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Review

Overview of Current Microgrid Policies, Incentives and Barriers in the European Union, United States and China

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Abstract: Continuously increasing demand of microgrids with high penetration of distributed energy generators, mainly renewable energy sources, is modifying the traditional structure of the electric distribution grid. Major power consumer countries are looking for alternative energy sources to avoid the impact of higher fossil fuel consumption. Thus, different policies have been promulgated to promote renewable energy technologies (RETs) and distributed energy resource (DER) deployment and are encouraging technological innovation. These policies aim to reduce greenhouse gas (GHG) emissions and achieve energy security and independence to meet an ever-increasing electricity demand. Many studies have been performed on the successful integration of RET and DER operation and control, protection and stability issues, all simultaneously and satisfactorily implemented during feasible microgrid operation. However, apart from the technical challenges, few microgrid studies exist on effective policies and incentives for microgrid promotion and deployment. This survey investigates the policy, regulatory and financial (economical and commercial) barriers, which hinder the deployment of microgrids in the European Union (EU), United States (USA) and China. In this paper, a clear view on microgrid policy instruments and challenges are investigated to aid future developments.

Keywords: microgrid; policy; incentive; barrier; renewable energy; distributed generation

1. Introduction

Although the microgrid (MG) has been researched for decades [1], the debate is ongoing regarding an unanimous definition of a microgrid. Some research and development (R&D) organizations and researchers defined the microgrid as:

- a cluster of micro sources and loads operating as a single controllable system that provides both power and heat to its local area [2].
- a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries, which act as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and islanded-modes [3].

- a combination of various distributed energy resources, operated in three different categories, namely isolated, islanded, and remote sites, which is capable of balancing captive supply and demand resources to maintain a stable service within defined boundaries [4].

However, increasing penetration of distributed energy resources (DERs) into the existing power sector is developing a promising power scenario for the electric power generation, transmission and distribution infrastructure globally. This increasing penetration is due to issues such as:

- fossil fuel shortage;
- political instability in the major energy-supplying countries;
- fossil fuel power generation environmental emission which causes global warming; and
- Distributed energy resources technologies development and per unit cost reduction.

These factors have attracted the attention of government bodies and industries globally towards maximum utilization and installation of MGs, to protect the climate and the wider environment from the impact of fossil fuel use, to improve energy security and independence to meet the growing electricity demand which can provide power that is customized, efficient, reliable, and clean [5,6].

The microgrid is gaining importance because of its operation and the trouble-free plug and play of DERs, both from renewable energy (RE) and fossil fuel power sources, into the larger electrical distribution system. Such microgrids may either be operated in conjunction with, or islanded from the utility power grid and are utilized in a variety of settings including commercial applications, community/utility deployment, institutional power systems, military installations, and off-grid microgrids that provide electricity to remote villages and other sites.

According to the Navigant research report of fourth quarter 2015, the microgrid market opportunity is expected to grow over 3.5 times between 2015 and 2020. More than 1437 microgrid projects that represent nearly 13,400 megawatts of capacity are proposed, planned, under construction or operating worldwide [7]. By the end of 2014, the countries with the most total installed renewable (not including hydropower) electricity capacity were China, the USA, and Germany; they were followed by Italy, Spain, Japan, and India, which all ended the year with approximately similar capacity levels, as depicted in Figure 1 [8].

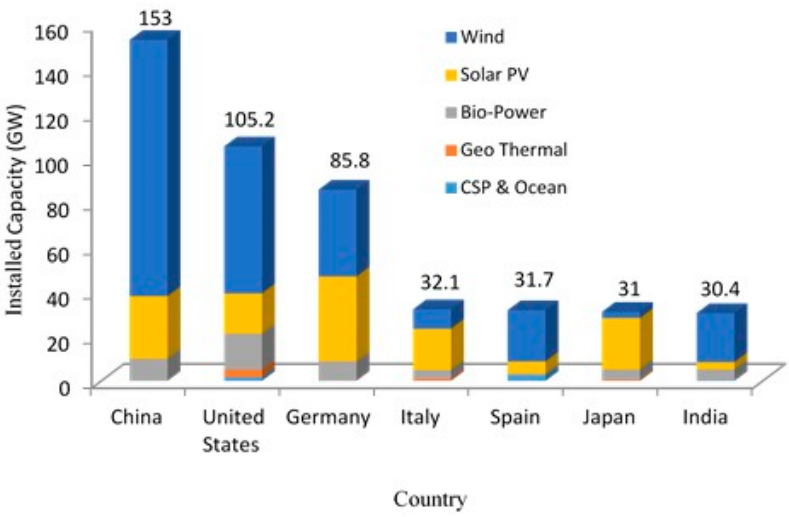

Figure 1. Renewable power installed capacity top countries.

As seen in Figure 1, the European Union (dominated by Germany, Italy and Spain), the United States of America (USA) and China are the leading contributors in RE/MG project deployment, so are the main focus of this RE/MG overview. North America leads with 149 microgrid projects in various states. Under different framework programs (FP5, FP6 and PF7) more than 80 microgrid projects

are funded by the European Commission (EC) in different EU member states. In addition, Horizon 2020 is a seven years (2014 to 2020) funded project for research and innovation program with almost €77 billion of funding. So far, Innovation and Networks Executive Agency (INEA) signed a grant agreement for 14 projects of total €135 million from the EU's Horizon 2020 program, for developing new clean energy solutions on the Smart Cities & Communities and Smart Grids & Storage topics to help modernize the European energy grid through developing solutions integrating renewable energy technologies. There are 22 large-scale MGs deployed in China [9]. Although the microgrid sector is promising, with clear advantages over conventional power generation system, including contributing to achieve growing energy demands and greenhouse gas (GHG) reduction, the microgrid is not fully capable of replacing traditional distributed energy sources. Traditional systems can provide efficient and sufficient power to end users, while DER are mostly interconnected to the utility grid as a secondary energy source or as a backup system due to intermittency issues [5,10,11].

However, with a growing energy demand and environmental issues, many countries have set targets to increase the penetration of renewable energies into their electricity generation systems, viz., EU 20/20/20 target [12], US grid 2030 national vision for electricity [13] and China's 12th five-plan [14–17]. These are key policy drivers for promoting RETs and DER, changing the MG role from a secondary energy source to a primary energy supply. The integration of DERs into microgrids thus plays a major role in achieving these targets and balancing power in the electricity grid [1].

The rapidly increasing trend of microgrid integration into electricity grid presents technical, regulatory and economic barriers and problems, where MG grid interconnection, voltage stability, distribution system operation, control and protection are the key technical issues discussed [18–22], Technical challenges have been investigated and developed for over a decade, and now can offer a stable and smooth energy supply. There are many regulatory and economics issues retarding microgrid deployment.

Many studies exist on microgrid technologies and operation, but few studies on policies, incentives and barriers to microgrid promotion and deployment. It is to be understood that microgrid policies are unavoidably related to distributed energy polices and precisely renewable energy. Therefore, the findings of this survey continue in this vein through the lens of microgrid programs across Europe, USA and Asia (focused on China), with discussion on policies and regulations, incentives and benefit, barriers, challenges and issues which are directly or indirectly related with the microgrid, as depicted in Figure 2.

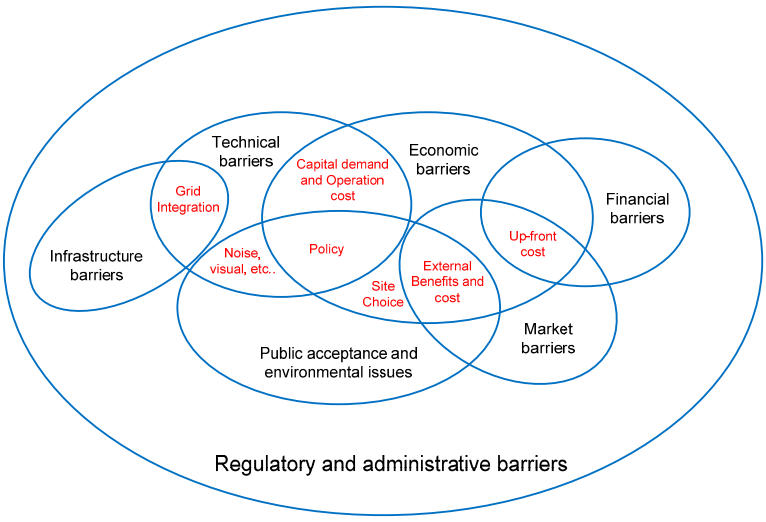

Figure 2. Renewable Energy (Microgrid) Development Barriers.

In Section 2 Microgrid policies and regulations are discussed. Section 3 provides an overview about policy and regulatory (financial and non-economic) barriers, issues and problem hindering

successful implementation of microgrid are highlighted. In Section 4 incentives and benefits are discussed. In addition, in Section 5 a conclusion is drawn.

2. Microgrid Policies and Regulations

2.1. Europe

The European Union electric power sector is structured on a centralized generation and consumption system, which implies economic, environmental and technical disadvantages. Within the context of growing electricity demand and environmental problems, the EU power sector is currently facing changes and evolution in response to three energy-related challenges: (1) GHG emission reduction "environmental sustainability"; (2) security of supply; and (3) competitiveness [23]. The solutions to European electric system problems are promotion and maximum utilization of renewable energy sources (RES), distributed generation (DG) and deployment of microgrids, by improving energy efficiency, decreasing GHG emission complying with European Commission energy 2020 targets. These are discussed in [24–27]. Most EU member states are endeavoring to achieve the 2020 target, as shown in Figure 3. In October 2014 the EU agreed on vision 2030, involving to further increase the penetration of renewable energy technologies and improve overall energy efficiency up to 27%, being 45% of total renewable energy electricity production in the EU power sector with a 40% reduction of greenhouse gases, along with an ambition 2050 target to reduce greenhouse gases by up to 95% as depicted in Figure 4 [28,29].

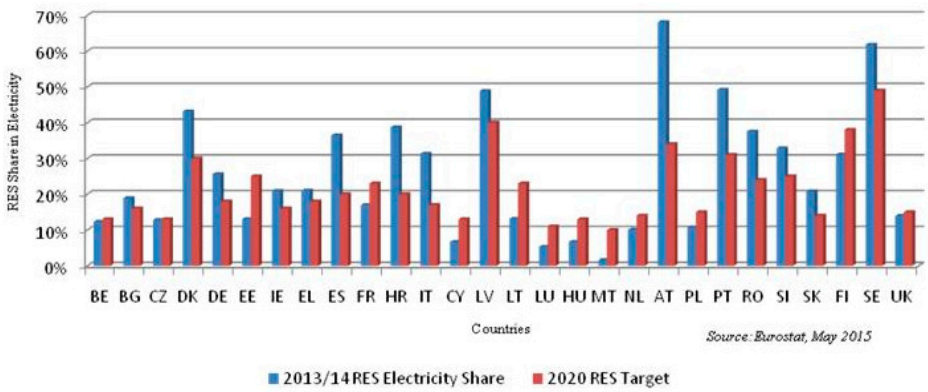

Figure 3. EU member countries 2020 target for RES share in Electricity.

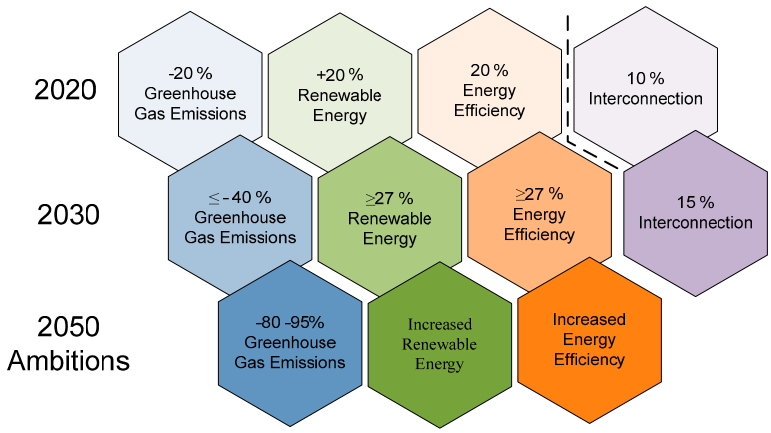

Figure 4. EU 2020 and 2030 target for renewable energy technologies penetration with GHG reduction.

2.1.1. Policies and Directives on Renewable Energies in the EU

There are no specific regulations and policies formulated on the utilization and deployment of distributed energy generation and microgrids in the EU. This is even though the European Commission has launched different directives (2013/347/EC, 2004/8/EC, 2009/72/EC, 2006/32/EC, 2009/28/EC and 2001/77/EC, etc.) [30] and framework programs (FP5, FP6 and FP7) corresponding to renewable energy penetration into EU countries and development of microgrids, and formed the "Smart Grids Task Force" in 2009 for proposing recommendations and standardization roadmaps in this field [27,31,32].

2013/347/EC "Trans-European Energy Infrastructure"

The European Council agreed with the Commission's proposal on 26 March 2010, to launch a new strategy with reference to Europe 2020 project. For union-wide integrated networks and deployment of smart grids for achieving an optimal utilization of energy infrastructure. To increased energy efficiency and integration of distributed renewable energy sources and for promoting growth, employment and sustainable development. The importance of smart grids in achieving the Union's energy policy objectives has been acknowledged in the communication from the Commission of 12 April 2011 entitled "Smart grids: from innovation to deployment".

2009/28/EC "Renewable Energy Directive"

2009/28/EC is an EU directive on "Renewable Energy", which mandates the promotion and use of energy from renewable sources which include solar PV, wind, solar thermal, geothermal, ocean energy, mini and micro hydropower, biomass, landfill gas, sewage treatment plant, and biogases. The directive was published on 23 April 2009 and amends and repeals parts the 2001/77/EC directive on "Electricity Production from Renewable Energy Sources". The directive requires that 20% of the energy consumed within the European Union is renewable by 2020 [33,34].

2001/77/EC "Renewable Energy Sources in the Internal Electricity"

Directive 2001/77/EC of the European Parliament and the Council was issued on 27 September 2001 for the promotion of electricity produced from renewable energy sources in the internal electricity market. The scope of this directive is to promote and increase the share of renewable energy sources (RESs) in to electricity production in the EU electricity market, by setting national indicative targets for future consumption of electricity produced from renewable energy sources in terms of a percentage of electricity consumption for the next 10 years and to create a future community framework [35].

2006/32/EC "Energy Efficiency and Energy Service"

Directive 2006/32/EC issued on 5 April 2006, repeals directive 93/76/EEC of the European Parliament and the Council on end use energy efficiency and energy services. The main objectives of the directive is to increase the cost-effective improvement of end use energy efficiency in the member states, as well to make necessary amendments in member countries legal frameworks to remove existing market barriers and imperfections that impede the efficient end use of energy. Also, the directive sets out the conditions for the development and promotion of a market for energy services and for the delivery of other energy efficiency improvement measures to final consumers [36].

2009/72/EC "Rules for Electricity Market"

Directive 2009/72/EC issued on 13 July 2009, repeals Directive 2003/54/EC of the European Parliament and the Council on common rules for internal electricity market. The aim of the directive is to formulate basic rules for generation, transmission, distribution and supply of electricity, together with consumer protection provisions, plus energy efficiency and environmental protection must be taken into consideration during the tendering and granting of authorization for power plant commissioning [37].

2004/8/EC "Cogeneration of Energy Market"

Directive 2004/8/EC issued on 11 February 2004, of the European Parliament and the Council is based on promotion of cogeneration and use of heat demand in the internal energy market. The aim of this directive is to improve security of supply and increase energy efficiency by creating a framework for the promotion and development of high efficiency cogeneration systems for heat and power based on energy demand [38].

As discussed, there are no specific policies and regulations formulated for distributed generation (DG) and microgrid (MG) systems in the European Union. Each EU member state transposes the mentioned directives following the particularities of their national energy policies and regulatory frameworks for the promotion and development of renewable energies and microgrid systems. Table 1 presents the main articles from the discussed directives, which are adopted as references by EU member states for renewable energy and microgrid promotion and development.

Table 1. EU Directive to be considered for Renewable Energy, Microgrid, Grid Integration and Energy Storage.

Directive	Objective	Articles No.	To be Considered for Renewable Energy & Microgrid Promotion and Development
2009/28/EC	Promotion of the use of energy from renewable sources	7	Promotion of electricity produced from renewable energy sources in the internal electricity market.
		27	Expansion of electricity produced from renewable energy sources with public support is necessary to reach target of 20% by 2020.
		37	Import of electricity, produced from renewable energy sources outside the Community.
		38	To undertake joint projects with one or more third countries regarding the production of electricity from renewable energy sources.
		41	To take into account lack of coordination between the different authorization bodies to hinder the deployment of energy from renewable sources and giving permission to construct and operate plants and associated transmission and distribution network infrastructures for the production of electricity.
		52	Guarantee of origin issued for that a given share or quantity of energy was produced from renewable sources.
		53	To allow the emerging consumer market for electricity generation from renewable energy sources to contribute to the construction of new installations for energy from renewable sources appropriately.
		59	Integration of electricity produced from renewable energy sources between member countries.
		60	Integration of electricity generated from renewable energy sources into the internal on priority basis.
		61	To ensure transmission and distribution of electricity produced from renewable energy sources without affecting the reliability or safety of the grid system.
		62	The costs of connecting new producers of electricity from renewable energy sources to the electricity grids should be the main objective.
		63	Electricity producers who want to exploit the potential of energy from renewable sources in the peripheral regions of the Community, in particular in island regions and regions of low population density, should, whenever feasible, benefit from reasonable connection costs in order to ensure that they are not unfairly disadvantaged in comparison with producers situated in more central, more industrialized and more densely populated areas.
		64	Integration of electricity from renewable energy sources into the grid according to directive 2001/77/EC.
2006/32/EC	Energy end-use efficiency	1	To improve energy end-use efficiency and promotion of the production of energy from renewable energies.
		2	Improve energy end-use efficiency to contribute in reduction of primary energy consumption, to mitigate CO_2 and other GHGs
		3	To improve energy end-use efficiency for cost-effective energy saving and help the community to reduce its dependence on energy imports.
		8	To initiate energy-efficiency pilot projects.

Table 1. *Cont.*

Directive	Objective	Articles No.	To be Considered for Renewable Energy & Microgrid Promotion and Development
			To Be Considered for Grid Connection
2009/72/EC	Electricity Grid Connection	6	To provide appropriate incentives for investing in new power generation, including in electricity from renewable energy sources.
		8	To provide cross border facility for electricity generation and supply at competitive price.
		16	Setting up of a system operator or a transmission operator that is independent from supply and generation interests should enable a vertically integrated undertaking to maintain its ownership of network assets
		27	To encourage the modernization of distribution networks, such as through the introduction of smart grids, which should be built in a way that encourages decentralized generation and energy efficiency.
		36	National regulatory authorities should fix or approve transmission and distribution tariffs.
			To Be Considered for Energy storage and Self Consumption
2004/8/EC	Promotes Cogeneration of Heat, energy efficiency and Security of Supply	1	Promote use of high efficiency cogeneration based on a useful heat demand in community with regard to saving primary energy, avoiding network losses and reducing emissions, in particular of greenhouse gases.
		3	Shift towards energy efficient production plants, including combined heat and power towards a European strategy for the security of energy supply.
		5	To increased use of cogeneration geared towards making primary energy saving.
		15	Harmonized method directive should be established for calculation of cogeneration electricity generation
		20	Define 'small scale cogeneration' comprises micro-cogeneration and distributed cogeneration units such as cogeneration units supplying isolated areas or limited residential, commercial or industrial demands.
		21	To increase transparency for the consumer's choice between electricity from cogeneration and electricity produced on the basis of other techniques.
		23	To ensure increased market penetration of cogeneration in the medium term.
			To Be Considered for Smart Grid Development and Integration
2013/347/EC	Deployment of smart grids for achieving an optimal utilization	1	Union-wide innovation to deployment of smart grid
		2	Cost effective integration of smart grid (power producer and consumer) in order to ensure an economically efficient and sustainable power system with low losses and high levels of quality, security of supply and safety
		6	Coordination between EU member states for better deployment of smart grid
		13	For promotion and development of smart grids, national regulatory authorities will grant the incentives on the methodology of cost benefit.

EU directives lay down certain end results that must be achieved by every member state. National authorities have to adapt their laws to meet these goals, but are free to decide how to do so. Each directive specifies the date by which the national laws must be adapted, giving national authorities margin for maneuver within the deadlines necessary to take account of differing national situations. However, the significant differences due to the particularities of each member state appears a considerable barrier, which means the same EU directive can be transposed in multiple ways, leading to different national regulations.

So far more than 60 different policies have been promulgated in the last fifteen years in different EU member state countries for the development and deployment of different renewable energy technologies, as shown in Table 2, in accordance with EU directives. These policy instruments are also considered for microgrid development.

2.2. The United States of America (USA)

The United States of America is the largest energy user in the world, and predominately relies on fossil fuel power plants. Since the 1970s oil crises, significant changes have been made in its energy policy with closely connected challenges on the nation's energy security of how to reduce the dependency on imported supplies (fossil fuels) and how to address growing emissions of greenhouse

gases [39]. The history of renewable energy policies and markets in the USA has been divided into three distinct phases as shown in Table 3.

Table 2. Energy Policies Considered for Microgrid in selected EU member states.

Title	Country	Year	Status
Renewable Energy Law of Poland	Poland	2015	In force
2014 Amendment of the Renewable Energy Sources Act -EEG-	Germany	2014	In force
Act on Energy and amendments to certain acts (No. 251/2012)	Slovakia	2013	In force
Royal Decree Law on urgent measures to guarantee financial stability in the electricity system	Spain	2013	In force
Electricity Market Reform (EMR)	UK	2013	In force
National Energy Strategy	Italy	2013	In force
Energy Act 2012	Croatia	2012	In force
Regulation on Net-metering for the Producers of Electricity for Own Needs	Denmark	2012	In force
Danish Energy Agreement for 2012-2020	Denmark	2012	In force
Energy performance requirements for residential buildings 2012-2020	Luxembourg	2012	In force
Act on Regulatory Office for Network Industries (Act No. 250/2012)	Slovakia	2012	In force
Law on Energy from Renewable Sources	Lithuania	2011	In force
Regulation of small power plants connation to the electricity grid (Royal Decree 1699/2011)	Spain	2011	In force
Energy White Paper 2011	UK	2011	Superseded
Regulation on load management activity within the electricity system involving energy charging services	Spain	2010	Ended
National Renewable Energy Action Plan (NREAP)	Slovakia	2010	In force
Correction of the tariff deficit in the electricity sector (Royal Decree-Law 14/2010)	Spain	2010	Ended
Energy Concept	Germany	2010	In force
Promotion of Renewable Energy Act	Denmark	2009	In force
New regulatory framework for administrative procedures for renewable energy facilities	Spain	2009	In force
Law on establishing the promotion system of energy production from renewable energy	Romania	2008	In force
Feed-in tariffs for renewable energy	Luxembourg	2008	In force
Retailer Sustainable Commerce Agreement	France	2008	In force
Net Metering	Italy	2008	In force
Regulation on electricity market organization	Luxembourg	2007	In force
Ordinance: rights and obligations of the electricity market participants	Slovakia	2007	In force
Ordinance on Acquiring the Status of Eligible Electricity Producer	Croatia	2007	In force
Ordinance on the Use of Renewable Energy Sources and Cogeneration	Croatia	2007	In force
Regulation on the Minimum Share of Electricity Produced from RES and Cogeneration Whose Production is Incentivized	Croatia	2007	In force
Electricity Market Act 2007	Greece	2006	In force
Energy Transition	Netherlands	2006	Superseded
Obligation for Power Purchase from Renewable Sources	Poland	2005	In force
Decree on Notification on the Origin of Electricity	Finland	2005	In force
Act on Energy and amendments (Act no. 656/2005)	Slovakia	2005	Superseded
RES promotion - Decree Implementing Directive 2001/77/EC	Italy	2004	Superseded
Reorganization of Energy Sector Regulation	Italy	2004	In force
Green Certificate Scheme—Federal	Belgium	2003	In force
Electricity Market Act 2003	Estonia	2003	Superseded
Renewable Energy Guarantees of Origin (REGOs)	UK	2003	In force
The Electricity Law (No. 318/2003)	Romania	2003	Superseded
Renewables Obligation (RO)	UK	2002	In force
Green Electricity Act	Austria	2002	Superseded
Law on Energy	Lithuania	2002	In force
Feed-in Tariffs and Premiums	Slovenia	2002	In force

Table 2. *Cont.*

Title	Country	Year	Status
Green Certificates Scheme—Wallonia	Belgium	2002	In force
Energy Management Act (Act No. 406/2000 Coll.)	Czech Republic	2001	In force
Climate Change Levy	UK	2001	In force
Act No. 250/2012 Coll. on Regulation in Network Industries	Slovakia	2001	In force
Energy Act (Act No. 458/2000 Coll.)	Czech Republic	2001	In force
Instrument for Structural Policies for Pre-Accession (ISPA)	Hungary	2000	Ended
Access to the Grid (Renewables and CHP)	Belgium	2000	In force
Renewable Energy Sources Act	Germany	2000	Superseded
Demand Side Management to Reduce GHG Emissions—ENEL Voluntary Agreement	Italy	2000	Ended
Electricity Law 2000	France	2000	In force

The first phase, from 1978 to 1990, was Public Utilities Regulatory Policy Act, so-called "PURPA era." Prior to 1978, electric utilities had no obligation to purchase power from third parties and were not interested in investing in non-hydro renewable energy themselves. (Geothermal in California was a notable exception, developed commercially by a utility during the 1960s and 1970s.) That situation changed with the introduction of the 1978 Public Utilities Regulatory Policy Act (PURPA), which required utilities to purchase power from qualifying third parties at the utility's "avoided cost." The definition of "avoided cost" and implementation of the law varied from state to state. In several states, implementation of PURPA represented the first use of the "feed-in" policy [40,41].

Table 3. Major Renewable Energy Policy Milestones.

	Year	Policy
Era-1	1978	Public Utilities Regulatory Policy Act (PURPA) enacted.
	1978	Energy Tax Act provided personal income tax credits and business tax credits for renewables.
	1980	Federal R&D supporting fund for renewable energy Technologies
	1980	Windfall Profits Tax Act gave tax credits for alternative fuels production and alcohol fuel blending.
Era-2	1992	California delayed property tax credits for solar thermal power, which caused investment to stop.
	1992	Energy Policy Act provides tax credits for ethanol fuels for vehicles.
	1994	Federal production tax credit (PTC) takes effect as part of the Energy Policy Act of 1992.
	1996	Net metering laws started to take effect in many states.
	1997	States began establishing policies for renewable portfolio standards (RPS) and public benefits funds (PBF) as part of state electricity restructuring.
Era-3	2001	Some states began to mandate that utilities offer green power products to their customers.
	2002	Federal production tax credit (PTC) expired and was not renewed until later in the year, causing the wind industry to suffer a major downturn. This happened in 2000 also, and again in 2004.
	2004	Five new states enacted renewables portfolio standards (RPS) policies in a single year, bringing the total to 18 states plus Washington DC; public benefit funds (PBF) were operating in 15 states.
	2005	Energy Policy Act 2005 (EPAct-2005)
	2007	Energy Independence and Security Act. (EISA-2007)
	2009	American Recover and Reinvestment Act. (ARRA-2009)

The second phase following the PURPA era was not so favorable, however. Several factors caused renewable energy markets to stagnate, including a long period of electric power sector restructuring, repeal of federal and state incentives, and sharply lower natural gas prices. Little capacity was added. This "stagnation era" lasted until around 1997.

The third phase, starting around 1997 to 2004, represented a new era for renewable energy in the USA. By then, some of the uncertainty surrounding electricity reform had lessened, and state renewable energy policies that were enacted during restructuring started to take effect.

New directions were set in the energy policy Act 2005 (EPAct-2005), which opened the gateway for renewable energy and distributed energy generation (DEG) in the USA power sector [42].

A single policy does not transform the market for a clean energy economy in states and localities. Therefore, state governments formulated and adopted different policies aimed at diversifying the mix of generation sources with a greater percentage of renewable energy and distributed energy resources, reducing the carbon intensity of the sector, and increasing the use of DER and more localized generation units. Some of the main policies and incentives contributing in DRE development and microgrid promotion in the USA are given in Table 4.

Table 4. Energy Polices in USA Considered for Microgrid Development.

Title	Year	Status
State-level Renewable Portfolio Standards (RPS)	Multiple years	In Force
Final Rule on Renewable Energy and Alternate Uses of Existing Facilities on the Outer Continental Shelf	2009	Superseded
Onshore Renewable Energy Development Programs	2009	In Force
Wind & Water Power Program	2008	In Force
Energy Provisions—National Defense Authorization Act for fiscal year 2009	2008	Ended
Renewable and Energy Efficiency Portfolio Standard—Illinois	2007	In Force
Solar America Board for Codes and Standards	2007	In Force
Solar America	2006	Superseded
Renewable Portfolio Standard—Nevada	2005	In Force
Interconnection Standards for Small Generators	2005	In Force
Energy Policy Act (EPAct)	2005	In Force
Renewable Portfolio Standard—Colorado	2004	In Force
New York State Energy Plan	2002	In Force
Renewable Portfolio Standard—California	2002	In Force
Farm Security and Rural Investment Act of 2002 (Public Law 107–171)	2002	Superseded

2.2.1. State Policies to Support Renewable Energies

The number of renewable energy installations across states varies widely, reflecting individual state or regional priorities. A brief description some most important state policies contributing in the development of renewable energies and promotion of microgrids, follows:

Energy Policy Act of 2005

The Energy Policy Act of 2005 (EPAct) is a national USA policy that mandates to enhance and extend possible coordination and communication among Federal agencies. The act promotes dependable, affordable and environmentally friendly production and distribution of energy for the USA's future. To achieve this, the act takes major steps to strengthen the energy infrastructure, promote energy efficiency, expand the use of renewable energy, and boost the domestic production of conventional fuels [43].

Renewable Portfolio Standard

The Renewable Portfolio Standard (RPS) mandates that a state's utilities must produce a specific amount or a percentage of total energy by promoting and increasing production of energy from renewable sources such as solar PV, wind, mini and micro hydropower, and other alternatives to

fossil electric generation by a specific year (e.g., 20% renewable energy by 2025) [44]. Further detailed explanation about the USA RPS and different countries is discussed in [45–47].

Energy Efficiency Resource Standard

Energy Efficiency Resource Standard (EERS) or energy efficiency target is a mechanism to encourage more efficient generation, transmission and use of electricity. An EERS is similar in concept to the Renewable Portfolio Standard (RPS) or the Alternative Energy Portfolio Standard (AEPS), in that an EERS requires utilities to reduce energy use by a specified and increasing percentage or amount each year. EERS policies require that utilities improve the efficiency of their own processes and distribution systems, as well as offer demand-side management programs and incentives that encourage end-user electricity savings [48].

Renewable Energy Standard

A renewable energy standard (RES) is a policy standard that binds utility companies to produce and sell a certain amount of energy generated from renewable sources such as solar and wind. RES establishes an incremental target that increases renewable generation by 2% each year for the following ten years, eventually resulting in 20% renewable power in that state. Over half the states have some type of renewable energy standards or goal in place. National RES policies have been considered by Congress but have yet to be signed into law [49].

As discussed, a single energy policy cannot transform the market for clean energy. Therefore the USA has formulated different policies and made amendments in their existing national policy (EPAct-2005) for the promotion, development and deployment of renewable energy generation (REG) and distributed energy generation (DEG) to reduce the dependency on imported supplies and the reduction of greenhouse gases emissions, by setting the target of 20% renewable energy generation by 2020. The target as applied to electricity consumption will be phased-in gradually. Agencies must draw not less than 10% of their electricity from renewables by 2015, 15% in 2016 and 2017, 17.5% in 2018 and 2019 and not less than 20% by 2020. Additional to these targets and policies, all states have their own policies, standards and targets for maximum utilization of renewable energy power generation.

2.3. The People's Republic of China

Renewable energy and distributed generation are elementary resources for China and play an important role in its energy sector by fulfilling the rapidly growing energy demand. Such energy plays an increasingly important and strategic role in China's energy security and economic development [50]. The Chinese government has taken steps to encourage large-scale development and deployment of RE and DG in order to achieve its non-fossil energy target of 11.4% by the end of 2015 and 15% by 2020 [13]. A rapid increase in the exploitation of solar PV and wind energy systems in 2012–2013 involved increased focus on distributed generation, following trends in leading RE regions and countries in Europe (Germany and Denmark) and in the USA. In 2012 and 2013 more than 20% of the China's electricity production came from renewable energy and distributed energy generation systems.

RE and DG policies attempting to promote the microgrid concept and facilities in China are in developmental stages under the direction of the National Development and Reform Commission (NDRC), China's Center for Renewable Energy Development (CRED), China National Renewable Energy Centre (CNREC) and the National Energy Agency (NEA). Between 1996 and 2015, China has formulated, amended and replaced more than 70 policies. These policies involve research and development (R&D), promotion, utilization, incentives and prevention of environmental issues on all the RE technologies including solar PV, wind (off- and onshore), hydro (mini and micro), thermal, biogas, geothermal and bio energy. The most important Chinese policies on RE and DG are listed in Table 5, with a brief description of Chinese policies on MG (RE and DG) to follow.

Table 5. Energy Policies Considered for Microgrids in China.

Title	Year	Status
Renewable electricity generation bonus	2013	In Force
The Notice of further improvement of New Energy Demonstration implementation	2013	In Force
China Energy White Paper 2012	2012	In Force
The Notice on New Energy Demonstration City and Industrial Park	2012	In Force
The Renewable Energy Tariff Surcharge Grant Funds Management Approach	2012	In Force
Energy saving and new energy automotive industry development plan 2012–2020	2012	In Force
2012 Renewable Energy Electricity feed-in tariff	2012	In Force
12th Five Year Plan for National Strategic Emerging Industries	2012	In Force
The Twelfth Five-Year Plan for Renewable Energy	2012	In Force
Renewable Electricity Surcharge	2009	In Force
Renewable Energy Law amendments	2009	In Force
National Climate Change Program	2007	In Force
Renewable Energy Law	2006	In Force
Preferential Tax Policies for Renewable Energy	2003	In Force

2.3.1. Renewable Energy Law

China's Renewable Energy Law was promulgated on 28th February 2005 and came into force in 2006. It is the first renewable energy legislation in China that focuses on the development and utilization of renewable energy to improve the country's energy structure [51,52]. It incorporates five major components including grid connection, price categorizing, cost sharing mechanism, special funding mechanism and total volume target , with subsidies and supervision [53,54].

The law was amended by the National People's Congress (NPC) in December 2009 and took effect on 1st April 2010 in which three major amendments were made to cater for RE sector rapid growth, especially solar PV and wind power.

1. More detailed explanation and clarification is provided for renewable planning and co-ordination with the overall electric power sector development and transmission, and co-ordination between central government and local (provincial) governments on national development plans. In addition, responsibilities and roles of electric utilities are elaborated in reference to grid-interconnection of renewable energy generation and definition of different classes of renewable generators (including small-scale generators with positive net power production). The law revision also addresses areas such as energy storage and smart grids.
2. New provision has been made to guarantee that all renewable power generated will be purchased by electric power companies. Previously, utilities were only bound to buy if there was sufficient power demand. This has been strengthened so that utilities must buy the power in all circumstances, and can transfer it to the national grid for use elsewhere.
3. The Renewable Energy law 2005 funding component, where the Ministry of Finance collected a 0.4 fen/kWh surcharge on electric power sales nation-wide, was strengthened and consolidated. Originally the fund was utilized in funds that the government used to support renewable energy projects and the costs of feed-in tariffs. However, the surcharge did not kept pace with expenditure, so the revisions allow the Ministry to supplement the renewable energy fund from general revenue.

2.3.2. Medium and Long-Term Development Plan for Renewable Energy in China

China's medium and long term development plan for renewable was promulgated in 2007 under the principle of China's Renewable Energy Law in order to accelerate the development of renewable energy, promote energy conservation and reduce pollutants, lessen climate change, and better meet the requirements of a sustainable social and economic development. The medium- and long-term renewable energy development guiding principles build on the following major components [55–57].

- Renewable Energy Law conscientiously implementation.
- Take up renewable energy development as a key strategic measure to attain China's goal of establishing an environmental friendly society and sustainable development.
- Speed up the development and deployment of renewable energy and distributed generation.
- Technical progress promotion.
- Increase market competitiveness.
- Incessantly boost the share of RE and DG in China's overall energy mix.

2.3.3. China's 12th Five-Year Plan for Renewable Energy

The National People's Congress approved China's 12th Five-Year Plan on 14 March 2011 for the period 2011–2015 [17]. The plan had three main priorities including sustainable growth, industrial upgrading and the promotion of domestic consumption particularly focusing on maximum utilization of renewable energy applications and promoting the integration of RE and DG into the total energy mix and to improve the overall capability for innovation in renewable energy technologies.

Key indicators of the 12th Five-Year Plan, focusing on China's renewable energy development and deployment, are [58,59]:

- The percentage of renewable energy in energy consumption will significantly increase by 2015. Renewable energy development is key to China achieving its goal of 11.4% of primary energy consumption from non-fossil sources in 2015 and 15% in 2020.
- Electricity generated from renewable energies will be an important source of China's overall power system. During the 12th Five-Year Plan period, the installed capacity from renewable energy sources will reach 160 GW, including 70 GW from wind, 20 GW from solar PV, 61 GW from hydropower and 7.5 GW from biomass power, which accounts for more than 20% of total electricity generation by 2015.
- Renewable energy and distributed generation applications will be scaled-up. Development and deployment of grid-supporting and management systems in favor of distributed electricity generation such as solar power and wind power systems; installation of 30 new energy micro-grid demonstration projects; integrating diversified renewable energy technologies such as distributed electricity generation (solar power, etc.) and renewable energy for heating and fuel applications. Establishing 100 New-Energy City and 200 Green-Energy pilot projects and take advantage of distributed energy to supply electricity to areas where the grid cannot cover. The energy supplies of more than 50% of rural households will get access to renewable energies such as biogas, solar energy and biomass-gasification.

In order to achieve these objectives and targets of the plan, the following policies and measures will be adopted to support the development of renewable energy:

- **Establishing sustainable and stable market demand**: Sustainable and stable renewable energy market growth, expansion of renewable energy utilization, technical progress, and development of renewable energy manufacturing industries will be stimulated by means of favorable price policies, and mandated market share (MMS) policies. The MMS policies will be adopted for renewable power generation according to 12th Five Year Plan targets.
- **Improve the market environment**: According to the China's Renewable Energy Law (RELaw), state utility companies are bound to purchase renewable power, and energy administrative authorities under the state council are responsible for formulating all regulations for grid connection operation and management of renewable power generation. Also state power grid companies are responsible for deployment of transmission lines for renewable power stations, thereby maximizing renewable energy resource utilization.
- **Renewable power tariff and cost-sharing policies**: The administrative authorities under the state council are responsible for adjusting feed-in tariff (FIT) as per China's Renewable Energy

Law and to improve the renewable energy price policy system. They will do so based on the different technical and regional characteristics of various renewable energy technologies.

- **Increase fiscal input and tax incentives**: In accordance with RE Law, the ministry of finance is responsible for arranging renewable energy funds. The scale of the funds will be determined according to the renewable energy development and the financial strength of the country. The state should support the renewable energy and distributed generation R&D and its deployment through preferential tax policies.
- **Industry development and technology acceleration**: According to the 12th Five Year Plan for education, industry development and renewable energy promotion, cooperation will be enhanced between R&D organization, educational institutions and industries for renewable energy technologies improvement and development, to produce and manufacture indigenous RE equipment and products to achieve the 2020 target, with local man-power.

2.4. Observations

Growing concern about energy security and climate change have significantly increased the interest in harnessing renewable energy resources (RES) and distributed energy generation (DG) to counter these critical issues. Electricity generated by RES and DG will be delivered to the point of use via large-scale transmission and distribution systems. Consequently, successful integration of RE generation into large power systems has become a fundamental issue to successfully addressing climate change and energy security concerns.

As discussed in Section 2, the EU, USA and China are adopting and promoting renewable energy sources and distributed generation to reduce their dependency on fossil fuel, and are increasing the penetration of RES into the power generation system for future energy security.

All have formulated numerous policies, directives and standards, and set targets for the maximum utilization and deployment of RES and DG. Weaknesses and ambiguities exist and appropriate remedies are not defined or clearly explained, like under article 16 (1) of EU 2009/28/EC Renewable Energy Directive, that Member States shall take "appropriate steps" to develop transmission and distribution grid infrastructure . . . in order to allow the "secure operation of the electricity system". Article 16 (2) involves (a) guaranteeing of transmission and distribution of electricity produced from RES; (b) priority or guaranteed access to the grid; and (c) priority dispatch and minimization of curtailment.

Because of such ambiguities, RE developers are reluctant to build transmission lines where no electricity generation facilities exist. The barriers to commercial feasibility and broad utilization of RES and DG is not the lack of RES but more the inadequacy of existing transmission lines to move energy from generation to consumption or support the anticipated growth in RES requiring grid access.

(i) The EU commission must remove any possible ambiguity relating to grid connection and extension and simplify the policy regulations for innovative small and medium-sized enterprises to enable better integration of RES into the utility grid, including cross-border grid connections.

(ii) The USA is in a transition to a clean economy. Renewables such as solar and wind energy in particular are becoming a real part of a distributed generation power system that moves toward grid freedom from a traditional infrastructure of centralized generation. The USA utility grid has 12% renewable energy generation, of which about 10% is hydropower. That is, only about 2% of electricity comes from non-hydro renewable energy sources.

A national Renewable Portfolio Standard (RPS) sets a target of 10% renewable energy generation by 2020 and 25% by 2025. This dramatic increase would be an important step toward establishing a low carbon economy and help combat global warming.

Reaching the RPS set target requires grid modernization and new transmission, yet how to proceed is a contentious and difficult policy challenge. For example a project called CapX 2020 will add more than 700 miles of new transmission in Minnesota, in order to help meet the RPS.

The project is encountering obstacles (including weather conditions), which reveal the difficulties scaled up renewable electricity production is likely to encounter [60,61].

According to the Energy Policy Act of 2005 the Secretary of Energy is responsible for designating "any geographic area experiencing electric energy transmission capacity constraints or congestion as a national interest electric transmission corridor (NIETC)". The law also authorizes the Federal Energy Regulatory Commission to grant permits for interstate transmission lines if a transmission developer is not able to site a line at the state level after a year or under certain other conditions.

Recently renewable power generation has been supported by a number of government policies and subsidies. Federal Renewable Energy Production Tax Credit (PTC) and State Renewable Portfolio Standards (RPS) are successful recent support mechanisms. The PTC Renewable Power subsidies were created 22 years ago under the EPAct-1992. The subsidies have been extended many times, and the act was scheduled to expire on 31 December 2013.

In the USA, 36 States have developed their individual State RPS and Renewable Energy Standards, for promotion and deployment of RES. The targets of these 36 RPS is to supply about 20% of total power consumed from renewable power by 2020.

To avoid significant risks to the reliability of future USA Power Grids, and to achieve real-sustainable energy security and carbon reductions, the Federal Government needs to formulate a National Renewable Energy Policy (NREP) or National Clean Power Standard (CPS) to promote new energy corridors. This is especially important in view of the RPS, the increasing demand of renewables to meet new electricity demand, grid stabilization, transmission and dispatch system expansion and to facilitate renewable electricity grid connection.

(iii) To expand the renewable energy share in its energy mix is a pillar of China's vision 2020, for future energy security and its GHG reduction strategy. China is planning to inject a further 1000 GW of electricity generation into its national grid in the next 10 years, practically doubling the installed capacity of its current power plants. It is, therefore, important to enact a robust legal framework that can incentivize and manage the expansion of these renewable energy and distributed generation resources. Steps towards establishing a legal framework, like the Renewable Energy Law 2005 (amended in December 2009), 12th Five year Plan, Medium and Long-Term Development Plan for Renewable Energy and its associated implementing regulations, have played a major role in the rapid growth of China's renewable resources in the past few years. However, the rapid growth in renewable energy, particularly solar PV and wind, is hampered, because although grid companies are bound to purchase all the power generated by renewables and interconnect the RE and DG to utility grid according to RELaw 2005, in practice this is not happening. This is because grid transmission capacity has not matched the growth rate of China's solar and wind power plants. According to statistics from China Electricity Council and the China Wind Energy Association (WEA) only 72% (8.94 GW) of China's total wind power capacity was connected to the grid and at the end of 2015 this had only increased to 80.2%.

China is facing a bottleneck in renewable deployment that must be addressed before the country can achieve its renewable energy target. This bottleneck can be partly attributed to the grid companies' lack of resources and incentives to invest in the grid infrastructure; it is necessary to keep pace with the rapid increase in renewable power facilities. Even if a renewable generator is connected to the grid, grid companies have difficulty integrating a large amount of intermittent renewable resources into the grid network because the country's grid lacks sufficient transmission capability. Most RE is located in central China, up to 1,000 miles from the industrial east coast (for example the 6.8 GW Gansu Province Wind Farm Project). With less than 12% energy consumed near the remote source, dedicated UHVDC transmission systems need to be installed for transmitting the power. Such transmission systems take 3 to 5 years to install, are foreign-technology reliant, are point to point, and are limited in capacity to a few GW.

3. Barriers and Challenges

As production costs decline and technology performance improves, the renewable energy sector has witnessed a boom in the past decade [62]. Deployment of RET and DER on large scale in many countries has diverted the focus of policy makers towards the risks associated with renewable energy project deployment, both economic but non-economic barriers and risks [63–65].

3.1. Non-Economic Barriers

Non-economic barriers relate to factors that either prevent deployment altogether (no matter how high the willingness to pay) or lead to higher costs than necessary or distorted prices. These barriers can be differentiated further [66]:

- Regulatory and policy uncertainty barriers, which relate to bad policy design, or discontinuity and/or insufficient transparency of policies and legislation.
- Institutional and administrative barriers, which include the lack of strong, dedicated institutions, lack of clear responsibilities, and complicated, slow or non-transparent permitting procedures.
- Market barriers, such as inconsistent pricing structures that disadvantage renewables, asymmetrical information, market power, subsidies for fossil fuels, and the failure of costing methods to include social and environmental costs.
- Financial barriers associated with an absence of adequate funding opportunities and financing products for renewable energy.
- Infrastructure barriers that mainly center on the flexibility of the energy system, e.g., the power grid, to integrate/absorb renewable energy.
- Lack of awareness and skilled personnel relating to insufficient knowledge about the availability and performance of renewable. Plus insufficient numbers of skilled workers.
- Social acceptance and environmental barriers linked to experience with planning regulations and public acceptance of renewable energy.

Regulatory, economic and commercial challenges are also significantly hampering the deployment of distributed generation in present systems [65]. A literature survey summary on the expected regulatory and financial issues associated with microgrid development and deployment follows.

3.2. Financial and Economic Issues

3.2.1. Power Purchase Agreement (PPA)

A PPA is an instrument of project finance, and is a technical, legalistic and voluminous document developed with the support of experts in engineering, finance, law and project management teams. Mostly PPAs are justified for large-scale DER demonstration projects for periods over 15 years from the date of commencement, because the PPA contract agreement anticipates a future fraught with uncertainties. Small-scale power plants sell power to the central operators who owns the transmission and distribution networks [67].

3.2.2. High Upfront Cost

Large-scale renewable energy power plants are notoriously expensive to build, because of renewable energy technologies (RET) high capital costs, and investors are particularly concerned about the payback time on their investment. Every region and country has to promulgate effective policies and regulations that include packages of financial incentives for deployment of renewable energies, like concessional import duties, excise tax benefits, corporate and personal income tax benefits (including tax exemptions, holidays, credits, and deductions, as well as accelerated depreciation), subsidies against investment costs, low-interest loans, and premium power purchase prices [68,69].

However regulatory barriers still exist at the federal and state levels, which hinder the effort to deploy renewables, such as:

- Lengthy administrative procedures for approval and permit.
- Policy instability with sudden changes and stop-and-go situations.
- Cost competitiveness and fraction.

3.2.3. Grid Connection Costs or Transmission Expansion

Due to the rapidly decreasing cost of RES generating units, grid connection costs become a barrier for the development of DERs, which substantially increases project capital overheads [70]. According to a World Bank (WB) study for grid extension to rural areas in developing countries, costs are typically USD (8000–10,000) per kilometer, plus USD 7000 for material costs. There are no clear regulations and standards in many developed and developing countries for remote area small-scale renewable energy system grid connection, as to who will pay the costs associated with connecting the distributed energy generator to the grid. Thus, the regulatory authorities need to investigate offers for RE grid connection to transmission and distribution systems [71].

3.3. Regulatory Issues

3.3.1. Identifying Renewable Energy Zones

Site selection is a regulatory issue during the design and planning of large-scale wind (on- and offshore) and solar PV (rooftop and ground-based) power plant projects that raise environmental concerns. Concerns include relocation and devastation of habitats for animal and plant species, water supplies and waterways, and cultural resources such as areas of historical or ethnographic importance and scenic beauty. Also there are concerns with site selection, where the majority of land is owned by the government or local people and is being used for multiple purposes, including agriculture, wildlife habitat, livestock grazing, and open space. Therefore, careful and efficiently planning of large-scale solar and wind projects can reduce land and wildlife impact created in delivering a renewable energy future [72].

3.3.2. Distributed Generation Integration

In spite of growing interest in DG, there is as of yet no clear policies, standards or regulatory instruments associated with the repercussions of DG integration into electric power systems [73].

In the absence of clearly defined policies and regulatory instruments associated with DG grid penetration, it is improbable that these systems can thrive. Current transmission and distribution generation systems were developed and are operated as passive networks. In order to foster DG and RES deployment, there is a need to formulate and articulate policies and regulations that support DG and RES integration into an electricity grid, and in so doing, increase supply security and ensure economic competitiveness [74].

3.3.3. Transmission Planning

Transmission planning is a DG project regulatory process, which identifies routing issues and constraints. A project cannot begin until the "transmission" planning process is complete. Fair and equitable DG access to existing transmission lines is an issue because of multiple power generation sources, bi-directional power flow, power flow time co-ordination and management, all bringing significant challenges for existing and emerging power grids and microgrids. The effect of distributed generation on protection concepts and approaches needs to be understood [75–77].

4. Incentives and Benefits

For all of its positive aspects, the reality of green power is that it is not cheap compared to conventional energy sources, with some exceptions. Solar power plants are considered costly power generation systems, but costs have fallen substantially. Onshore wind power and small hydro power

plant costs are also expensive compared to those of coal-fired plants, although they compete with them if local conditions are favorable [23]. Due to higher costs of renewable energy electricity generation, most countries and regions are providing and offering various forms of support and incentives in order to increase their share in energy production and consumption, to achieve set targets [27].

4.1. Europe

Since the publication of the white paper on "Energy for future" in 1997 and the adoption of the renewable energies directives "2001/77/EC (RES-E) and 2009/28/EC" (RES), the EU renewable energy sector has rapidly developed. All 28 member states have introduced national policies and regulations to promote and deploy RES. Most policies improve the corresponding administrative framework conditions and introduced feed-in tariffs, quota obligations based on tradable green certificates (TGCs), investment grants, tender procedures, and tax measures [78–80] as shown in Table 6.

But the different policy schemes effects RES market development in the EU. RES support measures have been implemented on a national level, aiming to meet the national indicative targets of at least 20% of the EU's final energy consumption will be renewables by 2020.

Presently, of the 28 EU member states, 19, including Austria, Bulgaria, Cyprus, Denmark, Estonia, Italy, Latvia, Romania and Sweden may exceed their policy targets. However, some states, including France, Luxembourg, Malta, The Netherlands and the United Kingdom, and to a lesser extent Belgium and Spain, need to assess whether their policies and tools are sufficient and effective to meet their renewable energy objectives. Achievement of the 2020 renewable energy targets is also not certain in the case of Hungary and Poland. Only with optimistic assumptions related to the future energy demand and country-specific financing conditions, do 2020 renewable energy targets appear achievable, as described in map shown in Figure 5 [81–83].

One reason for this shortfall is that the support levels offered for renewable energy sources are heterogeneous among the EU countries and too low in many, and may be below long-term marginal costs. The identified key barriers to RES development are financial, administrative, and social in nature as well as insufficient electricity grid capacity to integrate RES, which are not being appropriately addressed by national authorities, given time is of the essence [84].

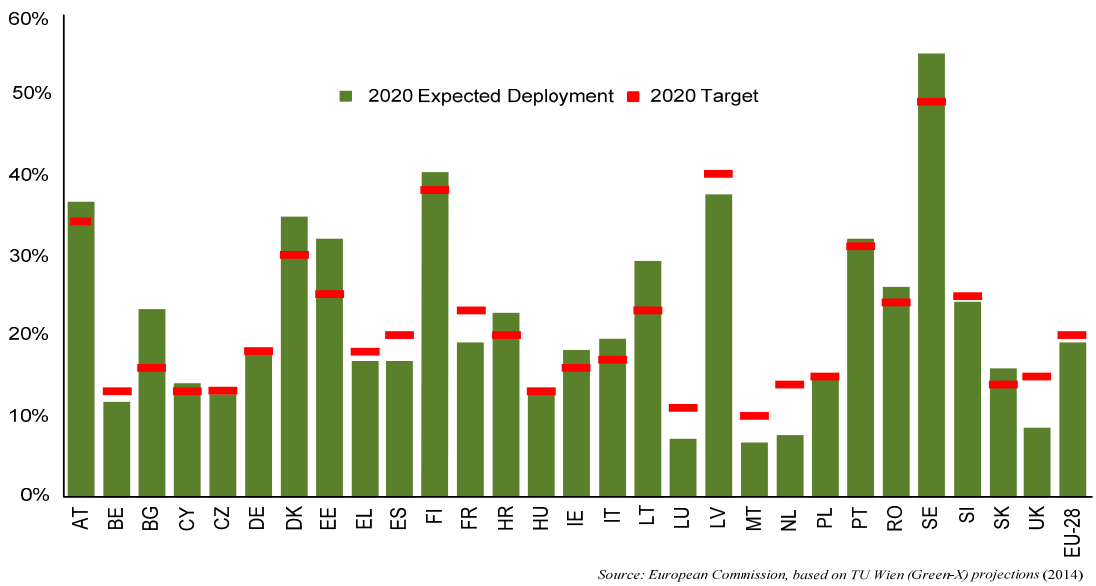

Figure 5. EU Member States 2020 Target Map.

Table 6. Renewable Energy Electricity Support Instruments in EU 28 Member States.

Country		Incentives																							
		FIT			Quota System									Premium						Net Metering			Tax Exemptions		
					% of Quota			No. of Certificates According to Tech.			Minimum Price per Green Certificate			Amount			Cap								
		PV	Wind	Hydro	PV	Wind	Hydro	PV	Wind	Hydro	PV	Wind	Hydro	PV	Wind	Hydro	PV	Wind	Hydro	PV	Wind	Hydro	PV	Wind	Hydro
Austria	AT	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Belgium	BE	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	✓	✓	✓	x	x	x
Bulgaria	BG	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Croatia	HR	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Cyprus	CY		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	x	x	x	x	x
Czech Republic	CZ	✓	✓	✓	x	x	x	x	x	x	x	x	x	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x
Denmark	DK	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓	x	x	x	✓	✓	✓	x	x	x
Estonia	EE	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x
Finland	FI	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	✓	x	x	x	x	x	x	x
France	FR	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓
Germany	DE	✓	✓	✓	x	x	x	x	x	x	x	x	x	✓	✓	✓	x	x	x	x	x	x	x	x	x
Greece	GR	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	x	✓	✓	✓
Hungary	HU	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓	x	x	x
Ireland	IE	x	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓
Italy	IT	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓	✓	x	x	✓	✓	✓	✓	✓	✓
Latvia	LV	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓	x	x	x
Lithuania	LT	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓
Luxembourg	LU	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	x	x
Malta	MT	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Netherlands	NL	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poland	PL	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	✓	✓	✓
Portugal	PT	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Romania	RO	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x
Slovakia	SK	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	✓
Slovenia	SI	✓	✓	✓	x	x	x	x	x	x	x	x	x	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x
Spain	ES	x	x	x	x	x	x	x	x	x	x	x	x	✓	✓	x	x	✓	✓	x	x	x	x	x	x
Sweden	SE	x	x	x	✓	✓	✓	✓	✓	✓	x	x	x	x	x	✓	✓	x	x	x	x	x	x	✓	x
UK	GB	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	x	x	x	x	✓	x	✓

4.2. USA

In the USA, state government agencies, utilities service providers and others offer a variety of incentives (feed in tariff, tax rebates, renewable energy certificates, etc.) and financial incentives (grants, loans, rebates, and tax credits). These are to encourage the use of renewable energy sources and support efforts to conserve energy and lessen pollution for the purposes of meeting state targets and goals. Nationally available financial incentives for RES in every state of the USA are listed in Table 7.

Table 7. Renewable Energy Incentive in U.S States.

State	FIT	Net Metering	Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loan	Bonds	Performance Base Incentives
Alabama	x	x	✓	x	x	x	✓	x	✓	x	✓
Alaska	x	✓	x	x	x	✓	x	✓	✓	x	✓
Arizona	x	✓	✓	✓	✓	✓	✓	x	✓	x	x
Arkansas	x	✓	x	x	x	x	✓	x	✓	x	x
California	✓	✓	x	x	✓	✓	✓	x	✓	x	✓
Colorado	x	✓	x	x	✓	✓	✓	✓	✓	x	✓
Connecticut	x	✓	x	x	✓	✓	✓	✓	✓	x	✓
Delaware	x	✓	x	x	x	x	✓	x	✓	x	✓
Florida	✓	✓	x	✓	✓	✓	✓	x	✓	x	✓
Georgia	x	✓	x	x	✓	x	✓	✓	✓	x	✓
Hawaii	✓	✓	✓	✓	x	✓	✓	x	✓	✓	✓
Idaho	x	✓	✓	x	x	✓	✓	✓	✓	✓	x
Illinois	x	✓	x	x	✓	✓	✓	✓	✓	✓	✓
Indiana	x	✓	✓	x	✓	✓	✓	✓	✓	x	✓
Lowa	x	✓	✓	✓	✓	✓	✓	x	✓	x	✓
Kansas	x	✓	x	x	x	✓	✓	x	x	x	x
Kentucky	x	✓	✓	✓	✓	x	✓	✓	✓	x	✓
Louisiana	x	✓	✓	✓	x	✓	✓	x	✓	x	x
Maine	✓	✓	x	x	x	x	x	x	✓	x	✓
Maryland	x	✓	✓	✓	✓	✓	✓	✓	✓	x	✓
Massachusetts	x	✓	✓	✓	✓	✓	✓	✓	✓	x	✓
Michigan	x	✓	x	x	x	✓	✓	✓	✓	x	✓
Minnesota	x	✓	x	x	✓	✓	✓	✓	✓	x	✓
Mississippi	x	x	x	x	x	x	✓	x	✓	x	✓
Missouri	x	✓	x	✓	x	✓	✓	x	✓	x	x
Montana	x	✓	✓	✓	x	✓	✓	x	✓	x	x
Nebraska	x	✓	✓	✓	✓	✓	✓	x	✓	x	✓
Nevada	x	✓	x	x	✓	✓	✓	x	✓	x	✓
New Hampshire	x	✓	x	x	x	✓	✓	✓	✓	x	x
New Jersey	x	✓	x	x	✓	✓	✓	✓	✓	x	✓
New Mexico	x	✓	✓	✓	✓	✓	✓	x	✓	✓	✓
New York	x	✓	✓	✓	✓	✓	✓	x	✓	x	✓
North Carolina	x	✓	✓	✓	x	✓	✓	x	✓	x	✓
North Dakota	x	✓	✓	✓	✓	✓	✓	x	✓	x	x
Ohio	x	✓	x	x	✓	✓	✓	x	✓	x	✓
Oklahoma	x	✓	x	✓	x	✓	✓	x	✓	x	x
Oregon	✓	✓	✓	✓	x	✓	✓	✓	✓	x	✓
Pennsylvania	x	✓	x	x	x	✓	✓	✓	✓	x	✓
Rhode Island	x	✓	x	x	✓	✓	x	✓	✓	x	✓
South Karolina	x	✓	✓	✓	✓	x	✓	x	✓	x	✓
South Dakota	x	x	x	x	✓	✓	✓	x	✓	x	x
Tennessee	x	x	x	x	✓	✓	✓	✓	✓	x	✓
Texas	x	✓	x	✓	x	✓	✓	x	✓	x	✓
Utah	x	✓	✓	✓	✓	x	✓	x	✓	✓	x
Vermont	✓	✓	✓	x	✓	✓	✓	✓	✓	x	✓
Virginia	x	✓	✓	x	x	✓	x	x	✓	x	✓
Washington	x	✓	x	x	✓	x	✓	✓	✓	x	✓
West Virginia	x	✓	x	✓	x	✓	✓	x	x	x	x
Wisconsin	x	✓	✓	✓	✓	✓	✓	✓	✓	x	✓
Wyoming	x	✓	x	x	x	x	✓	x	✓	x	x
District of Columbia	x	✓	x	x	x	✓	x	x	✓	x	x
Palau	x	x	x	x	x	x	x	x	x	x	x
Guam	x	✓	x	x	x	x	x	x	x	x	x
Puerto Rico	x	✓	✓	x	✓	✓	✓	✓	x	x	x
Virgin Islands	x	✓	x	x	x	x	✓	x	x	x	x
N. Mariana Island	x	✓	x	x	x	x	x	x	x	x	x
American Samoa	x	✓	x	x	x	x	x	x	x	x	x

4.3. China

China is currently under rapid industrial and urbanization development with a growing economy along with an increasing energy supply demand [85]. China was the highest primary energy consuming country in 2014 with 21% of the total world energy [86]. The government is promoting renewable energy technologies (RET) to meet the growing energy demand and simultaneously to optimize the energy consumption structure [87]. Different policies and regulations have been promulgated like the Renewable Energy Law (RELaw-2005) and China's 12th Five Year Plan, to promote renewable energy sources (RES) which will play an important role in energy diversification and the development of a low-carbon economy [88].

Due to these supportive policies, China's renewable energy sector has developed in both installed and generating capacity during the last few years, exceeded planned goals in some aspects [53]. There are no specified incentives and benefits for renewable energy power generation, but some state or province level subsidies have been announced under different policy directives, as shown in Table 8 [51]. Current subsidies to RE in China are mainly for power generation projects. It is difficult for the Chinese government to encourage public support for clean energy development and pay for renewable energy costs because of a low level of per capita income, according to World Bank and IMF 2013 reports. The government has renewable energy financial support involving subsidies, tax policies, pricing mechanisms, and a reward scheme for green production which determine the future development of RE in China.

China does not have a fully developed financial incentive system for renewable energy. Therefore financial incentives come from central or local governments, and can be on a case-by-case basis and technology specific. Pricing for renewable energy is not standardized and is set by contracts negotiated between projects and utilities [89].

The Renewable Energy Law was amended in 2009 and added under article (14) that all grid companies are legally bound to connect renewable energy projects and buy all the energy they produced. Power companies refusing to comply will be fined an amount up to twice the "economic loss" of the renewable energy producer. Under article (25) preferential loans with subsidized interest rates and article (26) granted tax benefits for renewable energy projects would be provided by state or provincial governments.

4.4. Observations and Opinion

Appropriate government incentives are an important tool to enhance the deployment and reduce costs of clean energy technologies. As discussed in Section 4; the EU, USA and China have formulated and promulgated many policies and regulations to provide different incentives and benefits to confirm the exploitation and utilization of DERs and RETs and to handle environmental issues and electricity demand. Most regions have developed their own plans and targets to stimulate the penetration of renewable energy into the energy mix and to overcome key financial and economical barriers as shown in Table 9. Different types of loans and incentives are provided for DERs and RETs projects and electricity purchasing agreements are set to purchase the generated power accordingly. However, after providing the funds and incentives for maximum deployment of microgrids, new challenges and barriers arise, such as the differences in national policies and regulation of each EU member state, which highlights that the EC directives cannot be transposed and implemented uniformly, so the benefits and incentives cannot be delivered to small- and large-scale DERs and RE power producers equally.

The USA has an enormous renewable energy technology potential and that can be explored at a reasonable cost. However, both economic theory and experience identified significant financial and economic barriers and failures that limit renewable development, unless special policy measures are enacted to encourage development. These hurdles are: (i) price distortion from existing subsidies and unequal tax burdens between renewables and other energy sources; and (ii), lack of access to capital, "split incentives" between building owners and tenants, and high transaction costs for making small purchases.

Table 8. List of Policies (P), Regulations (R) and Notifications (N) on RE in China.

Policy Type (Incentive/ Subsidy)	Changes On	Type			Date of Effective	Policy Status	Target	Implementing Agency(s)
		P	R	N				
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Offshore wind power electricity price policy			✓	5 June 2014	In force	Wind, Offshore	National Development and Reform Commission
Economic Instruments, Fiscal/financial incentives, Taxes	State Grid Corporation of China to buy distributed PV power generation electricity			✓	3 June 2014	In force	Solar PV	State Administration of taxation
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums, incentives	Renewable electricity generation bonus			✓	25 Sept. 2013	In force	All RE Sources	National Development Reform Commission
Economic Instruments, Fiscal/financial incentives, Tax relief	Policy of Solar PV electricity VAT	✓		✓	23 September 2013	In force	Solar PV	Ministry of Finance
Economic Instruments, Fiscal/financial incentives, Grants and subsidies	PV industry promotion by exert the price leverage effect			✓	1 September 2013	In force	Solar PV	National Development Reform Commission
Policy Support, Institutional creation, Economic Instruments, Fiscal/financial incentives, Grants and subsidies	Distributed power grid management procedures		✓		18 July 2013	In force	Solar PV	National Development Reform Commission
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Solar PV Feed-in Tariff (FIT) support			✓	30 August 2013	In force	Solar PV	National Development Reform Commission
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Renewable Energy Electricity feed-in tariff 2012		✓		12 June 2012	In force	All RE Sources	Ministry of Finance/NDRC/NEA
Economic Instruments, Fiscal/financial incentives, Grants and subsidies	Renewable energy development fund Imposition and Management	✓			1 January 2012	In force	All RE Sources	Ministry of Finance/NDRC/NEA
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Feed-in tariff for solar PV		✓		2011	In force	Solar PV	National Development and Reform Commission (NDRC)
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Solar PV building Integration program		✓		2010	In force	Solar PV	Ministry of Finance
Economic Instruments, Fiscal/financial incentives, Taxes, Economic Instruments, Feed-in tariffs/premiums	Renewable Electricity Surcharge	✓	✓		2009 (amended 2011 and 2013)	In force	All RE Sources	Ministry of Finance
Policy Support, Institutional creation, Economic Instruments, Direct investment, Economic Instruments	Renewable Energy Law (amendment)	✓	✓		2009	In force	All RE Sources	State Council
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Onshore wind feed-in Tariff	✓	✓		2009	In force	Solar PV	National Development and Reform Commission (NDRC)
Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Off shore wind feed-in Tariff	✓	✓		2009	In force	Solar PV	National Development and Reform Commission (NDRC)
Policy Support, Institutional creation, Economic Instruments, Fiscal/financial incentives, Grants and subsidies	Special Fund for the Industrialization of Wind Power Equipment		✓	✓	2007	In force	Wind	Ministry of Finance

Table 9. Comparative analysis of regulatory policies, financial incentives and public financing between EU, US and China.

Country		Renewable Energy Targets	Regulatory Policies					Fiscal Incentives and Public Financing						
			Feed-in-Tariff/ Premium Payment	Electric Utility Quota Obligation/RPS	Net Metering	Tradable REC	Tendering	Heat Obligation/ Mandate	Bio Fuels Obligation/ Mandate	Capital Subsidy or Rebate	Investment or Production Tax Credits	Reductions in Sales, Energy, CO_2, VAT, or Other Taxes	Energy Production Payment	Public Investment, Loans or Grants
EU Member Countries	Austria	○	R[a]	●		○			●	○				○
	Belgium	○		●	●	○	○		○	◊ [a]	○	○		○
	Bulgaria	○	○						○					○
	Croatia	○	○						○					
	Cyprus	○	○		◊		○		○	R				
	Czech Republic	○	X			○			○	○	○	○		
	Denmark	○	○		○	○	○		○	○	○	○		R
	Estonia	○	○						○				○	○
	Finland	○	○			○			○	○		○	○	
	France	R	R			○	R		○	○	R	○		○
	Germany	○	R					○	○	○	○	○		○
	Greece	○	R		◊				○	○	○	○		○
	Hungary	○	○						○	○		○		○
	Ireland	○	○			○	○	●	○					
	Italy	○	R	○	○	○	R	○	○	○	○	○		○
	Latvia	○	○		◊		○		○			○		
	Lithuania	○	R	○					○					○
	Luxembourg	○	○						○	○				
	Malta	○	○		○					○		○		
	Netherland	○	R		R	○			○	○	○	○	○	○
	Poland	○		○		○	R		○			○		○
	Portugal	R	R	○			○	○	○	X	X	○		X
	Romania	○		○		○			○					○
	Slovakia	○	R			○			○			○		○
	Slovenia	○	○			○	○			○	○	○		○
	Spain	○			○	○			○	○	○		○	
	Sweden	○		○		○			○	○	○	○		○
	UK	R	R	○		○		○	○	R		○	○	○
	USA	R [a]	R [a]	R [a]	R [a]	●	R	●	R	○	X	○	○	R
	China	R	R	○			○	○	○	○	○	○	○	○

○—existing national, ●—existing sub-national, ◊—new, R—revised, X—removed/expired, a—sub-national. Source: Renewables 2014 Global Status Report (REN21).

China has promulgated different policy drivers and introduced benefits for low carbon growth and clean energy promotion, as discussed in Section 3. New regulations have been enacted to promote widespread microgrid projects, but without adequate incentives and benefits in place, RE and microgrid deployment targets cannot be achieved. The NEA is actively promoting the development of RETs and microgrids. However, the various RETs and microgrid incentive instruments are dispersed across different departments, because of a lack of management and policy guidance. This is a barrier to RET and MG promotion, preventing delivery of financial benefits to power producers when needed.

5. Conclusions

The microgrid concept is providing the platform to rapidly increasing distributed electricity generation and delivery with cost effectiveness and environmental protection. For successful DER integration, proper operation and control, protection and stability need all be implemented for feasible microgrid operation. Apart from technical challenges, a long-term view is needed when developing policies, which must address regulatory, economical and non-economical issues that differ with each country's social, political and policy preferences concerning a particular technology. As well, growing concern about energy security and climate change have significantly increased the interest in harnessing renewable energy sources (RES) and distributed energy generation. To counter these critical issues most regions are adopting and promoting renewable energy sources and distributed generation to reduce their dependency on fossil fuel to overcome key financial and economical barriers and are increasing the penetration of RES into the power generation system for future energy security. The right statutory package and appropriate government incentives is an important tool of measures which must be in place at the right time if renewables are to be effectively utilized and to enhance the deployment and reduce costs of clean energy technologies. In this survey the authors emphasize the necessity to investigate the feasibility of microgrid policies, regulations and incentives which are factors affecting the acceptability of microgrid as an emerging power system. If the policies and regulatory factors discussed can be addressed, effective microgrid implementation can rapidly move forward. However, the currently intertwined regulatory and policies barriers are impeding MG deployment rate. Therefore, regulatory frameworks to entice DER and RET power producers and stakeholder need further research in order to support effective MG implementation.

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