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An investigation of green energy policy and its university-level engineering education in Taiwan

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Abstract

With the global warming issue and high dependence on imported energy in Taiwan, energy engineering education at the university level has been a leading tool to promote environmental sustainability since the 1990s. In this paper, the status of energy engineering education at the departments/graduate institutes from 14 universities in Taiwan was analyzed for overview assessment, including teaching units (department/institute/college), faculties (number, educational background and position), students (annual recruitment number and diploma), and major research fields (renewable energy sources and energy conservation technologies). It was found that most of the energy-related engineering departments/institutes were established in the past decade (2000-2010). Consistently, the major research topics at the departments/graduate institutes were devoted to solar electric energy, solar thermal energy and energy storage material (including fuel cell), which are connected with the department of mechanical engineering. Furthermore, the Renewable Energy Development Act promulgated on 8 July 2009 will promote the utilization of renewable energy sources and foster renewable energy industry in Taiwan. It is thus prospective that the government's policy on promoting green energy will be in line with the efforts in the directions of energy engineering education. Finally, some recommendations for reforming energy engineering education at the university level were addressed in the paper.

Keywords: Green energy policy; Renewable energy; Engineering education; University; Faculty

1. Introduction

All the energy we use is basically to satisfy human need and therefore contributes to human well-being because it plays a vital role in national economic development. The situation is particularly important to the region or country with limited primary energy

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resources. Taiwan, located in the southeastern rim of Asia and has the population of about 23,000 thousands by the end of 2010, is a high population density nation with over 99 % of energy supply by imported fuels in 2010 [1]. With the rapid industrialization in the past two decades (1990-2010), the country is now on the way to developed countries. Today, one of the most important indicators showing the sustainability level of countries is the energy consumption that is indicative of energy intensity and renewable energy [2], inputting into the fields of technology and industry.

In the past decade, the total energy consumption of Taiwan had increased from 91.7 million kiloliters of oil equivalent (KLOE) in 2000 to 120.3 million KLOE in 2010. Due to the energy policy on the energy saving and renewable energy development, the annual growth rate of energy consumption in the period (i.e., 1.2%) was relatively smaller than those (i.e., 2.6%) in the 1990s (1990-2000). However, the total of CO_2 emissions without land-use change and forestry (LUCF) in Taiwan area was over 260 million metric tons in 2008 [3]. The largest source of CO_2 emissions was from the energy sector (combustion of fossil fuels) while the next important source was from the sector of industrial processes. As a result, the Taiwan government approved "Renewable Energy Development Plan" in 2002 and "Sustainable Energy Guidelines" in 2009. One of the action plans concerning research & development on energy technology is to promote green energy industry (including renewable energy and energy conservation) towards a clean energy economy by the subsidiary demonstration project, national research plan and professional talent cultivation.

Every country has made the cultivation of human talents in response to the different industrialization and economic stages. In addition to on-job trainings, the education system plays an important role in sustaining industry developments and also upgrading professional levels because it is fostering high-quality human resources for the need of industry. In this regard, energy engineering education for cultivating professional talents is the key tool to moving society towards sustainability and to boosting green energy industry for competitiveness. For meeting the new century, the United Nations thus declared the "United Nations Decade for Education for Sustainable Development" (2005-2014). The core goal of the Decade is an important framework for integrating the knowledge and values of sustainable development into all aspects of learning, and outreaching efforts within all academic institutions. In the meantime, there have been a number of reports on renewable energy education in their countries or at the university level [4-16]. However, there was less literature on analyzing the energy engineering education at the university level. As demonstrated from a Brazilian experience [12], scientific literacy can be considered as a new educational demand in order to foster education for sustainability throughout students' academic careers. In the study by Reijalt [13], main activities in the field of hydrogen and fuel cell education in Europe were reviewed with the aim to facilitate an accelerated uptake of the public awareness in future energy and transport systems. As pointed by Davidson et al. [14], engineering education must account for limitations in materials and energy as well as the needs for pollution prevention, meaning that university's teachers must revise courses and curricula with the new challenges to engineering graduates. In the survey by Lozano [15], the diffusion of sustainable development in over 5800 courses at Cardiff University was analyzed using the Sustainability Tool for Auditing University Curricula in Higher Education (STAUNCH), showing that transformation from compartmentalization, over-specialization and reductionism towards more balanced, synergistic, trans-disciplinary and holistic perspectives is required. As reported by Desha and Hargroves [16], they surveyed the extent of energy efficiency (EE) education at Australian universities. They thus identified preferred methods to assist in increasing the extent to which EE education and sustainability are embedded in engineering curriculum and engineering education.

In the present study, the updated information about the engineering education at the university-level departments/institutes focusing on the energy technology and its talent cultivation was accessed through the official website (i.e., the Ministry of Education) of Taiwan (http:// www.moe.gov.tw). Based on the collected data, an investigation on the energy engineering education at the university level in Taiwan, including teaching unit (department/institute/college), faculty (number, educational background and position), student (annual recruitment number and degree), and major research field (renewable energy sources, and energy conservation technologies), was carried out. It should be noted that the detailed curriculum and syllabus for energy engineering education was not discussed in the study.

2. Situation of energy supply and energy consumption in Taiwan

With the increase in the economic development and the rise in living level over the past decade (2000-2010), the total amounts of energy supply and consumption in Taiwan were on the increasing trend. On average, the annual growth rates of energy supply and energy consumption during the period are 1.5% and 1.2%, respectively [1]. In 2010, the total energy supply in Taiwan was 146.0 million KLOE, of which imported energy accounted for 99.4% and indigenous energy contributed for only 0.6%. By contrast, the total energy consumption of Taiwan in 2010 was 120.3 million KLOE. Due to the energy policy on the energy saving and renewable energy development, the annual growth rates of energy supply and energy consumption were relatively smaller than those (i.e., 2.5% and 2.6%, respectively) in the 1990s (1990-2000). For example, the energy supply from solar photovoltaic & wind power remarkably increased from 0.1×10^3 KLOE in 2000 to 100.4×10^3 KLOE in 2010.

3. State of Taiwan's energy policy concerning research & development on energy technology

With the Kyoto Protocol adopted in Dec. 1997 and becoming effective in Feb. 2005, three National Energy Conferences were convened for the purpose of promoting a sustainable development in Taiwan's low-carbon society where economic development, energy supply, and environmental protection get an equal focus. Meanwhile, the Executive Yuan of Taiwan adopted the "Renewable Energy Development Plan" in Jan. 2002. In June 2008, the Taiwan government further approved "Sustainable Energy Guidelines". The Guidelines aimed at creating a new low-carbon economy with emphasis on sustainable development that balances industry competitiveness, environmental protection and energy security. The Guidelines were intended for attaining a definite goal: cutting annual emission of CO_2 to 2008 levels between the years 2016 and 2020, and curtailing annual emission of CO_2 to 2000 levels in 2025. Furthermore, the Renewable Energy Development Act promulgated on 8 July 2009 will promote the utilization of renewable energy sources and foster renewable energy industry in Taiwan.

In order to reduce the dependency on imported energy and in response to the era of fossil energy-deficiency as well as the voluntary reduction for greenhouse gases emissions, the relevant strategy framework and action plans concerning energy technology development include as follows:

1. Promote green energy industry (including renewable energy and energy conservation) towards a clean energy economy. To enhance Taiwan's competitiveness in the industrial development, the Executive Yuan announced green energy industry as one of the six key new industries in April 2009. The Dawning Green Energy Industry Program approved by the Executive Yuan of Taiwan called for the investment of NT$ 45 billion (≒ US$ 1.5 billion)

over five years to boost the overall production of the green energy industry from 1.2% of overall manufacturing value in 2008 to 6.6% in 2015 with primary emphasis on the solar energy (the renewable energy field) and light-emitting diode (LED; the energy conservation field) industries. NT$ 20 billion out of the total investment of NT$ 45 billion will go into the research & development on energy technology, and the other NT$ 25 billion into the subsidies for the installation/purchase of renewable energy and energy-saving facilities. In addition to those two key industries, the Taiwan government has also addressed potential development plans for other green energy industries, including wind power, biomass energy, hydrogen power and fuel cell, energy information and communication (e.g., smart grid and advanced metering infrastructure), and electric vehicles.

2. Increase the budget for the annual energy research within the next four years from NT$, 5 billion (≒ US$ 170 million) to 10 billion (≒ US$ 340 million). In June 2009, the master plan of the National Science and Technology Program-Energy (NSTPE) was triggered. The contents of the Plan were mainly grouped into the four categories: energy strategies, new energy technologies, energy saving & carbon reduction, and talents cultivation. With respect to engineering technologies on green energy industries, the top priority in the master plans of NSTPE can be generally divided into two major sectors:

- New energy technology: solar thermal and electric energy; wind power; bio-energy; nuclear power; energy storage.
- Energy saving and carbon reduction: clean coal; carbon capture and storage; illumination (lighting) and electric appliances; smart grid and advanced metering infrastructure.

4. Overview of engineering education at the university's level in Taiwan

During the past two decades, the Taiwan's economic transition from labor-intensive to technology and capital-intensive industries has created significant changes in production ratios for our economic sectors. One of the key success factors of Taiwan's economic accomplishments is attributed to the engineering education at the university-level education system, which include college and university educations [17].

In the college education, it falls into two categories: the five-year junior college and the two-year junior college. The former admits junior high school graduates and offers five-year courses of study. The latter admits senior vocational high school graduates and offers two-year courses of study. By contrast, the university system (including universities of technology) provides undergraduate and graduate educations. University undergraduate programs generally require four-year courses of study. Students will be awarded a bachelor's degree (BA) while completing their undergraduate study. Graduate programs leading to a master's or doctoral degree (MS or Ph.D.) require 1-4 year and 2-7 year courses of study, respectively. However, students who enter the graduate school as part of the on-job training can be granted an extension of up to two years. It should be noted that the curriculum at most universities focuses on academic (or research-oriented) studies, while universities of technology put emphasis on practical and specific skills (or technology-oriented) trainings.

In 2010, there were more than 394,000 students studying in the engineering education of colleges and universities, including civil engineering, mechanical engineering, electrical engineering and chemical engineering [17]. The number of students had increased to about 320,000 students in the college and undergraduate (BA) levels, to 60,000 students in the MS graduate institutes, and to 14,000 students in the Ph.D. graduate institutes. On the other hand, these students awarding the degrees of BA, MS and Ph.D. were in alliance with the class

numbers of 7,203, 2,253 and 513, respectively. Although the World Wide Web for delivering university courses in energy studies and renewable energy to a national and international market offers the students to interact with other on-line students via discussion groups [18], the Internet teaching system is still not granted by the Ministry of Education in Taiwan.

5. Analysis of energy engineering education at the university's level in Taiwan

Based on the collected data from the official website (i.e., the Ministry of Education) of Taiwan (http:// www.moe.gov.tw), an investigation on the energy engineering education at the university level in Taiwan was carried out to improve or reform the education system, which can be merged into green energy industry of creating a large number of high-quality "green jobs". It should be stressed that the detailed curriculum and syllabus for energy engineering education was not discussed in the study.

5. 1. Teaching unit

Concerning the teaching units participated in the energy engineering education; the present study was carried out among 14 different universities in Taiwan. Table 1 listed the energy-related engineering departments/institutes of universities in Taiwan. Based on the data in Table 1, some notable points were further addressed as follows:

1. In these universities, there are 8 departments, 4 graduate institutes, and 2 graduate (MS) programs. With the exception of the Dept. of Green Energy at the National Univ. of Tainan, these departments/institutes and graduate programs were categorized into the college of engineering.
2. With the grant permission by the central competent authority (i.e., the Ministry of Education), most of the departments/institutes were established in the past decade. This should be attributed to the educational policies on talent cultivation for the job needs in the green energy industry and "green" industries.
3. Due to the multidisciplinary sciences and knowledge-based integration in the field of energy engineering, several institutes of energy engineering were recently merged into the Department of Mechanical Engineering, which has been established for many years in these universities, including the National Central Univ., Southern Taiwan Univ., and Kun Shan Univ.

5. 2. Faculty

As listed in Table 2, the total persons of faculty at the energy-related engineering departments/institutes of 14 universities are 185 members, which include full-time and joint-appointment faculties. Academic titles of the faculties are also summarized in Table 2, showing that the percentages of professor, associated professor, assistant professor and lecture are 39, 34, 24, and 3%, respectively. This may indicate that the professional base of the academic faculties has been relatively high as compared to those in Turkey [9], which majorities of the academic titles of the faculties are assistant professors (36%) and research assistants (25%). The Ph. D. educational backgrounds of faculty members at the energy-related engineering departments/institutes of universities were further present in Table 3. According to this table, the faculty members were mainly trained in the areas of mechanical engineering (91/185, or 49%), material engineering (27/185, or 15%), chemical engineering (22/185, or 12%) and electrical engineering (13/185, 7%), although there were some of them trained in natural and biological sciences (i.e., chemistry, and physics and life science).

Table 1. List of the department/institute of university level focusing on energy engineering education in Taiwan [a]

University (Abbrev./web site)	College/school	Department/Institute	Year started	Comments
National Central Univ. (NCU/www.ncu.edu.tw)	Engineering	Inst. of Energy Eng.	2005 (MS) 2010 (Ph.D.)	Merged into the Dept. of Mech. Eng.
National Univ. of Tainan (NUTN/www.nutn.edu.tw)	Environmental Sciences & Ecology	Dept. of Green Energy	2005 (BS) 2008 (MS)	Dept. of Environ. & Energy (Formerly)
National United Univ. (NUU/www.nuu.edu.tw)	Engineering	Dept. of Energy & Resources	2004 (BS)	
National Chia-Yi Univ. [a] (NCYU/www.ncyu.edu.tw)	Science & Engineering	Dept. of Mechanical & Energy Eng.	2011 (BS)	
National Taipei Univ. of Technology (NTUT/www.ntut.edu.tw)	Mechanical & Electrical Engineering	Dept. of Energy, Refrig. & Air Conditioning	2004 (BS) 2005 (MS) 2008 (Ph.D.)	Dept. of Refrig. & Air Conditioning Eng. (Formerly)
National Formosa Univ. (NFU/www.nfu.edu.tw)	Engineering	Inst. of Mater. Sci. & Green Energy Eng.	2006 (MS)	Merged into the Dept. of Mater. Sci. & Eng.
National Chin-Yi Univ. of Technology (NCUT/www.ncut.edu.tw)	Engineering	Dept. of Refrig., Air Conditioning & Energy Eng.	2005 (BS) 2008 (MS)	Dept. of Refrig. & Air Conditioning Eng. (Formerly)
Feng Chia Univ. (FCU/www.fcu.edu.tw)	Engineering	Graduate Program for Green Energy Sci. & Technol.	2009 (MS)	
Yuan Ze Univ. (YZU/www.yzu.edu.tw)	Engineering	Graduate Program for Renewable Energy Eng.	2007 (MS)	Inst. of Renewable Energy Eng. (Formerly)
Ming Dao Univ. (MDU/www.mdu.edu.tw)	Applied Science	Dept. of Electro-Optical & Energy Eng.	2005 (BS)	Dept. of Energy Eng. (Formerly)
Far East Univ. (FEU/www.feu.edu.tw)	Engineering	Dept. of Energy Application Eng.	2009 (BS)	
Kao Yuan University (KYU/www.kyu.edu.tw)	Engineering	Dept. of Green Energy Sci. & Technol.	2010 (BS)	
Southern Taiwan Univ. (STU/www.stut.edu.tw)	Engineering	Inst. of Energy Eng.	2008 (MS)	Merged into the Dept. of Mech. Eng.
Kun Shan Univ. (KSU/www.ksu.edu.tw)	Engineering	Inst. of Energy Eng.	2007 (Ph.D.)	Merged into the Dept. of Mech. Eng.

[a]Not included in the statistical survey of Tables 2 and 3.

5. 3. Student

In Taiwan, the professional energy engineering topics were taught at different levels: both in undergraduate departments and graduate institutes from 14 different universities (see Table 1). Following the completion of the BA diploma in the energy studies, students who wish to specialize in energy technology may focus on academic studies and research topics to obtain a MS and/or Ph. D. degrees in the graduate institute upon completion of their courses and dissertations. Presently, annual student recruitment number at the energy-related engineering departments/institutes from 14 universities was listed in Table 4. The number of undergraduate students majoring in energy engineering had increased to 659. Furthermore, there were 211 graduate students based on annual recruitment number, which included 193 students for studying master's programs and 18 students for doctorate (Ph. D.) programs.

Table 2. Position title summary of faculty at the department/institute of university level focusing on energy engineering in Taiwan[a]

Department/Institute (University)	Faculty[a] number	Faculty position			
		Professor	Assoc. prof.	Asst. prof.	Lecture
Inst. of Energy Engineering (NCU)	15	8	3	4	0
Dept. of Green Energy (TUT)	12	6	3	3	0
Dept. of Energy & Resources (NUU)	11	2	6	3	0
Dept. of Energy & Refrig. Air Conditioning Eng. (NTUT)	15	7	6	2	0
Inst. of Mater. Sci. & Green Energy Engineering (NFU)	19	5	7	7	0
Dept. of Refrig., Air Conditioning & Energy Eng. (NCUT)	15	2	6	3	4
Graduate Program for Green Energy Sci. & Technol. (FCU)	22	13	5	4	0
Graduate Program for Renewable Energy Eng. (YZU)	20	8	6	6	0
Dept. of Electro-Optical & Energy Eng. (MDU)	8	1	4	3	0
Dept. of Energy Application Eng. (FEU)	6	0	3	2	1
Dept. of Green Energy Sci. & Technol. (KYU)	12	1	5	6	0
Inst. of Energy Engineering (STU)	16	6	9	1	0
Inst. of Energy Engineering (KSU)	14	14	0	0	0
Sum (%)	185 (100%)	73 (39%)	63 (34%)	44 (24%)	5 (3%)

[a] Including full-time and joint-appointment faculty.

5. 4. Research field

Generally, the green energy industry can be divided into renewable energy and energy conservation. According to the website information about the energy-related engineering departments/institutes from 14 universities, the major research topics were devoted to solar electric energy, solar thermal energy and energy storage material (including fuel cell) (Table 5). This is consistent with the Ph. D. educational backgrounds of faculty members at the energy-related engineering department/institutes of universities (Table 3). On the other hand, minorities of research topics were devoted to the classical energy subjects: biomass energy, wind power, electric vehicle, LED and energy saving (including refrigeration & air-conditioning). This is partly due to the renewable energy research & development concentrating on the industrial sector and the energy-related engineering education contributing by other department/institutes, especially in the departments of chemical engineering, environmental engineering, electrical/electronic engineering, chemistry, and biological/agricultural engineering.

Table 3. Ph. D. educational background summary of faculty at the department/institute of university level focusing on energy engineering in Taiwan

Department/Institute (University)	Faculty[a] number	Educational background at Ph.D.[b]												
		ME	EE	ChE	EnE	MaE	ArE	EoE	NE	AgE	Ch	Ph	LS	Others
Inst. of Energy Engineering (NCU)	15	13				2								
Dept. of Green Energy (NUTN)	12	6	2	1							2	1		
Dept. of Energy & Resources (NUU)	11	4		2	1	2				1		1		
Dept. of Energy & Refrig. Air Conditioning Eng. (NTUT)	15	11	2				2							
Inst. of Mater. Sci. & Green Energy Engineering (NFU)	19	7				12								
Dept. of Refrig., Air Conditioning & Energy Eng. (NCUT)	15	8	4											3
Graduate Program for Green Energy Sci. & Technol. (FCU)	22	4	1	3	3	5	2				1			3
Graduate Program for Renewable Energy Eng. (YZU)	20	6		9	1	2					1			1
Dept. of Electro-Optical & Energy Eng. (MDU)	8	2	1	1		2		1			1			
Dept. of Energy Application Eng. (FEU)	6	2	1	3										
Dept. of Green Energy Sci. & Technol. (KYU)	12	4	2	3	1								2	
Inst. of Energy Engineering (STU)	16	13				1			1			1		
Inst. of Energy Engineering (KSU)	14	11				1						1		1
Sum (%)	185	91	13	22	6	27	4	1	1	1	5	4	2	8

[a] Including full-time and joint-appointment faculty.
[b]ME: mechanical eng. (including aerospace eng. and applied mechanics) ; EE: electrical eng.; ChE: chemical eng. (including polymer science); EnE: environmental eng.; MaE: material sci. & eng.; ArE: architectural eng. (architecture); EoE: electro-optical eng.; NE: nuclear eng.; AgE: agricultural eng.; Ch: chemistry; Ph: physics; LS; life sciences; Others: including civil eng., electrophysics, mathematics, industrial education, engineering science, soil & water conservation, resources management, etc.

6. The engineering education needs of the renewable energy industry and society

As a result of the present study and analytical surveys [11-16], the needs for renewable energy engineering education at the university level in Taiwan were identified as follows:

1. Strengthen continuing education and extension to retrain technicians and engineers (preferably majoring in mechanical engineering, chemical engineering, environmental engineering, and electrical & electronic engineering) who wish to move into the renewable energy and energy service industry.

2. Establish undergraduate/graduate multidisciplinary program for energy fields at the relevant colleges (e.g., the college of engineering for solar energy, energy storage material and energy saving, and the college of agriculture for biomass energy) to educate the students who wish to work in this green job industry.

3. Foster the joint between the industrial enterprise and the educational institution to establish the master's program in the renewable energy research & development fields,

Table 4. Summary of annual student recruitment number at the energy-related departments/institutes of universities in Taiwan [a]

Department/institute (University)	Student recruitment number per year			Sum
	Ph.D.	MS	BA	
Inst. of Energy Engineering (NCU)	3	18		21
Dept. of Green Energy (NUTN)		34 [a]	41	75
Dept. of Energy & Resources (NUU)			50	50
Dept. of Mechanical & Energy Eng. (NCYU)			40	40
Dept. of Energy & Refrig. Air Conditioning Eng. (NTUT)	10		86 [a]	96
Inst. of Mater. Sci. & Green Energy Engineering (NFU)		54 [a]		54
Dept. of Refrig., Air Conditioning & Energy Eng. (NCUT)		36 [a]	225 [a]	261
Graduate Program for Green Energy Sci. & Technol. (FCU)		12		12
Graduate Program for Renewable Energy Eng. (YZU)		9		9
Dept. of Electro-Optical & & Energy Eng. (MDU)		15	90 [a]	65
Dept. of Energy Application Eng. (FEU)			67	67
Dept. of Green Energy Sci. & Technol. (KYU)			60	60
Inst. of Energy Engineering (STU)		15		15
Inst. of Energy Engineering (KSU)	5			5
Sum (%)	18 (2%)	193 (22%)	659 (76%)	870 (100%)

[a] Including regular and continuing education.

especially in solar electric energy, light-emitting diode (LED), electric vehicle, fuel cell, hydrogen energy, and energy storage materials.

4. Deepen the basic and professional courses (core courses) at the department of energy-related engineering [19], including thermodynamics, applied physics, applied mechanics, applied mathematics, heat transfer, engineering drawing, thermal engineering, thermal system analysis, refrigeration & air-conditioning, mechanical workshop practice, and electrical workshop practice.

5. Broaden the non-professional courses (selective and optional courses) at the department of energy-related engineering, including engineering economics, renewable energy policy, environmental science & policy, environmental resource management, cleaner production, eco-friendly design, and life cycle analysis [20-25].

6. Transfer comprehensive information about renewable energy technology development and daily energy saving & carbon reduction practices to the general public who wish to be aware of the philosophy and lifestyle of ecologically sustainable development concerning air pollution, global warming and climate change [26-28].

Such information and educating & training should be not confined to engineering and technology knowledge because energy is related to a diversity of fields, including economic, social and environmental issues. Therefore, the disciplinary courses at the undergraduate level should include science, engineering, policy & planning, and system analysis. More importantly, the joint-venture between educational institutions and renewable energy enterprises should play a promoting catalyst in the future directions of on-job training and research & development. In addition, the Environmental Education Act in Taiwan was promulgated in June 2010 and will begin to be effective in June 2011, meaning that the

Table 5. Summary of major research fields at the energy-related engineering department/institute of university level in Taiwan[a]

Department/Institute (University)	Major research fields [a]											
	BE	WP	STE	SEE	LED	H_2	EV	ESE	ESM	CCS	RAC	EPM
Inst. of Energy Engineering (NCU)			•			•		•		•		
Dept. of Green Energy (NUTN)	•			•			•		•			
Dept. of Energy & Resources (NUU)		•		•					•			•
Dept. of Mechanical & Energy Eng. (NCYU)	•	•	•					•				
Dept. of Energy & Refrig. Air Conditioning Eng. (NTUT)			•					•	•		•	
Inst. of Mater. Sci. & Green Energy Engineering (NFU)				•	•	•			•			
Dept. of Refrig., Air Conditioning & Energy Eng. (NCUT)			•					•	•		•	
Graduate Program for Green Energy Sci. & Technol. (FCU)	•			•		•			•			
Graduate Program for Renewable Energy Eng. (YZU)	•	•		•					•			
Dept. of Electro-Optical & Energy Eng. (MDU)				•	•	•	•					
Dept. of Energy Application Eng. (FEU)		•	•	•					•			
Dept. of Green Energy Sci. & Technol. (KYU)	•			•	•				•			
Inst. of Energy Engineering (STU)			•	•				•	•			
Inst. of Energy Engineering (KSU)			•	•	•	•						

[a]BE: biomass energy (bioenergy); WP: wind power; STE: solar thermal energy; SEE: solar electric energy; LED: light-emitting diode; H_2: hydrogen energy; EV: electric vehicle; ESE: energy saving & efficiency; ESM: energy storage material (including fuel cell); CCS: carbon capture & storage; RAC: refrigeration & air conditioning; EPM: energy policy & management.

energy-related engineering department/institute could act as training personnel center at promoting energy education and achieving sustainable development.

7. Conclusions and recommendations

Engineering education is an essential tool for boosting industry development and also achieving environmental sustainability. In the past decade, there are several universities in Taiwan that are offering different undergraduate and graduate programs related to energy engineering and energy-based disciplinary courses. This is attributed to the government's legislation and policy on talent cultivation for the green job needs in the present and future markets. The faculty members at the energy-related engineering departments/institutes from 14 universities amounted to 185 persons, which majorities of the academic titles of the faculties are full professor (39%) and associated professor (34%). Based on the Ph. D. educational backgrounds of faculty members, they were mainly trained in the areas of mechanical eng. (49%), material eng. (15%), chemical eng. (12%) and electrical eng. (7%). Furthermore, the major research topics at the departments/graduate institutes were devoted to

solar electric energy, solar thermal energy and energy storage material, which are consistent with the training background of faculty.

From the characteristics of energy and its technology development, the present status of energy engineering education at the university level in Taiwan could post several problems. To upgrade the levels of energy engineering education at the universities for the purpose of raising talent cultivation and boosting energy industry development, the relevant recommendations were addressed as follows:

1. Due to the multidisciplinary sciences (e.g., chemistry, physics) and engineering-based integration (i.e., mechanical eng., chemical eng., and environmental eng.), the energy engineering education should be switched to the graduate education, not focused on the undergraduate education.

2. The graduate program for green or renewable energy science and technology, established under the college of engineering, may be the best energy engineering education system for the students upon completion of their undergraduate study in the mechanical eng., chemical eng., or environmental eng.

3. The research topics at the energy-related engineering departments/institutes should keep in place with the industry needs, which include wind power, electric vehicle, clean coal, carbon capture and storage, smart grid and advanced metering infrastructure.

4. The accreditation of engineering education at the universities in Taiwan has executed by the Institute of Engineering Education Taiwan (IEET) since 2007. Therefore, the energy-related engineering departments/institutes were encouraged to apply for the accreditation.

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