Renewable and Sustainable Energy Reviews 63 (2016) 13–18

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Rethinking solar energy education on the dawn of the solar economy

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ARTICLE INFO

Article history:
Received 1 July 2015
Received in revised form
12 January 2016
Accepted 3 May 2016

Keywords:
Solar energy education
Renewable energy education
Solar energy boom
Helionomics

ABSTRACT

Combining different approaches, this article describes a multidisciplinary graduate course (*Solar Master*) on solar energy for science, engineering, economics and management students aimed to shape professionals capable to understand, develop and disseminate solar energy seen as a strategic and critical resource. Eventually, students ending the *Solar Master* will become professionals whose companies will not only use or install high quality solar energy systems, but will be able to increase public perception of solar energy as an intrinsically reliable and cost competitive energy source to produce electricity on utility scale as well as electricity, heat and light for all sort of buildings across the world.

Contents

1. Background

Accompanying the world's solar boom, [1] the cost of generating electricity from solar power using the photovoltaic (PV) technology has decreased by >80 percent over the past 10 years. Clean, safe and low-cost renewable solar and wind energy, are poised to meet the world's energy needs in the near future, ending threats to public health, energy security and the environment due to combustion of fossil fuels, and nuclear fission of uranium [2].

The feasibility of 100% renewable electricity supply in top industrialized countries such as Germany is no longer a futile exercise, but rather a realistic perspective for which thorough recent studies indicate how the transition could be achieved; [3] including the roadmaps of Jacobson and co-workers to convert 139 countries of the world to wind, water, and sunlight using technologies selected to provide electricity which include wind, concentrated solar power (CSP), geothermal, solar PV, tidal, wave, and hydropower. for all energy purposes by 2050 [4].

The transition to large-scale use of renewable energy, namely to a true solar economy with its economic, environmental and social benefits due to non polluting electric power and low temperature heat generation, [5] requires a better education of scientists, engineers, and managers one for which true understanding of renewable energy becomes a significant part of their

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http://dx.doi.org/10.1016/j.rser.2016.05.008
1364-0321/

scientific literacy [6]. Education in solar energy science and technology, indeed, is not as developed as it should, and this despite the pioneering efforts of Broman and other scientists who first argued in the mid 1980s that education had to become a central part of worldwide solar energy activities [7].

Prior to the global solar boom started in the early 2000s, research in solar energy science was largely restricted to a few specialists based on the wrong assumption that the cost of both photovoltaic and solar thermal energy technologies would inevitably remain high, being limited by "physical" thresholds.

All has changed during the ongoing global solar boom started from the "Feed-In-Tariff" (FiT) in Europe, and to the massive market entrance of new solar cells manufacturers based in China, which has rapidly led to widespread diffusion of the PV technology to produce electricity from sun's radiation in both developing and developed countries at unprecedented low cost [1].

On the verge of said solar boom, about a decade ago, the authors started educational activities on solar energy in Italy, today the country with the largest fraction (8.7% in 2014) [8] of electricity production provided by PV modules. We readily realized that available books on the topic of solar energy were either outdated or simply absent.

This led us to write some of the first new books [9] on solar energy in order to fill this educational gap and provide students with updated educational resources.

We outlined the concept of a new course dubbed *Solar Master* and, alongside with Giovanni Palmisano (now a professor of chemical engineering at a prestigious institution abroad), [10] in less than four years gave ten consecutive editions of a course whose practical outcomes, including the foundation of four new solar companies and high customer satisfaction recorded in student's evaluation of the course, prompted us to further expand our educational efforts with the aim to offer a similar new course to an international audience.

Was obsolescence in solar energy education a feature of Europe only? At least not apparently. For example, at the 2014 meeting of the American Society of Mechanical Engineers, the outcomes of a review of engineering curricula in the US included the following findings [11]:

> "Engineers and scientists have failed on large extent to fully address the sustainability issues… Engineering graduates do not possess necessary skills to tackle sustainability related problems. Current engineering curricula are not equipping them to properly deal with these challenges due to little integration of sustainable and green design strategies and practice… These concepts and methods are still relatively new to engineering curriculum and are not an established practice for most of such programs."

In 2014, Broman and Kandpal, a scientist at Indian Institute of Technology, published an ample review with over 370 references to the international published literature on renewable energy education and training at university, school and professional training level [12]. Twenty five years after the foundation of the International Association for Solar Energy Education (see below), its co-founder reported that during the previous three decades several countries had started academic programs on renewable energy technologies. Yet, a lack of availabile well structured curricula as well as of competent teachers were clearly identified as the main causes creating a lack of human resources with required knowledge and skills needed for accelerated dissemination of renewable energy technologies.

Similarly, a 2010 study reporting first attempts to "nourish green minds" in United Arab Emirates and related oil-rich countries, found that most universities in the region had not yet introduced or integrated solar energy in their curricula [13].

Prolonged past experience across the world has shown that modern solar energy education requires the integrated and multidisciplinary study of technology, resources, systems design, economics, industry structure and policies. Said another way, attempts to add one or two units of study on renewable energies into traditional science and engineering degrees will *not* produce graduates with sufficient knowledge to use solar energy effectively [6]. Accordingly, new graduate courses on solar energy are being organized at several universities worldwide, with the aim to integrate sustainable energy into the basic university education in physical and chemical sciences [14].

In this rapidly evolving context, after describing the main features of the emerging solar economy, we identify the requirements of an innovative course for undergraduate and graduate students of science, engineering, economics and management aimed to shape professionals capable to understand, develop and disseminate the use of solar energy as a strategic and critical resource to make sustainable our common development.

2. The solar economy

Energy is a critical resource which plays a vital role in the socioeconomic development and human welfare of a country [15]. Electricity, in particular, is a strategic commodity whose availability at affordable cost is directly linked to economic development [16].

From a purely economic viewpoint, thus, a solar economy is one in which making power from sunlight costs less than making it from burning the cheapest fossil fuel, namely coal. In early 2015 a solar PV module manufacturer signed a power purchase agreement for a 200 MW project in Dubai that will profitably sell electricity for $0.0584 per kilowatt-hour (kWh) [18]. A few months later, in the US a local utility agreed to buy electricity generated by a 100 MW solar farm comprised of CdTe thin film solar modules at a price of 3.87 $ cents per kWh [19]. These figures alone may explain the origin of the global solar boom (Fig. 1), analyzed in detail elsewhere [1].

Seen from the distributed generation viewpoint, on the other hand, the consequences of PV modules being profitably sold at $<0.5$$/W imply that families and businesses can efficiently self-generate electricity at lower cost than the price of electricity sold by utilities through the grid.

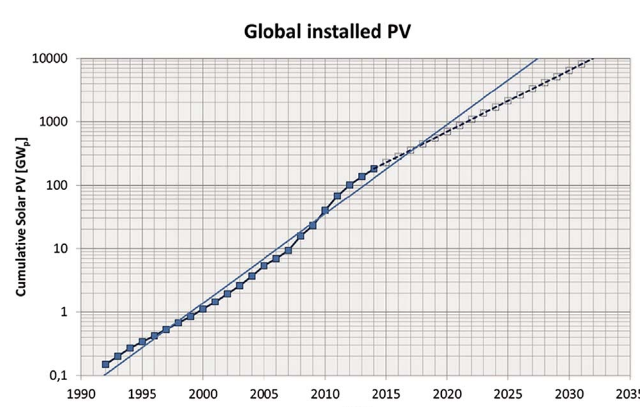

Fig. 1. Cumulative global PV installations has grown exponentially between at constant growth rate of about 25% per year (the dotted line). Blue dots show the installed PV in the world. [Image courtesy of Dr E. Heindl; reproduced from Ref. [17], with kind permission]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)