Education in Photovoltaics as a part of the REPowerEU

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Abstract

Photovoltaics has been recognised as a renewable energy technology having the potential to contribute significantly to future energy supply. The European Green Deal has added to the importance of photovoltaics as one of the most important component in the future energy mix, and the new REPowerEU programme further emphasizes its importance. To establish an infrastructure and to meet the requirements of the market, education and training are needed for specialists in this field. Different aspects of education in photovoltaics are discussed.

Keywords: photovoltaics, photovoltaic cells, photovoltaic modules, photovoltaic systems, education.

INTRODUCTION

Atmospheric pollutions and climate changes represent a serious problem for present civilization. There is very important to decrease pollutions at energy generation. This year, incoming European Commission proposed as one of its most important political priorities the 'European Green Deal'[1].

The European Green Deal has been at once conceived of as a climate project, aimed at making Europe a climate neutral continent; as a social project, to support a just transition; as an economic project, seeking to rejuvenate EU investment and competitiveness; as a European project, to give new purpose and unity to the EU; and as an international project which will take a more geopolitical approach to global climate security [2]. One of the most important targets is the transition from using energy sources based on fossil fuel combustion to using Renewable Energy sources (RES). The 2018 energy mix [3] is shown in Fig.1a.

Problems connected with the energy mix transition were in details studied at LUT University [4]. The result of this study is shown in Fig.1b. This study shows that 69% of electricity needs to be generated by photovoltaics in order to meet the needs of electricity by renewable energy only. Some other studies assume a lower share of photovoltaics in the energy mix in 2050 (e.g. [5]), as demonstrated in Fig.1c.

From that can be expected that in 2050 the share of photovoltaics could exceed 30% of total energy production [6]. Therefore, photovoltaics is a strategically important part of the coming sustainable energy system.

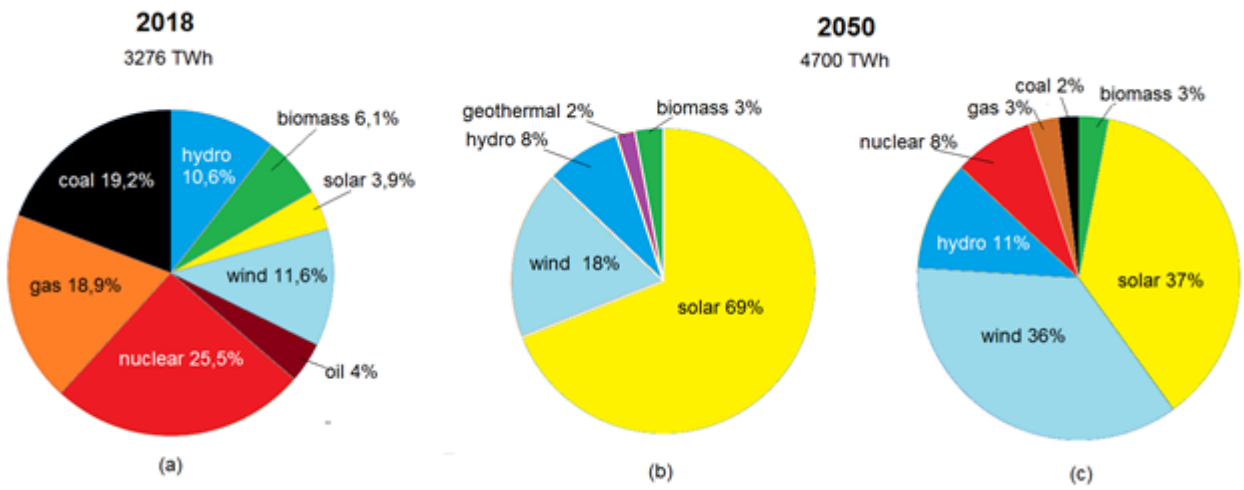

Fig.1. Shares of primary European energy supply in 2015 (a) and 2050 (b),(c).

Thanks to the abundant availability of sunlight, the technology's modularity, and continuous cost reductions and photovoltaics can become the largest source of energy worldwide.

PHOTOVOLTAICS IN ELECTRICAL ENERGY PRODUCTION

The photovoltaic industry has recently shown an unprecedented rate of growth with the installed global PV power increasing by more than forty fold over the past twelve years: from 20 GW_p in 2009 to nearly 1 TW_p in 2021 of cumulative installed power (about 165 GW_p in EU). The global annually installed photovoltaic system power grew from 8 GW_p in 2009 to about 175 GW_p in 2021 [7], as demonstrated in Fig.2.

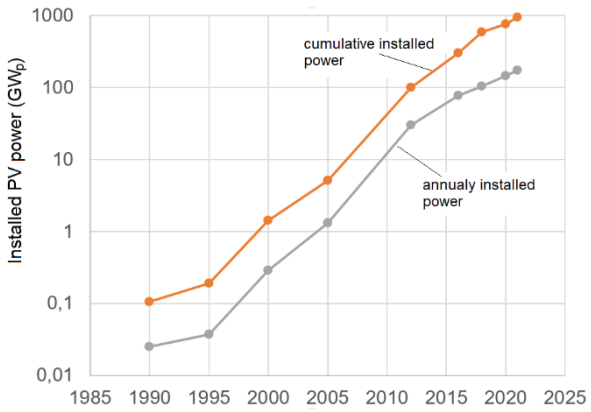

Fig.2. The developments of the PV cumulative installed capacity and annual production

It results in a considerable decrease of the costs of electrical energy produced by photovoltaic systems close to the long-term costs of receiving traditionally produced and supplied power over the grid. Already today photovoltaics provides a power generation solution, which is more efficient and cheaper than conventional energy sources in a large part of the world, as demonstrated in Fig.3.

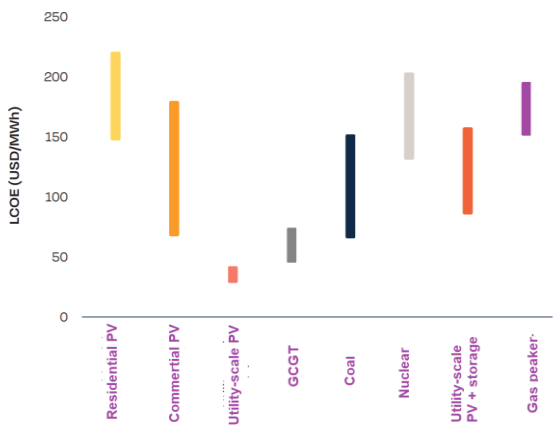

Fig.3. PV elektricity generation cost in comparison with conventional power sources in 2021 [8]

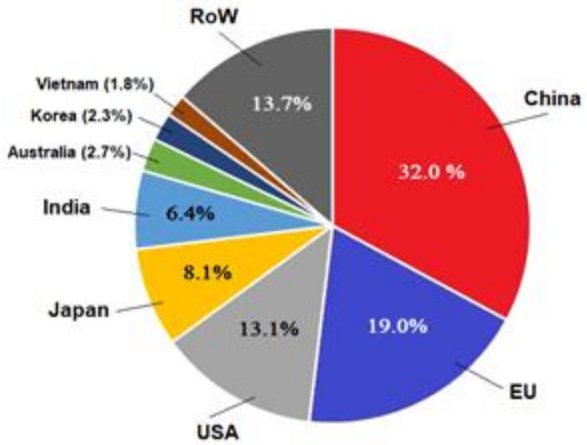

Fig.4. Distribution of cumulative installed PV power in 2021 by country

The most of PV installations is in China, followed with EU and USA [7], as demonstrated in Fig.4. In Europe, a very high increase in annual photovoltaic installations in the period 2005-2011 was followed by a decrease in the period 2012 – 2016. Since 2019, annually installed power has started grow again, as shown in Fig.5.

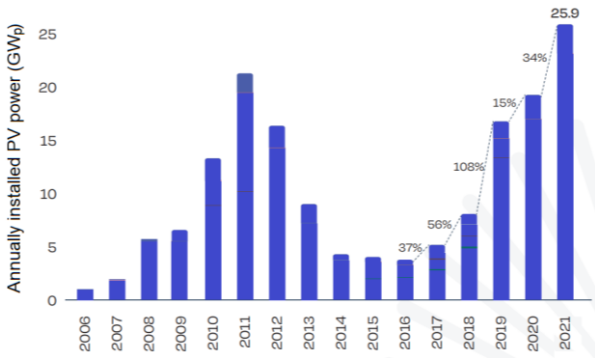

Fig.5. The development of the annually installed PV capacity in EU [9]

China plays a key role in the entire field of photovoltaics. 95% of PV modules is currently realized from crystalline silicon. China produces 64% of the world's polycrystalline silicon, more than 95% of silicon wafers, 80% of photovoltaic cells and 75% of modules. The EU's share of this production is very low. From a strategic point of view, therefore, at least the majority of production of all key parts of the production chain needs to be realized in the EU.

In response to the hardships and global energy market disruption caused by Russia's invasion of Ukraine, the European Commission presented the REPowerEU Plan [10] for

- saving energy
- producing clean energy
- diversifying EU energy supplies

Renewables are the cheapest and cleanest energy available, and can be generated domestically, reducing the need for energy imports. The European Commission is proposing to increase the EU's 2030 target for renewables from the 40% to 45%**.** This EU Solar Energy Strategy will boost the roll-out of photovoltaic energy. Under the REPowerEU plan, this strategy aims to increase the cumulative capacity of solar photovoltaic power plants to at least 320 GW_p (nearly double today's level) by 2025 and to 740 GW_p by 2030.

PRIORITIES IN THE FIELD OF PHOTOVOLTAICS

Priorities for the field of photovoltaics have been set for the implementation of this ambitious project [11]:

- Delivering solar industrial leadership
- #Solar4Buildings
- Transitioning former coal regions to solar
- Providing skills and training programmes to support the energy transition
- Unlocking the potential of flexible large-scale solar installations
- Accelerating solar-powered mobility
- Prioritising renewable-based electrification of the European economy and developing truly renewable hydrogen

All these priority areas are multidisciplinary and require the cooperation of many specialists. The training of experts and executives is the task of specialist workplaces, especially universities.

Very important part of projects above are problems connected with distribution and transmission of hard-to dispatch control PV power generation become more and more important. Dispatching tools such as peak power curtailment or reactive load connections significantly reduce converse efficiency. Therefore, the introduction of new tools such as energy storage, cogeneration, and consumption of produced electricity as close as possible to their place of production and at the time of production is necessary. It is also useful optimizing grid codes and other tools for the electricity transition [12]. Digitization and new market patterns are essential for a new efficient integration solution energy production built into local distribution networks, interactions and sharing additional services between distribution and transmission system [13].

EDUCATION ASPECTS IN PHOTOVOLTAICS

The expected growth of photovoltaics is connected with an increased demand for new specialists. In past SET Plan [14] sets a target of 12% electricity generation by PV by 2020. This target would require a cumulative total capacity of some 308 GW_p, producing 400TWh of electricity per annum. Till the end of 2020, only 139 GW_p have been installed and the SET target will not be reached. Next increase of PV power demand on the level over 700 GW_p is expected in period 2020-2030 under REPowerEU plan. And to realize European Green Deal, it will be necessary to increase the installed photovoltaic power in Europe to more than 1 TW_p by 2050. Tens of thousands of new jobs in the photovoltaic sector are likely to be created to implement these plans during the next few years in Europe.

Given the decline in installed capacity annually from more than 20 GW_p in 2011 to about 8 GW_p in period 2014 – 2017, the demand for specialists in photovoltaics was not as high as expected by EPUE [15]. However, the area of photovoltaic installations has been growing since 2017 and reached the level of 28 GWp in 2021, and due to future ambitious plans, increased demand for installations as well as for specialists in the field of photovoltaics is expected in the future [1].

The education and training of professionals in the field of photovoltaics is essential for the establishment and maintenance of the market and its infrastructure. It will also be necessary to raise public awareness of the nature and use of photovoltaic systems. In addition to training new professionals, it will also be necessary to retrain employees from existing professions, particularly those related to energy production and transmission and the construction of buildings.

A broad-based education system needs to be put in place to increase knowledge about photovoltaics. The education system should combine relevant information with the relationship between this knowledge and everyday life. In addition to universities, many studies can contribute to the study of photovoltaics at different levels. In order to improve the general knowledge of the public, it is necessary to present basic information to children in primary and secondary schools. The implementation of the curriculum requires teachers with extended knowledge and therefore education of teachers should be an important aspect of the program.

The temporary shortage of experts can be solved by organizing short retraining courses for engineers from various fields of technology (electrical, civil, mechanical, architecture, chemistry, economics), which often take place without practical exercises. Short courses can only

provide an incomplete set of information. Therefore, the training of future experts is an important task for universities (higher education).

One problem with teaching photovoltaics is that the field of photovoltaics is in fact relatively broad and interdisciplinary. On the one hand, knowledge of the physics of materials and interactions with incident light is required, cell structure optimization, anti-reflective coating to understand the physical design of various types of solar cells. Many different technological processes are used to produce solar cells and photovoltaic modules. The knowledge in this field enables better orientation in many types of modules offered on the market. On the application side, knowledge of characteristics, load-to-peak relationships as well as relatively deep knowledge of power and control electronics is important. Because the output power of photovoltaic systems depends on temporary solar radiation, some basic knowledge of solar physics and meteorology is very important for proper system design and implementation. Photovoltaic systems should be resistant to environmental degradation processes, so knowledge of material degradation and reliability issues is desirable. AI should be broadly used both in production and in PV system monitoring. And the economic analysis of projected systems is also very important. Last but not least, it is necessary to understand the basic problems associated with connecting photovoltaic systems to the grid, energy storage and the basics of smart grids.

The training of professionals in the field of photovoltaics can be implemented in many different ways, from short courses and vocational training to high-level university programs. The organization of international summer schools and intensive courses is very useful for the exchange of knowledge and for improving the level of teaching. However, the preparation of curricula and specific lectures requires well-developed links between universities and industry.

The general course "photovoltaics" covering the whole field could be introduced at the bachelor level in the electrical engineering curriculum. Courses that are more oriented on e.g. materials, physics and cell technology or system applications aimed at preparing new specialists for research, development and production of solar modules and other parts of photovoltaic technology could be introduced at master and doctoral level.

Application-oriented courses with an emphasis on optimum use of current photovoltaic technology will be very useful for architects, designers and installers of PV systems, utilities and some other professionals, e.g. in the energy or building authorities. These types of courses may highlight some areas with regard to specific orientation, but some basic knowledge of the whole area is desirable. But it is also very important to ensure that substantial knowledge is passed on to politicians and government officials who have a major impact on technological development.

With increasing installed PV power, system diagnostics and increased reliability are also very important. In addition to theoretical knowledge, practical laboratory or project work is highly desirable for the preparation of future specialists. There are various educational programs at universities around the world with an emphasis on different parts of photovoltaic technology using different tools, from computer simulation to experimental work on photovoltaic systems. A very important part of the education system is the doctoral study preparing new scientists for research activities to achieve innovation. In addition to traditional methods of university (or high school) teaching, new forms such as e-learning can be very effective and very promising for the dissemination of knowledge [16], [17]. Thousands of participants can take such courses. The disadvantage of e-learning courses is that the theoretical parts are supplemented only by virtual experiments.

The development of new teaching and learning methods at bachelor's, master’s, and doctoral levels, including interdisciplinary and experimental approaches, research-based or digital media training, as well as ongoing training for professionals, is also an important part of the ambitious European Green Deal plan and its implementation. Vision 2050 Plan [18]. And the REPowerEU program further emphasizes the importance of skills training.

This specially oriented event – International Workshop on Teaching in Photovoltaics – could help us to exchange experiences that might be useful for optimising education and training in the field of photovoltaics and relative areas.

REFERENCES

[1] EC Communication „The European Green Deal“ https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

[2] Gaventa, J.: How The European Green Deal will succseed or fail, December 2019, www.e3g.org

[3] https://www.agora-energiewende.de/fileadmin2/Projekte/2018/EU-Jahresauswertung_2019/Agora-Energiewende_European-Power-Sector-2018_WEB.pdf

[4] Ram M., et al,: Global Energy System based on 100% Renewable Energy – Energy Transition in Europe Across Power, Heat, Transport and Desalination Sectors, study by LUT University and Energy Watch Group, Lappeenranta, Berlin;2018

[5] http://taiyangnews.info/markets/bloomberg-expects-1400-gw-pv-for-europe-by-2050/

[6] Jäger-Waldau, A., *PV Status Report 2019*, EUR 29938 EN, Publications Office of the European Union, Luxembourg, 2019,

[7] 2022 Snapshot of Global PV Markets, Report IEA-PVPS T1-42:2022 April 2022

[8] Global Market Outlook For Solar Power 2022 – 2026, Solar Power Europe 2022

[9] EU Market Outlook For Solar Power 2021 - 2025 Solar Power Europe 2021

[10] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

[11] https://www.solarpowereurope.org/advocacy/european-green-deal

[12] IRENA (2018), Power System Flexibility for the Energy Transition, Part 1: Overview for policy makers, International Renewable Energy Agency, Abu Dhabi

[13] G. Masson and I. Kaizuka: IEA PVPS TRENDS 2019 IN PHOTOVOLTAIC APPLICATIONS, www.iea-pvps.org

[14] EC Communication "Preparing for our future: Developing a common strategy for key enabling technologies in the EU", SEC (2009) 1257

[15] EPUE report, 2013

[16] https://online-learning.tudelft.nl/courses/solar-energy/

[17] http://pvinnovation.ca/pv-resources/pv-education/

[18] European technology and innovation platform for smart networks for the energy transition, Vision 2050, 2018, https://www.etip-snet.eu/etip-snet-vision-2050/.

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