Achieving 100 % Renewable Energy

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***Abstract*— People worldwide are confronted with the reality of climate change in many parts of the world as a result of natural and anthropogenic emissions of air pollutants, particularly greenhouse gases (GHGs), which are creating large-scale effects on the climate and threatening the climate life on Earth. The combined consequences of urbanization and climate change are posing a severe threat to the world's environmental, economic, and social stability. Renewable energy plays an essential part in long-term sustainability and has numerous potential benefits, including lower greenhouse gas emissions, increased energy supply diversification, and less reliance on fossil fuels. Cities are the core of the renewable energy shift; therefore, city governments worldwide are taking steps to accelerate the global use of renewable energy in municipal operations and throughout the city.**

1 Introduction

Climate change has emerged as a key problem for the twenty-first century. By the end of this century, the Paris Agreement sets a specific objective of keeping global temperature rise to "below" 2 degrees Celsius (°C), ideally 1.5 °C, compared to pre-industrial levels. To meet this climate goal, a significant shift in the global energy sector is required. [1] [2] Climate change has impacted natural and human systems on all continents and across oceans in recent decades. According to the IPCC, human influence on the climate system is obvious and expanding, with consequences seen across all continents and oceans. Between 1970 and 2010, CO2 emissions from fossil fuel combustion and industrial activities provided around 78 % rise in GHG emissions, with a similar percentage contribution from 2000 to 2010. [3]

Renewable energy technology can help governments achieve their policy goals of secure, reliable, and affordable energy, universal access to power, lower price volatility, and social and economic prosperity. Recent and anticipated cost reductions in renewable energy generation technologies show that renewables are becoming a more cost-effective means of accomplishing these goals. [4] Rising renewable energy deployment expands the scale and competitiveness of renewable technology markets, with costs falling by as much as 18% to 22% for solar photovoltaic (PV) modules and 12% for wind with every doubling in cumulative capacity of a renewable technology. [5]

2 Current status of Renewable energy

Global renewable energy consumption, including traditional biomass applications, reached 64.2 exajoules (EJ) in 2018, up 2.1 % year over year. [6] In recent years, the cost of producing electricity from wind and solar energy has decreased dramatically. Since 2010, the global weighted average Levelized cost of electricity from utility-scale solar photovoltaics (PV) has decreased by 85 %, while the cost of onshore wind power has decreased by 56 %. Low operating costs and preferential access to electricity networks during periods of low electricity demand helped renewable energy attain its highest recorded share of the global electricity mix in 2020 - an anticipated 29 %. [7]

2.1 Solar Power

In 2017, a total of 99.1 GW of grid-connected solar power was installed. This is a nearly 30% increase over the 76.6 GW added in 2016. [8] All continents contributed significantly to global growth in 2020, with an expected 20 countries adding at least 1 GW of new solar PV capacity, up from 18 countries in 2019. Solar PV demand is growing as it becomes the most cost-effective alternative for energy generation in an increasing number of areas, including residential and commercial applications and utility-scale projects – even before factoring in the external costs of fossil fuels. [7] PV module costs have dropped by more than 70% in recent years [9] due to increased efficiencies that allowed for the creation of modules with higher power ratings, lower material costs, economies of scale, and a step deeper to R&D. R&D, both public and commercial, has traditionally been a fundamental driver of module cost reduction and can continue to be useful in improving module efficiency and decreasing material use in the future. [10] The adoption of a new cell standard known as Passivated Emitter Rear Contact (PERC) improves efficiency by 0.5-1% while requiring little additional production equipment. Jinko Solar revealed the latest record efficiency PERC cell of 23.95 % in 2018, followed by a 23.6 % cell from LONGi Solar. Increasing module power with half-cut cells is a simple yet effective method. Resistance losses can be decreased by splitting a completely processed cell into two pieces, resulting in a power increase of around 5 to 6 W at the module level. [8] PV cost reduction trends are expected to continue in the future, with LCOE for utility-scale solar PV expected to drop by 58 % to USD 0.040/kWh by 2030 as a result of higher module efficiency levels and newer architecture cells like PERC (passivated emitter rear contact) in the period leading up to 2025. [2]

2.2 *Wind Power*

In 2020, more than 93 GW of wind generation capacity was expected to be constructed globally, with more than 86.9 GW onshore, the largest ever, and approximately 6.1 GW offshore. [11] By the end of the year, total global wind power capacity had increased by 14% over the previous year, approaching 743 GW (707.4 GW onshore and the rest offshore); this was more than double the capacity in operation only six years earlier, at the end of 2014. In a rising number of countries, wind power contributes a significant portion of electricity. Wind energy is expected to generate enough electricity to meet 15% of the EU-27's yearly electricity demand by 2020. [7] Between 2000 and 2002, turbine prices for onshore wind farms in the United States fell to around USD 750/kW, but by 2008, average prices had risen to above USD 1500/kW, [12] and the downward trend in turbine pricing is expected to continue in the coming years, leading to increased industry consolidation and lower commodity prices, such as reduced growing competition from Chinese manufacturers. [4] Between 2018 and 2030, the LCOE of onshore wind is expected to drop by 25%, while the LCOE of offshore wind will drop by 55%, thanks to a continued shift to larger wind turbines with higher hub heights and innovations in operation and maintenance (O&M), such as real-time data and predictive maintenance. [2]

2.3 *Bioenergy*

Biomass generated 637 TWh of power globally in 2018. Solid biomass sources accounted for 66% of all biopower generated, with municipal and industrial waste accounting for 19%. Biogas accounted for 14% of the total. In 2018, 1.12 EJ of heat was generated from biomass-based sources, with solid biomass accounting for 53% and municipal solid waste accounting for 26%. Bioenergy is one of the most promising ways to decarbonize the heat sector, which includes residential, commercial, agricultural, and fisheries applications. Since 2000, the sector has grown at a pace of 6% each year. [13] Where minimal capital costs and low-cost feedstocks are available, bioenergy can produce very competitive electricity. Indeed, with an LCOE of around USD 0.04/kWh, this technology may deliver dispatchable energy output. [14]

2.4 *Hydropower*

In 2020, the hydropower sector produced a record 4,370 terawatt-hours (TWh) of clean electricity, surpassing the previous high of 4,306 TWh set in 2019. In 2020, the total installed hydroelectric capacity was 1,330 gigawatts (GW), increasing by 1.6 percent to 21 GW, up from 20 GW the previous year. With 160 GW of installed capacity and 9,000 GWh of energy storage capacity, pumped storage hydropower now accounts for over 90% of the world's grid-scale energy storage applications. [15] Hydropower has long been the foundation of low-cost electricity generation in many countries around the world. The global weighted-average cost of hydroelectric electricity in 2020 was USD 0.044/kWh, up 16 % from USD 0.038/kWh in 2010. However, the LCOE of 56 % of hydropower projects commissioned in 2020 was lower than the cheapest new fossil fuel-fired option. [14]

2.5 *Green Hydrogen*

Green hydrogen can enable energy-intensive, hard-to-decarbonize industries including steel, chemicals, long-haul transportation, shipping, and aviation achieve net-zero CO2 emissions. [16] Hydrogen and hydrogen-based fuels accounted for less than 0.1 percent of total final energy consumption (TFC) in 2020, but by 2030, they would have risen to 2%, and by 2050, 10%. Natural gas is the most common fuel for hydrogen generation, accounting for 60% of annual global output and 115 Mtce of coal (2 percent of global demand) accounting for 19% of hydrogen production. [17]

The cost difference between low-carbon hydrogen and hydrogen produced from unabated fossil fuels is a major impediment. In most regions of the world, creating hydrogen from fossil fuels is now the most cost-effective method. The Levelized cost of hydrogen production from natural gas varies depending on regional gas prices, ranging from USD 0.5 to USD 1.7 per kg. The cost of producing hydrogen using renewable electricity ranges from USD 3 to USD 8 per kilogram. [17] Lower electrolyze costs and, ultimately, cheaper green hydrogen will result from a mix of government support for research programs in combination with the formation of rules and targets and private sector initiatives toward standardization and optimal designs. 40% cost reduction might be realized in the short term, with an overall cost reduction of 80% when all targets are met in the long term. [16]

2.6 *Geothermal*

With a total capacity of 14 gigawatts at the end of 2020, geothermal power generation stations accounted for 0.5 percent of the total installed renewable power generation capacity worldwide (GW). By the year 2020, total installed capacity would have increased by 41% over 2010. The majority of this capacity is found in active geothermal zones. [14] In 2020, geothermal energy generation was estimated to be around 97 TWh, while direct useable thermal output was over 128 TWh (462 PJ). In the year 2020, an estimated 0.1 GWiii of new geothermal power generating capacity was expected to come online, bringing the total global capacity to roughly 14.1 GW. Between 2014 and 2019, at least 440 MW of additional capacity was added per year. The global weighted-average total installed cost of the eight plants in

IRENA's database in 2020 was USD 4 486/kW, up from the 2015 low of USD 3 538/kW. [7]

Around 78 % of drilling wells succeed globally, with the average success rate improving in recent decades. This is most likely due to advancements in surveying technology, allowing for more precise targeting of the optimum locations for producing wells. [18] Eavor Technologies Inc. created a closed-loop system that circulates a working fluid to harvest heat from bedrock without bringing geothermal fluid (brine) to the surface, using directional drilling techniques established in the oil and gas industry. Over 24 hours, a 10 MW plant can deliver 240 MWh in practically any form. Energy can be stored underground and strategically extracted by modifying operational parameters to create peak energy when it is needed, promoting system flexibility and grid stability. The rapid advancement of cost reduction is anticipated due to this development method. [19]

3 Global overview of Renewables in cities

Cities contain more than half of the world's people [20] and produce up to 70% of dangerous greenhouse emissions despite occupying only 2% of the planet's territory. The substantial increase in energy use, land-use changes, and emissions from industrial activity are the main human sources of GHGs. Changes in higher per capita income (up 77%) and population expansion (up 69%) promoted increases in GHG emissions between 1970 and 2004. Many of the sources of GHG emissions are urban, with the combustion of fossil fuels by commercial and residential buildings or electricity generating plants for heating and air conditioning, commercial and individual use of energy to run motor vehicles for transportation, and energy used in industrial processes accounting for these emissions. [21] Urban population growth has accelerated to unprecedented levels in recent years, with total urban populations nearly massively increasing between 1950 and 2011. During the same period, the urban population has risen from less than a third of the global population (28.8% in 1950) to more than half of the worldwide population (50.8 percent in 2011). [22] By 2030, a projected 59 percent of the world's population will be living in cities, with industrialized countries accounting for 81 percent of the total. Meanwhile, by 2030, the average in developing countries is expected to reach approximately 55%. [23]

As a result, city administrations increasingly recognize renewable energy's potential to aid in the creation of clean, livable, and equal communities. By the end of 2020, at least 834 cities in 72 countries, with a population of 558 million people, had adopted a renewable energy target in at least one sector. Although renewable energy targets have primarily been set for the power sector, they have expanded to include the heating, cooling, and transportation sectors. Several cities have adopted detailed plans to transition to renewable heating systems. In contrast, the number of cities adopting targets to increase renewables in the transportation sector and expand the use of battery-electric or hydrogen vehicles (both of which can be powered by renewables) has increased. At least 67 cities, up from 54 in mid-2019, will have e-mobility targets by the end of 2020, allowing for greater use of renewables in transportation. [20]

3.1 *Electricity*

Modern economies rely on electricity to support communications, healthcare, industry, education, comfort, and entertainment. [24] Over the last 23 years, electricity usage has doubled, with a 33 percent increase in the last decade. In 2018, coal-based sources produced 38 % of worldwide electricity with a total of more than 10 000 TWh, [13] while renewables accounted for 21% of total final energy consumption (TFEC), owing to increased use of solar and wind as considerable contributions from hydropower and biomass. [6] Today, industry and buildings account for over 90% of worldwide electricity demand, whereas transportation (rail) accounts for less than 2%. [24] Energy from power use, space heating, and cooling are linked to GHG emissions from commercial and residential buildings. According to IPCC estimations, global emissions from residential and commercial buildings are estimated to be 10.6 billion tons of CO2 equivalent per year, accounting for 8% of global greenhouse gas emissions. [25] Buildings (including families and the services sector) continue to be the largest source of energy demand, with consumption predicted to climb by 60% in developing nations. [24] Heavy sectors, such as iron and steel production, cement production, and chemical manufacturing, account for 23% of global GHG emissions. [26] The majority of the power consumed in the industry is for motor-driven systems (including pumps, fans, and compressors). Motor systems presently account for 30% of worldwide electricity demand, with that percentage expected to rise to 31% by 2040 as demand climbs by over 4 500 TWh. [24]

Renewables remained the fastest-growing source of energy in buildings, growing at a rate of 4.1 % between 2009 and 2019, despite accounting for only 14.8 percent of total industrial energy demand and being used primarily in industries with low-temperature process heat requirements. In 2018, renewable energy accounted for less than 1% of total energy demand in heavy sectors such as iron and steel, cement. [7] Renewables, headed by wind and solar PV, account for three-quarters of the growth in electricity supply, thanks to government backing and lower technology costs. Renewable energy generation rises from 26 % to 44 % in 2040, with solar PV and wind combined rising from 7 % to 24 %. [24] During the epidemic, installed renewable power capacity increased by more than 256 (GW), the most significant growth ever. At least 19 nations had more than 10 GW of non-hydro power renewable capacity by the end of 2020, up from 5 countries in 2010. China alone installed about

117 GW, bringing more renewable capacity online in 2020 than the entire globe did in 2013. Renewable energy now accounts for a record-high 29 percent of worldwide electricity generation. [7]

Hawai'i achieved overall value of 126 in evaluation-matrix calculation because of its steadily progressing toward ending its dependency on fossil fuels and transitioning to a renewable portfolio standard of 100% renewable energy by 2045, with interim objectives of 30% renewable energy by 2020, % renewable energy by 2030, and 70% renewable energy by 2040. The amount of renewable electricity on Hawai'i's systems rose, with an RPS of 36.07 percent for the calendar year 2020, exceeding the level mandated under HRS 269-92 of 30 percent. The amount of electrical energy generated by renewable energy resources, including customer-sited, grid-connected technologies, increased by 12.9 percent to 320,384 MWhr in 2020, compared to the previous year. [27] In 2020, the number of new customer-sited energy resources and Feed-In Tariff installations will total 65.6 MW. On December 11, 2020, one grid-scale project, the 24 MW Na Pua Makani wind plant on O'ahu, began operations. On Hawai'i Island, the Puna Geothermal Venture facility has reopened in part. [27] Since 2013, the RPS levels reported by Kaua'i Island Utility Cooperative (KIUC) have more than tripled, approaching 67%. [28]

Because of its renewable portfolio standard, Burlington received an overall score of 116 in the assessment matrix calculation. Different energy sources, such as hydro (35%), wind (19%), solar (2%), and biomass from wood ships, are used to power the city (44%). Burlington, Vermont, created the city's 2030 goal to make a Net Zero Energy City in 2016, with cooperation from the Burlington Board of Electric Commissioners. The city purchased the Winooski One Hydroelectric Facility, a 7.4-megawatt hydro plant, in 2014. The Burlington Electric Department (BED) buys renewable electricity credits to meet its annual goal of 100 % renewable energy. By September 2014, renewable energy sources had completed 100 percent of the city's electrical demand. The first city in the United States to generate all its electricity from renewable sources. [29]

3.2 Transport

Transportation accounts for approximately 25% of overall energy-related GHG emissions and 13% of global GHG emissions globally. [2] Furthermore, as economies grow, transportation operations rise, and this trend is projected to continue in the next decades, particularly as urbanization increases. For both internal and external movements of goods and people, urban regions rely significantly on diverse transportation networks. [21] In 2018, renewable energy in transportation increased by 0.28 EJ, the fifth highest year-on-year increase since 1990 and the largest since 2012. [6] Renewables' share of the transportation sector was 3.7 percent at the end of 2020, unchanged from the previous year. [7] Liquid biofuels, primarily crop-based ethanol and biodiesel combined with fossil transport fuels, accounted for the majority of renewable energy consumed (91 percent). [6]

The United States has set a goal for biofuels to account for 15% of US transportation fuels by 2030 and 30% by 2050. [30] By 2030, Zimbabwe will have implemented a national biofuels program that includes targets for ethanol blends of up to 20% and biodiesel blends of up to 2%. [31] Several technologies are being developed that can reduce emissions in road freight transport to zero. Most commercial light-to-medium-duty vehicles that drive 100 to 200 kilometers each day might be plug-in battery EVs or completely electric trucks. [2] According to a recent survey, 70 different models of electric trucks are already available in the United States from 27 other manufacturers. Lithium-ion technology is being developed and implemented in delivery vans and semi-trucks for usage by logistics organizations. [32] At least seven governments will have rules to encourage EV charging by 2020. California allocated USD 233 million to install public EV charging stations, [33] and Hawaii approved legislation to offer incentives for the addition and upgrade of charging infrastructure. [34] The HSEO is trying to execute methods that will make a transformational investment in Hawai'i's clean energy economy in order to reduce Hawai'i's petroleum consumption in the ground transportation sector. [35] HSEO has taken a lead role in promoting the adoption of clean transportation in Hawai'i, including facilitating the deployment of zero-emission vehicles (ZEVs) and associated electric vehicle charging and infrastructure, all of which help reduce petroleum consumption emissions in the transportation sector. [28] As of October 2020, Hawai'i has one of the highest per capita rates of electric cars (EV), with over 12,000 electric vehicles registered. [35] The company's Electrification of Transportation (EoT) team is striving to guarantee that the infrastructure required for continued EV adoption is in place. [36] On O'ahu, Maui, and Hawai'i Island, there are also 286 public electric vehicle charging stations and eight new electric vehicle fast charger stations. [35] [36]

By 2030, Oslo, Norway, plans to phase out fossil-fuel-powered automobiles and replace them with zero-emission vehicles. Oslo will prioritize significant public transportation investments to bolster this endeavor. A new central tunnel, a tram line along Ring 2 (the second ring road), and a considerable expansion of the cycling path network are among them. The city of Oslo will step up its efforts to make cycling more appealing. By 2025, the city hopes to have 25% of daily trips made by bike. Furthermore, Oslo has achieved substantial success in reducing greenhouse gas emissions per capita, making public transportation more inexpensive, promoting universal design, and expanding public transportation services in the city's outer districts. By 2028, the entire public transportation system will be emission-free, and it will stop emitting greenhouse gases in 2020. Automobiles will be replaced with zero-emission vehicles that run on biogas or a sustainable biofuel. [37]

3.3 Heat

Heat is the most common energy end-use on the planet, accounting for half of all TFEC (177 EJ). In 2018, total heat consumption increased by 1.1 percent compared to 2017. [6] Heat-only and mixed heat-and-power plants produced 15 EJ of heat globally in 2018. Coal and natural gas account for more than 85% of worldwide heat production, a figure that has been constant since the turn of the century. Over the last 18 years, renewable energy technologies such as biomass, geothermal, and solar thermal have doubled their proportion of world heat generation. However, renewables account for only 7.7% of heat production, compared to 26% of electricity generation. [13] Building heating and cooling demand accounts for about 25% of total final energy consumption. While fossil fuels now provide the majority of this demand, there is substantial potential for further usage of renewables. [38] In 2018, bioenergy accounted for roughly 87 percent (14.1 EJ), whereas solar thermal consumption climbed by 3.7 percent, accounting for 8.5 percent (1.4 EJ) of current renewable heat usage. [6] In 2018, geothermal heat consumption increased by over 14%, accounting for 4.2 percent (0.7 EJ) of modern renewable heat consumption. Ground-source heat pumps capture about 60% of geothermal heat around the planet. [39]

Copenhagen's carbon neutrality objective by 2025 entails the city becoming the world's first carbon-neutral capital. The City Council established the CPH 2025 Climate Plan to minimize greenhouse gas emissions as a step toward reaching this goal. Efforts to minimize carbon emissions from energy production in Copenhagen have been divided into four action areas: carbon-neutral district heating, carbon-neutral utilities, wind and solar power, and resources and waste. BIO4, HOFOR's new biomass-fired power station unit, was commissioned at Amager Power Station in 2019. The last coal-fired power plant unit in Copenhagen has been replaced by BIO4, which means that all heat and electricity production at Amager Power Station, which supplies district heating to Copenhagen, has been converted to biomass. Copenhagen's district heating is carbon neutral to the tune of more than 80%. The other 20% of heat is created by the city's peak load and reserve load plants, as well as the fossil fraction in the trash. [40]

Malmö, Sweden, intends to meet its 100 percent renewable energy target using a combination of renewables, waste-to-energy, and recycled energy. Around 43% of Malmö's power came from renewable sources by 2020, primarily wind energy. The city of Malmö is building a 50 M W geothermal deep-heat plant that will be operational in 2022. To replace the usage of biofuels and biogas for heat generation, the city aims to construct five geothermal heat plants, each with a 50 MW installed capacity, by 2028. [41]

4 Conclusion

Renewable energy capacity has continued to develop in the power sector around the world, owing to supporting regulatory frameworks that have enabled solar PV and wind power become the most cost-effective sources of new electricity. The transportation sector is failing to meet global climate objectives. A comprehensive transportation decarbonization program is still lacking in many communities. Only a few cities have used e-mobility to enhance the share of renewables in their energy mix. Policies affecting building heating and cooling have remained more limited than policies affecting power generation and transportation.

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