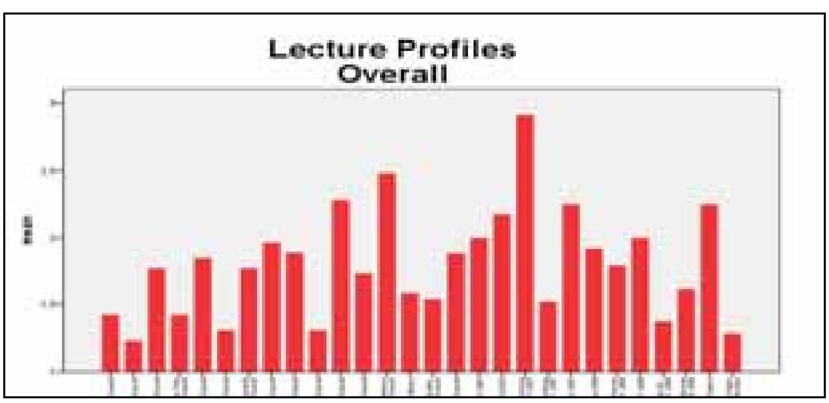


**Fig. 7: Student's overall lecture grading winter term. (1=excellent, 3=satisfactory)**

At the end of every semester, students are encouraged to give confidential feedback via an internet-based feedback procedure. The procedure incorporates evaluation on the entire Programme, the overall semester, the individual lectures including external guest lecturers giving a single presentation, and allows personal written comments. Feedback is given by almost all students (return rate >80%). Grading is in five steps from excellent to poor. As an example, the lecture profiles are displayed in Fig. 7. The range in this graph is from excellent to satisfactory. The x-axis is made anonymous. The results are discussed in the above mentioned closed lecturers' and staff meetings.

*Lecturers Feedback to Students - Exams*

Well-designed examination strategies contribute to the quality of a program.

While PPRE started with a single final oral exam in the early years, students now have to pass an exam in every unit. The current discussion is on how to find a suitable compromise between the two extremes.

In our belief, exams serve the Programme internally to motivate students to recapitulate contents of lectures, to make students extract the important contents of lectures, to have students learn how to capture contents (learning how to learn), to give feedback to students on their capabilities and to gauge them and to give feedback to lecturers on their didactical concepts and skills. Externally, exam results serve to supply an indicator of strengths and weaknesses of a job candidate and to simplify the employee selection process.

We detect different dimensions of exam focuses: level of abstraction, content, and feedback time. Different exam types cover different dimensions and their specificity.

In the dimension 'feedback time' (see Fig. 8) the time between question, reflection, answer and feedback from the lecturer is characteristic. Question – Feedback is asynchronous for lab reports while in an oral exam the process is synchronous. Asynchronous exams are characterized by free time management of the student while, in synchronous exam types, students need to immediately answer and have the right to get immediate feedback helping them to adapt their output.

For the dimension 'content', we gauge between detail and context. An exercise within a lecture will focus on a very specific problem while a final oral exam will rather deal with the general concept of the Programme. Tutorial, 'antestat', assignment etc. are in-between the extremes. The arbitrary distribution along the axis in Fig. 8 reflects the dependency of the exam content on the individual examiner and exam.

The abstraction level varies between full abstraction, typically found in oral exams and examination of application skills in a practical exam. When we consider lab work an exam, PPRE's strength is its focus on examining application skills of our students. Individual students have individual strengths in the different dimensions described. On the job, different skills will be requested. It is therefore necessary to train students in different dimensions of problem solving as well as giving them the chance to demonstrate their strengths and create awareness of their weaknesses. Consequently, it is desirable to offer different types of exams. Furthermore, in an international master program with multicultural students, it will be necessary to give students the chance to gain experience with the PPRE types of exams and allow compensation of individual failures. The latter is in favor of a large number of exams, while a large number of exams may lead to an unacceptable workload and therefore failure in exams and their objectives. In this aspect,

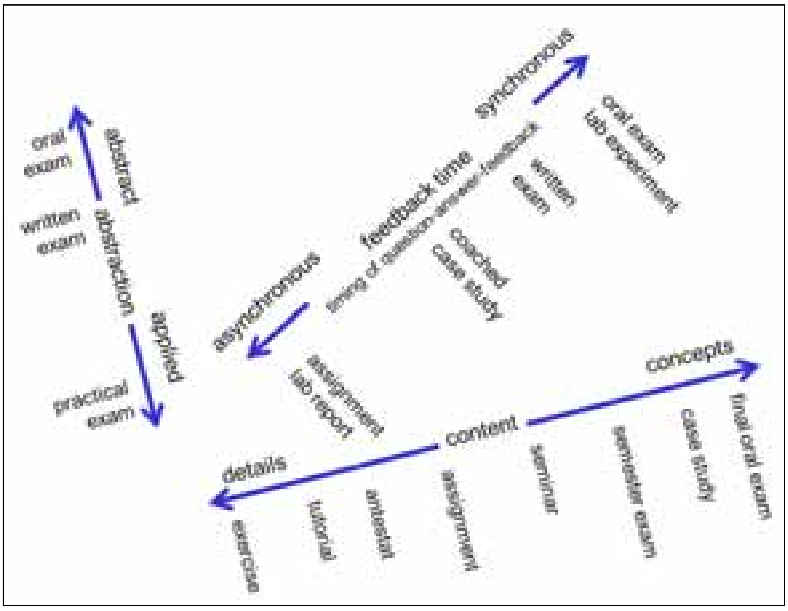

**Fig. 8: Dimensions of Examination**

we are still in the process of finding the right balance.

## 11. Conclusion

In the late 1980s, a few members of the University of Oldenburg have proactively developed the Master Programme on Renewable Energy. Since then, almost 350 students have achieved their M.Sc.in PPRE while less than 3% exited the Programme with merely a diploma or dropped out. Due to increased public interest in energy supply, the demand for skilled personnel in the field of Renewable Energy technology is increasing. This is reflected by the increase of RE's share in the world's energy supply, the increase in programs teaching RE, the number of applications for PPRE and last but not least by the manifold job opportunities of our graduates. In order to follow the dramatic development of RE technology, PPRE has enjoyed a continuous evolution. External developments (Bologna Process) have further propelled PPRE's design. Quality assurance of the Programme finds its foundation in accreditation, student exams and feedback by both students and staff. Whereas the findings of the local research groups provide important input for the PPRE lectures, our students support the research groups through their master's projects in a fruitful cooperation. Furthermore, cooperation on an international level widens the scope of experience and opportunities for our Programme. Our alumni network is vivid and cannot be overestimated in its advantages. Last but not least, the project PPRE is confronted with the continuous challenge of balancing development opportunities (external alumni input, new technology, societal interest, …) and limited resources (workload of students, manpower, lecture and lab room, financial, …).

## 12. Outlook

PPRE's development is not at its end. PPRE has to add more electives (options) for the students, primarily those attached to the research units at the University of Oldenburg (wind energy, storage technology, photovoltaics, energy meteorology, sustainability and economics). Moreover, students need to have more options to do their internships and master thesis and part of their studies within other programs on behalf of cooperation with partner universities. Staff mobility supplies experience from other programs and increases the quality of the Programme. Complementary to face-to-face lectures, a demand for a flexible blended learning program arises. At present, an impact study of the Programme is in process. We therefore will present results on this issue at the 25-year anniversary celebration in October 2012. As a Programme motivated by global climate change among other things, it will have to deal with the energy consumption for travelling of its students and staff by elaborating its own carbon footprint.

## 13. Literature

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