RENEWABLE ENERGY IN GERMAN UNIVERSITY EDUCATION – OVERVIEW OF DIFFERENT APPROACHES AND LESSONS LEARNED

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1. Abstract

The tremendous increase in the renewable energy (RE) sector requires many more people to be educated at all the various levels in RE and at the level of tertiary education: vocational training and various levels of university education.

This paper describes the adaptation of the German universities (Universities and Universities of Applied Sciences) to this change in the society in the recent years.

Until now, there are many more than 100 different graduate and post-graduate disciplines and courses offered at German universities on all RE and energy efficiency (EE) subjects. Mostly, the courses are in the German language, but increasingly in English. The increasing level of intensity in RE and EE stems from a few general subjects up to special Ph.D. programs on solar thermal system designs and optimization, and wind energy technology.

The disciplines and courses can be categorized into various groups, with a common educational approach. This paper describes the different approaches and their specialties. Special focus is given to the relevance of RE and EE to German industry and business.

Examples of typical curricula for the various categories are presented. Finally some lessons learned from the various approaches are presented and discussed.

Thus, the purpose of this paper is to show an overview of the very diverse situation in Germany. This may serve as an example for other countries to build up their RE and EE educational systems, to cope with any forthcoming changes.

2. Introduction

The increased development of renewable energy (RE) is an important focus for German politics and the economy. RE is now contributing around 10% to German primary energy consumption, with renewable electricity contributing around 18% to total electricity consumption. In 2009, the total turnover in RE in Germany was Euro. 16.4 Billion, while the total worldwide investment in RE was around Euro 100 Billion. Up to 340 000 jobs have been created in Germany in the various sectors of RE by the end of 2009, which was 160 000 more than at the end of 2004[1].

In addition to investments in research and development and the promotion of demand through incentive programs, it is essential to ensure adequate tertiary education for an anticipated skills shortage, due to an expected increased number of workers in this sector.

The results of a survey conducted by the German Federal Environmental Agency shows that enterprises in the field of renewable energies have a higher than- average- demand for employees with university degrees.

[1] http://www.erneuerbare-energien.de/inhalt/46910/42454/

"On average, 82 % of people employed in the renewables sector have completed vocational training; nearly 40 % of these have a university degree. The average for all industrial sectors is just below 70 % of people with vocational qualifications and just below 10 % with a university degree. Among the various technologies that contribute to the renewable energies are those divisions that are still relatively new and thus serve development-intensive technologies, which are the most influenced by university graduates. Deep geothermal plants, using liquid biomass in stationary mode, or the concentration of solar thermal technology are examples.[2]"

Tab.: 1: Types of employment in the renewable energy sector (BMU, 2010)

A prominent feature of companies in the renewable energy sector is their high proportion of skilled employees.

	Without vocational qualifications	With vocational qualifications	With a university degree
Photovoltaics	5.8 %	81.7 %	34.7 %
Hydro	1.7 %	93.8 %	57.0 %
Wind	0.9 %	79.7 %	27.1 %
Solar thermal	9.5 %	80.3 %	24.4 %
Solar thermal power plants	6.7 %	84.8 %	44.1 %
Deep geothermal	2.1 %	85.6 %	50.4 %
Near-surface geothermal	6.6 %	81.1 %	15.3 %
Biogas	2.5 %	82.5 %	33.1 %
Liquid biomass	0.0 %	92.2 %	57.3 %
Solid biomass	3.1 %	86.5 %	29.7 %
RE overall	**4.1 %**	**82.1 %**	**32.1 %**
Manufacturing jobs	22.7 %	63.2 %	0.6 %
Technical jobs	4.0 %	88.3 %	37.7 %
Total	**15.0 %**	**69.5 %**	**9.9 %**

Concerning higher education in RE and EE, German-speaking countries like Germany and Austria are already far advanced. In these, more than 100 degree courses and further education courses deal with the subject of renewable energies - ranging from single introductory courses up to programs entirely specialized in renewable energy. This makes these areas world leaders in RE education..

Until now there is no consistent list of degree courses (cf. Vajen, 2010), though there exist several initiatives attempting to formulate surveys. The following evaluation is based on two studies conducted by the "Wissenschaftsladen Bonn (Wila)" in April 2009 and October 2010 (cf. Wila 2009, Wila 2010) and on the website www.studium-erneuerbare-energien.de.

These compile almost 350 bachelors, masters and diploma programs in the three sources named above. This seems to be a big number, though, on closer inspection, there appear many programs with only have a very small rate of RE and EE course - or even none all. Nevertheless, although not all-encompassing, as these are the only nearly-complete lists available, they have been used for the following analyses.

2.1 Overview of degree program

2.1.1. Regional distribution of degree programs

The first chart shows the regional distribution of German programs, divided by federal states. In the four

[2] http://www.gws-os.com/discussionpapers/gws-paper09-6.pdf, page 10

largest states - Lower Saxony, North Rhine-Westphalia, Baden-Wuerttemberg and Bavaria - students are offered around 40 programs, most of them bachelors and masters programs. Diploma courses still exist, even if they are eventually phased-out or converted gradually. Noteworthy is the great number of masters degree courses in the field of RE and EE.

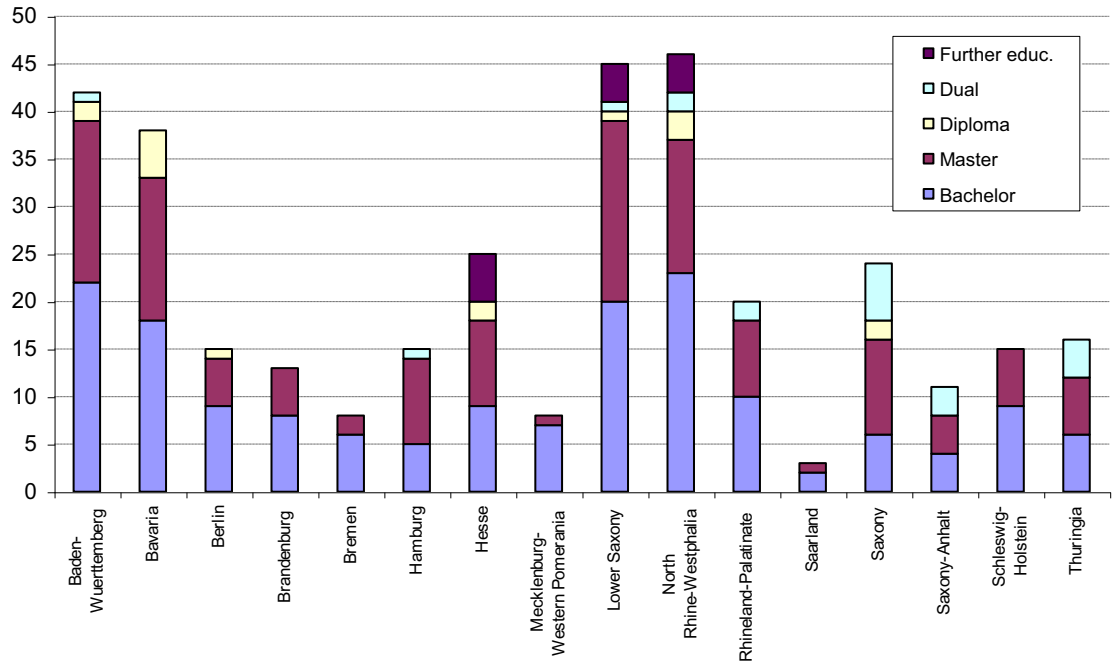

Fig. 1: Survey of all German RE and EE degree programs listed by Wila Bonn and at www.studium-erneuerbare-energien.de

Relative to the population, the two city states of Bremen and Hamburg are in the vanguard, with the greatest selection of choices, as the following graph shows.

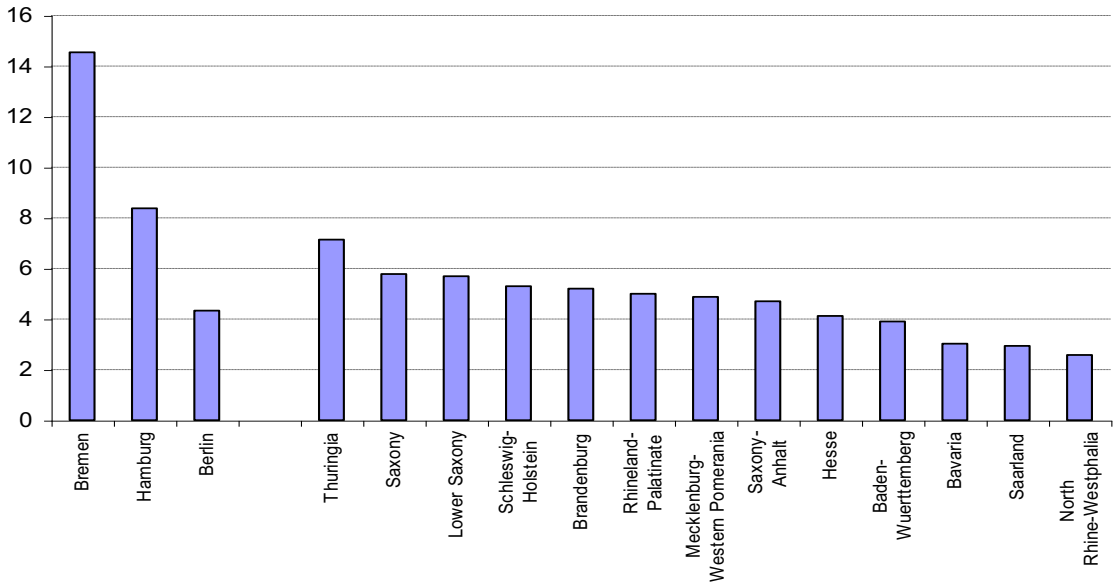

Fig. 2: Number of RE/EE programs per 1 million inhabitants

Among the territorial states, Thuringia and Saxony offer the most courses per inhabitant. This may possibly be related to the fact that universities in the eastern part of the Federal Republic of Germany have undergone a big change during the German reunification – at a time, when the increased demand for education in the

fields of RE and EE became apparent. They could be possibly be more easily integrated than at West German universities, with their long-standing and well-established educational structures.

Below, the German bachelors and masters degree programs are analyzed in detail.

2.1.2. Approaches of Bachelors and Masters degree programs

In effect, most of the listed bachelors and masters degree programs are assigned to the "traditional" degree programs. These total 160 study courses. For example, Electrical Engineering, Mechanical Engineering, Building/Supply Engineering and Process Engineering/Chemistry in many instances, now concentrate on RE and/or EE.

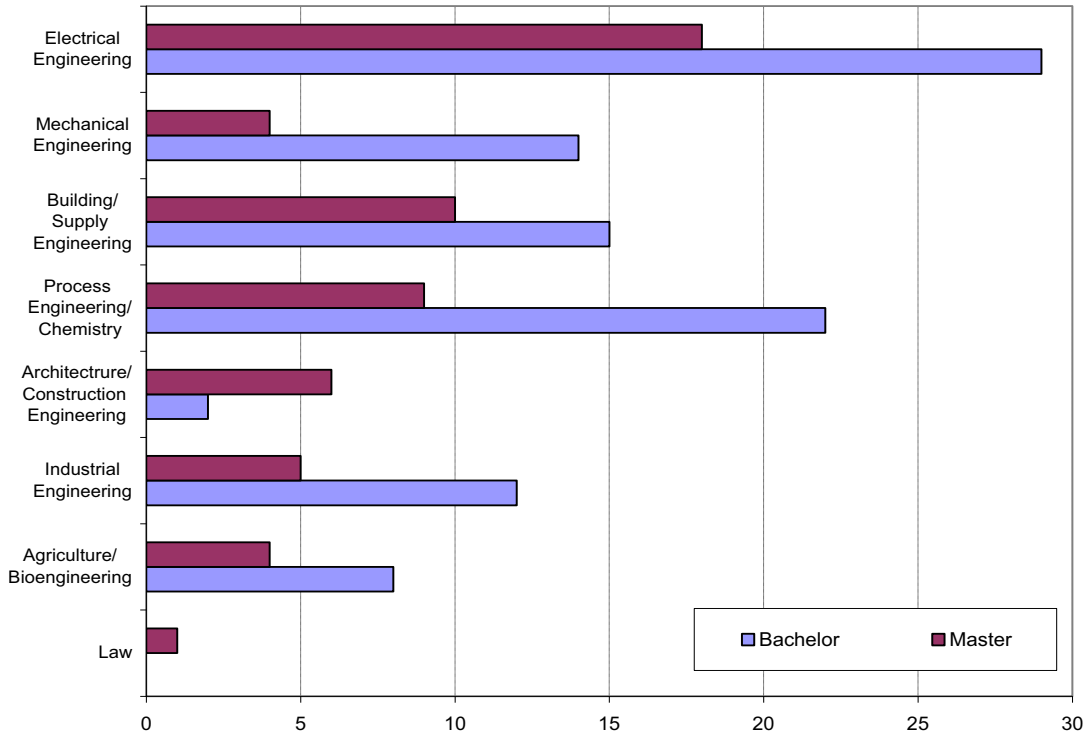

Fig. 3: Linkage of RE/EE degree program to traditional study courses

It is worth noting that Electrical Engineering, in absolute terms, has the highest number of programs, with nearly 30 bachelors degrees, while the field of Architecture/Construction Engineering has only six bachelors and two masters degree programs is still very weak.

This assignment of courses to the traditional disciplines and their relative distributions, also reflects the different assignations of importance in the field of RE. The discussions of renewable energy still focus heavily on the area of renewable electricity generation, while the areas of renewable heat or energy efficiency, especially in the building sector, are only very weakly represented. There would appear to be a an imbalance here, as these areas have the greatest importance for implementing higher degrees of RE and EE in the future. Especially the integration of building design and the respective energy systems and its optimization is still lacking in the degree programs.

Simultaneously a great number of entirely new degree programs were created, emphasizing their commitment to RE/EE by appropriate designations. In total, there are 90 new courses, although there are a few studies, under these categories that have already been available for many years. Most frequently, courses under these categories are listed under the following headings:

- Energy Management
- Energy Systems

- Energy Economics
- Renewable Energies

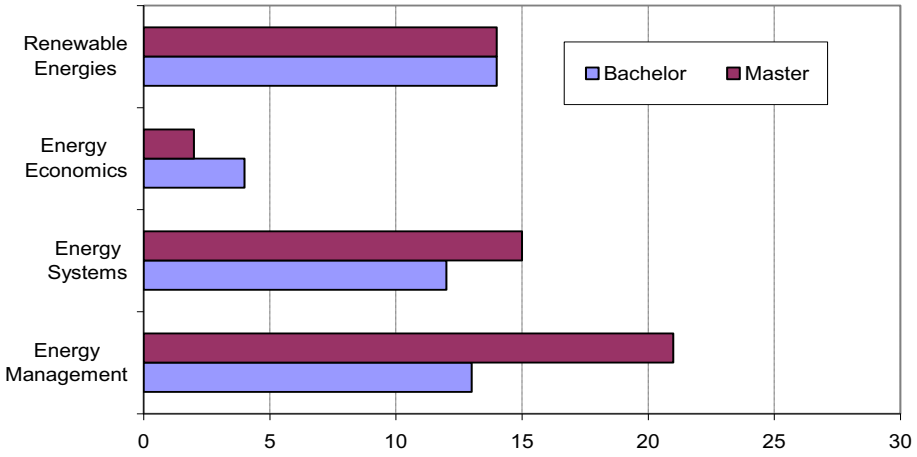

Fig. 4: Newly created RE/EE degree courses and their titles

Energy Management, Energy Systems and Renewable Energies are almost equally distributed, each with about 15 degree courses as bachelors and masters degrees. This equal distribution also reflects their importance in rebuilding the energy sector. A focus of degree courses only on the renewable energies would ignore the reality in the energy market.

Of note, is the low number of degree programs in Energy Economics. This will probably expand in the future, when issues such as "smart grids" and electric mobility will come to fruition.

Generally, a total of about 250 courses could be assigned to the above-mentioned categories, including 160 "traditional" and 90 "new" studies.

The Wila Bonn, which has listed only 240 degree courses in total, also distinguishes between programs that offer only an increasing emphasis on RE/EE, and those that are focused entirely on renewable energy.

Among the bachelors, diploma and masters degree courses there are

- 180 with increasing emphasis on RE/EE
- 60 entirely focused on renewables

This division between an ever-increasing and/or complete realignment show clearly the approach of many universities in the integration of RE and EE subjects. They prefer to integrate the content of RE and EE into existing programs and offer new modules within the traditional studies. A straight focus on RE and EE is only rarely chosen, so it is possible to preserve the applicability of graduates to the traditional areas of industry.

Moreover, about 60 to 80 per cent of the lectures are concerned with traditional issues such as Thermodynamics – at least within the technical studies – and there is hardly any difference between traditional disciplines and re-assignments.

Among the re-assignments, the difference between the eastern and western part of Germany seems apparent:

- New Federal States (former East Germany): more than 30% of all courses with RE reference are completely dedicated to RE
- Old Federal States: less than 20 per cent of courses are completely dedicated to RE

It is to be assumed that the times of change during German reunification, were used to create completely new studies that meet the specific requirements of the RE industry. In the old federal states, these new contents

were rather integrated into the established traditional courses.

3. Typical Course Structure in RE and EE Education

The following programs for each category are analyzed in detail as examples.

3.1. Bachelors Degree Courses

3.1.1. Degrees in Electrical Engineering

First, three bachelors programs of the FH Münster (University of Applied Sciences Münster), Technische Universität Darmstadt (Darmstadt University of Technology) and FH Koblenz (University of Applied Sciences Koblenz) are presented as examples in Electrical Engineering.

All three programs impart, in the first semesters, the basic principles of electrical engineering and information technology. Only in the later semesters, students can specialize with the help of elective modules and/or choosing a major.

At the FH Münster, specialization in "Renewable Energies" is offered as a required subject.. At the FH Koblenz and the TU Darmstadt, RE / EE are only offered in the elective modules.

In all three programs, modules generally on "**Renewable Energy Systems**" (2.5 - 5 Credit Points, (CP) [3]) are offered. Two programs deal with "**Photovoltaic**" (5 CP) and "**Wind Energy**" (2.5 to 5 CP), one program beyond that with "**Energy Storage Technology**"(5 CP). Here, a very large variation of what is considered a reasonable amount of RE focus is evident. It varies from 25 CP in the compulsory field (Münster) down to only an offering of elective subjects (TU Darmstadt).

3.1.2. Degrees in Mechanical Engineering

Also among the Mechanical Engineering, three bachelors degree programs were examined: Beuth Hochschule Berlin, TU Freiberg and FH Köln.

As well at the traditional Mechanical Engineering, the classic basics are taught in the first semesters. Specialization is later in the program. At two universities, students have to take compulsory modules, while at the third RE and EE issues are only offered as elective modules.

All analyzed programs offer "**Wind Energy**" (2 to 3 CP), two universities offer "**Bioenergy**" (5 to 6 CP), "**Hydropower**" (2 to 3 CP) and "Solar **Energy**" (2.5 to 3 CP). Only at one place, there are modules dealing with "**Renewable Power Plants**" (6 CP) and "**Combined Heat and Power**" (4 CP).

Similar to the Electrical Engineering, the Mechanical Engineering shows the bandwidth, both in content and in scope, considered to be called as "deepening of RE": from around 15% (30 of 210 CP) in Berlin down to an elective share of only 7% (15 of 212 CP) in Freiberg. Noticeable, is the larger variety of topics compared to Electrical Engineering.

3.1.3. Degrees in for Building Service Engineering/Supply Engineering

Three bachelors degree programs for Building Service Engineering/Supply Engineering of FH Trier, FH Erfurt und FH Rosenheim were analyzed in detail.

Here also, the classic basics are taught in the first semesters with the chance to specialize in later semesters. At two universities, students have to take compulsory modules, while at the third RE and EE issues are only offered at elective modules.

All three programs deal with "**Renewable Energies**" as a general module (2 to 5 CP), but only one university offers a special module for "**Solar Thermal Energy**" (2 CP).

3.1.4. "New" Degree Programs in RE and EE

[3] CP means Credit Point: one CP is a work load of 25 to 30 hours work for a student. Typical courses have 2 to 5 CP.

The "new" programs are designed strongly aimed at RE/EE and do not adhere much to the classical curriculum. As an example, three studies are presented.

3.1.4.1. FH Stralsund: Renewable Energies – Electro Energy Systems

Compulsory modules (RE): 21 CP out of 180 CP

- Introduction into Renewable Energy Technics (2 CP)
- Renewable Energy Storage (2 CP)
- Hydrogen Technology (4 CP)
- Renewable Energy Converters I (4 CP)
- Renewable Energy Converters II (5 CP)
- Basics of Renewable Energy Systems (2 CP)
- Renewable Energy Systems – Laboratory (2 CP)

3.1.4.2. FH Heilbronn – Energy Management

Compulsory modules (RE/EE): 12 CP out of 210 CP

- Electrical Energy Technics/Combined Heat and Power (2 CP)
- Bioenergy, Geothermal Energy, Solar Thermal Energy (2 CP)
- Photovoltaic, Wind Energy (2 CP)
- Local Energy Systems (2 CP)
- Optimization of Energy Supply (2 CP)
- Environmental Economics and Environmental Management (2 CP)

3.1.4.3. FH Trier – Energy Engineering – Renewable and Efficient Energy Systems

Compulsory modules (RE/EE): 25 CP out of 210 CP

- Renewable Energy Systems I: Solar Thermal Energy (5 CP)
- Renewable Energy Systems II: Biomass (5 CP)
- Renewable Energy Systems III: Photovoltaic, Wind Energy (5 CP)
- Efficient Energy Systems I: Heat Pumps (5 CP)
- Efficient Energy Systems II: Combined Heat and Power (5 CP)

For these new courses, subjects from different disciplines are combined and even non-technical subjects are integrated to a larger extent. The share of pure RE/EE subjects in these new programs is much higher. But it has to be noted that, even in these focused new degree programs, around 80% of the subjects are “classical” study courses. This is valid for nearly all degree programs in Germany. The reason for this is that although RE and EE do contain new subjects, the basics of engineering are the same and should not be neglected in the degree program, to ensure a sound tertiary education.

3.2. Masters Degree Courses

The masters degree courses are much more specialized in renewable energy or energy management than the bachelor programs. As an example two universities and their masters degree courses are presented here.

3.2.1. Renewable Building System Technology at the University of Applied Sciences Magdeburg-Stendal

This innovative master degree program focuses on the integration of renewable energies technologies (solar, heat pumps, passive solar, etc.) and energy efficient technologies into the building design. The special focus is on system analysis, optimization and integration. To achieve this integration 30% of all courses are taught

in conjunction with the master degree program "Energy Efficient Construction of Buildings" from the civil engineering department. This close cooperation among departments is innovative and necessary to overcome the classical "communication problem" between the different disciplines.

3.2.2. Renewable Energies Masters Degree Courses at the University of Kassel

Four different post-graduate education programs on renewable energies are offered at Kassel University. The table shows an overview of the education programs.

Tab. 2: Overview of the post-graduate programs at Kassel University

	Renewable energy and energy efficiency	**Renewable energy and energy efficiency for the MENA Region**	**European Master in Renewable Energy**	**Energy and Environment**
Degree	Master of Science	Master of Science	Master of Science	Certificate(s)
Duration	18 months	21 months	16 months	6 to 12 months
Start date	April and October	July	September or October	October
Languages	German	English	English, French, Spanish	German
Tuition Fee	Free	≈ 10.000 €/program	≈ 7.300..11.500 €/program	900..2.300 €/Module
Website	www.energie.uni-kassel.de	www.uni-kassel.de/remena	www.master.eurec.be	www.uni-kassel.de/e+u

The interdisciplinary master's program "*Renewable Energies and Energy Efficiency*" has been offered at Kassel University (Germany) since 2005. The masters program is directed to students with a bachelor or comparable degree in technical or natural sciences or in, for example, environmental engineering. The arrangement of the curriculum allows the students to choose from more than 100 courses in renewable energies at the master's level. 80 students can enroll per year, but many more apply for the program. Detailed information about the master's program is given in (Vajen et. al. 2011) and on the website www.energie.uni-kassel.de.

The bicultural master's program "*Renewable Energy and Energy Efficiency for the MENA Region*" has been offered at Cairo University (Egypt) and Kassel University, since 2009. The master's program is addressed to young professionals with working experience. The program starts each year in July in Cairo and consists of three parts: Seven months at Cairo University, six months at Kassel University and approximately an eight-month internship in the MENA region[4] for the master's thesis. At present, nine students have successfully completed their studies.

The international master's program "*European Master in Renewable Energies*" is organized by the European Renewable Energy Centers (EUREC) and is hosted by nine Universities. The program has a total duration of 16 months and consists of three parts: a core phase (Sep. / Oct. to Jan.), a specialization phase (Feb. to June) and a project phase (Jul. to Dec.). During the program, the students are guaranteed to spend time in at least two different European countries. Kassel University has been part of the master's program since the beginning (2002) and offers the specialization module "hybrid systems".

The further education program "*Energy and Environment*" has been offered at Kassel University since 1982. The target groups are employed engineers, natural scientists and technicians. Therefore, all lessons are given

[4] Countries in the Middle East North Africa (MENA)

at weekends. The program has a modular structure and at the end of the modules the participants are award a certificate. At present, five modules are offered: rational use of energy (15 weekends), energy consultant for buildings (nine weekends), energy consultant for non-residential buildings (two weekends), construction planner renewable energies (five weekends) and construction planner wind energy (six weekends).

4. Teaching Language

The following list gives an overview of the degree courses having English titles. Most of them probably include some English-taught modules, but only very few are entirely taught in English language, like in Kassel. Unfortunately there is no overview about degree programs with English as the teaching language available. To develop and implement English RE and EE degree programs in Germany is seen as one of the future development aims of the universities, as they do have already well-established German language degree programs. But one challenge is that not every lecturer in Germany is happy to teach in English and the existing workload of them is already quite high due to the limit number of lectures in these subjects.

Tab. 3: Degree courses with English titles

BTU Cottbus	Electrical Power Engineering (Sustainable Energy Supply)
BTU Cottbus	Environmental and Resource Management
BTU Cottbus	Power Engineering
Business and Information Technology School, Iserlohn	Green Business Management
FH Aachen	Energy Systems, Sustainable Energy Systems & Energy Economics
FH Amberg-Weiden	Environmental Engineering
FH Bremerhaven	Process Engineering & Energy Technology (PEET)
FH Darmstadt	Electrical Engineering
FH Erfurt	Renewable Energy Design
FH Kiel / FH Flensburg	Wind Engineering
FH Nordhausen	Systems Engineering
FH Offenburg	Energy Economics
FH Offenburg	European Energy Economics (EEE)
FH Offenburg	Master Studium Energy Conversion and Management (ECM)
FH Oldenburg / Ostfriesland / Wilhelmshaven	Engineering Physics
FH Oldenburg / Ostfriesland / Wilhelmshaven	Environmental Technology and Management
FH Oldenburg / Ostfriesland / Wilhelmshaven	Technical Management
FH Ostwestfalen-Lippe	Environnemental Sciences
FH Stuttgart / FH Ulm / FH Rottenburg	Sustainable Energy Competence (SENCE)
FH Trier (Birkenfeld)	International Material Flow Management
HAW Hamburg	Environmental Engineering
HAW Hamburg	Renewable Energy Systems
Leuphana Universität Lüneburg	Sustainability Sciences
TU Berlin	Global Production Engineering (GPE) for Solar Technology
TU Berlin	Renewable Energy Systems
TU München	ClimaDesign
Universität Bayreuth	Biotechnology and Process Engineering
Universität Bayreuth	Engineering Science
Universität Bayreuth	Engineering Science and Technology
Universität Bayreuth	Internationales Elite Master Studium Global Change Ecology
Universität Flensburg	Internationales Master Studium Energy and Environmental Management
Universität Freiburg	Photovoltaics
Universität Freiburg	Renewable Energy Management

Universität Hannover	Water Resources and Environmental Management
Universität Kassel	Renewable Energies and Energy Efficiency
Universität Kiel	Materials Science and Engineering
Universität Oldenburg	Postgraduate Programme Renewable Energy
Universität Oldenburg	Sustainability Economics and Management, Spezialisierung Erneuerbare Energien
Universität Oldenburg / Universität Kassel	EUREC - European Master in Renewable Energy
Universität Oldenburg / Universität Kassel	EUREC - European Master in Renewable Energy
Universität Stuttgart	Water Resources Engineering and Management
Universität Ulm	Energy Science and Technology
Universität Weimar	Environmental Engineering and Management

5. Internship and collaboration with industry in degree programs

Intensive collaboration with local industry is an integral part of German engineering tertiary education since a long time. Especially the so called "dual" degree programs, where students receive a bachelor's degree and a vocational training degree, based on close cooperation. Here the students are spending around one third of their time in industry and the rest at the university. This kind of dual program is usually one year longer than a regular bachelor's degree program at Universities of Applied Sciences. It is highly demanding on the students, but ensures high quality bachelor's degrees. Therefore, only the best students are recommended to join this dual degree program.

In the usual bachelor's program 20 weeks, and/ or six months internship in industry are mostly required at Universities before the first two years are finished, in the Universities of Applied Sciences, often as an integral part in the third year at University. Through this linkage, a clear additional focus to the education is given and it ensures that the student is orienting his further education towards the needs of industry as well.

Close cooperation among universities and local industry is fostered through guest lectures by industry and through research activities. Additionally, bachelor's and master's degree theses, at least at the level of Universities of Applied Sciences, are written either directly in - or in very close cooperation with - industry Master's theses at Universities are much more often written at the university itself or at research institutes, also, often in close cooperation with industry.

This approach of technical tertiary education in German speaking countries has contributed to its strength and to a very close exchange with industry. As the companies in RE and EE are often SMEs, (Small and Medium size Enterprises), their willingness for cooperation with local universities is very high and keenly sought.

If regional clusters of industry exist, cooperation with any such groups is even more effective and universities are playing an important role here. As one such example is the "Solar Valley Mitteldeutschland e.V." for solar industry or the "CEwind e.G." in Northern Germany, on wind industry.

To strengthen the cooperation further, formation and construction of a data-base about RE and EE industry and their needs, as well about capabilities and specialist knowledge at Universities, would help to improve this collaboration further (K. Vajen).

6. Conclusions

More than 100 universities in Germany already offer degree courses' with increasing emphasis on renewable energy or energy efficiency. The Universities of Applied Sciences, compared to most Technical Universities, have already oriented their aims much more towards this new study subject. The new federal states of Germany (former East Germany) have adopted the subjects much more than the older federal states (former West Germany). Here the subjects are mainly integrated in already-existing engineering programs, and, even now, more than 60 degree programs are having a clear focus on RE or EE subjects. The RE and EE bachelor's or master's degree courses are mainly in engineering subjects (mechanical/electrical), while

architecture and civil engineering subjects have not yet entered the renewable energy degree programs, neither on the level of bachelor's nor master's degrees. Thus, non-technical RE degree courses hardly exist as yet.

Although almost all of the degree courses are offered in the German language, a small number offer partial or complete degree programs in English.. With its experience in the RE field, it might be a good opportunity for German- speaking Universities to broaden their degree program to encompass English as well.

The strength of the German degree program is their close cooperation and linkage with local industry - even sometimes with industry groups. Internships are often mandatory for at least 20 weeks, featuring guest lectures from industry and some practical exercises. The fact that bachelor's and master's theses presented at Universities of Applied Sciences, are very often written, either directly in industrial companies or in close cooperation therein, ensures the relevance of their theses to the needs of industrial research objectives. In addition, once the students have graduated, they can find an interesting job offer, concomitant with their acquired knowledge and skills. As many companies in RE and EE are small or medium- sized industries, even development and applied research flourishes much more in close cooperation with Universities than in other fields of industrial cooperation. It seems, that the University of Applied Sciences tends to cooperate more with smaller industries, while Technical Universities have major research programs and have closer collaboration with national personalities and international companies.

While the tertiary educational system in Germany has adapted to the new energy situation, some major issues are still pending:

- Non-technical degree programs have not yet focused on RE or EE issues
- Architecture and civil engineering have not focused on RE and EE aspects and have not yet anticipated the needs of the market, especially the integration of building design and energy system and its optimization is still lacking in the educational approaches.
- Coordinated collaboration between universities and industry is still hampered by the non-existence of a data base.
- The existing databases on RE and EE study degree programs in Germany do not allow for a better overview or for a more detailed evaluation of the specialization and the degree of penetration in the various subjects. Finally, it is recommended to establish a more detailed database of existing degree programs and their specialty, to allow a better overview for students and for the industry, outlining the knowledge offered and the extent of what specialization in the individual subjects is to be proffered.

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