

EU Climate Policy and Electricity Market Design

Developing a Climate Change Lens to analyze and inform the EU debate on the reform of the Electricity Market Design



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I. Introduction

Concept & Methodology

This paper aims at creating a framework for analyzing the European Commission (EC) proposal on electricity market reform through the lens of Climate Change Policy and provide stakeholders with a tool for examining and analyzing the proposal.

To this end, ERCST developed a two-dimensional framework matrix, which includes the following:

- On the vertical axis are the issues or elements to be examined, Provisions in the EC proposal on Electricity Market Reform
- On the horizontal axis are different criteria, Desirable Outcomes wanted to be achieved; These can be climate related or not.
- This analysis consists of looking at how the elements of the vertical axis, in interaction with EU-ETS and other climate policies, impact (positively or negatively) on the Desirable Outcomes given on the horizontal axis.

Developing a climate change lens to examine the elements of the EC proposal and their impacts on the desirable outcomes, could be seen as having a three-dimensional matrix, which would include specific climate policies.

The first step of the analysis consists of looking at the interactions of the electricity market design elements with Climate Change Policies (particularly EU ETS and RED). The second step aims at analyzing how these interactions impact on the desirable outcomes.

The first section of this document will introduce and define the different constituent elements of the matrix. Will then follow the analytical part of the paper, in which the different interactions and impacts are described. The last section of this paper presents ERCST's framework and overall results, in the form of a qualitative impacts scoring matrix. Impacts are ranked using a +/- scoring system.

II. Elements of the Matrix: definitions

Desirable Outcomes

- ✓ What do we want the interaction between Climate Changes Policies and Electricity Market to achieve?
- **Short- and Long-term signals for decarbonization** : Ensuring Short-term/Long-term price signals for decarbonization provide incentives for actions and investments towards decarbonization ambition's targets.
- **Competitive advantage**: Ensuring EU industries remain internationally competitive to avoid industries leakage and a loss of industrial sovereignty in the new green technologies.
- **Affordability**: Ensuring all consumers can assess decarbonized energy at the moment of need, at a cost that does not expose them to the risk of serious negative consequences.
- **Security of Supply**: Ensuring the availability of energy at all times in various forms, in sufficient quantities, and at reasonable and/or affordable prices

Electricity Market Design Provisions

✓ What are the key elements of the EMD that interact with the EU Climate Policies?

- **Short-term Pricing Mechanisms:** includes the *marginal pricing system* and *market interventions*. The wholesale market in the EU is a system of marginal pricing, also known as pay-as-clear market. The EU put in place a set of emergency interventions to address the energy crisis. This paper looks at: inframarginal revenue cap, and tax on windfall profit.
- **Medium to Long-term Instruments:** include Power Purchase Agreements (PPAs), Contracts for Differences (CfDs), and Forward Markets, and Capacity Remuneration Mechanisms (CRMs)
- **Flexibility Options:** include Storage and Demand-Side Management

III. Analyzing the impacts of the EMD provisions on the Desirable Outcomes through the Climate Change Perspective

Short-term Pricing Mechanisms

✓ Marginal pricing – Pay-as Clear

One of the main characteristics of electricity is that it cannot be stored, or at least in an economically viable manner. Electricity production is therefore meant to be constantly adjusting to consumption, i.e electricity demand. The electric network must be continuously supplied and maintained with controlled frequency and voltage, so that the system is well balanced in real time. The liberalized wholesale market in the EU is a system of marginal pricing, also known as pay-as-clear market. The cost price depends on the plants marginal production cost, meaning the production cost (in euros/MWh) of one additional unit (including fuel, maintenance, and operational costs), independently of fixed costs (such as depreciation, rent, or salary costs). Variable renewable energies do not use fuel, so their marginal production costs include mainly the operational and maintenance costs. For the other technologies, their marginal production costs are mainly determined by the fuel costs (uranium, coal, lignite, oil, gas), potentially increased by their respective CO₂ emissions costs. Renewables and nuclear plants produce relatively cheap electricity, while fossil fuel-based plants have higher marginal production costs. This marginal unit production cost is then ranked from the lowest to the highest, thus classifying the plants based on the “order of merit”. Electricity demand is extremely variable but can be active. For instance, shift from expensive to cheap hours, meaning that active demand is also part of the order of merit. To cover electricity demand instantly and at all times, the market follows the merit order and privileges the most economical plants. During off-peak demand, the cheapest plants are dispatched until the demand is fully met. During peak demand fuel-based are being “called-in” to meet this higher demand or demand shifts/reduces. Electricity producers and active demand bid into the market and establish their price according to their marginal costs.

The main implication of this system is therefore that the electricity price is determined based on the last, and therefore most expensive offer required to meet the market demand at a certain point in time: This offer, which has the highest marginal costs sets the market clearing price. Once the demand is met, all market participants, mainly electricity generators, get the same price for the power they are selling in a given settlement period.

Interaction with Climate Policies (ETS)

The fossil fuel-based power plants have higher marginal production costs, partly due to the CO₂ price component. The more electricity producers emit CO₂, the more they must compensate for their carbon footprint by buying CO₂ certificates. The unit price of CO₂ certificate represents an element directly accounted for in the production costs for electricity producers. Increasing the marginal production costs, through the carbon price, shift the fossil fuel-based plants at the end of the merit order, reducing their chances of being needed to meet the electricity demand. In case fossil-fuel based plants remain in the merit order curve and set the electricity prices, their carbon costs contribute to increase revenues of all other electricity technologies.

Moreover, the implementation of a CO₂ price signal increases the variable production costs in order to reduce the competitiveness of the most CO₂ intensive plants in favor of the less CO₂ intensive plants, thus also potentially changing the dispatch order of the fossil-fuel based plants between themselves.

Impacts of interaction(s) on Desirable Outcomes

The EU ETS, in interaction with the marginal pricing system, provide a short-term signal for decarbonization: through marginal pricing, electricity producers are incentivized to bid at their true electricity production costs in order to stay in the merit order and get dispatched. To reduce their overall marginal production costs, and becoming more competitive in the merit order, electricity producers are incentivized to reduce the share of these variable costs attributed to carbon emissions, by switching between different generation sources as supply and demand needs change.

Through the marginal pricing system of the wholesale market, energy consumers are provided with clear signals about scarcity, giving them the ability to adjust their consumption in line with changing conditions. Recurrent peak prices provide incentives for efficient plants to push the expensive generators out of the market, thus reducing costs for consumers. The marginal pricing mechanism, with the EU ETS, therefore, provides short term signal for decarbonization (it delivers a cost-effective signal to use decarbonized energy sources in priority). In the long term however, this mechanism does not provide such signals: if the expensive generators are pushed out of the merit order, the market clearing price, then set by cheaper generators, will very likely not be high enough for the renewable and nuclear generators to be able to recover on their fixed costs. This may disincentivize investments for decarbonization in the power sector.

The marginal pricing system provide a competitive advantage to the EU industry under certain conditions, when electricity with low marginal costs is abundant and sufficient to meet demand contributes to and energy affordability and security of supply in that scenario. In the short-term, however, the affordability for consumers will depend on the balance between supply and demand for electricity and the marginal costs of the technology setting the marginal price. If such technology is a fossil-fuel plant, consumers will be exposed to high marginal costs (including carbon costs), regardless of the production costs of all other technologies.

✓ Market Interventions

Marginal pricing encourages the production of lower cost energy from renewable and low-carbon sources, which are remunerated for their electricity production at price levels set by costlier fossil fuels. In the long run, marginal pricing encourages Member States to work towards phasing out the costliest fossil fuels and to address problems of peak demand. However, in the current energy crisis, marginal pricing means that

wholesale electricity prices are largely set by the price of gas (although in some countries the marginal fuel source is coal). Gas prices have reached record levels in Europe, in large part due to the breakdown of energy relations between the EU and Russia. As a result, power sources whose costs are not affected by changes in gas prices such as wind, solar and nuclear – so-called inframarginal plants – have all seen their revenues rise significantly due to the higher prices. This electricity market model has exacerbated the energy crisis for consumers, paying far more for their electricity than is justified by the cost of production (especially in Member States where most electricity is generated by nuclear energy and/or renewable energy sources).

This situation has been framed as electricity producers extracting unreasonable profits, and consumers seeing their electricity bills skyrocketing.

Iberian exception

Spain and Portugal established an exceptional and temporary mechanism to adjust electricity production costs which impacts on the generation of the electricity market price for the wholesale reference market of the Iberian Electricity Market (MIBEL)¹. This intervention targets the marginal plants: a cap is placed on the price that gas-fired plants bid into the market, tagging the price for power offered by these generators to a below-market price for gas. Generators are then compensated for the difference between the level of the cap and the natural gas price they face in the spot market (MIBGAS, virtual balancing point). This temporary measure aims at ensuring gas generators submit lower bids into the power market, thus depressing prices. This measure is partially decoupling gas and electricity prices: gas remains in the merit order and usually, sets the final electricity price, however, at lower levels than the full gas price.

On one hand, this model suits the specifics of the Spanish market as a relatively high proportion of domestic consumers are on short-term contracts and thus highly exposed to market volatility. A downside of this idea is that it distorts the price signal for consumers and, in the absence of other measures, leads to increased gas consumption.

At the European level, the Council agreed an urgent regulation², setting different temporary mechanisms to address high energy prices in the EU.

Inframarginal Revenue Cap

The Council regulation introduced a temporary revenue cap on 'inframarginal' electricity producers. Excess revenue is then collected by Member State governments and used to help energy consumers reduce their bills.

Interaction with Climate Policies

The regulation, however, does not provide a common and harmonized European approach for implementing the inframarginal revenue cap. While this allows Member States (MS) to design the implementation of the cap in a way that best fits their national priorities, the non-harmonization of implementation across Europe impacts on the level playing field. Moreover, the level of the cap and the duration of this intervention could have a strong impact on the decarbonization objectives.

¹ Iberian mechanism, Decree-Law no. 33/2022 of 14th May 2022 ; [https://www.dgeg.gov.pt/en/statistics/energy-statistics/iberian-mechanism/#::~:~:text=Decree%2DLaw%20no.,Iberian%20Electricity%20Market%20\(MIBEL\).](https://www.dgeg.gov.pt/en/statistics/energy-statistics/iberian-mechanism/#::~:~:text=Decree%2DLaw%20no.,Iberian%20Electricity%20Market%20(MIBEL).)

² Emergency intervention to address high energy prices in the EU; [https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733687/EPRS_BRI\(2022\)733687_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/733687/EPRS_BRI(2022)733687_EN.pdf)

Tax on windfall profits

Fossil fuel producers have benefited considerably from the sharp rise in wholesale prices over the course of 2022, leading to windfall profits that are not justified by any exceptional levels of investment. In the European Union, a temporary windfall tax (solidarity contribution) was approved in September to curb fossil fuel companies' excess profits made in 2022 and/or 2023.

Interaction(s) with Climate Policies (RED)

Taxing the windfall profits of fossil fuel producers may disincentivize them from investing in renewables, hampering the efforts for the development of renewable energy across all sectors of the EU economy.

Impacts of interaction(s) on Desirable Outcomes

These mechanisms have been implemented to address the shortcomings of the marginal pricing system in a situation of crisis. These shortcomings have resulted in some inframarginal producers extracting unreasonable profits, and consumers seeing their electricity bills skyrocketing. In this context and given that these mechanisms remain as short-term emergency intervention, they should be addressing the issues they have been designed for, allowing for the EU industry to maintain their competitive advantage, and ensuring electricity affordability for all consumers. However, the magnitude and extent of their impact on affordability and competitive advantage depends on how those revenues are redistributed to energy consumers: general principles of such redistribution are set in state aid rules and depends on national decisions.

However, these interventions have, by nature, a distortive effect on the marginal pricing system, which consequently does no longer provide short-term signals for decarbonization. Some renewable generators have fixed long-term off-take contracts in place but some of them remain exposed to wholesale price swings. Emergency interventions create policy uncertainty, not only on energy policies, but also on climate policies, given their close interactions. In general terms, situations in which policy uncertainty is high may result in investments being postponed until a clear and stable market environment has been reached, thus impacting the decarbonization targets negatively.

Medium to Long-term Instruments

To improve price stability and predictability and make the EU industry more competitive, the short-term market must be complemented with better functioning long-term pricing mechanisms in a way that supports low carbon technologies and renewables, such as green Power Purchase Agreements (PPAs), Contracts for Difference (CfDs) for low carbon technologies and more liquid forward markets.

✓ Power Purchase Agreements (PPAs)

PPAs are bilateral commercial contracts between an electricity consumer (supplier or industrial consumer) and a generator (typically renewable or low carbon). PPAs usually last anywhere between 5 and 20 years, during which the generator agrees to sell energy (directly) to the consumer at a certain and pre-defined price.'

Interaction(s) with Climate Policies (ETS)

ETS is a cap-and-trade system which brings additional costs to carbon-based energy production. As previously explained, the EU wholesale marginal pricing mechanism ranks the various electricity generation sources in a merit order based on their production costs. As previously mentioned, the CO2 price, embedded in the production costs of fossil fuel-based generation plants shift them toward the end of the merit order curve.

The EU ETS mechanism interacts with PPAs on both the seller and buyer sides. On the electricity generators side (PPA's seller), PPAs incentivize the decarbonization of the energy mix in the long run. Given that the power sector is covered by the EU ETS, the increasing amount of RE power generated reduces the power sector's CO2 emissions, which in turn reduces to some extent the overall volume of carbon emissions included in the EU ETS, therefore reducing the demand for CO2 emissions allocation. On the other hand, ETS also interacts with PPAs on the buyer side, in this case industrial players. Once industrial consumers enter PPAs with renewable energy producers, industrial consumers can guarantee the reduction of their direct and/or indirect carbon emissions related to electricity.

Targets of CO2 emissions in industry and the energy sector are predefined at EU level. This cap defines the total amount of GHG emissions that EU ETS sub-installations are allowed to emit. If they emit over a pre-defined threshold, they will have to pay heavy fines. The cap is continuously reducing over time according to the fixed number of certificates auctioned (volume of EUAs) annually. In case that a compliant entity (i.e., steel plant, production of steel is covered by the EU ETS), is entering into a green PPA with a renewables-based power producer i.e., wind plant, this entity guarantees that it is consuming decarbonized electricity and reducing its emissions related to electricity consumption. If ETS compliant entities emit less than what they need according to this cap, they will have a surplus of EUAs. In this case, the compliant entity, making use of the PPA, thus reducing its carbon intensity, will have an opportunity to sell this surplus of allowances in the carbon market to other compliant entities.

Impacts of interaction(s) on Desirable Outcomes

Overall, PPAs are creating a win-win situation for the parties of the contract:

- **Fostering renewables and low-carbon investment through long-term price visibility/stability for electricity generators, and,**
- **Providing clarity and long-term hedging opportunity to reduce risk of price volatility for consumers or suppliers.**

PPAs, together with EU ETS, may provide end consumers with a competitive advantage giving them access to more predictable and stable electricity costs depending on the overall market design and the interaction between short- and long-term markets.

Interaction(s) with Climate Policies (RePowerEU, RED, Hydrogen Strategy)

The EU's hydrogen strategy and REPowerEU plan have put forward a comprehensive framework to support the uptake of renewable and low-carbon hydrogen to fast forward the green transition and reduce its dependence on imported fossil fuels.

The REPowerEU plan³ assigns an important role to hydrogen in freeing the EU from its dependency on fossil fuels from Russia. To achieve this goal, the plan envisages producing 10 million tons of renewable hydrogen within the EU and importing the same amount into the EU by 2030.

The EC⁴ also estimates that around 500 TWh of renewable electricity is needed to meet the 2030 production's target, which equals which represents more than half of the renewable power generation in the EU in 2020 (905,76 TWh)⁵. The 10Mt ambition in 2030 corresponds to 14% of total EU electricity consumption. This ambition is reflected in the Commission proposal for the EU's 2030 renewable energy target to be set at 45%.

The RED, currently under a revision process, provides a binding mandate for determining what proportion of the hydrogen used must be renewable for the EU industry and the transport sector by 2030.

Given that Hydrogen is not itself a source of renewable energy but an energy carrier, the hydrogen produced with electrolyzers can only be considered renewable if it is produced from renewable electricity generation. Moreover, in order to avoid the risk of increased fossil fuel power generation, the electricity demand for producing hydrogen must be matched with additional renewable energy. The concept of additionality guarantees that any hydrogen that is produced from electricity is produced from additional renewable electricity, i.e., from newly built renewable power generation capacity which would not have existed if not for the production of hydrogen.

Two Delegated Acts⁶, as required under the Article 27(3) of the Renewable Energy Directive (2018/2001), define what constitutes renewable hydrogen for the EU. The first Delegated Act sets out the requirements criteria to qualify electricity to produce hydrogen as renewables. These criteria are the following: additionality, temporal and geographical correlation, and PPAs.

The overall regulation therefore gives both a binding target for the EU industry and transports sectors, as well as detailed criteria to be applied in order to reach this target. Overall, this is a strong incentive for the development and uptake of renewables through the establishment of PPAs, providing a long-term signal for decarbonization. This will increase the volume of PPAs on the market. PPAs for hydrogen production will impact positively the supply side of renewables, however the impact on the competitiveness of the EU industry, the demand side remains unclear: if the criteria are too strict, this could translate into high priced of RE hydrogen.

✓ Contracts for Differences (CfDs)

Two-way Contracts for Difference (CfDs) are similar to a reverse auction system. They are designed to give investors the confidence and certainty they need to invest in low-carbon power generation. CfDs work by

³ REPowerEU Plan, May 2022. https://eur-lex.europa.eu/resource.html?uri=cellar:fc930f14-d7ae-11ec-a95f-01aa75ed71a1.0001.02/DOC_1&format=PDF

⁴ Q&A on the EU Delegated Acts on Renewable Hydrogen, Feb 2023.

https://ec.europa.eu/commission/presscorner/detail/en/ganda_23_595

⁵ Hydrogen: The imports dimension of REPowerEU, ERCST, Feb 2023. <https://ercst.org/hydrogen-the-imports-dimension-of-repowereu/>

⁶ Delegated regulation on Union methodology for RFNBOS, Feb 2023, https://energy.ec.europa.eu/delegated-regulation-union-methodology-rfnbos_en

Delegated regulation for a minimum threshold for GHG savings of recycled carbon fuels and annex, Feb 2023, https://energy.ec.europa.eu/delegated-regulation-minimum-threshold-ghg-savings-recycled-carbon-fuels-and-annex_en

setting the prices received by low-carbon generation, reducing the risks they face, and ensuring that qualifying technology receives a price for the electricity produced that supports the investment. CfDs also reduce costs by setting the price consumers pay for low-carbon electricity. This forces generators to repay money when wholesale electricity prices are higher than the strike price and provides them financial support when wholesale electricity prices are lower.

Interaction(s) with Climate Policies (ETS)

This section shows some of the comparison between CfDs and electricity market and cCfDs

CCfDs have also been considered as means to de-risking projects by “hedging” against volatile EU-ETS prices and providing long-term stability for investments.

However, CCfDs have some of their inherent limitations in addressing volatility of electricity prices.

CCfDs primarily offset the difference between the market price for emissions allowances and the carbon avoidance cost. In doing so, CCfDs only address the carbon revenue stream, without hedging against other important revenue streams for electricity generation such as input prices to produce electricity.

Despite of this, CCfDs should be viewed positively as an instrument to foster industrial decarbonization for industries or sectors where the cost of carbon represents one of the main risks to be hedged. CCfDs could also be a useful tool in the absence of a clear reference price as the EU-ETS price could be used as a reference across different industries.

It should be noted that the impact that such an instrument may have on the EU-ETS is unclear and insufficiently analyzed, which should serve as a caveat against rushed implementation. Some of these include:

i) Reducing efficiency and liquidity of the EU ETS market.

Industrial market participants benefiting from CCfDs would have a reduced need for acting/hedging on the secondary carbon market, leading to reduced liquidity and thus less efficient price formation.

ii) Surplus of EU allowances and weakening of the EU-ETS price.

Supported projects will lead to emission savings and thus to a surplus of EUA. While emissions may decrease at project level, the overall cap will not. Instead, this will lead to freeing up EUAs, which will then be bought and used by other emitters in Europe. It is still unclear what the treatment of these allowances would be.

iii) Interaction with free allowances.

It is still unclear how such an instrument will interact with the granting of free allowances. If free allowances are not factored in the strike price, there may be a risk of overcompensation.

✓ Forward Markets

Similarly, to PPAs, forward contracts are based on bilateral electricity trade between producers and customers of electricity at an agreed price for the future physical delivery. Forward markets provide generators with a stable revenue path and consumers with predictable electricity costs. Liquidity plays an important role in capability of forward markets to foster long term decarbonization targets as well as the hedging period beyond 3-year a-head timeframe.

Forward markets in the EU have not functioned well and faced several shortcomings i.e., lack of liquidity, accessibility, competition, and transparency⁷. Improved liquidity within the market and longer hedging periods will impact long term decarbonization signals positively by providing longer term opportunity to renewable investors hedging their risks against future price changes or volatility.

For encouraging renewables investments, lowering the risks, and guaranteeing the return on investments in a specific period is critical. Financial institutions are more likely to offer investments opportunity to stable businesses. Forward markets are enabling the investors to reach financial resources required to decide on renewables investments and entering the market. This is also valid for the consumer side. One of the parties to forward contracts is the consumers. Once the consumers guarantee a lower and/or fixed cost of electricity, then financing the investments in low carbon technologies would be easier on the consumer side.

Impacts on Desirable Outcomes

Overall, long-term instruments, such as PPAs and CfDs, and enhanced forward markets offer the opportunity to de-risk the investments through long term revenue stability and hedge final customers against price volatility. In this sense, they provide long-term signals for decarbonization, through incentivizing the necessary investment in renewables and low carbon capacity. Those mechanisms must be well designed and used in a balanced and proportionate way to maintain competition, encourage market liquidity, and deliver the right long-term investment signals.

Capacity Remuneration Mechanisms (CRMs)

In a market environment, the financial sustainability of power plants should not be considered an objective. However, the existence of available capacity to enable security of supply shall be ensured through instruments additional to the market (i.e., reliability options).

Capacity mechanisms are defined under the EU regulation on the internal market for electricity⁸ as “a temporary measure to ensure the achievement of the necessary level of resource adequacy by remunerating resources for their availability”. The regulation also specifies that the national implementation of these mechanisms must be implemented and in the same regulation, it is required by Member States to implement these mechanisms in a way that avoids market distortions.

There is no common framework for implementing capacity remuneration mechanisms and their features of the schemes across the EU: while some Member States are implementing quantity-based schemes⁹ i.e., capacity obligations or capacity auctions, others are applying price-based schemes¹⁰ like strategic reserves or capacity payments.

⁷ ACER, Policy Paper on the Further Development of the EU Electricity Forward Market, Feb 2023.

[Electricity Forward Market PolicyPaper.pdf \(europa.eu\)](#)

⁸ [Article 2, point \(22\), of Regulation \(EU\) 2019/943; EUR-Lex - 32019R0943 - EN - EUR-Lex \(europa.eu\)](#)

⁹ The required volume of generation or flexibility to be supported is determined by a central agency i.e., TSO.

¹⁰ The price (the amount of support) is determined by a central agency i.e., the regulator or the TSO.

Interaction(s) with Climate Policies (ETS, RED)

Most of the fossil-based producers, which were traditionally dispatched through the system as base load units, have reduced their hours of operation, and started to function as peak power plants, because of the increasing share of RES production. The marginal pricing system in the electricity spot market, together with EU-ETS, have significantly reduced the hours of fossil fuel plants operation due to the priority dispatch of RES. So, the presence of fossil-based plants in the market is not ensured in decarbonized energy market. Moreover, the flexibility provided by flexible thermal units (e.g., combined cycle gas turbines) has been significantly decreasing. Instead of those fossil-based balancing providers, reliability can be ensured by rewarding new flexibility technologies best suited to provide it (DSR, batteries etc.). To further decarbonize the energy mix, more flexibility shall be guaranteed, and capacity remuneration mechanisms shall be used as effective tools for providing incentives for DSM and storage.

CRMs in Europe generally distinguish between 2–3-year time horizons. Longer time frames might contribute to the development of business cases for storage or DSM and enable those to enter and compete in the market.

The success of CRMs is also linked to the better functioning of long-term markets (forward market) and/or instruments (long-term contracts).

Impacts on Desirable Outcomes

By providing additional revenues to new flexibility sources, CRMs support the power system when intermittent sources cease to generate. CRMs therefore contribute to medium term signals for decarbonization. Competitive market-based approaches for capacity remuneration mechanisms are likely to better provide long term investment signals for decarbonization.

Flexibility Options

✓ Flexibility Options (Demand Side Management and Storage)

The adequacy of a power system refers to its capability and/or capacity to meet demand at all time scales. Additional to the balance between the demand and the supply, power systems have a third element, the network. The adequacy of the transmission network must be ensured to maintain timely delivery of the energy to the final consumers.

Flexibility adequacy, on the other hand, corresponds to the ability of a power system to respond to unforeseen generation and/or consumption changes in real-time operation. In carbon-neutral electricity markets, the need for flexibility adequacy has been increasing with the replacement of the conventional fossil fuel-based generators with more variable and non-controllable renewable sources. Therefore, traditional balancing sources (thermal power units) also need to be replaced with new non-fossil flexibility options such as storage units, demand side management assets, while hydropower will remain a key resource of flexibility. Nuclear power plants which are traditionally operated as ‘must run’ generation units, are also providing flexibility in some countries (in France for instance).

Interaction(s) with Climate Policies (ETS)

EU ETS sub-installations can buy CO₂ permits in the EU ETS to compensate for their emission footprint. The less CO₂ the EU ETS installations emit, the less certificates these sub-installations need to buy. Then, investment in low carbon technologies and storage of energy incentivizes EU ETS installations to reduce their footprint. The Innovation Fund also incentivizes the development of low carbon and storage technologies through specific calls to innovative projects.

Interaction(s) with Climate Policies (RED)

Storage

Renewable capacity is weather dependent and variable throughout the day and across seasons. Therefore, these power plants can only produce energy when wind or solar power are available at a given moment. However, this availability or the amount of production cannot be accurately forecasted. The closer to real time we get, the more accurate the production forecasts are. This feature of variable sources makes them non-dispatchable unless they are coupled with flexibility assets i.e., storage systems. Storage systems are crucial elements of decarbonized electricity markets. They enable balancing of the supply and demand, storing excess renewable generation in times of low demand and feeding back into the grid in times of higher demand and less renewable generation). The volume of storage highly depends nevertheless on the transmission network that allows to share RES at the level of the European continent.

DSM

Traditional energy systems were designed and operated on the principle that “*the generation follows the consumption*”. However, in today’s power market, this approach has been complemented with “*the consumption follows the generation*”.

In decarbonized energy systems, the market is expected to produce signals for consumers to shift their consumptions, either from peak hours to off peak hours and/or from the hours with low renewable based electricity generation to the hours with higher share of renewable based electricity generation.

With the growing share of intermittent RES, the part of the demand, which is flexible, which means that can be shifted, must also be activated as much as possible in the respect of the choice of consumers which must remain at the center of the sustainable transition.

DSM helps the electricity demand to be met at a lower price by reducing the peak demand and supports the phasing out of fossil fuel-based power plants from the merit order.

Impacts of interaction(s) on Desirable Outcomes

Diversifying the decarbonized flexibility options in addition to hydropower and nuclear and increasing the available flexible capacity through new solutions i.e., storage systems, demand side flexibility assets etc., will enable the system to provide efficient short-term signals to dispatch the cleanest plants.

Activation of flexibility by supply prices or access of consumers to wholesale electricity markets to trade their flexible capacity or energy, increases the liquidity of market and helps to reduce the price volatility. Taking advantage of their consumption flexibility, all consumers could make additional profit by adjusting their demand due to system signals.

Together with RED, DSM supports the switching of traditional consumers to flexible consumers i.e., prosumers who can produce and/or store the part of their electricity needs. This can be achieved

through the investments on behind the meter flexibility assets i.e., storage units, electrical heating, etc. Enhanced flexibility on the consumer side facilitates renewables integration into the power system, by improving its capacity of absorbing unexpected disturbances and/or variabilities. DSM and storage provide long term signals for decarbonization.

iv) Framework Matrix – Overall Results

<i>Desirable Outcomes</i> <i>EMD Provisions</i>	A. Short-term signals for decarbonization	B. Long-term signals for decarbonization	C. Competitiveness	D. Affordability	E. Security of Supply
1. Short-term Pricing Mechanisms					
1. i) Marginal Pricing					
Marginal Pricing Mechanism	+	-	0	0	+
1. ii) Market Interventions					
Iberian Exception	-	-	+	+	0
Inframarginal Revenue Cap	-	-	+	+	0
Windfall Profit Tax	0	-	+	+	0
2. Medium to Long-term Instruments					
PPAs, CFDs, Forward Markets	0	+	+	+	+
Capacity Remuneration Mechanisms	+	+	+	+	+
3. Flexibility Options					
Flexibility Options (Storage and Demand Side Management)	+	+	+	+	+