Policy and Legal Foundations for Distributed Generation

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Abstract

Distributed resources have an important role to play in the global sustainable energy to a renewable electricity future by aiding the increased uptake of renewable energy, shape and reduce electricity demand, and facilitate the integration of variable renewables. It is important to create a level playing ground for the centralized and distributed energy resources which demands changes in the business models, policies, regulations, and changes in the electricity markets, to cope with a rapidly evolving technology landscape. Important policy and legislative measures focus on adapting traditional, centralized regulatory models to a new paradigm characterized by diverse, small-scale actors with two way flow of power and information.. A decentralized energy resources provide significant opportunities for deployment of renewable energy sources most of which are locally available. The dependency on fossil fuel-based energy sources has been growing with global increase in energy demand over the last few decades leading to significant growth in energy related environmental degradation. Energy sustainability has five major dimensions namely technical, social, economic, environmental and institutional dimensions each with unique measurable indicators. This study the institutional and political sustainability of various sources of energy resources is undertaken. For, potential decentralized energy resources are presented and compared in terms of their globalized institutional and policy frameworks. Indicators examined include price of energy resources, levelized cost of energy, and job creation potential, which have significant socio-economic impact to society but require political and institutional goodwill to flourish. The study showed that diesel power plants, fuel cells and battery storage supply the most expensive power source yet they ae critical for stabilization of power systems as dispatchable sources hence policy measures needed include encouraging use of renewable and sustainable energy resources for these technologies like biogas, green hydrogen. Bagasse through cogeneration, onshore wind and solid biomass offer the cheapest energy solution based on lifecycle assessment or levelized cost of energy, hence the need for governments to put in place policies that encourage development and use of these energy resources. On the basis of direct fuel cost the study showed that renewable sources have no direct resource price hence are more competitive but fossil fuels coal, natural gas and diesel are the most expensive to acquire. Governments should tactful control their use as dispatchable sources while putting in place policy incentives to shift to alternative sources like biofuel as direct substitute for oil, diesel and petrol, while policies to promote use of biomethane from biogas as a direct substitute for natural gas can also be pursued by countries.

Key words: Energy economics; indicators of sustainable energy; energy sustainability; energy sources

1. INTRODUCTION

Sustainable energy transitions, involve changes to societal practices of energy use; innovation and deployment of different low carbon technologies and a change in the mix of industries within national and global economies[1]. These changes bring new patterns of consumption and production as well as introduce different social groups, like new energy producers, new distributors, and retailers who capitalize on the changes whilst others face substantial losses. This conflict is often rife with technological development as economic rivals dispute the course of development and face resistance due to consequences like lost jobs, , regional decline, and environmental [2]

Renewable and sustainable sources face barriers to largescale deployment but their friendliness to the environment make them widely acceptable globally. For largescale adoption, and uptake of renewable sources, The electricity grid is undergoing modernization to become efficient, resilient, and reliable by replacing or upgrading the traditional grid with the smart grid grids and decentralized generation and replacing the traditional grid and its generation [3]. Renewable energy has a very important role to play in sustainable power generation to promote sustainability of environmental sustainability in power generation [4, 5]. Millions of people globally still rely on biomass and other traditional sources of energy for domestic utilities, at significant environmental, health and economic costs, yet many of these people in rural and urban are classified as underprivileged population, most of whom are found in rural and remote areas relying on minimal-quality energy resources and unsustainable technologies, that lead to low quality of life [11]. This situation is mainly occasioned poor access to centralized

energy, which can be mitigated, by decentralized energy planning (DEP) and distribution [12, 13]. As focus shifts to rural energy access, and sustainability of urban and rural energy systems, decentralization of energy supply will play a leading role in reduction of distance between energy source location and consumers hence transmission and distribution losses while at the same time increase the uptake of local energy sources most of which are often renewable [14, 15]. This generates significant social value to rural communities as both hosts and electricity customers,

Decentralization is a relatively new concept in power generation for many counties, in which energy systems are located closer to load centers or users to allow for more optimal exploitation of energy resources and at higher efficiency while increasing the use local energy resources most of which are renewable [6, 7]. Whereas the centralized or traditional power systems employ large, central power plants to produce power for long distance transmission and later distribution to consumers widely spaced and far away from energy sources, the decentralized power generation seeks to exploit the local resources located close to consumers using generally smaller diversified power plants connected to the distributed grid or onsite use with sell o excess [8, 9]. By sourcing energy and electricity in locally, utilities reduce the transmission and distribution costs as well as environmental impacts of power generation [10, 11]. The energy systems in decentralised power generation are often small-scale and designed to supply power to o local customers, as stand-alone or may be grid connected or both power systems [3, 12].

The grid integration of distributed power systems changes the commercial mechanisms in power systems in terms of maintenance, operation, maintenance, investment costs and financial benefits which should be resolved to facilitate deployment of decentralized power systems[13, 14]. Appropriate and adequate resources and power conversion technologies are desirable for optimal delivery energy in decentralized systems [15, 16]. Measures that can be employed to balance demand and supply includes energy efficiency, and balanced regulation of both central and decentralized energy systems to grantees sustainable power systems. Sustainability can be realized by measures like energy efficiency, social value, reliability of supply, public acceptance, technological innovation, competitive and cost reflective pricing, standardization. Market-sensitive interventions, regional integration, and power quality [17, 18].

The sustainability of energy resources can be measured using indicators and parameters like the cost of power generated, the levelized cost of energy, water consumption, socio-economic impacts like jobs created, accidents associated with the resource among others [19, 20].. Different sources having differences in terms of conversion efficiency, resource needs and investment as well as cost of operation and maintenance of the energy system [21] These factors are influenced by other factors like the technology employed, geographical locations, the political and legal through policy intervention which vary with state and regional governments as well as time [22, 23].

1.1. Problem Definition

Energy access remains a global challenge with about 1.2. Million people, most of them living in remote and rural areas having no access to electricity. The today is towards the global economy remains largely driven by non-renewable and conventional or commercial power production which has led to significant environmental destruction and limited access by the people residing in rural areas[6, 8]. Lack of clean energy has driven energy poverty and diseases like acute respiratory illness resulting from in-house pollution, high infant mortality as medical facilities lack refrigeration facilities for critical medicines and vaccine and the inability to power incubator, while educational facilities offer low quality education due to limited access to the ICT and power [24-26].

It is important for humanity to seek a balance between socio-economic development and the preservation of the environment and its mother. Although renewable energy resources remain critically important for decentralisation and sustainable energy transition, they face significant challenges ranging from resource availability, reliability of supply, access, resource location, security of supply, sustainability, and affordability while there intermittence and variability making the use of dispatchable sources and storage important[7, 17]. Therefore, policy makers should realise that a sustainable energy mix still requires dispatched sources, most of which are non-renewable fossil fuels, hence the ned to strike an acceptable balance between the non-renewable sources, storage and renewable sources in decentralised power generation [27]. The challenge of decentralisation of generation and efforts to promote more sustainable, more resilient, and equitable energy solutions may cause some unpleasant disruptions in the established political, social, technical and institutional relationships which calls for design and deployment of well though sustainable policies that enhance decentralisation of power generation[28-30].

Not all countries have critical primary energy resources, while conventional sources are generally expensive, scarce, exhaustible, polluting, and insecure and cause energy insecurity, while the fossil fuels generate greenhouse gas emissions and other pollutants to the environment. These concerns are the main drivers of sustainable energy transition which seeks to increase the use of renewable and low carbon clean energy sources which are abundant in remote and isolated areas and have potential to improve and widen power supply, enhance long term access and utility in energy production, decrease dependence on fossil fuel, and reduce

greenhouse gas emissions through decentralization of generation[31, 32].

The distributed energy resource exploitation faces a number regulatory and Institutional Challenges that include

i.) **Outdated Governance Structures**

The existing traditional model is based on vertically-integrated utilities with centralized control which needs new governance structures that may involve active role of local or municipal authorities who often lack critical technical expertise and capacity to manage the energy systems.

ii.) **Lack of Standardized Rules**

There is limited or lack of important regional and national standards and guidelines for distributed energy resource management which creates uncertainty for DG providers in terms of licensing, operation and control as well as timelines.

iii.) **Interconnection and Grid Access**

For decentralized energy systems, the of DGs to existing grid comes with legal and administrative challenges that necessitate the change in rules for harmonious integration and grid interconnection .to guarantee safety standards like islanding protection, and technical requirements to support the two-way power flow introduced by the distributed and decentralized energy and power systems.

iv.) **Ownership and Operation Models**

The traditional centralized frameworks define strict roles for generators, consumers and network operators but the decentralized systems introduce “prosumers" who are both power producers and consumers, a scenario that needs new legal definitions and rules to guide shared ownership and peer-to-peer electricity sales consistent with decentralized generation systems. .

v.) **Data and Information Sharing**

Decentralization of generation requires effective and transparent sharing of data on grid capacity and loading. However in the current centralized systems, some jurisdictions, some vertically integrated institutions have an incentive to withhold critical data for protection of their competitive advantage, which requires new regulations on data sharing.

vi.) **Policy Coherence and Coordination**

The current traditional coordination mechanism are important in ensuring that local policies like land use zoning, the construction and building codes remain consistent with broader national energy goals, which balances local autonomy with overall system stability. This is however has to be replaced with massive deployment of distributed generation systems which may create inconsistencies [33].

1.2. Rationale of the study

Decentralized and Distributed resources have important role to play like direct supply of renewable and sustainable electricity reducing grid electricity demand, and enabling flexibility and allow integration of high proportions of variable renewables.[33]. The energy transition is often considered as a single event, initially from traditional energy sources to fossil fuels involved different sectors and services between the years 1500 and 1920. The economic drivers for these energy transitions included opportunities to generate cheaper or better energy services. The existence of markets that were ready to pay more for these new energy sources and technologies made it competitive with traditional sources, but in a long process that took over 100 years with the diffusion phase taking about 50 years. Likewise, the low-carbon energy sources and technologies today offer attractive benefits like low carbon impact, which might be able to develop gradually in a niche market until they are able to compete with fossil fuels. However, a successful transition requires governments to provide protection of this niche market for some time probably decades, with past experiences pointing at a transition to a low carbon economy that will most likely be likely be a very slow process [2].

The global nature of climate change is an issue of policy and academic focus, which faces complex processes of agreeing and setting international targets. Governance targets already agreed upon include reducing greenhouse gas emissions to achieve a 2 °C limit to global temperatures rises from pre-industrial levels. Unfortunately, there is a mounting recognition this target is still not sufficient, yet may not even be met, and that international targets are only *one part* of the governance answer. There is need for a far greater understanding of climate mitigation governance at the national level, the possibilities and constraints[34, 35], so that sustainable measures and responses can be put in place for a truly sustainable energy future.

2. INSTITUTIONAL AND POLITICAL FACTORS ENERGY AND POWER GENERATION

The Institutional and political factors that affect decentralization include various government regulations, policies and guidelines the requisite political stability and governance needed for energy development and use[30]. This is, mainly through influencing the investor confidence and project implementation. Some geopolitical

factors may also affect energy security while others are international agreements, acceptance by the public and social equity that may support or inhibit decentralization. Institutional capacity is required for the proper management of decentralized energy systems and the enforcement of policies away from paper and pronouncements made[29].

In most developed nations, electricity is produced in large central station generators, that are often located in remote and far away, areas from the point load centers or point of use whose economics is largely a matter of costing. Energy or generation costs just like production technology, may be fixed or variable in nature, with fixed costs being relatively straightforward, compared to variable costs which are remarkably complex [21, 36].

The fixed costs of energy and power generation are generally the capital costs and land related costs and vary from region to region, mainly as a function of labor costs and regulatory costs, like obtaining siting permits, and environmental approvals [36, 37]. The Operating costs energy and power plants include fuel, labor, and maintenance costs associated with resource generation. Marginal costs are operating cost incurred in each MWh of energy produced. In power generation, the fuel costs dominate the total cost of operation and maintenance. For noncombustible renewables like wind, solar and hydro which are fuel free have lower cost of operation and maintenance, compared to combustible renewables like biomass and nuclear energy [36].

The central power plants generally have higher capital costs while fuel based stations generally have operating costs that are responsive to fluctuations in resource price [9, 36], hence there is an apparent tradeoff between capital and operating costs per unit [36, 38].

3. ENERGY SOURCES AND THEIR INSTITUTIONAL SUSTAINABILITY

Sustainability has become a major concern today because of growing concerns over the climate change caused by anthropogenic greenhouse gas emission. Power generation of which electricity generation is an important contributor[39]. Electricity is a very import product because it a global energy carrier which is a critical to support life, welfare and global sustainable development[40]. Currently, humanity is faced with a significant challenge to achieve new sustainable development Goals (SDGs) by the year 2030 [40, 41]. Sustainable energy and power generation refers to production and use of electric in a way that that does not compromise the ability of future generations their own energy and electricity needs [42, 43]. Sustainable energy also refers to energy sources that do not get depleted in a time frame that is relevant to humanity and thus contribute to the sustainability of all species on planet earth[44]. Sustainable Energy needs significant changes in the way the way electricity is produced, stored, transmitted, distributed and consumed with use of clean energy playing an important role in unlocking sustainable development [45-47].

It is in the Johannesburg world summit of 2002 that correlation between sustainable development with energy became a significant global concern and issue [19, 48]. Selecting the most the most appropriate energy systems in an energy mix is considered as a strategic decision in the realization of sustainable energy and sustainable development[49, 50].

Economic energy sustainability refers to the ability to meet energy demand in a cost-effective manner. Economic sustainability can also be expressed as a measure of access to requisite energy financing for resource development. The cost-effective energy operation ensures that the energy system viable and feasible making the investment attractive to investors and financiers [51]. The economic dimension of energy sustainability is thus concerned with economic of an energy system or power system.

Economic sustainability of energy resources is concerned with attaining operational stability in terms of cash flow, liquidity and ensure fair income and benefits to investors and other stakeholders in energy systems without exploiting consumers [52]. An energy system is said to have attained economic sustainability if they remain intact and stable while activities and processes are equitably accessible to all fair manner [53]. Therefore, energy systems should continuously generate competitive goods and services to so as to manage debts, pay bills, remunerate employees and guarantee sectorial balance [54]. It is important for energy systems to remain profitable and useful from one generation to another generation [55], if energy systems are economically sustainable by being operated profitably by investors or organizations while energy products and services remain competitive and accessible to all in the society[56]

Distributed generation is the core function of decentralized energy systems is also known as embedded generation, dispersed generation, on-site generation, and decentralized generation. Whereas both heat and electricity can be generated in a decentralized manner, it is difficult to transport heat over long distances compared to electricity [6, 12]. It is for this reason that heat generation and use has been traditionally done onsite, while power generation has traditionally been done in centralized power systems. For this reasons, decentralized power generation facilitate efficient use of combined heat and power plants resulting to higher system's efficiency with electricity and heat production because heat is a by-product of many electricity generating techniques[10, 11].

4.1. Energy Sources and their Characteristics

Unlike decentralized energy systems where it is to be used while DES networks are based on small-scale production units that utilize the locally available resources and distributes as per the specific requirement, the centralized energy systems are large-scale power generation units that supply energy to far-reaching areas. The energy systems can be stand-alone type, hybridized models or grid-connected while distributed energy networks are generally miniature-decentralized systems with users forming a

complex network of energy exchange. Energy sources like solar-wind hybrid decentralized energy can serve as options to address increasing energy needs with limited environmental[38].

Fossil fuels off a steady and reliable release of energy to sustain an energy system, which is a requirement for stability and reliability, which requirements for stability. On the negative side, are associated with high greenhouse gas emissions responsible for global warming, price supply fluctuation and market resource supply interruptions and negative social impacts lime conflicts, which negatively affects their sustainability. It is for these reasons that the energy transition seeks to substitute them with renewable and sustainable low carbon energy resources.

The sustainability of fossil fuels can be improved by measures like application of cogeneration for higher efficiency as a highly efficient conversion technology, application of clean coal combustion measures, as well as carbon capture and sequestration. For natural gas, controlling leakages along the entire supply chain is paramount due to the high global warming potential of methane which is the main constituent of natural gas[38].

Decentralized energy systems (DES) are one of the most opted alternatives and sustainable solutions to growing future energy needs while at the same time significantly reduces transmission and distribution losses at negligible footprints. The decentralized energy systems can be solo operated but may be affected variable resource availability. Different distributed energy resources can be used for electrification purposes as grid connected or standalone or hybrid system[13]. Decentralized energy systems have proved to be viable substitutes where generators are located closer to load centers to mitigate transmission and distribution losses[21]

There are diverse sources of energy that can be used in decentralized heat and power production by applying different conversion technologies as summarized in table 1 below

Table 1: Summary of energy options for the global transition

	Energy resource	**Level of Development/Deployment**	**Role in the transition**
1	Hydropower	Hydropower is the largest source of renewable power. Most feasible cites are developed in most countries	Opportunities remain in small and micro schemes which are ideal for decentralized generation
2	Solar Energy	Solar is currently the fastest growing source of renewable energy. Costs are reducing	Need to maintain the momentum and further reduction in cost
3	Wind Energy	Wind capacity is also growing fast, it is associated with significant variability and intermittence in supply	Modernize the grid and upgrade to the smart grid and smart micro-grids. Promote efficient grid energy storage for wind power systems.
4	Hydrogen	Hydrogen can be made by electrolysis and mainly by steam methane reforming. More research into efficient conversion and will produce green hydrogen from renewable sources.	Use in powering fuel sign to replace fossil fuels Use of green hydrogen instead the hydrogen from fossil fuels will add value to the hydrogen economy and transition effort as an energy carrier and fuel
5	Biogas	Biogas can be made by anaerobic digestion of energy crops, plant waste, and animal waste. Relevant policy measures necessary to make them competitive	Policies to encourage people to use farm wastes and incorporate biogas projects in waste treatment systems. Develop an attractive feed in tariff for electricity produced from biogas. Tax incentives on capital investment can also be employed.
6	Biomethane	Biomethane is upgraded biogas and syngas	Biomethane will replace natural gas as a renewable natural gas resource for virtually al current applications of natural gas.
7	Biodiesel	Biodiesels are produced from biomass as a renewable energy resource	The main challenge facing biodiesel is cost, making them more expensive than fossil fuels. Measures to cut cost through technology tax measures aimed at making biodiesel competitive should be put in place.
8	Bagasse	Bagasse is green energy, which is a solid	Modernize sugar factories to produce more electricity

		byproduct of sugar cane milling. A fuel for cogeneration	and sell excess to the grid. Facilitate access to funding for modernization and capital investment in cogeneration and connection to the local and transmission grids. An attractive feed in tariff will also encourage bagasse-based electricity production.
9	Solid Biomass	Biomass can be obtained as waste products, forest products or energy crops	Most biomass energy sources have competing applications like use as food, feedstock for industrial processes, those that Biomass can be used in power among others which can make them unattractive for energy use. Measures like good attractive grid tariffs and tax measures on non-energy uses can influence their energy applications.
10	Geothermal Energy	Geothermal contributes less than 1% of global electricity production. Main challenge is high upfront costs and risks, have long project development periods and may have land use conflicts[46, 57-60]	The solution to development and deployment of geothermal in decentralized systems include reductions in costs of conventional power plants development. The state can take over the risky and expensive upfront activities and encourage development of modularized wellhead generators [46, 57, 61, 62]
11	Producer gas	Huge quantiles of animals, plants, and combustible industrial wastes, most with significant energy potential, are produced continuously globally. They include municipal solid waste, agricultural waste, and animal waste like slaughterhouse waste	Various waste to energy technologies exists with more efficient systems being needed for efficient waste to energy conversion. Processes like biogas and biomethane production, direct combustion can be used both for a clean environment, generate green energy and electricity and reduce disposal costs and health risks in a sustainable manner.
12	Nuclear energy	Nuclear is a sustainable energy resource, with huge uranium deposits globally having very high energy density.	Conventional nuclear power plants are huge in capacity and may not be ideal for decentralized generation. Policy measures should be put in place to promote design and deployment of the small modular reactors (SMRs) which are smaller up to 300 MW, more flexible and hence more sustainable and suitable for decentralized generation[61].
13	Ocean /marine energy	This is a renewable energy resource mainly in the form of tidal power, wave power, osmotic and ocean thermal. Ocean thermal is limited by the low thermal gradient over which heat transfer is to take place. Marine energy has very limited contribution globally currently but has potential to play an important role in the energy transition	The role of marine energy in the energy transition can be enhanced by investing in efficient technology for extraction of energy with low thermal gradient in ocean thermal. Policy incentives and funding are necessary to increase generation from wave and tidal power. The main challenge with marine power is that supply is not continuous, but relatively predictable.
14	Natural gas	Natural gas is nonrenewable source but cleaner than other forms of fossil fuels in terms of carbon footprint. Coal, diesel, petrol, and global resources are huge. As the cleanest fossil fuel, natural gas can technologically be used as a substitute for oil, and coal in the middle term.	Natural gas can be used as a cleaner of the fossil fuels to substitute coal and oil applications. Policies to encourage a shift from coal as oil use can be put in place to incentivize the shift. This should however done in a way that does not discourage a shift to renewable and sustainable sources in the end. Strategies for direct substitution of natural gas with biomethane can also follow.
15	Coal	Coal is nonrenewable and currently the largest source of global electricity. Huge	Coal produces reliable power but has high emissions. It can stabilize generations. Consumption should

		reserves in some countries.	gradually be reduced by substitution. However, coal generate ash and carbon dioxide, N_2O and SO_2 hence high environmental impact
16	Oil	Oil produces high carbon emissions together and pollutants like nitrous oxides (NO_X) and (Sulphur dioxide) SO_2 and particulates. High reserves in some countries hence slow transition	Oil can continue to place an important role as a dispatchable source of energy for energy systems stability and peak power applications by application of efficiency measures like cogeneration and use of more efficient conversion

From Table 1, it is observed that both renewable and nonrenewable sources of sources of energy have an important role in decentralized generation and hence play a role in energy sustainability. As an example, coal and oil are nonrenewable but are easily accessible and are dispatchable sources of energy for grid and off grid energy supply.

Renewable energy sources particularly wind and solar, and to some extend hydro have the greatest potential but are significantly affected by reliability of supply due to intermittence and variability in resource supply. The main solution to these challenges is investment in storage, smart grids and micro grids that effectively increases the cost of investment [5, 61].

The unpredictable and unreliable nature of supply for variable renewables is a significant risk to energy security and the grid stability for the traditional grid, which increases the demand for smarter and resilient for decentralized generation [63, 64]. The use of smart grids increases the ability to absorb small producers and variable supplies especially for wind and solar and small hydro sources and which have a significant role in the global energy transition[64, 65].

4. INSTITUTIONAL INDICATORS OF ENERGY SUSTAINABILITY

The institutional indicators of energy sustainability assesses effectiveness and strength of various frameworks that do support sustainable energy transitions, like policy development, rules and regulations, institutional capacity and quality, institutional capacity for energy planning, and energy sector or services governance. Indicators include the existence of existence and implementation of national sustainable energy strategies, regulatory quality, and f capacity-building programs, and existence of effective control over corruption and mismanagement of resources. The Regulatory Indicators for Sustainable Energy (RISE) of the world bank is an example of an effective tool used to compare countries' policy and regulatory support for aspects like energy efficiency, energy access, and renewable energy development[29, 30].

Most distributed and decentralized energy resource utilize local resources like labor, materials, energy resources, including procurement of services from local investors [66]. It is important to ensure local energy revenue is invested in different ways like local material sourcing materials and payments, local taxes, local labor and dividends to investors. Therefore, decentralized generation should leave more economic benefits compared with imported fossil fuels or imported energy from the grid if decentralization is to be sustainable [8, 67]. It is necessary to make informed investment decisions because different energy resources have different socioeconomic as well as environmental impacts e.g. biofuel create more jobs than solar and wind power energy projects while power from fossil fuels is ex generated electricity is generally expected to be cheaper than imported power and fossil fuel sources [6, 19, 68]. It is critical to put in place relevant policy and legislative mechanisms to achieve this by strengthening policy and legislative systems to achieve these expectations [20, 69].

Costs are important indicators in measurement of sustainability of decentralized energy systems. These economic indicators and parameters include the initial investment cost, cost of fuel or energy resource, operation and maintenance cost, cost of generation, price of electricity generated which includes taxes and cost of finance, net present value (NPV), service value and the equivalent cost of energy system [70, 71]. Economic indicators of sustainability assessment are critical because they influence the technology adoption and its penetration as well as the investment decision by investors e.g. cost of substitutes both local and imported and profitability. Others indicators and parameters are fuel price increase sensitivity, plant availability, grid connection costs, direct and indirect taxes, plant peak load response, and security of energy supply [63, 65, 72]. States and governments should critically analyze the implication of these economic indicators and parameters and put in place relevant policy measures and incentive to influence the desired outcomes for both short term and long-term success of decentralization of power generation [73, 74]. .

6.1. Energy Resource Price

Different distributed energy resources have different resource acquisition price which is a very important factor in energy sustainability because it directly affects the price of electricity as well as demand[75]. Factors affecting price include resource availability, energy density and taxes imposed like carbon tax. The price of an

energy resource refers to the r acquisition cost and is usually based on prevailing market price.

Table 2: Energy resource price

	Energy resource	**Market Price Range (USD)**	**Institutional sustainability measures**
1	Hydropower	0	An indicator of low energy cost
2	Solar Energy	0	Encourage investments in solar and cut down on related costs e.g. integration costs
3	Wind Energy	0	Can reduce electricity cost
4	Hydrogen	0.5-8.5/kg	Among most expensive to acquire, reduce costs
5	Biogas	2-20 2/MBtu	Should be lowered
6	Solid biomass	44-85/tone	Needs careful development
6	Biomethane	USD 0.45–0.55/LGE (LiterGasoline Equivalent)	Can be used cost effectively
7	Biodiesel	50-69/liter	Biodiesel is relatively high, there is need to reduce costs especially related to processing and handing
8	Bagasse	9-22	Since bagasse has multiple applications like industrial feedstock, organic manures and others. It important to put in place measures that discourage other alternative used of bagasse by sugar factories
10	Producer gas	6.5 per mmBtu	Producer gas is almost 3 times more expensive than natural gas. The costs should be reduced further
11	Uranium	120-130 /kg	Has high energy density
12	Wave energy	0	Can reduce cost of power
13	Tidal power	0	Can reduce cost of power
15	Natural gas	2.63- 2.78/MMBtu	Can be substituted with biomethane economically
16	Coal	130-137.14 /kg	Cost competitive, measures to reduce demand
17	Heavy Fuel Oil	0.6-0.644 /kg	Cost competitive fossil fuel, may need measures to discourage deployment
18	Diesel	1.20-1.25/liter	Relatively expensive
19	Petrol	1.25-1.30/liter	Relatively expensive

From

Table2, it is noted that the price of energy resources varies with type of energy, while factors like quality and other costs like freight affect the price of the same energy resource. The zero cost for renewables implies that natural renewable sources should be the cheapest since they are freely supplied by nature. The only cost involved are acquisition costs.

6.2. Levelized Costs (LCOE)

The levelized cost of energy (LCOE) or levelized cost of power refers to the average cost of power generation over the entire lifetime of the power system. The levelized cost of energy is used to is employed to establish the viability and competitiveness of power systems and other energy projects on the basis of their lifecycle costs [21]. LCOE method is a widely used metric for comparison and ranking of different power generation technologies and

associated energy sources by putting into consideration their fixed and variable costs computed as a single cost metric for measuring the net average net present cost of producing power over entire life of the energy system. The challenge with the metric is that it does not capture all costs affecting cost of electricity like the system costs [14, 71, 76]. The levelized cost of different the energy sources based on their levelized costs from globalised values are shown in table 3

Table 3. Levelized cost of Energy

	Energy resource	Levelized cost of energy (USD)/MWh	Average USD/MWh
1	Hydropower	50-70	60
2	Solar PV-Utility scale	49-185	117
3	Solar PV-Roof top	117-282	199.5
4	Wind Energy-Onshore	33-35	34
5	Wind power-Offshore	79 - 81	80
6	Nuclear	141- 221	181.5
7	Coal	68-166	117
8	Combined cycle natural gas turbines	39-101	70
9	Bagasse	9-22	15.5
10	Hydrogen fuel cells	278 - 322	300
11	Battery energy storage	270-442	356
12	Biogas systems	50-190	120
13	Solid biomass	40.5 -46.3	43.4
14	Biomethane	80-200	140
15	Magneto hydrodynamic generation	212.2 - 218.9	215.6
16	Geothermal energy (conventional technologies)	40-140	90
17	Diesel power plants (using fossil fuels)	300-500	400

From table 3, it is noted that different sources of energy using conventional technologies have widely varying levelized values. The values are unique to specific installations across the world. These values are illustrated in figure 1

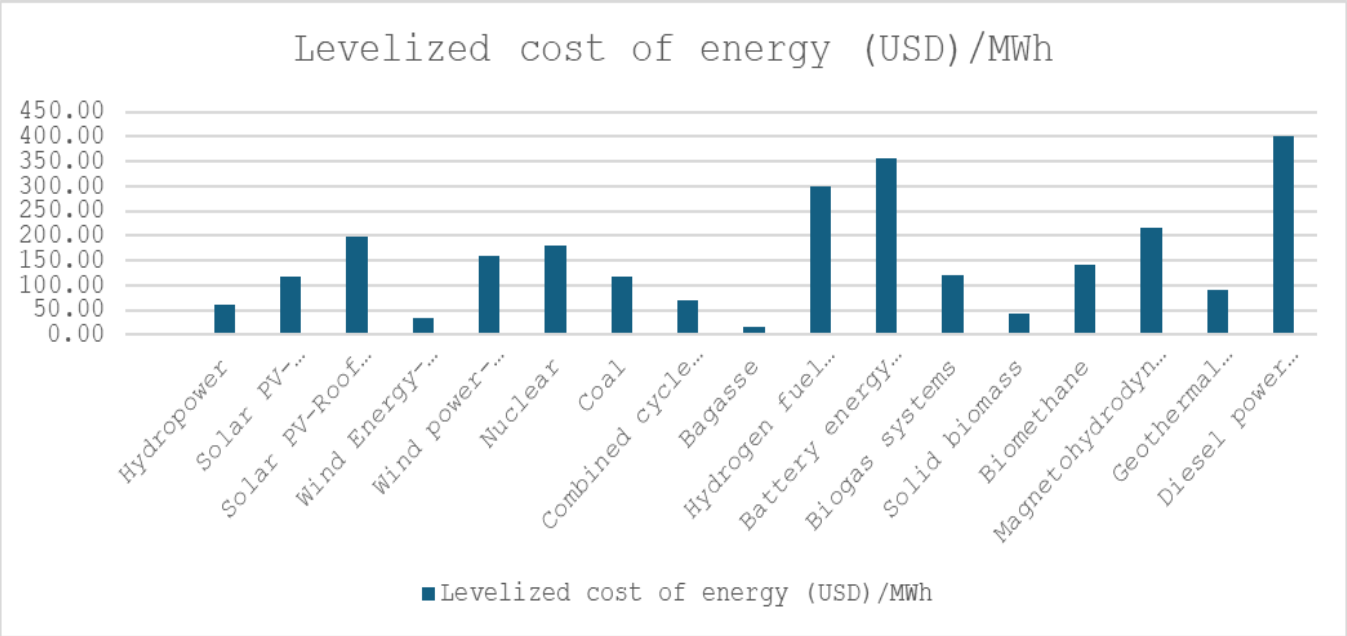

Figure 1: Levelized cost of energy from different sources [21, 38]

Figure 1 shows the global averages of Levelized cost of energy derived from different decentralized energy resources. It shows that diesel power is the most expensive followed by battery storage sources and hydrogen. The lowest values are presented by bagasse, which is a byproduct of cane sugar production, wind, and hydro as well as solid biomass, while fossil fuels, hydrogen and battery storage are among the most expensive in terms of levelized cost of energy. Desirable responses may be to avoid the expensive options like fossil fuels, make storage more competitive and likewise hydrogen. With most hydrogen coming from fossil fuels, both a shift in raw materials and cost reduction strategies should be adopted [77, 78].

Clearly, on basis of globalized levelized cost the renewable sources should be promoted because they are cheaper and cleaner. Diesel power is the most expensive, but it should be realized that it plays an important role in stabilizing decentralized power systems because it is dispatchable, a requirement for stability and reliability [17, 79]. Governments may make it affordable through selective tax measures while encouraging use of renewable fuels to substitute diesel and other fossil fuels to limit environmental impacts[29]. Another notable observation is the high levelized cost of battery storage which is very important for decentralized systems which are dominated by renewables whish face the challenge of intermittence and variability which are detrimental to the stability and reliability and also curtail the use and grid integration of the variable sources like wind and solar[7, 20]. Hydrogen fuel cells also emerge as one of the most expensive on lifecycle basis. As a displaceable source, its use in the energy mix is important and should be encouraged. Government should design policy measures and incentives that lead to cost reduction and encourage use of green hydrogen from renewable sources[78]. Most hydrogen today is derived from fossil fuels, a scenario that should be changed to encourage use of green hydrogen[77].

6.3. Job creation potential by energy sources

Different energy sources have varying degree in job creation potential as demonstrated in figure 4 below.

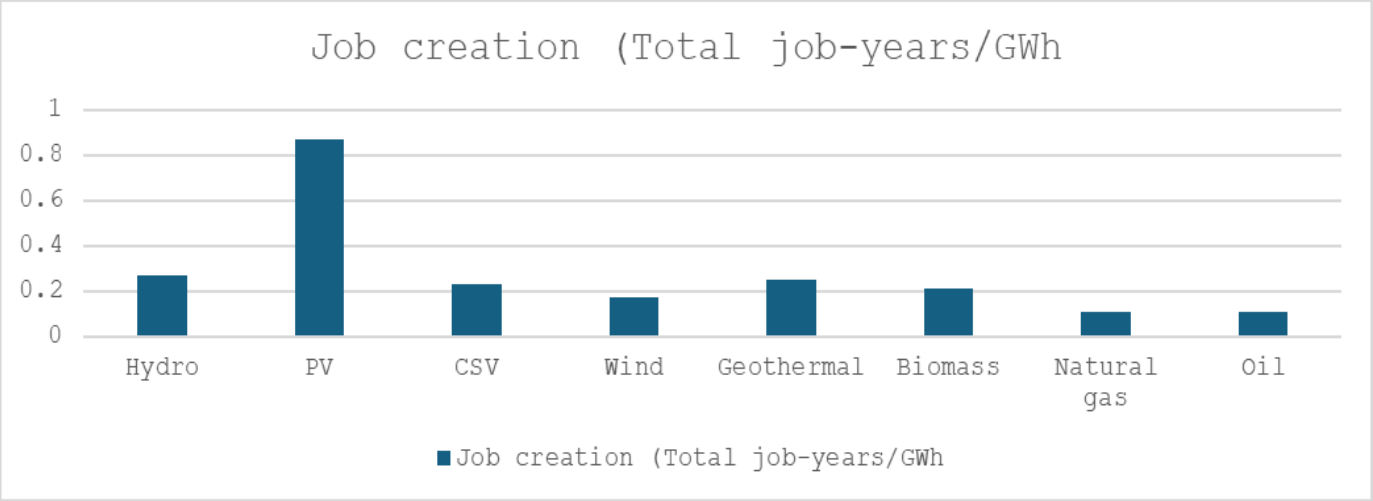

Figure 4: Job creation potential of energy sources for power generation

From figure 4, it is noted that solar PV has the highest job creation potential followed by geothermal and hydro. Fossil fuels namely natural gas and oil have the lowest job creation potential. Therefore, to maximize energy related jobs, policy measures should be put in place to maximize generation from renewable especially solar P, geothermal and wind and CSV.

7. RESULTS AND DISCUSSION

This study provides a new, interdisciplinary framework in the governance for sustainable energy system change by offering critiques of, socio-technical impacts related to decentralization of generation and propose desirable political and institutional measures to achieve sustainability. Different institutions including rules and norms within political and energy systems, have path-dependent qualities making them difficult to change, even when profound change has occurred in the past to enable transformations in the energy sector. Climate change mitigation must change the way energy is produced and utilized which depends on developing the right enabling conditions for the change to occur. Many of these measures are the highly political and contingent nature of attempts to drive innovations, how political institutions mediate between forces for sustainable change and forces for continuity, and specific interactions between governance and change within the energy sector[34]

Sustainable energy legal framework is required to facilitate sustainable decentralization of generation. A sustainable energy strategy should facilitate social equity, protect the environment, and maintain a sound socioeconomic base and preserve a natural capital for sustained economic generation and equity across human generations. A sustainable energy transition requires application of sound economic policy instruments and an effective institutional mechanism to deliver economically feasible energy future [19]. Humanity needs energy to manage developmental issues related to the environment, economic growth, and social equity that can only be realized through planning that is based on reliable analyzable data and information on various energy options. Various energy sources are identified and feasible application in decentralized generation. The same energy resource can be used in multiple conversion systems and power plants having different performance characteristics in terms of efficiency, environmental impact, which may further influence their specific preference in different conversion and power generation systems [19, 21].

Since many decentralized energy sources renewable and more environmentally sustainable as compared with the traditional sources, the concept of decentralized generation leads to more exploitation of renewable sources in power generation and other applications which reduces energy related pollution and greenhouse gas emissions thus mitigating hence helps in mitigating the impact of climate change and increasing energy access [4, 10, 19]. For this reasons, policies to support decentralization of generation should be harmonized with those of sustainable energy transition and sustainable development, and avoid conflicts [17, 79]. Development and use of advantageous energy carriers, development and deployment of efficient technologies are some of measures that be enforced to achieve sustainable energy successful decentralization and integration of the DERs Electricity generation and distribution should be structured such that current distribution model contributes to actual economic and financial growth levels and willingness to pay by the people [80].

Decentralized energy systems should be designed and implemented in a way that benefits enables the realization of benefits in a manner that is uniform and inclusive in growth of marginal sections and contribute to a healthy society and accelerate economic growth for rural economic which mitigates migration which causes congestion in cities. Sustainable decentralization should be able to fill the existing gap between the urban and rural areas in terms of access services.

Policymakers should introduce higher visibility to distribution energy resources and power systems, create opportunities for cost reduction and high share of renewables.it is difficulty to evaluate the impacts of distributed energy systems on electricity grid because of lack of detailed information on capacity utilization. The detailed distribution feeder information often resides with the distribution utilities, with little or no access to this information for public and researcher use. .In order to streamline analysis a collaboration of stakeholders is important to simplify and standardize required analyses to evaluate the costs and benefits of distributed energy resources [17, 33]. Electricity utility business models reflect the legacy of decades of incremental structural modifications on systems designed around technologies, operational strategies, and assumptions about outdated and inaccurate customers' needs. [33, 81]

8. CONCLUSIONS

Institutional sustainability is one of the key dimensions of energy sustainability assessment together with the social, economic, environmental, and technical dimensions. The global sustainable energy transition strategies van be categorised into technological measures like the e demand side management, fossil fuel substitution, efficiency improvement, and fossil fuel substitution with renewable and sustainable energy sources. For decentralisation to be successful, technically and economically feasible and beneficial, and hence leave a positive environmental and social impact effective and relevant policy initiatives are required. Although renewable sources are preferred options for decentralised generation, the energy mix requires reliability by use of dispatchable sources, most of which are fossil fuels. However, their share should remain minimal, possible in a way the decentralised energy systems remain affordable and environmentally benign.

Various energy sources are available for selection and use in heat and power generation in decentralized generation. Whereas some energy resources have been in use for many years like coal, natural gas, oil, hydro and biomass, some resources are still under development and require massive investment in infrastructure and technology. They include hydrogen, biomethane, ocean thermal, ocean osmotic, wave and tidal energy. Most renewable energy resources like wind and solar are supplied freely by nature but require investment in infrastructure and technology which add to the final cost of energy. Decentralized systems typically use renewable energy sources, including small hydro, combined heat and power (CHP), biomass, solar and wind power. A decentralized energy system can increase security of supply, reduce transmission losses and lowers carbon emissions

A well-planned distributed energy system should maximize the use the use of local energy resources most of which are renewable and sustainable and still can be connected to the grid for maximum economic benefits to local communities in terms of revenue and job creation with solar energy demonstrating highest job creation capacity over its life cycle.

In the economic sustainability assessment of energy sources for distributed generation, it was established that, diesel power plants, fuel cells and battery storage supply the most expensive power source while, bagasse cogeneration, onshore wind and solid biomass offer the cheapest solution based on lifecycle assessment or levelized cost of energy. However, in terms of fuel cost, the renewable sources have no direct resource price making them more competitive while coal, solid biomass and diesel are the most expensive to acquire.

In as much as we have significant opportunities for distributed generation in all energy markets, there exist a wide range of potential economic barriers which may vary with the conversion technology applied and the specific energy resource that need to be considered in planning for a successful implementation by selecting most viable and come up with measures to overcome the identified challenges. Distributed energy resources have an important role to play in the sustainable energy transition by adding to renewable electricity supply, reducing demand for fossil fuels, and provide desirable flexibility for the integration of the variable renewables to grid. For this to be achieved, requires a level playing ground between the centralized and distributed resources. Measures include changes in electric utility business models and electricity markets as well as rules, regulation and policies to adapt to rapidly evolving technology.

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