EDUCATION IN RENEWABLE ENERGY - PAST SUCCESSES AND FUTURE AVENUES

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Abstract

The Department of Engineering and Information Technology at Berne University of Applied Sciences (BUAS) has been a center of competence in renewable energy solutions since the 1980s. In the past, BUAS has developed and implemented renewable energy solutions in partnerships and networks with stakeholder groups and thus created opportunities for both the next generation and the regional economy. Early successes are (i) the invention of the "feed-in tariff" for PV-installations, which forms the nucleus of the market breakthrough of the PV-industry worldwide, or (ii) pioneering research teams such as the "Solar Racing Car" team in the 1990s and solar- and PV-inverter companies like "Sputnik Engineering AG". More recent examples include the "Solar Impulse" research team on the development of a solar plane with Bertrand Piccard (www.solarimpulse.com) employing former student engineers educated at BUAS. Future educational and research avenues in renewable energy solutions will be concentrated in a new Institute for Energy and Mobility Research (IEM) at the Department of Engineering and Information Technology at BUAS. Engineering education will continue triggering an entrepreneurial and pioneering spirit and include sustainability engineering. This contribution presents some recent efforts on research and education in sustainable engineering and renewable energy solutions undertaken by the new IEM.

1. Introduction

The perception of European students regarding environmental changes and associated societal and economic feed-backs is often more strongly determined by the politically influenced media discourse or propaganda rather than by a comprehensive, unbiased science and engineering education (Schuepbach et al., 2009). As a consequence, major misconceptions persist among the next generation. Yet, the future society and economy needs engineers and scientists who are scientifically sound and able to address the frictions inherent to the reduction of carbon dioxide emissions and implementation of renewable energy solutions (IPCC, 2007). In order to address the sweeping challenges associated with shifting towards new renewable energy, educational efforts need to strengthen the competences in the field and offer unbiased scientific background information. This paper presents good practice in the gaps addressed above and illustrates past successes and future avenues of educating the next generation on the way towards renewable energy at Bern University of Applied Sciences in Switzerland.

2. Past Successes

2.1. Solar Energy and Electric Drive: Visionary Research and Market Application

Research training offered for student engineers registered at BUAS draws on a long history of experience and inventions in Biel and Burgdorf. BUAS has been open to new developments in sustainable energy production since the early 1980s. To illustrate the enormous potential of solar energy in combination with electric drive, a *Tour de Sol*, the first solar car race in Switzerland was organised in 1984. The light-weight construction and high efficiency of the vehicles allowed for a low energy consumption (2-5 kWh/100 km) so that - even with lead acid-batteries - a geographical range of 100 km could easily be achieved. Due to their expertise in electric motors, power electronics, solar photovoltaic power production and vehicle development, the then Engineering School of Biel (directed by Professor René Jeanneret) won the 2nd price in 1985 with its "Spirit of Biel/Bienne" (Figure 1). Following the success at the *Tour de Sol 85* in Switzerland, the solar car models of BUAS win several world champion titles like the Australian World Solar challenge in 1990 and beat car companies like Honda.

Fig. 1: Route of *Tour de Sol* Switzerland in 1985 with winning team Alpha Real / Mercedes Benz.

This pioneering role of BUAS attracted many ambitious students who aimed at starting their career in the business of power electronics and electric vehicles. The light-weight electric vehicles constructed by BUAS also inspired Mr Hayek to launch the “SMART” car project, which eventually went into production at Mercedes Benz. Since then, vehicles like hybrid racing cars from Porsche, solar boats and even the Antares 20E glider with a retractable electric motor have been developed at BUAS. The Antares glider is now produced by Lange Flugzeugbau GmbH in Germany and is the starting point for a new glider family. Today, former engineering students at BUAS work in the “Solar Impulse” team on the electronics of the solar plane developed by Bertrand Piccard. A spin-off company, DRIVETEK AG, is both applying know-how from BUAS and occupies several former students from BUAS.

2.2. Photovoltaics and the Invention of the First Worldwide Feed-in Tariff System (Burgdorf Model)

In the late 1980s, two students at BUAS Biel, Department of Information Technology and Engineering (then directed by Professor Dr. Viktor Crastan) also started with the construction of grid-connected photovoltaic (PV) inverters. Years later, they founded Sputnik Engineering AG that is now one of the leading PV-inverter companies in the world and employs many former BUAS engineering students. Sputnik Engineering AG currently builds a new company head quarter in Biel (western Switzerland) for 500 employees and serves as a role model and motivator for BUAS students working in solar photovoltaics. After his retirement, Professor Dr. Crastan wrote several books published in Springer Verlag. Together with Sputnik Engineering AG, these books are knowhow hubs on photovoltaic inverters to feed the next generation of engineers.

Research on photovoltaics was also started at BUAS Burgdorf in the late 1980s when Professor Dr. Heinrich Häberlin concentrated on solar photovoltaic (PV) system technology. In 1993, he equipped the new BUAS building at “Tiergarten” in Burgdorf with a 60 kWp photovoltaic plant, at that time one of the then biggest PV-plants in the world. Since then, the BUAS PV plant in Burgdorf has both developed into a leading centre for inverter tests and PV-system technologies and serves as a learning environment for engineering students to build PV-plants and PV-houses.

In the early 1990s, the city of Burgdorf invented the first worldwide “feed-in tariff system for PV”. It allows owners of a PV-installation to feed in the electricity they produce from their PV-installations into the grid, charge the grid owners for their electricity contribution and thus get a return of investment. This “Burgdorf Model” was later copied by German politicians during the “red-green-coalition” phase in the early 1990s and marked the beginning of the strong increase in the worldwide PV-market with growth rates of 50% (+) and an annual installed power of 17 GWp in 2010. Due to the big market, the price for electricity is now decreasing and “grid parity” in southern Europe is reached. Switzerland is expected to reach “grid parity” before 2020.

At the new test plant of BUAS Burgdorf, Professor Dr. Häberlin started testing PV-inverters in the late 1980s and extended the tests to the Lab for optimization purposes. Together with his students and assistants, he built several PV-inverter test simulators with up to a 100 kWp each. A unique high voltage test chamber with up to one megavolt has enabled BUAS Burgdorf to test components such as PV-modules, by-pass diodes, intelligent connector boxes, etc. With this know-how platform, Professor Dr. Häberlin established himself as a world leader and recognized specialist in overvoltage protection design and, at the same time, offers future engineers a unique insight into lightning protection and overvoltage control devices. An application of this expert knowhow in engineering is, e.g., the advantageous PV-installation at the new Monte Rosa hut in the Swiss Alps, at about 3'000 m asl near Zermatt (Figure 2).

Professor Dr. Häberlin also published several books about photovoltaics, e.g., "Photovoltaik: Strom aus Sonnenlicht für Verbundnetz und Inselanlagen" in 2010, VDE Verlag. This book compiles all the different aspects on the use of photovoltaics, is currently translated into English by John Wiley & Sons Inc. and will be published in 2012.

Fig. 2: Monte Rosa hut near Zermatt, Switzerland.

3. Future Avenues

To promote a leadership role of Bern University of Applied Sciences (BUAS) in the shift towards new renewable energy, BUAS founded a new Institute for Energy and Mobility (IEM) Research in 2011 in its Department of Engineering and Information Technology. IEM combines unique competences in almost all areas of energy and mobility to contribute to the above paradigm shift and concentrates on three pillars being (i) new renewable energy technologies and (ii) energy-efficient mobility. As an institution that adopts practices of corporate social responsibility, the new Institute also aims to deploy sustainable energy technology to developing and emerging countries (= pillar iii). Research activities at IEM, carried out in partnerships with public and private institutions are expected to feed-back into education to encourage the next generation, enhance employability and increase competences in inter- and transdisciplinary problem-solving, both among learners and teachers. Communication will be extended to new forms of visualising research results to raise the profile of the IEM and will engage with the civil society. Outreach efforts will also address the many misconceptions about sustainable energy concepts for a low carbon society among the public, politicians and the next generation as described in Section (1).

Activities in the IEM are based on the concept for sustainable development in education, research, service and operations adopted by the BUAS top-level management on 10 August 2010. By strengthening sustainability in engineering education, the Institute will comply with the "United Nations Decade of Education for Sustainable Development" (2005-2014), for which UNESCO is the lead agency. It seeks to "integrate the principles, values and practices of sustainable development into all aspects of education and learning." in order to address the social, economic, cultural and environmental problems we face in the 21st century (www.unesco.org/en/esd/). Here, we present research and education examples of (i) and (iii) at IEM.

3.1. Education in Solar Energy Production and Energy Security

It is important that future engineers view energy security and climate protection as an opportunity and hence, most students enrolled in a degree at BUAS are involved in industry projects and have contacts with distributors. Current student projects include PV-parking places for electric vehicles (EVs) in the BUAS building in Burgdorf, or the development of PV-plants for a house with high solar energy contribution as part of an energy management with heat-pump and electric vehicle in the house (jointly with ETH Zürich). More theoretical studies utilise the large data base from the PV Lab of BUAS Burgdorf. This Lab has equipped more than 40 PV-plants with measurement systems to track the long-term production of PV-plants (e.g., at Jungfraujoch at 3'580 m asl, Switzerland). The data is, e.g., feeding computer software that is applied as part of daily business in an engineer's life. The students compare and evaluate the accuracy of this software and gain essential competences and skills to advice end-users of PV-installations.

Another typical project involving students is carried out with Solarcenter Muntwyler AG (Zollikofen) and Müller & Kälin AG (Zürich), jointly with Baugenossenschaft Zurlinden BGZ, a traditional cooperation active in sustainable building projects. The project is a retrofit-activity aiming at two tall (60 m) buildings in Zürich on which thin film PV-modules instead of conventional façade elements are to be mounted. Façades produce about 70% of the energy of a tilted surface, and thin film solar cells with their lower efficiency have a lower price per square meter than crystalline solar cells, which are expensive due to their efficiency. It hence seems interesting to construct façades with thin film PV-modules. The thin film solar modules are to be installed on all four sides of the buildings (Figure 3), with an estimated power output per building of about 130 kWp.

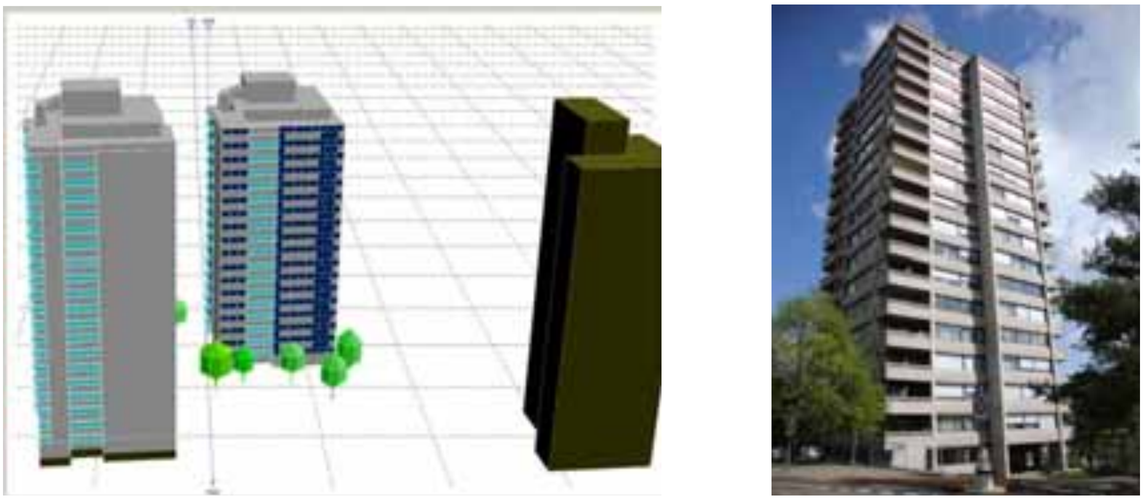

Fig. 3: The two buildings in Zürich with a model of the PV-thin film façade (left) and original building (right).

Electrical installations in a 60 m tall building with many fragmented PV-modules are very difficult to realise. Lightning protection, fire safety, optimization of cable length, partially shadowing of PV-modules and the choice of the inverters and their voltages have to be taken into consideration. Field tests were carried out in a student project on a 1:1 model either in Zürich or Burgdorf. Through the different earnings per square meter, different approaches were needed to sell the solar electricity to the local utility company (EWZ) and the "feed-in tariff" regime in Switzerland. Other selling possibilities were also studied, and the students calculated the energy production of the first building on all four sides. The producer of the PV-element supports this project and will use the two retrofit buildings in Zürich as a showcase for the application of thin film modules in the façade application. Construction of the first building started in summer 2011.

Most recently, and after the incident of the nuclear power plant in Fukushima, Japan, the students' concern regarding atomic energy increased and topics selected for research often concentrated on the role of new renewable energy for replacing energy produced in nuclear power plants in Switzerland. In a bachelor thesis, a student applied different PV-calculation programmes to compile Figure 4. It shows the 30 km circle (similar to the Fukushima evacuation zone) around a nuclear power plant in Switzerland (red) and the surface to produce all electricity consumed in Switzerland by photovoltaic (about 60 TWh) with an 11-12 km radius (yellow). In practice, 10-20 TWh would be enough to replace the production of all five nuclear power plants in Switzerland.

Fig. 4: Yellow: area needed to produce the total amount of consumed electricity using photovoltaic in Switzerland (60 TWh). Red area: 30 km circle similar to the Fukushima evacuation zone.

3.2. Education in Sustainable Energy Technology in Developing and Emerging Countries

Energy and mobility are viewed as important drivers for economic and social development (World Business Council for Sustainable Development, www.wbcsd.org). Today, over 20% of the global population lack access to electricity, most of them in rural areas. Scenarios indicate that this situation will not improve until 2030 and will be prevailing in sub-Saharan Africa, India and other developing Asian countries, excluding China (IEA, 2010). Sustainable energy technologies hence display a particularly great potential in providing energy services to developing countries.

For rural areas in developing countries, affordable water availability and control for crop production is a critical issue. Small-scale farmers mostly depend on rainwater and the wet season. During the rainy season, dumping prices on the market often don't cover the production costs while, in the dry season, these crops can sell at a price that is up to three times higher, if irrigation is available. In villages without electric power supply, manually-operated pumps and diesel pumps are vital for small-scale farmers to provide the badly needed irrigation water and hence additional income during the dry season.

However, manually-operated pumps are extremely labor-intensive and people in villages rapidly purchase diesel pumps, which are very costly in fuel. Many small-scale farmers hence cannot afford irrigation, and large-scale irrigation systems mostly cover certain areas only and do not reach the fields of small producers. When the villages are connected to the grid system, electric water pumps are preferred but then, grid electricity may go off after some hours while additional nine hours of irrigation would be needed for crop production.

In summary, harnessing solar energy for irrigation to replace part of the exhausting manual labor, avoid tremendous cost in diesel or unreliable grids can drive agriculture in rural areas. Sustainable energy concepts may also open the door to additional sources of income for the rural population (e.g., agritourism, see Raghunandan et al., 2010).

“To make it work, make it a business”. This idea is underlying a pilot project on introducing sustainable energy technology to pump irrigation water and generate micro-business for small-scale farmers in India. Photovoltaic water pumps, operating at 40-120 W and implemented for irrigation, are currently tested by BUAS students in Bangladesh (see Figure 5). Jointly with CARITAS Switzerland and IDE-Gates, they seek to evaluate whether our sustainable energy concept holds for future implementation in India.

Fig. 5: Swiss Solar Water Pump developed at BUAS Biel and implemented in Bogra, Bangladesh (left). Manually-operated water pump (right) in Bogra, Bangladesh (both photographs taken by I. Kunz and D. Tschanz on 10 and 6 April 2011).

4. References

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