Assesment of the Demand Respons Aplication in Europe and its Complementary/Competitive Character with Storage Technologies

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Abstract

Renewable energy sources are expected to take a very large share of electricity production in 2 degrees scenarios. The main objective of the study is to analyze the use of the demand response (DR) in high variable renewable depending electric power systems and explore the potential advantages of using DR to compensate intermittency. We also considered the interactions of DR with the entire power system, including the other flexibility options (storage, electric grid, and dispastchable power plants) using European Unit Commitment And Dispatch (EUCAD) model. In the supply and demand balance modelling, DR is similar to electricity storage: they both displace an electric load between two time-periods, although their technical operating constraints differ which makes their economic models and behaviours slightly different. We perform studies with very different renewable shares which are expected to be representative of different time horizons, today, in 2030 and 2060, years. We found that the need for implicit DR grows up to 20 % of the peak load but might have a value after which its use is saturated. Surprisingly, the competition with storage capacities appear to be very limited. Regarding to explicit DR, the level of usage is more sensible to the price when the high VRE claims for more flexibility.

Keywords: Demand Response | Flexible electricity demands | Demand side management

1 Introduction

The number of national power systems with a high share of wind and solar power is increasing rapidly. This is possible due to the improvement and decreasing costs of the technology, and increased concern regarding environmental problems of competing technologies such as fossil fuels which has often been translated in CO2 pricing. However, variable renewable power production has to be balanced. Today, this balance is achieved mainly trough a combination of conventional power plant flexibility and pumped hydro storage and with some help of Demand Side Response. In the future, the increase of Demand side flexibility offers an interesting approach to the balancing issues. The aim of this paper is to explore the impacts that might have the increment of Demand Response facilities in two points of one possible trajectory to reach the 2 degree goal.

We perform studies with very different renewable share which are expected to be representative of different time horizons, today, in 2030 and 2060, years. The associated electricity mixes, installed powers, and marginal costs are extracted from a 2 degrees scenarios in Europe extracted from a scenario produced by the coupling of Prospective Outlook for Long -term Energy System (POLES) [3] with EUCAD.

Here are some questions that we try to answer. How much, in percentage of peak load, demand response participation is needed in the market? If we increase twice the level of participation, is the use doubled? Does this use depends on the country energy mix ?Does this depends on the available storage. We also test how sensitive is the level of usage of Explicit demand response to the price. In a first approach we can think that the more expensive the service the less the production because of the competitions but how this situation changes when the level of intermittent power plants is higher ? We also do a brief estimation of the possible impact that DR can have in the price and CO2 emissions.

2 Methodology

To do this study we have seen how changes the result in the electricity production of Europe when changing the values of maximum DR power. For this purpose we use a tool developed by the laboratory: EUCAD (European Unit Commitment And Dispatch model) [Storage]. This code solve the production dispacth, by minimizing the total marginal cost, for all the EU. For this the inputs are: the demand load profile, installed power and variable cost for each producing and storing technology and as output the production, limits on interconnections. Variable cost includes eventual CO2 taxes. Some other constraints such as minimum technical power or ramping costs are taken into account but were shown to have limited impact[1].

Averaged values for all the year are extrapolated from the simulation performed in 12 representatives days of the demand load (6 for summer and 6 for winter) and of the different types of renewable production profiles that depends in the regional weather. The construction of those representative days was done on the base of historical data available for some European countries is discussed in [1].

For some test cases, a reduced version to just one country was used. This allows to separate more easily some effects by removing interconnections. In that case, the electricity mix simulated was the one of a country that looks like France. And the simulation was run for all the days of year 2012 during which the last winter storm with a serious low temperature period occurred.

Details of the modeling of storage and Demand Response are developed in following paragraphs.

2.1 Hydroelectricity

In our model, hydroelectricity is seperated in three agreagated technologies. First, run-of-the-river is modelled with almost zero marginal cost which makes it used at its maximum constant production capacity. This capacity has been adusted so as to reproduce year average production. Second, lake dams, are simulated with similar zero costs, but with a daily energy production limit. Whereas zero marginal cost tend to make hydro run-of-the-river a baseload production, this daily available energy reserve has its maximal impact where it replaces the most expensive productions, and is then used at peak hours. Third, Pumped Hydro Energy Storage (PHES) is simulated with almost zero marginal costs, but with a specific pumping efficiency. Minimizing total costs makes PHES produce during peak demand and pump during lowest demand hours. The level of energy displaced is a function of the efficiency.

Other storage such as batteries could fulfill the same requirements and be simulated in the same way as Pumped Hydro Energy Storage (PHES) in EUCAD. Even though they could have slighlty different performances and costs, their use and the change of their use are expected to be similar to those of PHES and are not discussed here.

2.2 Demand Response Modeling

Demand response is a change in electric consumption patterns by end-use consumers in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high market prices or when grid has a problem or is overloaded.

Demand Response is able to increase the system's adequacy and to substantially reduce the need for investment in peaking generation by shifting consumption away from times of high demand. It can act as a cost effective balancing resource for variable renewable generation. Adding stability to the system, it lowers the need for coal and gas fired spinning reserves. It furthermore decreases the need for local network investments, as it shifts consumption away from peak hours in regions with tight network capacity. Demand Response delivers these benefits by providing consumers –residential, commercial or industrial –with control signals and/or financial incentives to adjust their consumption at strategic times.

Demand response available power is probably a relatively small percentage a percentage of peak load [2]. Figure 1 shows the evolution of expected peak load in each country from POLES between 2030 and 2060 which means that in many countries the potential of DR is expected to increase in EUCAD.

We assume that the potential for DR can be called only 1 hour at full per day. Some applications may be called more often but some others do not.

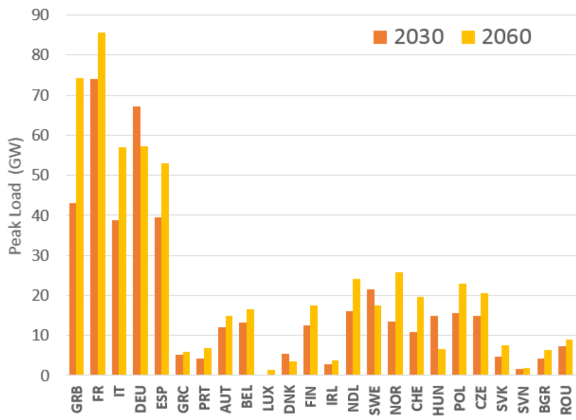

Figure 1: Peak Load in 2030 and 2060 for all European countries*.

*Countries: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxemburg, Netherland, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom.

2.3 Rebound Effect

For many applications, energy can be displaced only for sometime, typically only one hour in the case of building heating [4]. This means that Demand Response produces a ”rebound” effect. Depending on the cases, one hour before or after the call for a downward (respectively upward) change, a significative part of the displaced energy will be called on the other side. In EUCAD, this rebound effect is simulated by a rebound of one third of the displaced energy. Figure 2 shows the difference of use of DR as a function of the option chosen to place the rebound. Most of the use close to morning or evening peaks so as to try to make them less steep. In EUCAD, DR is expected to be a simple shift in demand : it is assumed that the rebound as a perfect efficiency, which is not the case of storage.

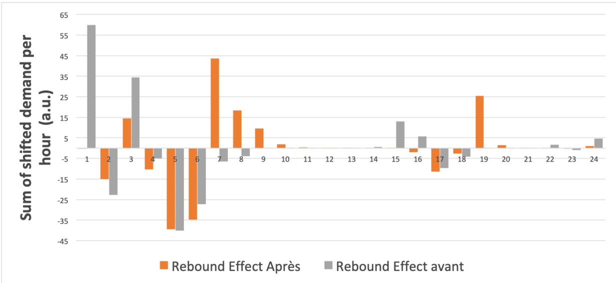

Figure 2: Sum of use of Demand Response for each hour of the day as a function of the rebound option : before or after power change.

2.3.1 Explicit and implicit DR

Demand Response programmes can be categorised into two groups:

- **Implicit Demand Response** Sometimes called “price-based”, refers to consumers choosing to be exposed to time-varying electricity prices or time-varying network tariffs(or both) that partly reflect the value or cost of electricity and/or transportation in different time periods and react to those price differences depending on their own possibilities (no commitment). These prices are always part of their supply contract.

- **Explicit Demand Response** In this demand competes directly with supply in the wholesale, balancing and ancillary services markets through the services of aggregators or single large consumers. Consumers receive direct payments to change their consumption upon request (i.e., consuming more or less). Consumers can earn from their flexibility in electricity consumption individually or by contracting with an aggregator.

In this paper we study the possible impact of both.

2.4 The scenario

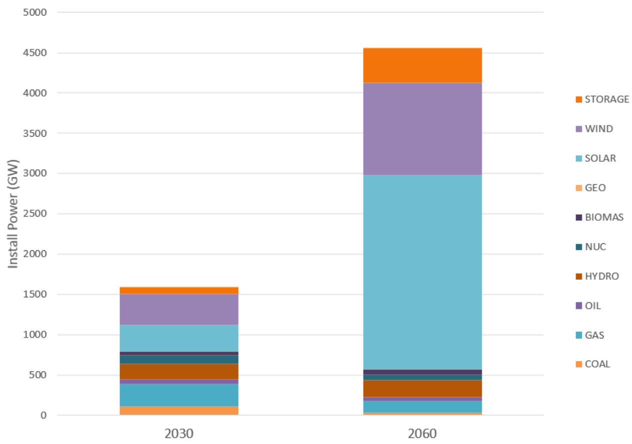

Figure 3: Installed capacities by Fuel: Coal, Gas, Oil, Hydro, Nuclear, Biomass, Geo, Solar, Wind, solar. Storage: Demand Side Management, CAES, Batteries, Hydropumping.

We perform our study in two different years, 2030 and 2060 of the one possible trajectory to reach the 2 degree objective. These years were selected to show how a smaller amount of nuclear (which is decreasing in Europe) and an increase in the VRE capacities affects the use of DR. The installed power for this two years are shown in Fig. 3.

3 Results

To do the assessment of the use of each DR, implicit and explicit, we increase the maximum power of both, one at the time, and compare how much demand is displaced. Here we increase the power from 5 to 10 and then 20 % of the peak load. The peak load for all the countries is shown in Fig. 1.

3.1 Implicit Demand Response

3.1.1 Potential increase

The Fig. 4 shows the shifted demand during the 12 days in each country for 2030 and 2060 respectively. Here we can see that if we increase the installed power then the shifted also grow. To have an order of magnitude we can think in the average of production per day is, for example, in France equal to 1GWh when the installed power is equal to 5% of peak demand. 1GWh means around 1% of the peak demand is displaced to a moment in the day of low consumption

To better figure out it the ratio between the shifted demand in the 12 days and the installed power is shown in the Fig. 5 for 2030 and Fig. 6 for 2060. In 2030, many countries do not use the potential of DR (1 hour per day allowed), and this use often decreases with the available capacity. Here we can see that in almost all the cases the ratio decrease, this is because there might be a value after which the production is saturated.

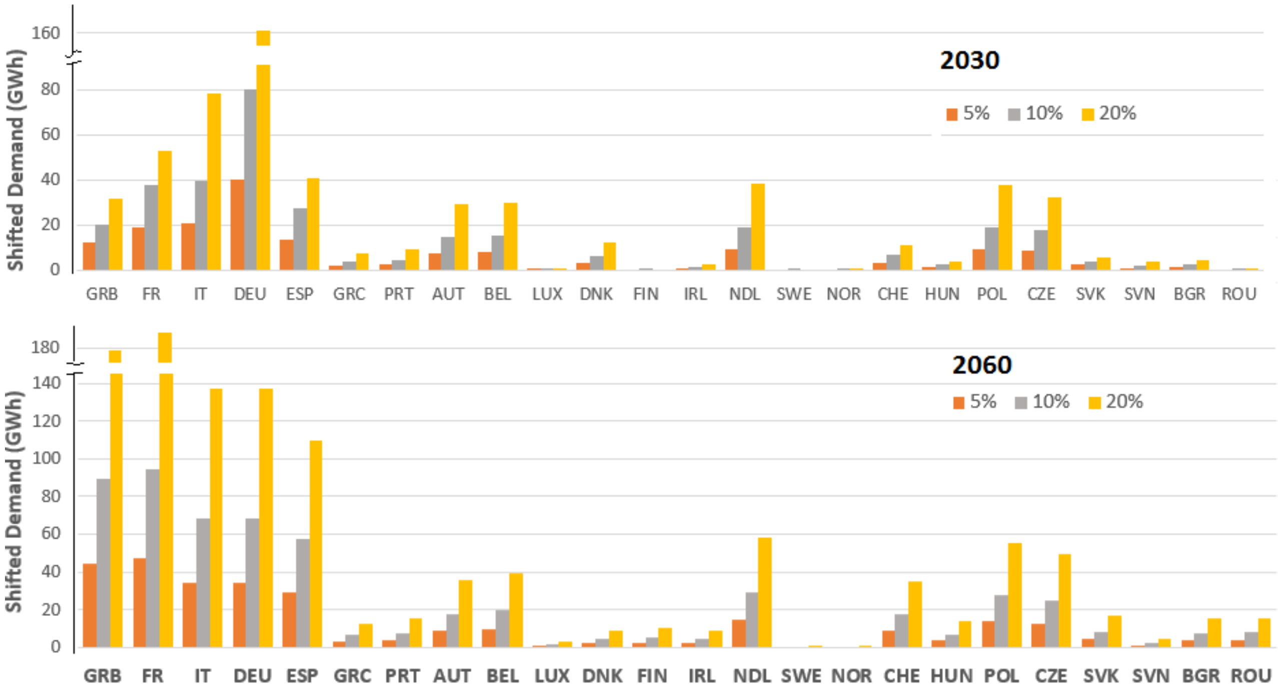

Figure 4: Shifted demand during the 12 representatives days in GWh for each European country in 2030 (up) and 2060 (down).

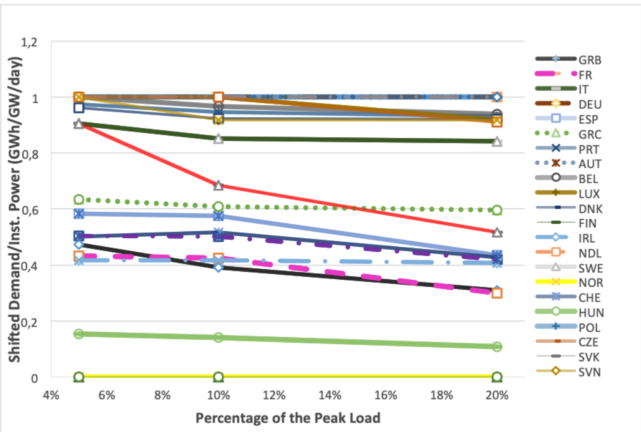

Figure 5: Ratio between Shifted demand(GWh) and Install power of DR (GW) for each country in 2030.

In 2060, the contribution of variable renewable in the mix has increased a lot, and the available dispatchable production capacities have decreased as can be seen on Fig. 3. Then, the need for DR increases a lot. One can see on Fig. 6 that not only most of the countries use the potential to the max, but that this use is not decreasing when more capacity is becoming available. Here the main difference with 2060 is that only 3 countries: Spain, Hungary, Romany has a decreasing ratio. This reflects the fact that in 2060 when renewable production penetrates in almost all the countries the need of flexibility that allows changes in the shape of the demand curve increases and is not fullfilled. We have not understood yet what makes the potential of DR not used to its maximum. Some countries with a lot of Hydropower (Norway, Sweden) do not uses a lot, but some others do, such as Austria.

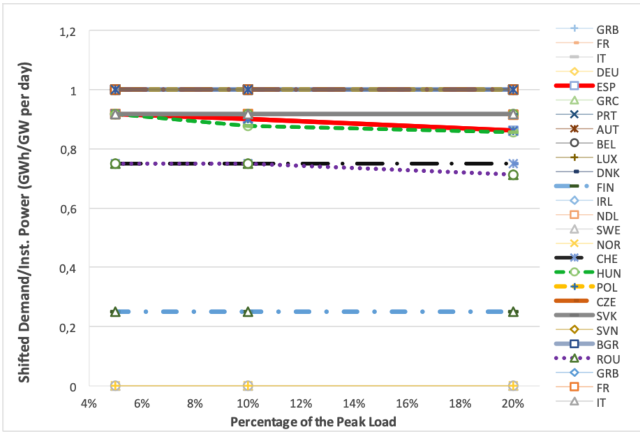

Figure 6: Ratio between Shifted demand(GWh) and Install power of DR (GW) for each country in 2060.

3.1.2 Competition between DR and storage

Figure 7 shows the evolution of energy displaced by storage and demand response as a function of growing DR installed power, for different level of PHES installed power. In this case, only one virtual country that would have the energy mix of France in year 2012 with its hourly total production but also variable renewable productions, ie run-of-river, wind and solar.

The use of demand response grows linearly with its installed power, meaning that its potential is higher than the 10% of peak power almost attained with 9 GW which is confirmed in next paragraph. The more interesting point is that this use is absolutely not changed by growing PHES capacity.

The use of Storage decreases linearly with the use of Demand Response growing capacity, but with a leading coefficient[1] that is two times smaller than the one of the growing use of Demand Response. The increase in Storage capacity hardly increase its use, which shows that its need is fulfilled by existing capacities. In our model, Demand Response is more efficient and then cheaper than PHES. PHES limited round-trip efficiency makes its use slighlty expensive as its operator will have to pay for the energy loss. So if DR could displaced the same energy, it would be used first and the leading coefficient will be the same with opposite sign. Because of its partial Rebound effect, DR cannot exactly replace daily Storage and then DR is not a direct competitor of Storage with our parameters.

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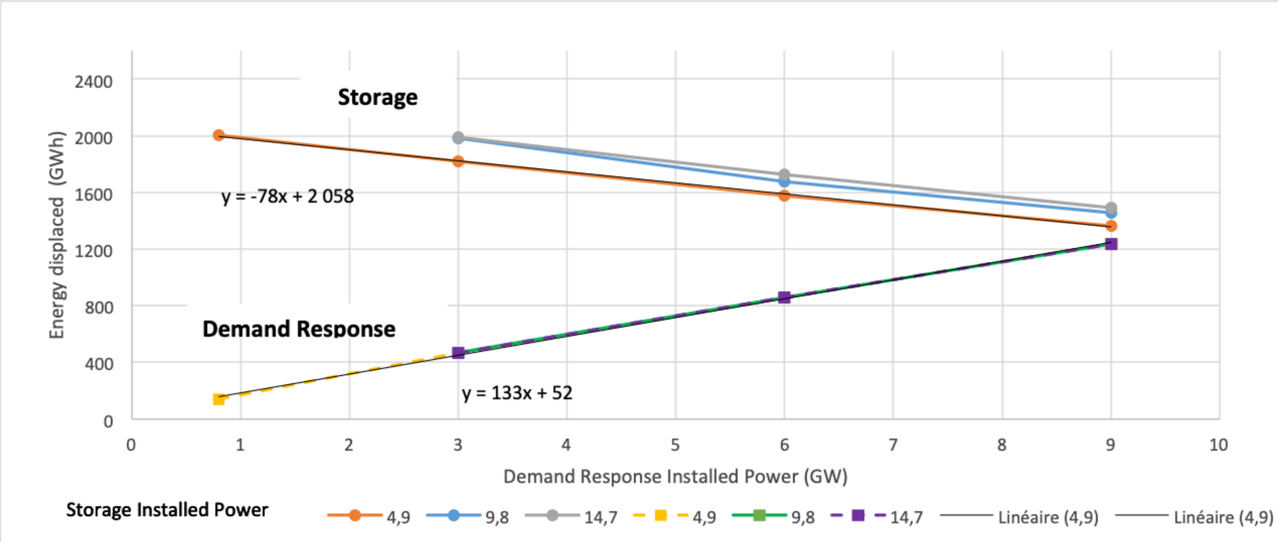

Figure 7: Energy displaced by Storage and Demand Response as a function of installed power of Storage and DR

3.2 Explicit Demand Response

To study the possible market for explicit DR we set 2 different values per KWh: 0.001 and 0.01 k$/kWh. The cheapest one has the same order of magnitude of Hydro pumping technologies, and the second one is almost the one of electricity from Coal or Gas turbine. In the minimization of the marginal cost DR will compete not only with the technology that has proximity in cost but also the efficiency will be in the balance.

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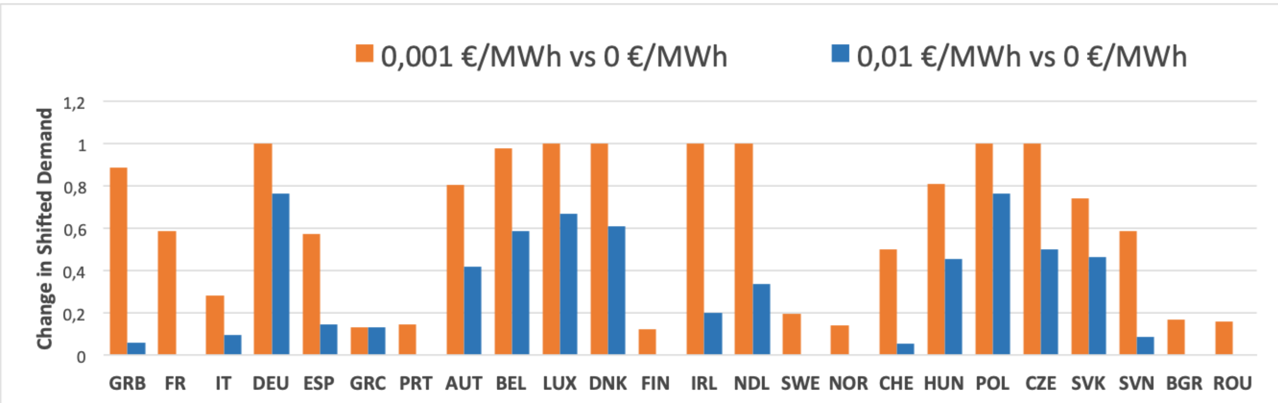

Figure 8: Change in Shifted demand if cost is changed for each European country in 2030.

[1]Rc̊oefficient are not shown as they are bigger than 0,998 which means that linearity is excellent

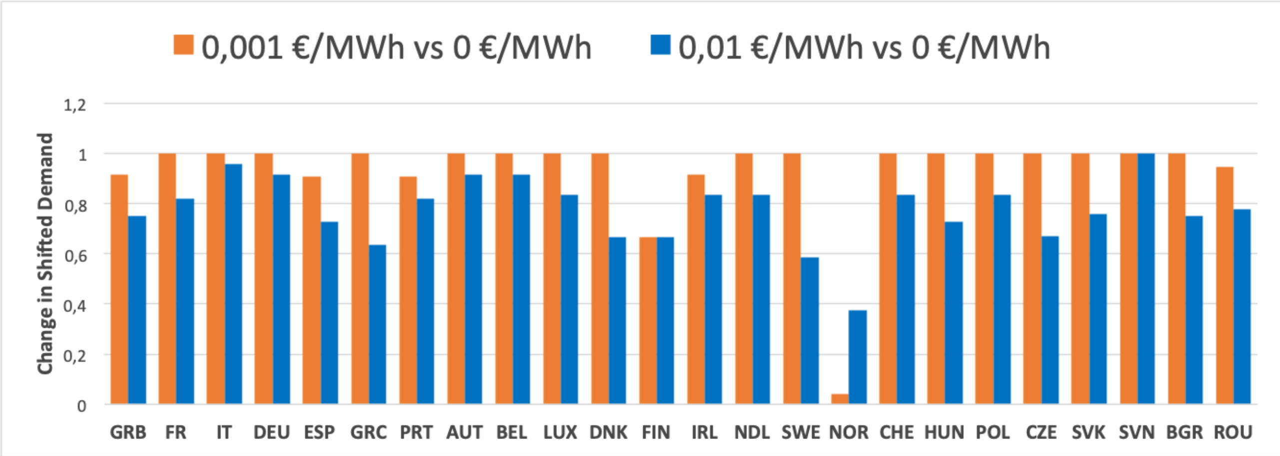

Figure 9: Change in Shifted demand if cost is changed for each European country in 2060.

Fig. 8 and Fig. 8 show the dependency of the shifted demand with the cost of the DR technology in 2030 and 2060 respectiveley. This graphs reflects the need for flexibility that a country has. In many countries, in 2030, the use of DR is very strongly reduced when cost increases. Whereas the same increase in cost do not trigger the same reduction in use in 2060. The increase of renewable installed power and the decrease of flexibility coming from dispatchable electricity production improves the economic model of DR.

3.3 The impact in the CO_2 emissions and variable electricity cost

We have seen that the use of DR will probably be very important with the development of variable renewable and the reduction of dispatchable fossil fueled productions, even when we assume up to 20% of the demand can be shifted one hour a day. Nevertheless, this one hour of use per day on a few % of the peak power means that DR has a relatively small impact in terms of total energy production. If we assume that all this energy is in fact a reduction in the peaks, which are typically provide by Coal or Gas technologies that have emissions of about 1 kgCO2/kWh and 0,3kg/kWh, the save in CO_2 emissions will always remain small in absolute value. It will also remain relatively small unless the mix is almost fully low carbon which would become the case when mixes with high shares of variable renewable should become the generic case.

From the economic perspective, the relative impact is also expected to be relatively small as DR is displacing a limited amount of energy. It tries to make better use of low marginal cost sources. In most of the cases, when normalized to global electricity production, the cost will remain low. But if you normalize by unit of energy displaced, then the value is much different, meaning that there will be a good economic potential for agregators. In some of the cases studied here we have seen values in the range of the value used in previous paragraph : 0,1$ per displaced kWh.

One key point is the cost structure of each country. Indeed, for countries with high share of low marginal costs sources, such as hydro and nuclear, who happens to be also low CO2 sources, if DR displaces these sources, its impact on cost and CO2 emissions may be small. But if it allows to reduce the remaining high marginal cost, high emission sources (e.g. fossils in high CO2 tax environment) then its economic impact will be much higher.

4 Conclusion

In this paper, we have used a dispatch model to assess the possible market of DR in Europe in a 2 degrees scenario. As expected, the need for DR is shown to increase with higher penetration of renewable and reduction of backup dispatch-able capacities between 2030 and 2060. We have seen that this increase may become very robust to pretty high cost of DR. We have found some other, more surprising, results related to the competition for flexibility :

- Competition with storage (PHES) is not total at least in one country. Maybe because of the rebound effect, the energy shifted by increased DR reduces only half of the energy that used to be shifted by storage.
- Some further studies must be done to understand why DR is not used to its full potential in some countries. Once again it is not clear what trigger that behaviour. The availability of hydropower, and then of cheap flexibility were not found to be conclusive arguments.

The diversity of behaviours observed in Europe is a reflection of the diversity of the electricity mixes. Further research is needed to understand competition with other flexibility options.

5 Acknowledgments

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