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Renewable Energy Industry Trends and Its Contributions to the Development of Energy Resilience in an Era of Accelerating Climate Change

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Abstract**—**Climate change and global warming vortex have grown to alarming proportions. Therefore, the need for a shift in the conceptualization of energy production is paramount. Energy practices have been created in the current situation. Fossil fuels continue their prominence, at the expense of renewable sources. Despite this abundance, a large percentage of the world population still has no access to electricity but there have been encouraging signs in global movement from nonrenewable to renewable energy but means to reverse climate change have been elusive. Worldwide, organizations have put tremendous effort into innovation. Conferences and exhibitions act as a platform that allows a broad exchange of information regarding trends in the renewable energy field. The Solar Power International (SPI) conference and exhibition is a gathering of concerned activists, and probably the largest convention of its kind. This study investigates current development in the renewable energy field, analyzing means by which industry is being applied to the issue. In reviewing the 2019 SPI conference, it was found innovations in recycling and assessing the environmental impacts of the solar products that need critical attention. There is a huge movement in the electrical storage but there exists a large gap in the development of security systems. This research will focus on solar energy, but impacts will be relevant to the entire renewable energy market.

Keywords**—**Climate change, renewable energy, solar, trends, research, SPI.

I. Introduction

THE contemporary rate of climate change is unprecedented, though significant action is still possible to reverse the dynamic. International effort must be coordinated to meet this crisis. Immediate measures are needed to produce this outcome [1]. The United Nations has defined energy use as a major contributor to climate change, responsible for 60% of total Global Greenhouse Gases (GHG) emissions [2], [3]. That international body highlighted steps toward combating this situation through their publication of Sustainable Development Goals-2030 (SDGs). The document detailed remedial global policies to increase the share of renewable energy by 2030. Among these measures, were an expansion of sustainable infrastructure and innovative technology in underdeveloped regions [2], [4]. Furthermore, in 2015 the Paris Convention bound signatories to adopt strategies limiting warming. The treaty established a baseline of 2 °C [5]-[7]. These two events have stimulated conversion to renewable energy as an alternative to fossil fuel [8]. According to a recent IPCC Special Report, an increase of 1.5 °C, on average, of worldwide temperature is inevitable [9].

All efforts must be directed towards preventing temperature rise, or catastrophic effects will become the norm. This is where renewable energy steps in. The 2015 Paris Agreement required 200 nations and jurisdictions to reduce their emissions, with the aim of stabilizing global temperature. Renewables are just the means to employ towards this end. This source is expendable without negative consequences that would result in heating of the planet [9]-[11].

Most major nations now view climate change as a threat, and as part of their national security strategy. But, a sense of urgency is absent. The spark which ignites unity of major powers lay in the work of experts collectively exchanging information. The more frequent the meetings, the more immediate the perception of crisis will become. In this way, a path to resolution will open [12]. The best places to display innovative technologies and discuss remedial action are academic and professional conferences. Events such as these allow dissemination of industry trends, bringing people from various fields together [13]. This study will investigate this development through review of the 2019 SPI and Energy Storage International (ESI) conferences, held in Salt Lake City, Utah. By examining this conference, it will be possible to collectively gather current information regarding the renewable energy industry.

II. Background

A. Climate Change Threat and Mitigation

Since industrialization in the early 19th century, human activity has continuously released various greenhouse gases into the atmosphere. The largest chemical offenders are carbon dioxide, methane, and nitrogen monoxide. Causation of global warming is closely associated with this activity [14]-[17]. To catalog all effects of industrialization would be impossible. However, there are examples which stand out. Polar ice has melted at a historically high rate over the past 30 years, at a pace of 3.2% per decade. Ocean heat content has experienced continuous increase, altering circulation patterns. Annual disappearance of the Arctic ice cap is projected to occur as a 100-year event, even if warming is contained below 1.5 °C. [18]. If global warming surmounts that 1.5 °C baseline, a wide range of meteorological anomalies are expected to follow. Sea surface temperature already has risen an average of 0.13°F per

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decade. Damage to coral reefs and algal blooms are the result. This will only be accelerated. Disastrous tropical hurricanes and cyclones will become commonplace. Furthermore, ocean levels are setting a new precedent, flooding hitherto safe areas and effecting freshwater supply. Snow cover and glaciers are in retreat, upsetting aquifer balance in areas with vulnerable populations [19], [20]. And, many scientists are still warning of the dangers of ozone layer loss. Fortunately, there has been concerted international effort to mitigate climate change [21] [22]. Representative achievements of this commitment are the Kyoto Protocol and the Paris Agreement. Also, the green construction is addressing built environment contribution to the crisis, and reduction of harm caused by this economic sector. Other mitigating factors include renewable energy research, climate finance, taxes, and tariffs. The last three decades have witnessed a spike in global energy usage. A great deal of focus has turned to development of renewable sources, but they only account for 14% of demand [23].

B. Policy Instruments

The Kyoto Protocol is a climate change treaty adopted by 37 industrialized countries, and the EU, in 1997. The parties committed to a carbon emissions target limiting GHG emissions to an average reduction, 5% below the 1990 level. Kyoto Protocol agreed upon implementation schemes, such as an Emission Trading System (ETS), Clean Development Mechanism (CDM), and Joint Implementation (JI). The carbon market is addressed through ETS, which allows entities to trade credits earned from emissions mitigation activities. The CDM tool is intended to provide developing countries with projects which reduce carbon emissions and create so-called Certified Emission Reduction units (CERs) [24]. This is a kind of carbon cryptocurrency within the ETS. Entities are offered opportunities, through JI, to develop joint GHG reduction projects. Emission reduction units (ERUs) are another cryptocurrency produced from JI. These are also tradable within the ETS. The Kyoto Protocol sought to slow the pace of climate change by allowing participating countries to reduce CO_2 emissions through efficient energy usage and aggressive energy-saving efforts. As a result, the renewable energy industry has begun to flourish [24].

The Paris Agreement, ratified by 192 countries, aims to keep the level of global temperature rise to well below 2.0 °C, compared to the pre-industrial level. The treaty advances a commitment to limitation of global warming to 1.5 °C. To this end, each participant is required to submit Intended Nationally Determined Contributions (INDCs), responding to post-2020-envisioned weather threats [6], [7].

The INDCs are the primary contribution that each country makes to reduce carbon dioxide equivalents. Jurisdictions which do not subscribe to post-2020 threats risk inactivity when facing median warming, estimated between 2.6 °C and 3.1 °C by 2100. Contributory participants develop a finance flow in line with declining GHG emissions and climate-resilient schemes. The agreement also pursues new technologies, and, improved transparency processes [6]. The renewable energy industry plays a significant role by supply of new and affordable sources. The main drivers of this initiative are Investment and Production Tax credits, along with a Clean Power Plan (or so-called Final Rule). In terms of both tax credits, a given government must provide financial assistance, in the form of offsets. Those authorities will pay up to 30% of upfront costs. For the Production Tax credit, ratepayer generated electricity may be sold for an allowance, or refund. Clean Power would operate through a given jurisdiction, in order to set target emission rates.

The 2030-goal would be to cut down total sector power use by 32%. Another proven strategy is widely adopted Renewable Portfolio Standards (RPS). An RPS policy requires electric utilities to increase sustainable output to their customers, in a specific timeframe. The US State of Texas, for example, installed 10,000 Megawatts of renewable energy generation by 2010, 15 years prior to the original goal. Even though RPS has been viewed as a successful policy, experts have suggested that it is economically biased in favor of authorities with greater portfolio diversity. For instance, some US states possess more natural gas than others [25]. Other reduction strategies are Feed-in Tariffs (FITs) and Property Assessed Clean Energy. 12 years ago, the EU set targets of 20% reduction in GHG emissions, 20% energy efficiency, and 20% of consumption originating from renewables, all by 2020. This was called the “20-20-20 Proposal” [26].

In 2012, Sweden became the first country in the EU to meet those renewable energy targets. Currently, 54% of Sweden’s total consumption is derived from that source, mostly through hydroelectric and biomass [4], [27]. They were able to achieve this milestone because their policy combined ecological sustainability, competitiveness, and security of supply [4], [27]. Complete dependence upon renewable electricity production by 2040 is next in line. This target is coupled with net zero GHG emissions by 2045 [28]. The nation’s success has been so marked that the International Energy Agency could assert that, "Sweden is a leader in the energy transition [29].”

Sweden’s renewables have been subdivided into nuclear; hydropower; small-scale production; consumption; energy efficiency; transmission and financing [29]. To promote their policy, Sweden, abolished tax on thermal output and reduced property tax on hydropower. Sweden also set out a 70% decrease in transport emissions by 2010 and 2030. At the same time, they introduced a bonus/penalty system to support new low-emission vehicles and increase biofuels use. Finally, the Scandinavian state established a green electricity certificate and also required electricity retailers to purchase a certain proportion of green electricity [4], [27].

C. Built Environment Contributions

The policies, elaborated above, have made a significant impact on economic and social aspects of environmental regulation. Likewise, the building sector has been developing their contribution through green construction. This type of project emphasizes design, erection, and operational phases that focus on reducing or eliminating negative environmental effects. This has the advantage of resource preservation and more amenable structures for habitation. A green building is characterized by energy and water efficiency, along with use of sustainable materials. When considering renewables, such projects employ solar, wind, and geothermal energy. This has the benefit of avoiding discharge of pollutants, and, enhancing recycling. In addition, renewable energy such as wind can reduce electricity bill and enhance environmental comfort even with adding nature and greenery to the space [30]-[32]. Other benefits include improvement of indoor environmental quality (IEQ), giving preference to non-toxic, materials, processes. Application of this kind of design philosophy creates a structure which is adapted to its surroundings. There are several certification programs in the field: LEED (Leadership in Energy and Environment), Green Globes, BREEAM (Building Research Establishment Environmental Assessment Method), Green Star and others. Climate change mitigation actions can be pursued by adopting new technologies that have substantial efficiency in energy consumption, and carbon emissions [15], [16], [21], [22].

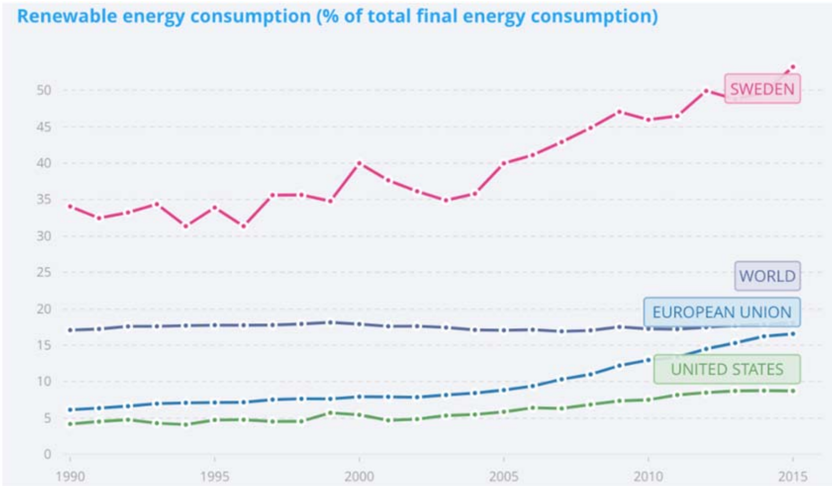

Fig. 1 Renewable energy consumption (Extended PTC and ITC% of Total Final Energy Consumption) [4]

D. Renewable Energy Market Growth

According to the 2017 Renewable Energy Status Report, as of 2015, renewable energy source accounted for 19.3% of global consumption. Among total market share, traditional biomass is responsible for 9.1%; hydropower, 3.6%; solar and geothermal, 4.2%; renewable electricity, 1.6%; transport biofuels account for 0.8%. Fig. 2 graphically depicts this information [33]. The associated report describes trends of use regarding biomass; geothermal; hydropower; ocean energy; solar power; solar thermal power; solar thermal heating and cooling; wind power.

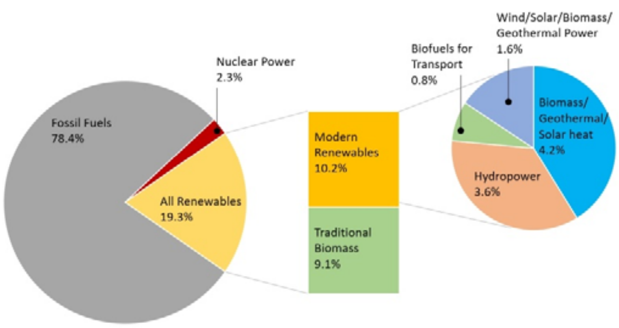

Fig. 2 Estimated Renewable Energy Share of Total Final Energy Consumption [33]

Biomass primarily refers to traditional fuelwood, animal excretion, and agricultural waste having poor combustion efficiency. It consumes the largest share of resources. Total biomass energy supply was around 62.5 exajoules (EJ) in 2016. The supply of biomass has been increased by about 2.5% annually since 2010. This increased rate is relatively low when considering that global energy demand rose 21% over the past 10 years [33]. Geothermal energy supplies electricity and heating/cooling energy. As of 2017, the global geothermal energy production is estimated at 9.8 GW. Both electricity and thermal heat and cooling are generated by geothermal plants. Indonesia and Turkey are the leading countries for new construction of geothermal. The United States has the largest geothermal power generating capacity (2.1 GW), followed by Indonesia (1.5 GW), the Philippines (1.2 GW), New Zealand (0.9 GW), Mexico (0.7 GW) [34]. Global hydropower's total capacity is estimated to be 1,292 GW in 2018. The primary countries that use hydropower are China, Brazil, the United States, Canada, Japan, India, and Russia. These countries are producing 61% of capacity. China is a leading country in this area, commissioning 27% of installed hydropower capacity by 2018 [35]. Ocean energy harnesses energy by using waves, tidal range and streams, ocean currents, and temperature or salinity gradients. However, there are few facilities that can utilize ocean energy up to date. The capacity of ocean energy is 536 MW in 2016, which is generated by the tidal barrage plants. South Korean Sihwa plant is producing 254 MW annually while France tidal plant generates 240 MW. Most ocean facilities are still in the nascent stage, need to be developed for commercial utilization [33].

Global solar power total capacity is 471.2 GW, 100.9 GW added newly in 2017. Asia accounts for around two-thirds of additions. The six countries, China, the United States, Japan, Germany, India, and Italy show the market share of 78% of global acquisitions. China installed 53.3% of the world's solar capacity in 2017. Market growth is primarily due to increasing competitiveness of solar panels, in addition to expanding demand for clean energy generation. A lot of countries now are aware of the potential of solar PV, and they recommend industry and private houses to install a solar panel, expecting the more solar panels, the less GHG emissions. Solar PV has a cost-competitive because its price drops rapidly these days and governments support the installation financially with FITs. China installed 52.8 GW solar PV aggressively in 2017, soaring its total solar capacity 68% to 130.2GW. Despite the economic downturn, in response to electricity demand growth and GHG reduction schemes, China still rushes to install solar PV [36]. Concentrating solar thermal power (CSP) is producing electricity through boiling water by utilizing the concentration of solar power. It had a 5.1 GW global capacity in 2017. While the US and Spain are the frontiers of this market, Morocco, South Africa, India and UAE are the new players in this market [37].

All new plants constructed recently integrated thermal energy storage (TES) with electricity facility. TES system is thought of as primary competitiveness of CSP through supplying the flexibility of dispatchability. Solar thermal heating and cooling have been declining for years. Especially in Europe, the primary market for the system lost its interest in solar thermal technology. To fight the markets' shrinkage, industry developed a new strategy to attract the clients by introducing new directions and taking various portfolios. Taking Austria for an example, some collector companies attached heat pumps and solar PV solutions to their system to supply complete thermal heating system solutions. The Chinese manufacturers focus on new systems that can heat and cool spaces as well as dehydrate agricultural products [33]. Finally, wind power has 590 GW of global total capacity, increasing around 50 GW in 2018. Over 90 nations had operated wind power facility, in the success of commercial wind electricity production. China is the leading country in this market, followed distantly by the United States, Germany, India, and Brazil. During several years, Asia was the largest local market, responsible for half of added capacity. The wind has become the most cost-efficient option for renewable energy. However, its market growth got affected by future policy changes, economic cycle, and policy-related shrink [38].

E. Financial Instruments

Governments are using various financial instruments to promote renewable energy. Typical examples are climate finance, tariffs, and taxes. Climate finance uses banking operations to promote mitigation. The Kyoto Protocol and the Paris Agreement call for parties to aid those vulnerable to consequences of large-scale initiatives. For example, the Global Environmental Facility (GEF) has played a significant role in supplying entities with such mechanisms. The Green Climate Fund (GCF) operates financial instruments in a similar mechanism. Moreover, GEF manages two special funds, the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF). An Adaptation Fund (AF) is also managed under the Kyoto Protocol [6] [24].

FITs are performance-based incentive programs. Several are active, encouraging the installment of renewable electrical facilities. While FIT was started in the United States, to spur a domestic boom in renewable energy, it has grown to international prominence. Under the system, customers with available generation (a solar photovoltaic array, for example) will be subsidized by the utility. They obtain this subsidy through credit for surplus electricity sold back to the regular grid [39]. The Renewable Market Adjusting Tariff (ReMAT) is a California scheme to support small generators who produce less than 3 MW. These "mom and pop" operators sell electricity to California's three Investor Owned Utilities (IOUs). Under ReMAT this type of generation has reached 493.6 MW capacity as of 2013 [40]. Gainesville, although suspended the program now, adopted the FIT, providing energy directly to Gainesville Regional Utility (GRU) through a 20-year fixed-price contract. The program capacity was 4 MW, annually. The average selling price was US$0.18/kWh [41].

In summary, climate taxes are other financial tools contributing climate action. A carbon tax places burden on carbon dioxide equivalents emissions, providing necessary impetus to emit less GHG. That tool would be applied to energy-intensive industries [42]. For example, a charge of US$40 per ton would impose 36 cents tax on the price of a gallon of gasoline. That revenue would be used to offset the impact of GHG emissions. The entity that has a heavy tax burden tries to lower the impact of climate tax on its profit by investing in clean energy and climate adaptation. That is the primary purpose of embracing climate tax [43].

F. US Solar Market Trend

Since the SPI conference concentrated on renewable power systems, it is meaningful to look at trends in US solar utilization and investment. In the fourth quarter (Q4) of 2018, the US market added 4.2 GW more an annual total of 10.6 GW was thereby achieved. It was 2% lower than that of 2017. Over the past six consecutive years, solar power was the primary source of new electricity production [44]. Since the SPI conference concentrated on renewable power systems, it is meaningful to look at trends in US solar utilization and investment. In the fourth quarter (Q4) of 2018, US market added the renewable power system at 4.2 GW to the total system. With the additional 4.2 GW, an annual total of 10.6 GW was thereby achieved. Even thought, with the 10.6 GW was achieved, it still was 2% lower than what US have achieved in 2017 [44].

Total operating aggregated solar PV capacity achieved 62.4 GW; 75 times larger than that of 2008. In 2017, the residential solar PV market experienced 15% contraction, but in 2018, market rebounded, growing by 7%. Q4 of 2018 was the hottest quarter for the residential solar installation over the latest couple of years. The commercial PV market faced an 8% decline in 2018 and seemed to have a decreasing momentum due to the policy changes in California and Massachusetts. As for utility aspect, there was a 6.2 GW installation for utility company, illustrating 58% of total US capacity additions of 2018. It is expected to grow about 14% compared to 2018 in 2019, with around total 12 GW installations. The entire PV installation will increase 100% more over the future five consecutive years, having an annual installation of 15.8 GW in 2021 [44]. Though statistics are available for the renewable sector, trends of use are absent from the literature. This research gap could be beneficial for study. Research presented here is the result of only four days intensive conference attendance.

III. Methodology

The SPI and ESI conference is arguably the largest renewable energy event in North America. Exhibitors include representative companies, marketing: solar panels; wind and hydrogen storage cells; geothermal systems; EV infrastructure. This paper references the 2019 Salt Lake City conference, which hosted more than 700 international firms, 19,000 attendees, and nearly 300 education sessions. This study utilized discussion with vendors and session subject matter to comment upon industry development. Participants have been sorted into major categories, and subcategories. These were analyzed depending upon energy component, or area of expertise. Although several companies provided a spectrum of services, this paper considered only their predominant orientation.

IV. Analysis & Discussion

The solar power industry is fragmented. The field is composed of various small-scale manufacturers, operators, contractors, and suppliers. This sustainability bazaar brought together an extensive alliance of leaders. The goal was encouragement of education, networking, and innovation. This convocation must therefore be considered the premier business-to-business event for professionals in solar and related fields. In the above enumerated process, it was found that manufacturing contributed approximately 43% of conference booths. It follows that about 500 companies, worldwide, may be associated with actual production capabilities. At the other end of the spectrum, recycling composed the least percentage of participants, occupying less than 0.26% share of the conference floor. Solar service-oriented firms were only slightly less numerous, with a 34% share. Fig. 3 summarizes those findings.

Fig. 3 Division of exhibitors according to their predominant function

The manufacturing category can be divided into eleven subcategories. Fig. 4 shows that most companies produce miscellaneous products. Typology of their contributions could be described as: connections; nuts; bolts. The share within manufacturing stood at about 30%. This is significant because these spare parts are crucial to supply the fledgling market with replacement components. Wind products had much less impact, totaling just 1% of all products.

Other major players could be segregated into five categories: environmental; NPO (Non-Profit Organization); financing; engineering services; software. An astounding 70% of services involve software. Close to 50% focus on design of systems and business development. That sector can be unbundled as shown in Fig. 5.

Putting a spotlight on the education sessions, it was observed that a complex space picture is emerging. Due to demands of technology and climate change, federal and local government agendas seem to be moving away from fossil-fuels. Design and finance innovation characterize the new modalities. Projects once financed over 25 years, can now amortize over 40 years. Government policy, therefore, has shown an increasing ability to incentivize adoption of solar. Although further research in every phase of renewable energy is necessary, certain targets stand out. Feasibility of system operation, to achieve peak performance is one such example. Finally, limitations to hours of productive capacity can prevent supply of continuous power to the consumers. This creates a grievous need for storage, illustrated in Fig. 6.

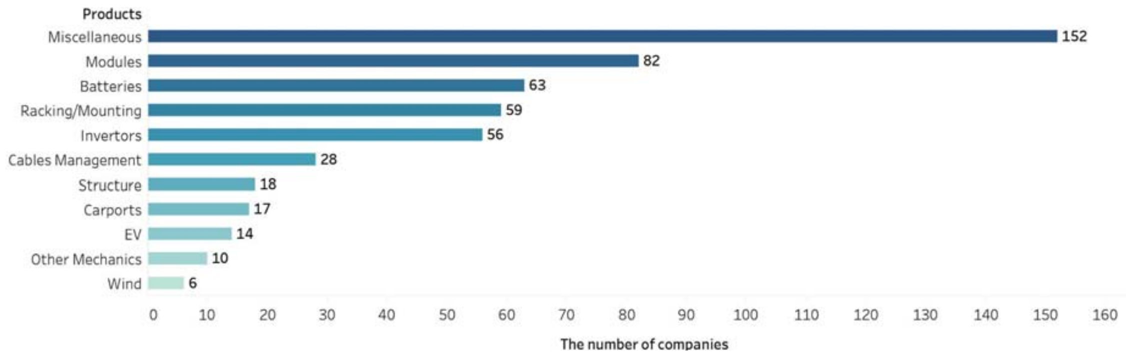

Fig. 4 Division of manufacturing exhibitors into their main products

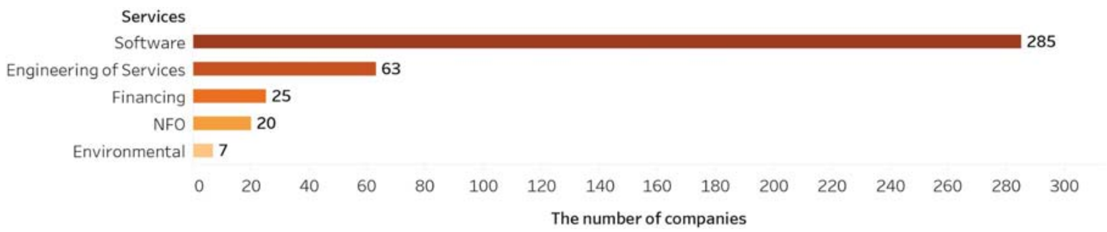

Fig. 5 Division of service providers into their main products, *The author*

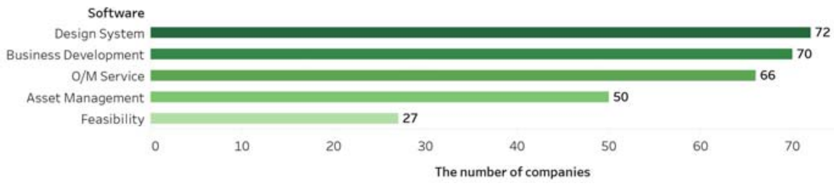

Fig. 6 Division of software platform providers

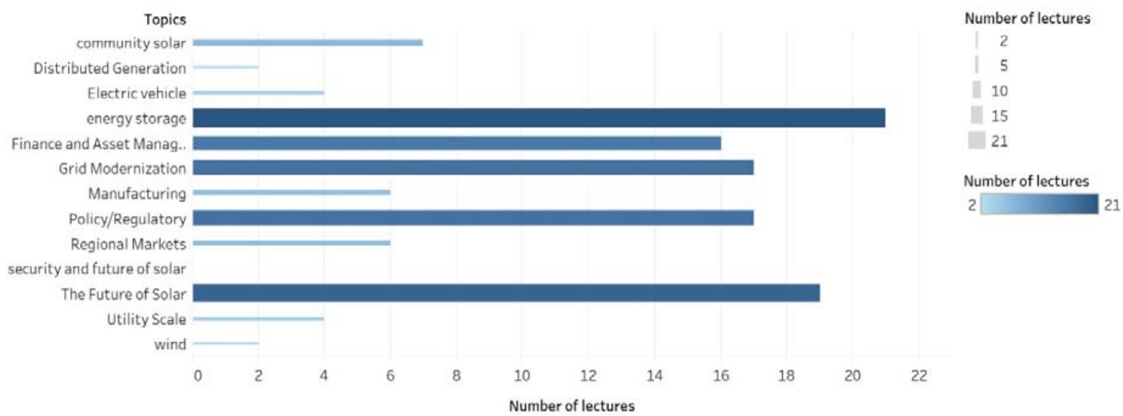

Fig. 7 Division of lecture providers

Technological advancement of module design has produced so-called bifacial modules which allow generation of electricity from the backside as well as the front side. In case of colder climates, traditional modules are hampered by snow;

bifacial modules perform even better as the in lower temperatures. Ground reflection melts snow collecting on an array. Exponential growth in solar power plants has made generator end of life issues a concern. Solar decommissioning is required not only for panels, but all Balance of System (BoS) components. This will be expensive and require, for example, bond issuance to spread risk. Financial innovation will become necessary as these effects mount. Currently, a common risk tool is a Power Purchase Agreement. There are other strategies: hedging; merchant markets; debt financing. The industry is becoming digitalized through artificial intelligence (AI) and big data. There are many research opportunities in terms of data management and Industrial Internet of Things (IIoT). These technologies can aid in design feasibility. They would also be useful in construction, operations, life cycle analysis. Environmental effects of installation are also a pressing concern. Some studies have shown that there is loss of habitat through the solar and wind power plants [45], [46]. This opens a serious conversation regarding protection of vulnerable species. It is also noteworthy that other technologies, such as hydrogen, have been sharing a good percentage of the market and show potential. There are several opportunities in effective hydrogen fueling and hydrogenic design systems which should provide fertile opportunities for future research.

V.Conclusion

The shift towards renewable energy sources to fight climate change and protect our ecosystem shows promising results. The industry has shown significant progress in a relatively short time with respect to technology and its implementation. Although the major market drivers are solar and wind, progress has also been made in case of hydrogen, fuel cells, biomass and geothermal energy. From the above study, it can be judged that there is still a long way to go for the renewable sector to reach a stage where the common man would feel confident in going zero fossil fuel. The primary indicator in getting faster results in reversing climate change is how aware the people of the planet are in terms of their energy generation and use. It is the responsibility of each enterprise in spreading awareness through literature, social media, academic platforms, conferences, news, policies and others. Secondly, technology, when developed, must consider end of life, for example, solar panels, cabling and others. In case of energy, federal and local regulations play a key role in people's behavior of energy usage. This can be seen through the progress made by different states in the United States.

Incentivization and subsidy programs can help boost the world to move to renewables at a much faster rate. In the realm of technology, this event did not cover new innovations such as building-integrated photovoltaics, architectural glass and others which have tremendous potential in the solar sector. The renewable sector has been found more vulnerable to natural disasters and in order to solve this problem, resiliency in the design and implementation is highly critical especially for countries which are prone to hurricanes, cyclones, tsunamis, earthquakes and others. Furthermore, energy storage which is mostly discussed from this event is also a major research area for development as it adds to the resiliency as well as it allows for continuous supply for electricity irrespective of weather conditions. In conclusion, there are a plethora of opportunities in every sector in the renewable energy space for both academics and professionals but there is an urgent need in research and innovation in the field of energy storage, environmental impact assessment, recycling and policies/regulations.

VI. Limitation

The paper mainly focuses on solar energy but not on other technologies such as hydrogen, biomass, wind and others.

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