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Review

The Renewable Energy (RE) Industry Workforce Needs: RE Simulation and Analysis Tools Teaching as an Effective Way to Enhance Undergraduate Engineering Students' Learning

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Abstract: The share of renewables in the U.S. electricity generation mix is increasing and one of the major obstacles to enhancing employment in the renewable energy (RE) sector is finding skilled/qualified labor to fill positions. RE systems engineer jobs mostly need bachelor's degrees but there are few RE engineering-focused degree programs. Therefore, there are needs to accurately train undergraduate engineering students at universities and match the education system offerings to meet RE industry demands. This study reviews RE employment by technology, RE industry workforce needs, and engineering programs accreditation, and then suggests possible means, along with theoretical RE concepts, to enhance undergraduate engineering students' RE learning at universities. In particular, RE industries require technology skills, including analytical, scientific, and simulation software programs or tools. These RE simulation and analysis tools can be used for teaching, training, techno-economic analysis, planning, designing, optimization, etc., and are the focus of this review.

Keywords: education; renewable energy; simulation; analysis; software; skills

Citation: Jafarinejad, S.; Beckingham, L.E.; Kathe, M.; Henderson, K. The Renewable Energy (RE) Industry Workforce Needs: RE Simulation and Analysis Tools Teaching as an Effective Way to Enhance Undergraduate Engineering Students' Learning. *Sustainability* **2021**, *13*, 11727. https://doi.org/10.3390/su132111727

Academic Editor: Tara Hosseini

Received: 1 September 2021
Accepted: 21 October 2021
Published: 23 October 2021

1. Introduction

With the adoption of new global and statewide environmental standards and policies for decarbonization, in today's challenging energy market [1–5], there is an increasing interest to produce energy by natural resources such as sunlight, wind, rain, waves, tides, and geothermal heat [6,7]. Renewable energy (RE) includes hydropower energy, solar energy (photovoltaic (PV), concentrating solar power (CSP), and solar thermal heating and cooling), wind energy, geothermal energy, bioenergy (e.g., biomass, biogas, and biofuels), and marine (ocean) energy (waves, tidal range, tidal currents, ocean currents, ocean thermal energy conversion and salinity gradients; it is essential to note that all ocean power systems, except tidal barrages, have not been commercialized) [8]. The RE industry is growing rapidly as the world confronts the challenges of climate change and the numerous negative societal implications of fossil fuel reliance [9,10]. According to the Annual Energy Outlook 2021 (AEO2021) with projections for 2050 from the U.S. Energy Information Administration (EIA), it is anticipated that the portion of REs in the US electricity generation mix will enhance from 21% in 2020 to 42% in 2050. Most of that growth will depend on wind and solar energy generation. In addition, the renewable portion of energy generation is estimated to enhance as nuclear and coal-fired energy production reduces while natural gas-fired energy production is anticipated to remain relatively constant. REs will collectively surpass natural gas by 2030 to be the prevailing source of energy generation in the U.S. By 2040, solar energy generation (which includes PV and thermal technologies) will surpass wind energy as the largest source of RE generation in the U.S. [11,12].

The RE industry needs a trained and qualified workforce of scientists, engineers, and technicians with knowledge of RE [13] who will be able to develop, design, finance, build, operate, and maintain RE projects [14]. In other words, RE employment opportunities may include construction, manufacturing, professional, and trade workers. Educational needs for RE jobs may range from high school diplomas to PhDs and post-graduate professional degrees in addition to vocational degrees and apprenticeships [15]. Higher education is a key element to power RE and academia/educational institutions can help prepare a future-oriented workforce for RE industries. It is obvious that trained/qualified professionals can effectively teach RE courses within educational institutions. In addition, they can design and implement effective and efficient policies within governments. Furthermore, they can accurately assess RE project proposals within financial institutions. In short, the RE industry will benefit from them [14].

In recent years, some studies have been carried out in the field of RE education. Ott et al. [16] discussed a pedagogical approach to solar energy education and made a tentative approach to include it within the framework of an upgraded version of the socio-cultural theory for learning. They concluded that making a "quantum jump" in RE education from "hard" discourses as science and mathematics to more "soft" discourses such as sociology of science, psychology of the mind, and neuroscience of the brain would be beneficial [16]. According to a survey administered to graduates and employers working in the sustainable energy industries in Australia, Lund et al. [17] reported that a generalist degree in engineering, with a stream in sustainable energy, is the preferred initial qualification for professionals in this field. In addition, they suggested several key areas to be included in sustainable energy courses including generic skills (research methods, teamwork, and report writing), generation technologies (especially PV, wind, and biomass), and enablers (such as economics, policy, and project management) [17]. Lucas et al. [18] studied the education and training gaps in the RE industry. Their findings indicated that there is a mismatch between education system offerings and RE industry demands (e.g., skills shortages). In addition, there is a mismatch in the suitability of the curricula. Furthermore, students and educators are moving towards online training for collaborating and learning [18]. Thus, preparing students for employment in the RE industry can be a multifaceted challenge for educators [19].

According to O*NET OnLine (sponsored by the U.S. Department of Labor, Employment & Training Administration, and developed by the National Center for O*NET Development) [20], 73% of the jobs in solar energy systems engineering and 70% of the jobs in wind energy engineering require a bachelor's degree [21,22]. Therefore, there is a need to accurately train the undergraduate engineering students at universities for RE industry career opportunities. The outstanding question, however, is how can we increase undergraduate engineering students' learning at universities to prepare a trained and qualified workforce for the RE sector? This study reviews RE employment by technology, RE industry workforce needs, and engineering programs accreditation, and then suggests teaching the RE simulation and analysis tools along with the theoretical RE concepts in classrooms as a potentially effective and inexpensive way to enhance undergraduate engineering students' learning at universities.

The remaining sections of this paper are organized as follows. In Section 2, RE employment by technology and RE industry job titles/occupations are briefly reviewed. Section 3 includes a discussion of RE industry workforce needs. Engineering programs' accreditation requirements are explained in Section 4. Section 5 includes several traditional and modern educational approaches and summarizes various RE simulation and analysis tools. Finally, Section 6 discusses conclusions and future perspectives of this study.

2. Renewable Energy Employment

It is necessary to review direct and indirect RE jobs by technology, RE industry job titles/occupations, and RE employment challenges.

2.1. Renewable Energy Employment by Technology

Global RE employment by technology in 2019 is shown in Figure 1. According to the International Renewable Energy Agency (IRENA), the RE sector employed 11.46 million people, directly or indirectly, in 2019, whereas employment in 2018 was 11 million people. Women hold 32% of these jobs. The biggest employers were the solar PV, bioenergy, hydropower, and wind energy industries with 33%, 31%, 17%, and 10% of the total RE workforce, respectively. The IRENA report highlights that more vocational training, stronger curricula, and more teacher training are needed for global energy transition from fossil fuels to renewables [23].

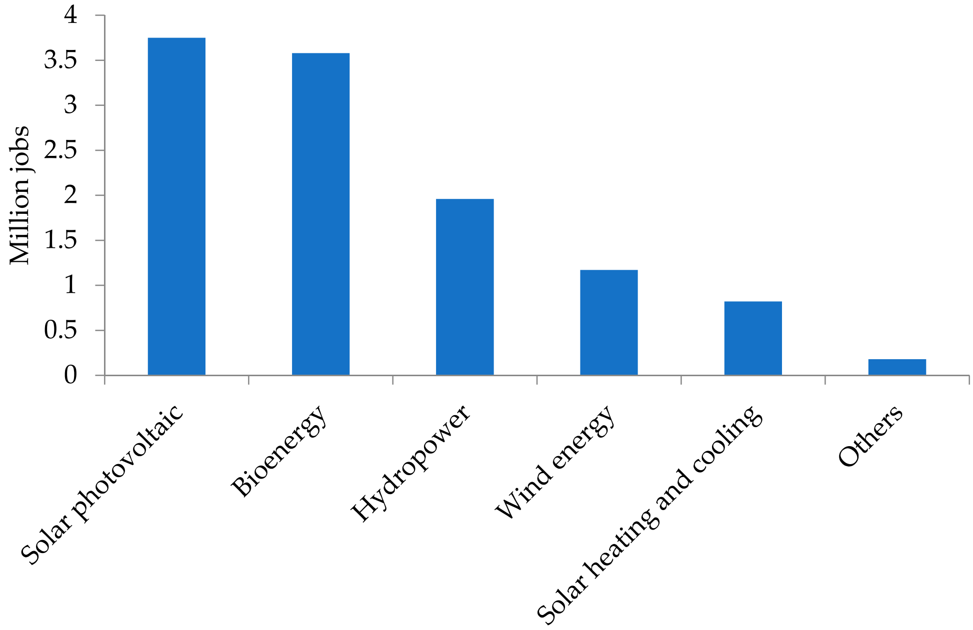

Figure 1. Global RE employment by technology in 2019. "Bioenergy" includes liquid biofuels, solid biomass and biogas; "Others" includes geothermal energy, concentrated solar power, heat pumps (ground based), municipal and industrial waste, and ocean energy. Modified from IRENA [23].

Estimated direct and indirect RE jobs in the U.S. by technology in 2019 are depicted in Figure 2. The RE employment in the U.S. was estimated at 756,000 in 2019. The biggest employers were the biofuels, solar PV, and wind energy industries [23]. RE firms surveyed for the U.S. Energy Employment Report (USEER) highlight that a substantial obstacle to enhance employment is finding skilled/qualified labor to fill positions [24,25], and there is a need to prepare a trained and qualified workforce for the RE sector.

2.2. Renewable Energy Industry Job Titles/Occupations

As mentioned before, RE employment opportunities may include construction, manufacturing, professional, and trade workers. Within these areas, the RE industry needs professors and teachers, professional trainers, engineers, technicians, construction labors, research scientists, applied/field scientists, product designers, assembly workers, developers, resource assessors, programmers, trade workers, sales/marketers, economics/policy experts, transportation and logistics workers, attorneys, accountants/bookkeepers, communication experts, and administrative assistants. Their performance is critical to the RE industry's overall success [15]. Some of the reported RE industry job titles include solar energy systems engineers, solar energy installation managers, solar thermal installers and technicians, solar PV installers, solar sales representatives and assessors, wind energy engineers, wind energy development managers, wind energy operations managers, biofuels/biodiesel technology and product development managers, biofuels production managers, biofuels processing technicians, biomass power plant managers, biomass plant technicians, geothermal production managers, geothermal technicians, hydroelectric production managers, hydroelectric plant technicians, etc. [20].

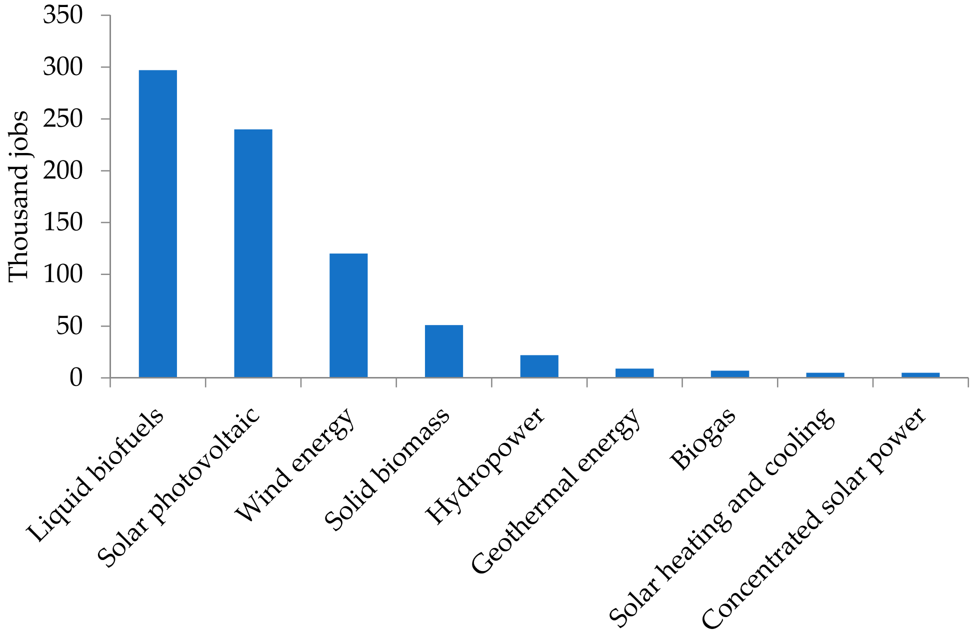

Figure 2. Estimated direct and indirect RE jobs in the U.S. by technology in 2019. "Solid biomass" includes biomass fuels and power, and biomass combined heat and power; direct jobs were only considered for "Hydropower"; direct geothermal power employment was considered for "Geothermal energy". Modified from IRENA [23].

To show the number/percentage of occupations in the RE industries, a broad array of occupations in the wind industry are reviewed as examples. Table 1 shows 2016 wind energy occupations in the U.S. based on industry surveys with 249 firms. Trade workers, engineers, and wind technicians occupied 14%, 12%, and 9% of the total wind industry workforce, respectively [15].

It seems that overall, the current largest needs in the RE industries are engineers and technicians for local design, installation, and maintenance of the systems. For instance, the key to a well-designed solar system is about understanding the system at the local level. This can include many facets such as understanding utility rate structures' interconnection requirements and incentives, understanding building energy profiles, geotechnical challenges, community needs and challenges, etc. This can apply to industrial, commercial, utility scale, and residential solar. The solar industry still has a long way to become more efficient, sustainable, and economical, and engineers will be the ones to advance this industry. Engineers need to be working for the people/groups that support the RE industry in solar panel, inverter, and analysis software R&D and eventually decommissioning and recycling R&D of solar panels, and well-trained electricians and technicians should surge projects that are currently being sold.

Table 1. A broad array of occupations in the U.S. wind industry in 2016 based on industry surveys with 249 firms. Modified from [15].

Occupation	Percentage
Trade workers	14%
Engineers	12%
Wind technicians	9%
Transportation and logistics workers	8%
Construction labors	8%
Attorneys	8%
Administrative assistants	6%
Applied/field scientists	6%
Professors and teachers	5%
Sales and marketers	5%
Accountants and bookkeepers	4%
Developers	3%
Product designers	2%
Resource assessors	2%
Programmers	2%
Assembly workers	2%
Communication experts	2%
Economists/policy experts	<1%
Professional trainers	<1%
Government employees	<1%
Research scientists	<1%

3. Renewable Energy Industry Workforce Needs

Each job title in the RE industry is typically associated with a specific set of tasks, responsibilities, work activities, work styles, and work values. In addition, each job title requires a specific level of education, a specific set of knowledge, abilities, skills, and technology skills. As an example, the needed knowledge, skills, technology skills, abilities, work activities, and tasks for the solar energy system engineers according to O*NET OnLine [21] are listed in Table 2. Note that some of the information in this table may be included in the employer job postings. Generally, RE engineers (e.g., solar energy engineers, wind energy engineers) should (1) design RE systems and direct energy production activities; (2) gather clean and reliable data about project sites; (3) prepare graphical representations of RE technologies/systems; (4) assess plans/specifications for determination of techno-environmental implications; (5) suggest technical design or optimize process variables to enhance efficiency and performance of RE production systems; (6) define design criteria/specifications for RE production technologies/processes; (7) give techno-economic direction to other personnel; (8) investigate design or application of RE production systems and/or build/develop engineering design models; (9) determine operational techniques for RE systems and/or carry out quantitative failure analyses of operational data; (10) inspect finished RE systems to determine/locate defects; (11) test RE systems/processes and analyze their design needs; (12) monitor RE systems to comply with standards; (13) analyze costs-benefits of the suggested RE system designs or projects; and (14) document RE systems designs or operational test results [21,22]. Therefore, it is necessary to enhance students' RE skills (e.g., technology skills) in addition to teaching the theoretical RE concepts in the classrooms at universities.

Table 2. Knowledge, skills, technology skills, abilities, work activities, and tasks for the solar energy system engineers. Adopted from O*NET OnLine (by the U.S. Department of Labor, Employment & Training Administration (USDOL/ETA); used under the CC BY 4.0 license) [21].

Item	Description
Knowledge	Mathematics, physics, engineering and technology, computers and electronics, design, building and construction, mechanics, English language, and customer and personal service
Skills	Reading comprehension, active listening, speaking, writing, critical thinking, judgment and decision making, complex problem solving, active learning, mathematics, science, monitoring, coordination, instructing, and time management.
Technology skills	Analytical or scientific software including RE-specific tools (e.g., Hybrid Optimization of Multiple Energy Resources (HOMER) micropower optimization model, SolTrace, PVsyst, RETScreen, etc.) and general computer tools (e.g., finite element method (FEM) software, MathWorks MATLAB, etc.); computer-aided design (CAD) software (e.g., Autodesk AutoCAD, Dassault Systemes SolidWorks, etc.); Customer relationship management software (e.g., Salesforce); data base user interface and query software (e.g., Microsoft Access, Structured query language (SQL), etc.); development environment software (e.g., Microsoft Visual Basic for Applications (VBA), National Instruments LabVIEW, etc.); enterprise resource planning software (e.g., Oracle Hyperion); industrial control software (e.g., Supervisory control and data acquisition (SCADA) software); object- or component-oriented development software (e.g., C++, Python, R); mobile location-based services software (e.g., Global positioning system (GPS) software); operating system software (e.g., Bash, Linux); program testing software (e.g., Debugging software); web platform development software (e.g., JavaScript); Microsoft Office; Microsoft Outlook; Microsoft Visio; Microsoft Word; Microsoft Excel; and Microsoft PowerPoint.
Abilities	Written comprehension, oral comprehension, deductive reasoning, oral expression, written expression, fluency of ideas, problem sensitivity, inductive reasoning, mathematical reasoning, information ordering, originality (the ability to provide creative solutions for problems), speech clarity, speech recognition, category flexibility (combining/grouping things in various methods using different sets of rules), near vision, selective attention, number facility (speeded performance of any simple calculation), and visualization.
Work activities	Acquiring information; updating and applying relevant knowledge; documenting, drawing, laying out, and specifying technical devices, parts, and equipment; assessing information to comply with standards; making decisions and solving problems; applying computers; communicating with supervisors, peers, co-workers, subordinates, and persons outside the organization; developing and maintaining interpersonal relationships; thinking creatively; analyzing data/information; quantitative estimate of products, events, or information; identifying objects, actions, and events; organizing, prioritizing, and accomplishing work using specific plans; drafting/recording information; providing guidance and advice to others; processing information; scheduling work/activities; developing/building teams to accomplish tasks; explaining/translating the meaning/application of information for others; monitoring and controlling resources; coordinating the activities of others to accomplish work; assessing the qualities of things, services, or people; inspecting equipment, structures, or materials; training, instructing, coaching and developing others; and selling to/influencing others.

Table 2. *Cont.*

Item	Description
Tasks	Preparing plans for activities of solar energy system development, monitoring, and evaluation; directing engineering site audits to gather structural, electrical, and related site information for use in the design of residential or commercial solar energy systems; designing or coordinating design of PV or solar thermal systems; applying CAD software to create electrical single-line diagrams, panel schedules, or connection diagrams for solar electric systems; reviewing specifications and suggesting engineering/manufacturing changes to reach solar design objectives; developing design specifications and functional needs for solar energy systems or components; directing/supporting installation teams technically during installation, start-up, testing, system commissioning, or performance monitoring; carrying out computer simulation for efficiency optimization of solar PV systems or energy production; developing standard operation procedures and quality or safety standards for solar installation work; creating checklists to review/inspect completed solar installation projects; testing/evaluating PV cells or modules; and conducting thermal, stress, or cost reduction analyses for solar energy systems.

4. Engineering Programs Accreditation

As mentioned before, it is crucial to accurately train undergraduate engineering students at universities and match the education system offerings to meet RE industry demands.

ABET accreditation assures confidence that a collegiate program meets the quality standards that can produce graduates prepared to enter science, technology, engineering, and mathematics (STEM) fields in the global workforce. In addition, it can provide opportunities for the industry to guide the educational process to reflect current and future needs. Furthermore, it can enhance the mobility of professionals [26]. A review of the ABET accreditation requirements and outcomes-based education, which is a link between academia and the industry, can generally identify the gaps and help enhance undergraduate engineering education.

According to the 2020–2021 ABET Criteria for Accrediting Engineering Programs [27], all engineering programs must satisfy all of the eight general criteria for baccalaureate level programs. In particular, they must have documented Criterion 3 or student outcomes (outcomes (1) through (7)) that support their educational objectives. For instance, regarding the RE theoretical course, one may consider outcomes (1), (2), (3), and (7), in which (1) "an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics" and (2) "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" [27] can be important. Performance indicators in the ABET outcome (1) may be "students will be able to combine mathematical and/or scientific principles to formulate models of chemical, physical, and/or biological processes and systems", "students will be able to relate theoretical concepts to practical problem solving", and/or "students will be able to formulate strategies for solving problems". Moreover, performance indicators in the ABET outcome (2) may be "students will be able to analyze and synthesize engineering unit operations, including integrated complex systems consisting of multiple unit operations", "students will be able to perform economic analysis for systems and processes", and/or "students will be able to apply constraints such as safety, ethical, environmental, and social considerations in designing systems and processes". Thus, at universities, students should learn how they can design, analyze, and optimize RE systems.

5. Educational Approaches

There are several traditional and modern educational approaches to enhance undergraduate engineering students' RE learning at universities: theoretical/lab courses, simulation tools, RE makerspace, university–industry interactions, and use of informal sources of knowledge (websites, videos, etc.). The theoretical RE course usually helps students understand the knowledge of RE technologies without adopting practical approach, whereas the RE lab course provides them with first-hand/hands-on experience with course concepts and with the opportunity to study techniques applied by scientists in the RE field. In the RE theoretical course, an overview and introduction to RE resources and technologies such as solar (PV, CSP, and solar thermal heating and cooling), wind, hydropower, geothermal, bioenergy (e.g., biomass, biogas, and biofuels), and marine (ocean) energy are usually discussed. In addition, RE generation and conversion, basic analysis and calculations regarding energy generation, conversion and efficiency, operational consideration, emerging trends, regulations, environmental impact, and economic issues are taught. Furthermore, energy storage systems such as batteries (lead acid, lithium ion, sodium sulfur, flow batteries, etc.), flywheels, capacitors, magnetic systems, phase change materials, etc., are discussed [7]. Depending on the available facilities/instruments in the university, the RE lab course includes some or all of the experiments on the following RE technologies: solar energy including PV, wind energy, hydropower, fuel cells, gasification of biomass, etc. [28–30]. RE simulation and analysis tools can be useful in teaching RE classes [31] and are discussed in detail in Section 5.1. RE makerspace can be an approach for hands-on learning with all the tools for creativity as students deeply engage in RE science, engineering, and tinkering. In other words, makerspace can provide a learning environment to enhance creative competence in engineering students [32]. University–industry interactions such as field trips (on-site or virtual) to RE industries [33] are important educational tools to connect students to classroom concepts. Experiential learning from these activities can enhance engineering students' interest, knowledge, and motivation [34]. Students may use informal sources of knowledge (television, newspapers, websites, videos, etc.) [35] to learn about RE technologies.

It is necessary to note that students may also learn from various other activities such as specific student clubs, design competitions, co-op opportunities, and internships.

In one study [36], the student ratings of educational means including theoretical course, lab course, makerspaces, industry visits, and workshops to intrigue and aid them for sustainable industries were assessed. Based on the results of the survey administered to students, researchers reported that industry visits and renewable makerspaces were among the most favorite [36]. These education approaches are beneficial to prepare students for employment at the RE sector; however, they need funds to be implemented. In addition, there are possible health and safety risks associated with industry visits and official guidelines must be followed as well. Alternatively, RE simulation and analysis tools (some of them are free tools) are suggested as an effective, easy, and inexpensive way to enhance engineering students' RE learning at universities.

5.1. Renewable Energy Simulation and Analysis Tools

Because of their various successes and advantages in education, simulation tools are utilized for teaching, training, and testing applications. With improving/advancing computer technology, simulations will attract increasing interests and transform applications in education [37].

As mentioned before, the RE industry needs technology skills including analytical or scientific software programs or tools. Use of these tools can be beneficial for teaching and training students in RE classes [31]. There are several RE simulation and analysis tools that have been developed and deployed across different sectors of RE industries [21,22,31,38]: System Advisor Model (SAM) [39,40], Solar Advisor Model [41], RETScreen [42], PolySun [43], HOMER [44], TRNSYS [45], greenius [46], Energy-10 [47], archelios Pro [48], DEKSOFT Photovoltaics [49], pvDesign [50], PVcase [51], PVWatts calculator [52], PV

Optics [53,54], PVsyst [55], Aurora [56], BlueSol [57], HelioScope [58], Pylon [59], SolarEdge [60], PV Sol [61], PV F-chart [62], Solarius PV [63], ETB [64], Solargraf [65], SolarFarmer [66], Skelion [67], SolTrace [68], windPRO [69], ReSoft WindFarm [70], WindSim [71], Openwind [72], Bladed [73], WindFarmer: Analyst [74], Wind Energy Finance [75], RETFinance [76], DTOcean [77], TidalBladed [78], etc. Each tool has specific applications and features. Table 3 lists these tools, their descriptions/applications, and their open-source/subscription status. As Table 3 demonstrates, these tools can be applied for site analysis (e.g., BlueSol, Skelion), resource assessment (e.g., WindFarmer: Analyst), planning (e.g., PolySun), technical analysis and design (e.g., pvDesign, Solarius PV, Bladed), economic analysis (e.g., HOMER), monitoring and controlling (e.g., ETB Monitor), etc. It seems that, among them, HOMER and SAM may be more suitable simulation tools for classroom use because they simulate the majority of RE technologies. Aung [31] compared Solar Advisor Model, RETScreen, and PolySun software tools and evaluated their effectiveness based on their use during an elective course at Lamar University, and reported that all software tools are suitable for classroom use in terms of effective modeling and simulation capabilities [31].

Table 3. Renewable energy simulation and analysis tools.

Simulation and Analysis Tools	Descriptions/Applications	Free/Open-Source	Reference/Link
System Advisor Model (SAM)	For performance and economic calculations of RE projects. SAM can model PV systems; battery storage with lithium ion, lead acid, or flow batteries for front-of-meter or behind-the-meter applications; CSP systems for electric energy generation including parabolic trough, power tower, and linear Fresnel; wind energy; marine energy wave and tidal systems; solar water heating; fuel cells; geothermal energy; biomass combustion for energy generation, etc.	Yes	[39]
Solar Advisor Model	For techno-economic analysis of solar technologies including PV systems for residential and commercial markets to CSP and large PV systems for utility markets.	Yes. Free to use it for any purpose whatsoever, except commercial purposes or sale.	[41]
RETScreen	The RETScreen Clean Energy Management Software is used for energy efficiency, RE and cogeneration project feasibility analysis as well as ongoing energy performance analysis.	No. RETScreen Expert, an advanced premium version of the software, is available in Viewer mode completely free-of-charge. It is also available in Professional mode on an annual subscription basis.	[42]
PolySun	For flexible and efficient planning, design, and optimization of energy systems	No. The free trial version expires automatically after 30 days.	[43]
HOMER	Micropower optimization model, for analysis of the energy technologies individually and in hybrid configurations to determine cost-effective solutions. HOMER models both conventional and RE technologies, either as a microgrid or as distributed generation within a larger grid.	No. Free trial for 21 days.	[44]
TRaNsient SYstems Simulation (TRNSYS)	For simulation of low energy buildings, RE systems including solar systems (solar thermal and PV systems), fuel cells, etc.	No	[45]

Table 3. *Cont.*

Simulation and Analysis Tools	Descriptions/Applications	Free/Open-Source	Reference/Link
Greenius	Mainly for feasibility studies of solar thermal power plants. However, it includes models for simulations of other RE technologies such as non-concentrating solar collectors for process heat supply, PV plants, and wind power parks.	Yes	[46]
Energy-10	Energy-modeling tool for small commercial and residential buildings.	No	[47]
Archelios Pro	For the design, calculation, and simulation of PV projects.	No	[48]
DEKSOFT Photovoltaics	For calculating electricity produced by PV systems.	No. 14-day free trial.	[49]
pvDesign	For the study, analysis, design, and engineering of PV plants in all its stages.	No. A free demo.	[50]
PVcase	For analysis of solar projects.	No	[51]
PVWatts calculator	For estimation of the energy production and cost of energy of grid-connected PV energy systems.	Yes	[52]
PV Optics	For design and analysis of solar cells and modules.	No	[53,54]
PVsyst	For design and data analysis of solar PV systems.	No. One month free trial.	[55]
Aurora	For creating a complete engineering design and sales proposal with only an electric bill and an address.	No. A free demo.	[56]
BlueSol	For designing a PV system, from the preliminary assessment of producibility to the realization of the project documentation. It can provide interactive design of layout over map and 3D view, and single-line electrical scheme as well.	No	[57]
HelioScope	HelioScope is a solar design software. Three-dimensional design, rapid proposals, simulations, unlimited designs, live support, single line diagrams, automatic CAD export, library of 45,000 components, global weather coverage, shade reports up to 5 MW systems are its features.	No. A free 30-day trial.	[58]
Pylon	Online software for designing solar systems. High resolution aerial imagery, 3D solar shading analysis, interval data analysis and load profiles, financial projections, web and PDF proposals, e-signatures and payment processing are its some features.	No	[59]
SolarEdge	A free online tool for PV design.	Yes	[60]
PV Sol	For PV system design.	No. A free 30-day trial.	[61]
PV F-chart	For PV system analysis and design. The program provides monthly-average performance estimates for each hour of the day.	No	[62]

Table 3. *Cont.*

Simulation and Analysis Tools	Descriptions/Applications	Free/Open-Source	Reference/Link
Solarius PV	For technical design and economic analysis of PV systems. Three-dimensional modeling of parametric PV system objects, solar irradiance data, calculation of photovoltaic shading directly from a photo, activating, sizing and configuring the storage system by defining the battery type and energy metering systems, wiring diagrams of the PV system, and financial analysis are its some features.	No	[63]
ETB	Energy Toolbase is an industry-leading software platform. It provides project modeling, storage control, and asset monitoring products. In reality, ETB developer is used to model and propose the economics of solar and storage projects. In addition, Acumen EMS^{TM} is an intelligent control system software utilizing machine learning and AI to forecast and optimally discharge energy storage systems. Furthermore, ETB Monitor is a monitoring platform providing complete transparency into the real-time operation and performance of solar and storage projects.	No	[64]
Solargraf	Solargraf is a solar design platform for solar sales teams, installers, manufacturers, and lenders to scope, sell, and manage solar proposals from any device.	No	[65]
SolarFarmer	For analysis, simulation and design of solar PV plants. It has a full 3D shading and calculation model, handling complex terrains and shading obstacles.	No	[66]
Skelion	Solar system design plugin for Sketchup.	No	[67]
SolTrace	For modeling of the CSP systems and analyzing their optical performance.	Yes	[68]
windPRO	windPRO is suitable for design and planning of wind farms projects. It is used for wind data analysis, calculation of energy yields, quantification of uncertainties, assessment of site suitability, calculation and visualization of environmental impact, and detailed post-construction analysis of production data.	No	[69]
ReSoft WindFarm	For analysis, design and optimization of proposed wind farms.	No	[70]
WindSim	For optimization of wind turbine placement in onshore and offshore wind farms using computational fluid dynamics.	No	[71]
Openwind	A wind farm design and optimization software for creating optimal turbine layouts.	No	[72]
Bladed	For wind turbine design.	No	[73]
WindFarmer: Analyst	For wind resource assessment.	No	[74]

Table 3. *Cont.*

Simulation and Analysis Tools	Descriptions/Applications	Free/Open-Source	Reference/Link
Wind Energy Finance	It is an online calculator for economic analysis of wind projects.	Yes	[75]
RETFinance	It is a levelized cost-of-energy model to simulate a detailed 20-year nominal dollar cash flow for RE projects.	Yes	[76]
DTOcean	For the design and analysis of ocean energy arrays.	Yes	[77]
TidalBladed	It is used for simulating tidal turbines at the design stage.	No	[78]

To overcome the instability/intermittence of solar and wind resources, hybrid energy systems incorporating two or more energy units came into existence for supplying electrical energy. Because these systems include multiple generation units, their techno-economic analysis is complex and needs software tools to be analyzed in depth [79–81]. Conducting class projects on hybrid systems analysis would be beneficial to enhance engineering students' RE learning at universities. Sinha and Chandel [79] reviewed 19 software tools (HOMER, Hybrid2, RETScreen, iHOGA, INSEL, TRNSYS, iGRHYSO, HYBRIDS, RAPSIM, SOMES, SOLSTOR, HySim, HybSim, IPSYS, HySys, Dymola/Modelica, ARES, SOLSIM, and HYBRID DESIGNER) for hybrid systems analysis, their main features, and research studies carried out using these software tools. They concluded that HOMER was the most widely used tool. In addition, the status of some software tools including HySim, HySys, SOMES, SOLSTOR, HYBRIDS, RAPSIM, ARES, IPSYS, and INSEL for hybrid energy system research was unknown [79].

6. Conclusions and Future Perspectives

In this study, the RE employment by technology, RE industry workforce needs, engineering programs accreditation requirements, and traditional and modern education approaches related to RE were reviewed. The key findings of this review are:

- In 2019, the biggest RE employers in the U.S. were the biofuels, solar PV, and wind energy industries.
- According to the AEO2021, the portion of REs in the U.S. electricity generation mix will enhance from 21% in 2020 to 42% in 2050.
- Women are a critical part of the RE workforce. According to IRENA, women occupied 32% of RE jobs globally in 2019.
- Generally, for employment as an engineer in the RE industry, one needs knowledge of mathematics, physics, chemistry, engineering and technology, computers, design, construction, mechanics, English language, and customer and personal service. In other words, the RE engineers should design RE systems and direct energy production activities.
- Theoretical/lab courses are used at universities as traditional educational approaches. Simulation tools, RE makerspace, university–industry interactions, use of informal sources of knowledge (websites, videos, etc.), etc., can be beneficial in enhancing undergraduate engineering students' RE learning at universities.
- Teaching the RE simulation and analysis tools along with the theoretical RE concepts in conducting RE classes was suggested as an effective and inexpensive way to enhance undergraduate engineering students' learning at universities.
- There are several RE simulation and analysis tools; however, it seems that, among them, HOMER and SAM may be more suitable simulation tools for classroom use.

To the best of our knowledge, it is necessary to note that limited information can be found for the application of RE simulation and analysis tools for undergraduate engineering students' education. In other words, the status of most tools for undergraduate education is unknown.

Faculty and students at universities and even RE industry representatives can be involved in the assessment and feedback on the effectiveness of the RE simulation and analysis tools. The 2020–2021 ABET Criteria for Accrediting Engineering Programs [27] specify that engineering programs must demonstrate that their students succeed in attaining Criterion 3, outcome (2) (see Section 4). Performance indicators for the ABET outcome (2) can be that "students will be able to analyze and synthesize engineering unit operations, including integrated complex systems consisting of multiple unit operations" and/or "students will be able to perform economic analysis for systems and processes". The procedure can be that students are given a "student course assessment form" prior to teaching the simulation tools. The same "student course assessment form" can be given again at the completion of the simulation tools. The pre- and post-student course assessment form scores can be compared statistically.

Author Contributions: Conceptualization, S.J. and L.E.B.; methodology, S.J., L.E.B., and M.K.; software, S.J. and L.E.B.; validation, S.J., L.E.B., and M.K.; formal analysis, S.J., L.E.B., M.K., and K.H.; investigation, S.J., L.E.B., and M.K.; resources, S.J. and L.E.B.; data curation, S.J., L.E.B., and M.K.; writing—original draft preparation, S.J., L.E.B., M.K., and K.H.; writing—review and editing, S.J., L.E.B., M.K., and K.H.; visualization, S.J. and L.E.B.; supervision, S.J.; project administration, S.J. and L.E.B. All authors have read and agreed to the published version of the manuscript.

Funding: L.E.B. acknowledges support from the NSF under grant number 2043990. S.J. acknowledges support from the DoD under grant number W911NF2110222.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The comments from the anonymous reviewers are appreciated.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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