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Simulation of consumers and markets towards real time demand response
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European Policies Aiming the Penetration of Distributed Energy Resources in the Energy Market

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Abstract

Energy policies have been widely developed in the recent past as sequence of the increasing relevance of distributed energy resources potential in power systems, namely in achieving the reduction of carbon dioxide emissions gaining independence from fossil fuels. Thus, the main factions in the world, as North America and Europe, have been focusing on the implementation of new energy policies capable of managing several types of energy sources considering their decentralized characteristics. In this way, the present work provides an introduction of how the new energy policies, concerning distributed energy resources, are working towards the increase of these resources penetration in the energy mix. Some successful case studies are presented, namely from Europe, to assess the benefits of such policies to consumers, to producers and to energy market as a whole.

Keywords: demand response, distributed generation, energy markets, energy policies, renew-able energy sources, smart grid

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1. Introduction

Several countries are facing serious problems with their constant growth, mainly with energy demand and the continuous dependence of fossil fuels usage for energy generation, leading to high CO_2 emissions [*1*], with high impact on the electricity industry [*2*]. Policy makers are promoting Renewable Energy Sources (RES) to decrease the use of harmful fossil fuels in electricity generation.

Currently, one way to counter this problem is the implementation of Distributed Generation (DG). DG relevance has increased since several years ago [*3*] and can be defined as a small-scale and decentralized electricity generation [*4*]. However, this definition is very diverse and ranges from 1 kW photovoltaic (PV) installations, 1 MW engine generators to 1000 MW offshore wind farms [*5*]. This may change between countries, not existing a general policy agreement for this type of technology.

DG allows a considerable reduction in terms of energy losses, since the generation is installed locally, i.e., near the loads. Also, CO_2 emissions are minimized due to the use of RES [*6*] such as wind, PV, small hydro, etc. The increasing of renewable-based DG led to a more complex power system, challenging the way it's planned and operated.

Demand Response (DR) [*7*] programs are being considered to increase reliability and improve energy quality. At economic level, DG presents the advantage of requiring a small investment because of its low production capacity when compared with centralized power plants [*8*].

Although DG presents many advantages, the fact is that their production unpredictability is a major issue for power systems operation planning [*9*], [*10*]. Also, these are small-size resources with low production capacities that aren't able to participate in energy auctions and markets, individually [*11*] – this feature is one of the main barriers of DG implementation. However, it can be surpassed with resources aggregation which enables a considerable sum of power able to participate in wholesale markets. This requires the creation of an entity capable of managing DG and obtain the capacity needed to participate in energy markets, fairly remunerating them for their contribution in case of being able to sell the offered power [*12*]. The activities of an aggregator in wholesale markets are the same as any other large producer, i.e., offering a certain amount of energy for a price per energy unit [*13*].

Other barriers have been encountered in the implementation of DG, covering aspects such as: distribution operator, administrative, economic and tax authorities. Electricity suppliers also have interest in DG, since they recognize that it as a tool that can help covering the demand necessities, creating a liberalized market. The DG allows players in the electricity sector to respond, in a flexible way, to the changes in market conditions. This flexibility is provided due to the fact of DG small-size and commissioning times, when compared to large central power plants. In this way, there's the need to evaluate and analyse the different policies that exist in Europe, in order to overcome the economic and technical issues related with the operations and activities for the management of the retail market. Also, the RES integration potential has to be considered.

In this paper four countries are compared in terms of RES penetration, energy policies and market. The studied countries are: United Kingdom (UK), Germany (DE), France (FR) and Denmark (DK). DG is the main focus of the present work, however, also DR is studied in order to provide an overall view of the integration of distributed energy resources in energy markets. This paper is organized as follows: after this introductory section, section II presents a characterization of DG, section III presents European energy policies, and section IV presents the analysis and discussion of the studied countries.

2. Distributed Energy Resources

The following subchapters 2.1 and 2.2 detail the features of two types of distributed energy resources, namely, distributed generation and demand response.

2.1. Distributed Generation

This section presents a detailed characterization of the common types of resources in DG. There are different types of DG, from the construction and technologic points of view, as shown in Fig. 1 *[14*]. About the DG capacities, these depend on the user type and the respective applications. The most common classifications used are also shown in Fig. 1.

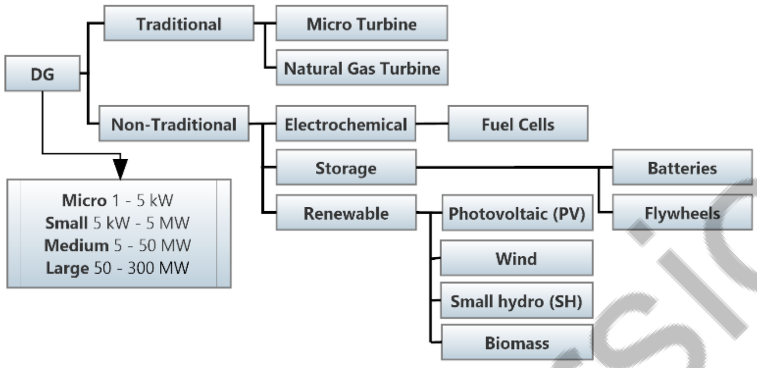

Fig. 1: Distributed generation types, technologies and sizes [*14*].

As mentioned before, DG and DR are not capable of participating in the wholesale market due to their installed capacities and production. Without an aggregator entity able to join these amounts of individual units, DG potential is not fully assessed. In fact, this aggregator concept [*15*] opens way to a new entity, as not just a seller but also as a resources manager and operator [*16*]. Considering the development in energy systems (high interest setting), the DG integration presents itself as a viable solution for a sustainable operation without energy systems dependence on fossil fuels.

In [*16*], an interesting point to DG integration is presented, as several features are pointed from different approaches. For example, from a consumer perspective, the integration of DG in the energy system provides the following advantages:

- receive financial support for installation of renewable technology (prosumer) and profit from energy sale;
- possibility of reducing energy costs due to a more local energy consumption and reduction of network congestion;
- through the use of own production, reduce electricity bill.

The set of EU policies that promote RES *[17*] (significant support implementation as financial instruments, e.g., feed-in-tariffs) drives significant penetration of RES in power generation. Appendix Table 8 [*18*], [*19*], presents the estimated price, in €/MWh produced, for the years 2016, 2020 and 2040. In fact, the share of RES in electricity generation continues to increase, driven by the increasing Emissions Trading System (ETS) prices, along with the continuation of some direct support schemes and of enabling polices, such as streamlined authorization procedures, priority access and the benefits that local population has from investing in local RES.

In Appendix, Table 9 and Table 10 present a prediction for the RES penetration in the network, considering the European countries studied in the present paper [*20*]. The RES share of the various technology types can be seen in Appendix Table 9 for the same regions previously mentioned.

The implementation of these types of technology can be complex since the associated installation costs, considering a domestic appliance, are significant. Initially, several countries in the European context weren't able to have confidence about the success of presenting these types of distributed technologies to its citizens. In this way, to guarantee an initial enthusiasm around the renewable and sustainable concept, promotion strategies had to be adopted by governments. In Europe, these strategies, described in Table 1 [*21*], present different solutions, such as, direct and indirect strategies, where the first causes an immediate interest in RES and the second a more underlined strategy that gradually improves the RES implementation course. According to [*22*], [*23*], the majority of the European countries address the promotion strategies with the use of feed-in tariffs (most used by European countries – 80% of them use this type of scheme – in the year 2010), investment grants, support fiscal measures, green certificates, and tenders. Each of them can be described as:

• **Feed-in tariffs** – feed-in tariffs are widely used in Europe and have become the most successful DG promotion strategy. This tariff enables the priority of renewable energy by applying high energy selling prices to the network. In this way, several advantages are unveiled, such as, a much lower payback time for the investment made. However, the application of this special tariff is limited by a period of time or quantity supplied, and after these goals are achieved the tariff is progressively reduced until a more reasonable one, considering the market conditions. Premium feed-in tariffs grant the seller a superior monetary income since, besides selling the energy in the market, a tariff is applied to the energy obtained from renewable sources, adding a second remuneration to the sale. The major issue with this approach is that usually the energy produced in these terms is mandatory sold to an entity (often the Distribution System Operator - DSO). When there is no need for this energy, overproduction raises as a problem to the entity, possibly causing problems in its operation.

• **Investment grants** – monetary support made by the country's government in order to help the RES interested entities with its implementation. It is important to notice that these investments are only for construction or installation purposes, and are compromised by their economic reliability towards the existing network.

• **Support Fiscal measures** – fiscal support is often used by countries to support potential investors, granting loans with small taxes (small-interest), providing reasonable economic conditions for RES integration. Fiscal measures consist of tax incentives for renewable energy providers and users.

• **Green certificates** – these certificates are a proof of existing share in renewable energy, i.e. the energy producers are obligated to have a certain share of renewable energy in their energy mix, granting therefore a mandatory interest from them in developing RES. Also, the certificates can be shifted between time periods, and can assume several time dimensions (e.g. by hour, day or year). This indicator is very useful, since the certificates define a quota obligation for the producers.

• **Tenders** – tenders can be very useful in an environment with many project developers and companies dedicated to energy supply construction. These contests are presented by the country's government, publishing several renewable energy projects. The better project development proposed by the candidates, wins the tender. However, these propositions have to include features, such as, project location, environment impact, duration, grid connection, project cost, etc. The competition factor is decisive in this kind of promotion, since it helps to develop better solutions and interest in RES. Two types of tenders exist: fixed feed-in tariffs or target-price feed-in tariffs.

Table 1: Promotion strategies [*21*].

		Direct		**Indirect**
		Price-driven	**Quantity-driven**	
Regulatory	Investment focused	-Investment incentives; - Tax credits; - Low interest/ soft loans;	- Tendering system for investment grant;	- Environmental taxes; - Simplification of authorization procedures; - Connection charges, balancing costs;
	Generation based	- Feed-in tariff; - Fixed premium system;	- Tendering system for long term contracts; - Tradable green certificate system;	-
Voluntary	Investment focused	- Shareholder programs; - Contribution programs;	-	- Voluntary agreements;
	Generation based	- Tradable green tariffs;	-	-

2.2. Demand Response

DR can be defined as the modification of the consumer usual consumption patterns in response to price signals, monetary incentives or when the energy system reliability is in risk [15],[24]. The integration of this type of resources has many features, similar to DG (especially at the aggregator level), since it's also part of DER, but mostly with smaller capacity.

DR besides being load reduction and curtailment, has many other features as load shifting (the load is transferred from a period to another) and energy efficiency (the consumption profile has the same pattern, however its values are lower). In the following bullets and Fig.2 are detailed the programs usually used and with more promising implementations [*7*], [*24*].

- **Direct Load Control** – the utility operator or aggregator has free access to the consumers' loads, enabling a direct control over the consumption of the load.

- **Interruptible/Curtailable –** the consumer signs a contract were he approves the curtailment or interruption of certain amount of load at a specific time or interval.

• **Demand Bidding –** the consumers can negotiate a price, for curtailing an amount of energy, with utility operator/aggregator.

• **Emergency DR –** consumers can choose to reply or not to emergency signals sent by the operator/aggregator, to reduce.

• **Capacity Market –** the consumer signs a contract where he commits to deliver a certain energy amount when the operator or aggregator are in need.

• **Time-of-use (TOU) –** one of the most used DR programs. It is based on a multi-tariff system that changes the energy tariff according to the hour of the day or the day itself.

• **Real-Time Pricing (RTP) –** the current electricity prices are available in real-time for the consumers, and therefore they can choose or not to reduce load when the prices are high.

• **Critical Peak pricing (CPP) –** the price applied to energy is higher when the network is on peak times or when system reliability is at risk. In this way, the consumers pay more for energy in these periods. This program joins TOU with RTP.

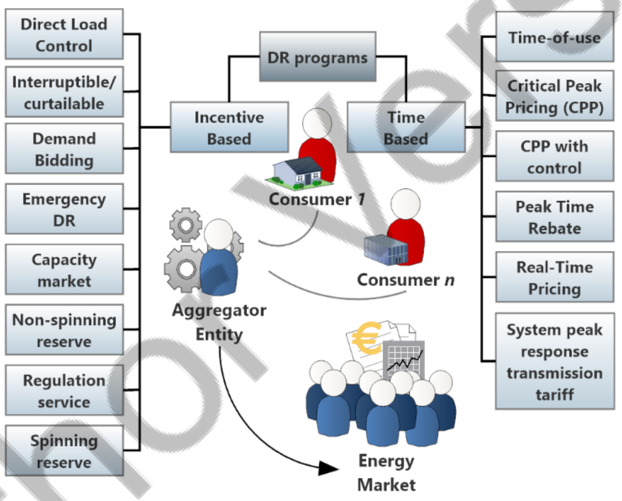

Fig. 2: Demand response programs and context [*24*].

3. European Energy Policies

In this section is presented detailed information about European countries and their energy policies. It is intended to approach the main barriers that these countries face when implementing DG and DR. The countries in analysis face their barriers in distinct ways, as follows.

3.1. United Kingdom

United Kingdom began working towards a greener future in the mid 90's, when renewable energy started to grow. The current legislation that specifies the implementation of RES in the

UK is designated Renewables Obligation (RO).It was introduced for the first time in England, Wales, and Scotland in April 2002, and in Northern Ireland in April 2005 [25]. The current obligation amounts to 15% of electricity supply by RES in 2020. The generation by wind source is the dominant RES technology in UK, and the main investors/producers are the major utilities [26].

Electricity suppliers with more than 5MW of capacity are supported by a quota system, named Renewables Obligation Orders (ROO) [27]. The ROO imposes the obligation on suppliers of electricity, to have an increasing share of their electricity from RES [26]. If the suppliers do not have sufficient share of RES, they have to pay a penalty per MWh into a buy-out fund (price adjusted annually with retail price index). In this way, they present the Renewable Obligation Certificates (ROCs). ROC is a certificate issued by a licensed electricity supplier to an accredited generator for eligible renewable energy generated and supplied to customers. This quota system supports plants above 5 MW, although plants between 50 kW and 5 MW are also entitled to choose between the feed-in tariff (FIT) system and the RO [27]. Independent RES producers can sell their production directly to traders/suppliers by purchase agreements, or sell in quarterly auctions of the Non-Fossil Purchasing Agency [28]. The RES producer sells the generated electricity on the market, since this is supported by the ROCs revenues. The RES have to deal with the uncertainties of two independent markets: forward electricity market and Tradable Green Certificate (TGC) market.

FIT system was announced into law by the 2008 Energy Act and it is more generally used in power plants with a capacity of 50 kW up to 5 MW [29]. The energy plants need to undergo an accreditation process, which may differ according to the plant size and source. The electricity exported to the grid by the plant is bought by an electricity supplier, at rates fixed and changed yearly by the Gas and Electricity Markets Authority (Ofgem) [27]. This system only applies in England, Scotland and Wales. Fig. 3 presents a summarization of the transactions scheme in the UK energy market.

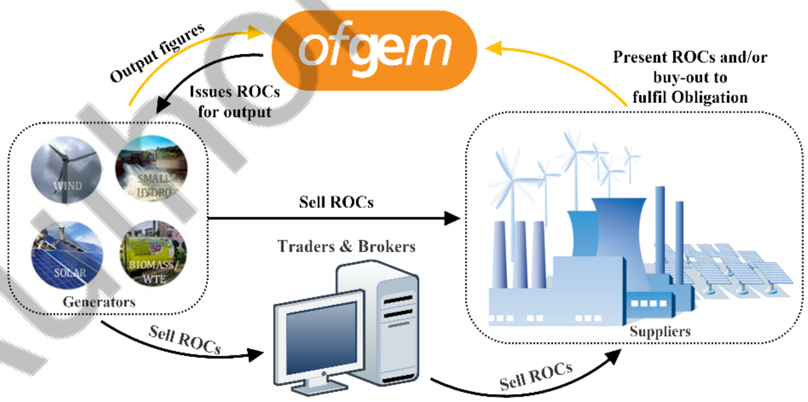

Fig. 3: Energy market scheme [27].

A FIT scheme was proposed and implemented with the RO, in order to use the concept of "contracts for difference" (CFD). This scheme was courtesy of the 2013 Energy Act [30]. The FIT-CFD is complex, involving the generators being paid the difference between the contract reference price and the electricity market price. The RO is criticized due to this expensive nature, when compared to the German system. This happens because developers have to pay a "risk premium" to investors due to the uncertain income stream under the RO [31].

A new form of risk is presented with CFD FIT, where the renewable operators have to trade in UK energy markets. This measure is seen as worst, since only electricity suppliers and large power plants are able to be electricity traders. This means that small producers have to ask the electricity suppliers to give them power purchase agreements, leading to receive no more than 70% of the stated CFD FIT reference price [*32*]. This, when compared with RO seems not so generous, therefore there will be less RES development due to these policies. Currently, this scheme is applicable in England, Wales and Scotland. In Northern Ireland it is expected to be introduced in 2016. From April 2017 the CFD scheme will be the only support scheme for all new RES-E plants exceeding 5 MW [*27*]. In Table 2 some of the subsidiaries schemes are represented for wind, solar photovoltaic and hydro plants.

Table 2: UK subsidiaries summary [*27*].

Type	Technology	Additional Rules	Duration
CFD	Wind	- Onshore (>5 MW) and Offshore	15 years
	Photovoltaic	>5 MW	
	Hydro	>5 and <50 MW	
FIT	Wind	- 50 kW with Microgeneration Certification Scheme - between 50 kW and 5 MW (accreditation based on ROO-FIT)	20 years
	Solar PV		
	Hydro	- accredited by the ROO-FIT	
RO	Wind	- Onshore and offshore wind are eligible under RO scheme - Offshore wind turbines cease to be eligible for ROCs after 20 years from their accreditation date	-
	Solar PV	- Building mounted and ground mounted solar PV are both eligible under RO scheme	
	Hydro	- Eligible, except for large plants (> 20 MW) that were commissioned before 01/04/2002	

According to the current energy policies, in United Kingdom, it is important to point out the need to improve and reform the Electricity Market, the installation of Smart Meters and the development of energy efficiency, while on the other hand, the increase of RES share is supported through feed-in tariffs, CFD system, a certificate system and a quota system in terms of a quota obligation (RO) [*33*].

Recently, UK policy-makers opened a discussion about the necessary regulatory changes required to accommodate the use of DR in their markets. Currently, the DR schemes used are: Short Term Operating Reserve (STOR), Firm Frequency Response (FFR) and the Frequency Control by Demand Management (FCDM) [*34*]. A STOR participant offers its load as reserve to the UK network during pre-determinate periods.

In this period the STOR participant must be available to start-up their generators or reduce the load by the agreed amount, when requested by the grid operator [*35*]. The FFR is an alternative approach to grid balancing. The UK network has a license obligation to control frequency within the specified limits, where the use of FFR with a monitoring software system, operating with a range of equipment such as UPS, generators, pumping systems, air conditioning and others, turning them into smart units which can react instantaneously to changes in demand [36]. The FCDM is a rapid-response service used to help maintain system frequency in the specified limits. An unexpected increase in demand or a generation plant outage, can cause system frequency to fluctuate and drop below the desired. The FCDM providers are contracted to respond automatically in these situations to help restore the system frequency to within the acceptable range, by instantaneously reducing load from their processes [37].

3.2. Germany

Germany's electricity market has a decentralized structure with a large number of private and public owned utilities [38]. The biggest difference of the German electricity system, when compared with many other countries, is the fact that there isn't a single system operator or a separate energy regulator. The four big utilities that dominate the electricity market are: RWE AG, E.ON Energy AG, Vattenfall Europe AG and EnBW AG [38]. These utilities are involved in the generation and supply activities. Their development is a response to the closure of 8 nuclear plants and the expansion of RES. Germany has the ambition by 2020 to phase out nuclear energy and have a system that has a share of at least 80% renewable by 2050. The federal Government's energy policies are based on the 2010 "Energy Concept", and the 2011 "Transformations of the Energy System". The first one, is looking for the implementation of a reliable, affordable and environmentalist energy supply system by 2050 [39]. The second one, focuses in the increase of renewable generation and complete exclusion of nuclear plants.

In terms of installed capacity, as one can see in Table 3, the share of generation using RES, accounts to 44% of total installed capacity, and is expected to exceed its national 2020 target, regarding the shares of RES in gross final energy consumption, set at 18% [20]. Wind and PV are those with the highest share in DG. In PV, the majority (about 65%) is connected to low voltage (LV), 35% are connected to medium voltage (MV) and only few plants are connected to high voltage (HV). In the case of wind, the overwhelming majority (about 95%) are connected to MV [40]. Concerning ownership, more than 50% of DG belongs to customers, such as private owners, industrial companies and farmers [3]. Fig. 4 presents the RES installed capacity by technology type, over the next years.

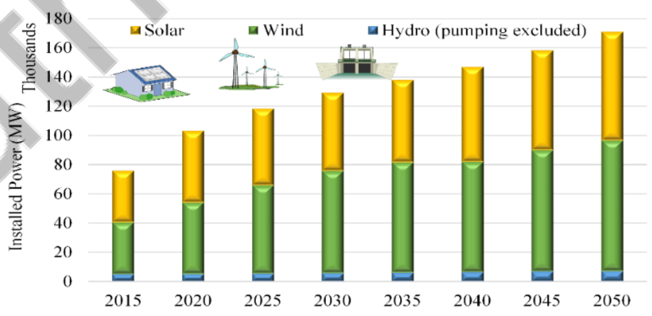

Fig. 4: RES installed capacity [20].

Germany was one of the first countries in Europe to implement the feed-in tariff scheme – since 1991. In this first scheme, only one single tariff was applied for all RES technologies. The introduction of the "Erneuerbare-Energien-Gesetz" (EEG), portraying a German Renewable Energy Act, in the year 2000, is a key element in the success of RES expansion. With EEG legislation, a priority and normal feed-in tariffs for each type of RES were guaranteed for a fixed period of time. For most technologies, this period corresponds to a total of 20 years. It is important to refer that tariffs for a new installation are decreased every year by a certain percentage in anticipation of technological learning. In 2009, the German government considered the introduction of a feed-in premium option in parallel to the fixed tariff scheme.

In addition, several modifications were made in this EEG in the last years. For example, generators with an installed capacity of at least 500 kW, that operate new plants, are required to sell their electricity in the energy market – thus the option of feed-in tariff is not applicable (however some exceptions may apply). Other example, is that from 2017 onwards, a tendering process will be implemented and will replace both the feed-in tariff and the market premium.

The tariffs are paid to RES by the DSO, whose grid the RES plant is physically connected, but sometimes, mainly in large wind parks, the connection and sell is made directly to the Transmission System Operator (TSO). The additional costs (price difference between feed-in tariffs and market prices) are passed from the operators through the electricity suppliers to the consumers. RES plants in Germany can be connected to the grid, but the network operator is allowed to curtail the output of these plants, if the network is already congested with the electricity for others plants. Newly installed plants need to be equipped with technical provisions for such curtailment. For example, in DGs new installations with capacity over 100 kW it's required the installation of control and communication equipment. In the case of PV, with a capacity between 30 kW and 100 kW, the owner can decide between installing the control and communication equipment that allows the reduction of generation output remotely, or be limited to 70% of their maximum effective exported capacity. Table 3 presents Germany's subsidies summary for RES [*41*].

Table 3: Germany subsidiaries summary [*41*].

<table>
<tr><th>Technology</th><th>Additional Rules</th><th>Duration</th></tr>
<tr><td>Wind</td><td rowspan="4">- Plant operators can chose monthly between adopting a FIT or a premium scheme
- Regarding FIT, the plant's capacity must be between a power range of 100 to 500 kW
- The Premium scheme for PV installation is only applied to a maximum of 10 MW capacity
- In Premium scheme, the plant operator can sell his electricity directly to a third party or stock market, allowing also the right to premium</td><td rowspan="4">20 years</td></tr>
<tr><td>Photovoltaic</td></tr>
<tr><td>Hydro</td></tr>
<tr><td>Others</td></tr>
</table>

In terms of DR, since 2012, Germany uses it, however only as interruptible loads in the industrial sector. The loads with this possibility are major consumption units connected at least at 110 kV network voltage levels. The TSO can then interrupt 2 types of loads: the immediately interruptible loads (SOL) and the quickly interruptible loads (SNL). The main difference between these two types of loads is reflected in the fact that the SOL loads, are dispatched within a second of frequency deviation, while SNL is activated within 15 minutes. The interruptible loads have a minimum tender quantity of 50 MW and a maximum of 200 MW with the following three availability options: (i) at least four times a week, several times a day for at least 15 minutes at a time, for a duration of up to one hour per day; (ii) once every seven days, be available continuously for at least four hours at any given time; (iii) once every 14 days, continuously for at least eight hours at any given time. The participants can earn up to 2500 €/month.MW of reduced load.

3.3. France

In this subsection, it is presented the energy policies applied in France. They can be completely different from the other countries, since France became highly dependent on nuclear energy after 1974, when the first oil crisis occurred. Nuclear technology allowed France to gain economic strength and huge capacity for demand supply. In 2015, France presents a total of 58 nuclear reactors plus another one under construction, operated by "Électricité de France" (EDF).

Nuclear energy is responsible for supplying about 76% of the country's electricity demand, as one can see in Fig. 5. The high capacity and low cost of nuclear energy makes France one of the largest energy exporters in the world. Despite the highly amount of nuclear energy generation, France is compromised to reduce their share from 75% to 50%, till the year of 2025 [*42*]. The share of RES for electricity generation are currently promoted by feed-in tariffs, tax benefits and tenders [*43*]. According to the information presented before, in the 1990s were implemented tendering systems for power plants with capacity higher than 12 MW.

A few years later, in 2002, the FIT emerged and were applied to power plants with capacity lower than 12 MW. EDF has the obligation to support onshore wind farms, geothermal and biomaterial power plants for 15 years, while offshore wind, hydro and solar power must be ensured for 20 years. On the other hand, the measures applied to the tax benefit allowed a 15% reduction of the investment cost for a maximum of 3000€ a person and a decrease of 7% in VAT, in 2011, over the purchased renewable equipment [*21*], [*44*]–[*47*].

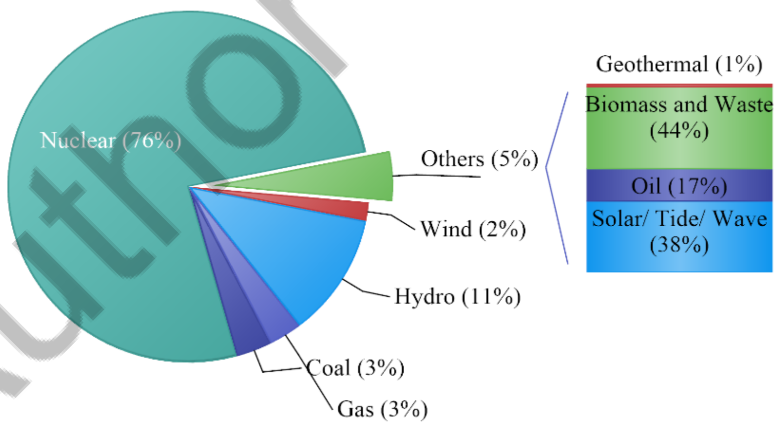

Fig. 5: Electricity generation in France, 2014 [*48*].

The Table 4 intends to schematize the existing subsidies applied to each type generation, in France.

Table 4: France subsidiaries summary [*47*].

<table>
<tr><th>Resource</th><th>Duration</th><th>Subsidies:</th></tr>
<tr><td>Wind (Onshore)</td><td>15 years</td><td>- 0.082 €/kWh for first 10 years
- Between 0.028 €/kWh and 0.082 €/kWh for the next 5 years depending on location</td></tr>
<tr><td>Wind (Offshore)</td><td rowspan="5">20 years</td><td>- 0.13 €/kWh for 10 years
- Between 0.03 and 0.13 €/kWh for the next 10 years depending on location</td></tr>
<tr><td rowspan="3">Solar</td><td>- Ground Based: 0.12 €/kWh</td></tr>
<tr><td>- Simplified Building-Integrated: 0.3035 €/kWh or 0.2885 €/kWh</td></tr>
<tr><td>- Building-Integrated
- 0.46, 0.40, 0.4025 or 0.352 €/kWh, according to the capacity of the power plant</td></tr>
<tr><td>Hydro</td><td>- 0.0607 €/kWh plus bonus between 0.005 €/kWh and 0.025 €/kWh for small power plants
- Extra 0.0168 €/kWh for energy generated during winter season</td></tr>
</table>

France intends to assume a new identity in energy generation, aiming to reach a share of 50% in renewable energy till the year of 2020, since in 2011 RES represented 13.1% of France's electricity production. Some political measures about the growth and development of renewable energy were discussed and adopted in 22nd of July of 2015, in the French Parliament. These policies will lead to the creation of jobs and work towards the energy independence, avoiding the import of fossil fuels by maintaining the energy sector balanced and giving the opportunity for intern companies to enter international markets.

This law also aims new key objectives, such as: a unique authorization for development and installation of wind farms, hydroelectric and biomass power plants, the promotion and encouragement to apply renewable energy in buildings or even the exemption of taxes related to the consumption of bioenergy in the internal market. It is then expected that the RES in 2030 will be responsible for supplying 32% of energy consumption [*49*]. Although France still maintain its dependence on nuclear energy, this already shows results of applying DR programs. In the present year, France's TSO proclaimed an increase by 300% in the total DR contracted capacity, when compared to the previous year, 2014 [*50*]. There are two main time-based programs implemented in France, TOU and CPP (this last one is also known as *Tempo* tariff) [*51*], [*52*]. More detailed information in [*53*].

3.4. Denmark

Denmark has become a European reference in what concerns energy policies and sustainable growing. Since the 1970s, the country has adopted new perspectives in energy use and generation, passing from almost total dependence in fossil fuels (>90%) to self-sufficient (one of the countries, in the EU28, with lowest energy dependence). Their policies establish an estimated goal of 100 percent renewable sources share by the year of 2050 [*54*], [*55*] – Fig. 6. The Danish Energy Agency (DNA), since the 70s, has been gradually increasing the taxes on electricity use, mainly to promote energy savings (energy education) amongst the consumers, gathering at the same time, budget for the energy network research and development. Although this policy is aggressive, it still achieves its creation goals quite successfully.

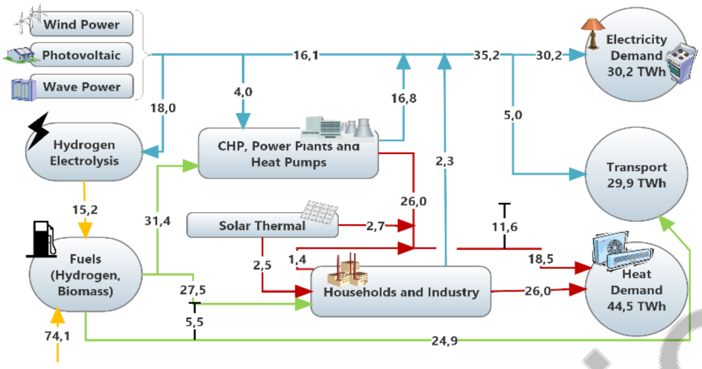

Fig. 6: Denmark 2050 scenario, adapted from [*46*].

In fact, the Danish consumers' electricity prices are within the highest of the EU. The electricity prices, without taxes, is below EU average. In this way, household consumers pay three times more for electricity than industrial consumers [*45*]. Denmark embraced the retail market liberalization in 2003, being possible to consumers the choice of continuing with regulated market prices or change to the liberalized market. However, by the end of 2015, most of the consumers have to adopt liberalized prices since regulated ones are to be removed.

After the market liberalization, the energy sector became in an overall stationary state, not occurring much progress until 2008, when the Energy Policy Statement was introduced. According to [*56*], three critical features for green energy were defined: efficiency, renewable and resources integration. Energy efficient becomes important when a sustainable energy use is required. In fact, several actions were implemented to improve the global efficiency of Denmark, such as, energy labelling and certification of buildings and appliances.

In Denmark, renewable energy integration is performed using several kinds of promotion strategies, such as fixed feed-in tariffs, feed-in premium tariffs, tenders, and tax benefits [*21*]. Such is the case of offshore wind farms, where their construction and implementation is approved by a tender, and afterwards a feed-in premium tariff is applied to the energy produced. Other DG resources are paid by a fixed feed-in tariff. These promotion strategies are implemented during 10 to 20 years, depending on the technology and scheme. For wind energy, the first 3000 monetary units of income are free of taxes [*21*]. This allows a much quicker payback time for the investment made, besides adding competition between investors for the development and use of renewable sources.

Renewable energy may not always be the most trustworthy due to the unpredictability. However, Denmark has been gradually developing its central and long-term planning in order to better predict the energy produced by their renewable sources, mainly wind as the one with more potential. In the actual operation, the DNA provides the following keys to Denmark success with DG and fluctuating renewable sources integration:

- Integration of small CHP units – the system allows a control over heat and electricity, enabling heat storage;

- Existing thermal power plants were updated in order to allow more flexibility in reasonable time.

The connection of DG to the network is performed in two ways [*9*] – DG onshore (e.g. CHP, wind, photovoltaic, biomass and others) is connected to the distribution network, while large wind farms located offshore, are connected to the transmission network. Due to this large use of the distribution network, Denmark has 77 DSOs and only one TSO, "Energinet" (created in 2005 for gas and electricity) [*9*]; it is important to refer that the energy system is divided into two areas, Eastern and Western Denmark (DK1 and DK2, respectively). More recently, Denmark has been focusing its research on the development of hydrogen-related technologies to apply in transportation and energy storage sector [*57*]. In this way, the country can reduce even further their dependence on fossil fuels for huge consumption sectors like transportation and heat supply.

Although Denmark is well advanced in DG implementation, the scenario for integration of DR is not so developed. The cause is not cultural as one may assume, since statistics tell in fact the opposite [*58*]. They show that the Danish people are more aware of environmental issues than other countries, embracing more naturally the use of renewable sources (existing solar panels are mostly consumer-owned) and adopting an energy efficiency posture. So the problem of integrating active consumers in the network and resources management is not because of the consumer itself, but due to technical, commercial and security issues for the operators. In Table 5 some of the subsidiaries schemes are represented for wind and solar energy. The Danish monetary unit is DKK/kWh. More information can be obtained in [*63*].

Table 5: Danish subsidiaries summary [*63*].

Resource	Duration	Tariff (m.u.)	Additional Rules
Wind (Onshore)	6 600 full load hours	0.25	- 0.01 m.u decrease by each point the market price exceeds 0.33 m.u. - 0.023 m.u. for balancing costs
Wind (Offshore)	22 000 full load hours	0.25	- 0.023 m.u. for balancing costs
Wind Tenders [a]	20 years	0.518 0.629 1.051	- Until 10 TWh - Until 10 TWh - Until 20 TWh
Household Turbines	10 years	2.50	≤ 25 kW
		1.30	≤ 6 kW - Annual decrease of 0.14 m.u., during the first 4 years
Solar	10 years	1.30	≤ 400 kW - Annual decrease of 0.14 m.u., during the first 4 years
	20 years	0.60/ 0.40	> 400 kW - First price for the first 10 years, and second price for the remaining years
	10 years	1.45	- Collective - Annual decrease of 0.17 during the first 4 years

[a] Three different regions are considered: Horns Rev 2, Rodsand 2 and Anholt

In Denmark, the generation is negotiated directly in the wholesale market, however when dealing with even smaller amounts (as the case of consumer reductions). The problem becomes more complex, mainly for the system operator that now would have to consider aggregation models for consumers and communicate with the grid company responsible of supplying consumers and dealing with producers [*59*]. Also, the wholesale market makes sense when having a known load to supply, taking into account a certain forecast error. With DR, one has to consider the considerable increase of forecast error, making more difficult for the system operator to balance its network. These are serious issues that slow down the implementation of DR in Denmark, as well as in other countries. Denmark has ongoing projects for DR, such as, Bornholm [*60*]–[*62*]. In order to support DR programs, the existing meters began to be replaced by smart meters in 2010/2011 achieving, four years later, more than 50% of the population.

4. Analysis & Discussion

According to the information analysed and presented along this paper, it is possible to refer that the major countries in European Union (EU) are making efforts to reach 2020 energy and climate outlined objectives. It is important to continually redefine new objectives, in order to achieve the development of energy policies and implementation of DG and DR, aiming the reduction of fossil fuels dependency. The need to implement DG is somehow different and innovative from country to country, since it depends, mainly, from the economic power of each one of them. However, they still have to fulfil the established policy goals of EU.

The present paper allows to understand how four EU countries are working towards the implementation of renewable energy, according to the actual energy policies. As seen, United Kingdom major renewable source is wind, seeking to achieve 15% of RES electricity supply by 2020. Nowadays, DR is being developed to be used in electricity markets, through the existing models, such as: STOR, FFR and FCDM. France is considered DR European leader, once it presents practical results and an increase of their clients year after year. However, in opposite, they are dependent of their high percentage of nuclear energy generation. Currently, France is aiming new policies to incentive the implementation of RES. Germany seeks to extinguish the nuclear energy of their energy programs and expects the RES energy consumption to exceed the value established, previously, in 18% by 2020. The best scenario is presented by Denmark, which is a country well known for their wind farms high generation, leading to a country with almost null dependency on fossil fuels, aiming to higher energy policies, as the case of 100 % RES by 2050.

In Table 6 and Table 7, it is presented the summary of the subsidiaries schemes studied through the analysis of the four countries considered. Also, the references for related information about each of the countries is represented, in what concerns DG and DR.

One can see that Europe is much more committed to DG than to DR, mostly due to the advanced producers' remuneration schemes and to the new energy policies imposed the EU. In what concerns DG, the schemes adopted are, in their majority, homogenous between countries, namely, the adoption of feed-in tariffs. In what concerns DR, the programs are very distinct or are applied to different types of consumers. Therefore, DR isn't yet a usually implemented resource, since Europe seems to still be experimenting the integration of this type of technology in their energy systems (mostly in small networks). This work presents a study about distributed energy resources, energy policies and electricity markets implemented in some EU countries, aiming at new challenges and strategies to a better energy use. Lastly, it is expected the EU to proceed with the improvement and establishment of new climate and energy policies, aiming to reduce CO_2 emissions, and to incentive and implement a higher share of RES.

Table 6: Promotion strategies summary.

Country	**Distributed Generation (DG)**		**Demand Response (DR)**	
United Kingdom	• Renewables Obligation (quota system) • Contracts for difference feed-in tariff • Fixed Feed-in tariffs	[*21*]–[*23*], [*25*]–[*27*], [*29*]–[32], [*53*], [*64*]	• Short Term Operating Reserve • Firm Frequency Response • Frequency Control by Demand Management	[*24*], [*34*]–[*36*], [*60*]
Germany	• Feed-in premium • Fixed Feed-in tariff scheme	[*9*], [*13*], [*21*]–[*23*], [*26*], [*31*], [*32*], [*38*], [*39*], [*41*], [*43*], [*64*]	• Interruptible loads in the industrial sector • Immediately interruptible loads • Quickly interruptible loads	[*7*], [*13*], [*60*]
France	• Fixed Feed-in tariffs • Tax benefits • Tenders	[*13*], [*21*]–[*23*], [*43*]–[*47*], [*53*], [*64*]	• Time-of-Use: Green Tariffs • Critical Peak Pricing Tariff called Tempo	[*13*], [*50*], [*60*], [*51*], [*52*]
Denmark	• Fixed Feed-in tariffs • Feed-in premium tariffs • Tenders • Tax benefits	[*9*], [*21*], [*22*], [*45*], [*56*], [*63*], [*64*]	• Ongoing projects, such as, Bornholm • Eco-design buildings and energy labelling to appliances • Frequency Control by Demand Management	[*7*], [*55*], [*59*], [*60*]

Table 7: Promotion strategies description.

Country	**Feed-in tariffs**	**Premium tariff**	**Tenders**	**Tax benefits**	**Quota System**
United Kingdom	• FIT since 2008, to all RES • CFD applied in 2013, subject to capacity	-	-	-	• Introduced in April 2002
Germany	• Used since 1991 with a single tariff for all RES • In 2000, EEG introduced a FIT system for each type of RES	• In 2009, this scheme was introduced by EEG	• This scheme intends to replace FIT and premium, by 2017	-	-
France	• Used since 2002, FIT are applied to RES (wind, hydro and solar)	-	• Introduced in 1990s, tenders were applied to power plants (except wind)	• In 2005, was implemented reduced VAT rate applied to renewable energy services, equipment and delivery	-

Denmark	• Used since 1993 for all RES • In 1999, this scheme was to be replaced by TGC • In 2004, the feed-in tariff was abandoned for wind energy	• By 2003, all wind generators were under this policy	• In 2009, tenders were introduced, only for offshore wind farms	• Were introduced in 1986, to Danish power generation families – removed in 1988 • Wind farms refund in 1993	-

Appendix

Table 8: Estimated level average generation costs [*18*], [*19*].

Resource	2016 (€/MWh)	2020 (€/MWh)	2040 (€/MWh)
Biomass	102.20	88.53	82.36
Wind	87.22	64.83	66.15
Solar PV	191.51	110.37	103.33
Hydro	82.11	73.55	79.19
Geothermal	90.55	42.10	53.55

Table 9: Renewable energy penetration [*20*].

Country	**RES Penetration (%)**				
	2015	**2020**	**2030**	**2040**	**2050**
UK	16.00	42.42	50.76	51.61	52.37
DE	44.90	53.53	61.33	63.69	66.20
FR	28.78	38.40	51.29	54.83	54.78
DK	34.05	45.29	57.59	61.58	59.55

Table 10: Renewable sources penetration [*20*].

Country	**Type**	**RES Penetration (%)**				
		2015	**2020**	**2030**	**2040**	**2050**
UK	SH	10.4	3.4	2.6	2.2	2.2
	Wind	77.6	82.1	80.8	83.4	82.3
	PV	10.1	12.7	14.1	12.3	11.2
	Others	2.0	1.8	2.5	2.2	4.3
DE	SH	6.5	5.0	4.4	4.4	4.2
	Wind	46.9	47.4	54.1	51.4	52.3
	PV	46.6	47.5	41.4	44.2	43.5
	Others	0.0	0.0	0.0	0.0	0.0
FR	SH	58.5	38.8	26.0	23.9	21.6
	Wind	28.1	46.9	56.5	52.2	54.9
	PV	12.7	13.6	16.6	23.1	22.4
	Others	0.7	0.7	0.9	0.8	1.1
DK	SH	0.3	0.2	0.1	0.1	0.1
	Wind	93.8	94.1	90.5	91.6	92.9
	PV	5.9	5.7	9.3	8.3	7.0
	Others	0.0	0.0	0.0	0.0	0.0

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