STUDY ON FLEXIBILITY VALUATION MECHANISMS FOR THE MANAGEMENT OF PUBLIC ELECTRICAL DISTRIBUTION GRIDS IN FRANCE

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Study commissioned by the CRE – Regulatory Commission of Energy

E-CUBE STRATEGY CONSULTANTS

SUMMARY

French electrical distribution grids face a surge in electrical connections of renewable power generation units[1] and a long-term trend of a rise in peak demand. These phenomena are likely to increase the physical constraints on the infrastructure and thereby the need for network reinforcement[2].

In parallel, distribution system operators are offered new and alternative options to network reinforcement thanks to the decreasing costs of some technologies, and the development of decentralized flexibility capacity[3] (which is boosted by mechanisms already in place for supply-demand balancing and for the management of constraints on the transmission network).

In 2016[4], a study commissioned by CRE[5] on fifteen illustrative cases of local network constraints aimed at quantifying the potential net unit value of flexibility for the distribution grid and describing the economic rationale for valuation. This theoretical study showed that in some cases, flexibility could have a positive net value for the management of distribution grids.

The aim of the present study is:

- To complement and to take further the analysis carried out in the previous study, in order to assess the value of flexibility for public electrical distribution grids in continental France;
- To analyze various mechanisms for flexibility use and valuation on a local scale;
- To study the way to coordinate local flexibility services with the existing national mechanisms and the possible windfalls of those services.

Phase 1: Assessment of the value of flexibility for public electrical distribution grids in continental France

The first step of the study consists in estimating the economic potential of flexibility for the management of public electrical distribution grids in continental France. There are two ways that local flexibility creates economic value:

- By temporarily relieving constraints on a piece of hardware, or even postponing or avoiding reinforcement (**value for planning: deferral or avoidance of investment**);
- By enabling to reconnect customers faster after an outage, or reducing outages due to work on the grid or incidents (**value for operation: reduced cost of unserved energy**).

These sources of value were assessed by analyzing five configurations[6], four of which have value for planning, whereas the last one has value for operation. Each configuration is defined by a type of constraint to address, a piece of network hardware, and a type of flexibility need[7, 8]:

[1] More and more renewable energy power generation units are connected to the distribution grid.
[2] Investment in hardware to increase the injection or withdrawal capacity of the network, in the present case high / medium voltage transformers (63kV – 15/20kV), and medium / low voltage transformers (15/20 kV – 400V).
[3] In this study, flexibility is defined as a temporary increase or decrease of the amount of energy exchanged with the grid, which is dispatched in real time (automatically or manually) based on the needs of grid operators and to local variables.
[4] *Etude sur la valeur des flexibilités pour la gestion et le dimensionnement des réseaux de distribution*, CRE, January 2016.
[5] French Energy Regulator (*Commission de Régulation de l'Energie*).
[6] A configuration is defined as the combination of a cause for the constraint (injection or withdrawal) and an impacted piece of hardware (transformer, grid…). In each configuration, a method was defined to assess the local value of flexibility.
[7] The study was not extended to hardware located on the low-voltage network (below medium/low voltage transformers), mainly for two reasons: because aggregated generation and consumption values are more volatile, the ability to predict, anticipate and study constraints is still limited to date; there is little data available.
[8] The configuration where withdrawal from the medium voltage grid is constrained is not presented in this study. Indeed, according to DSOs, such occurrences are very rare under normal circumstances, and they are difficult to

- Injection constraints on high/medium voltage transformers;
- Withdrawal constraints on high/medium voltage transformers;
- Injection constraints on the medium-voltage grid;
- Injection and withdrawal constraints on medium/low voltage transformers;
- Outages due to work on the grid or incidents.

1 At the scale of continental France, the annual gross[9] value of flexibility for the distribution grid lies between 20 and 60 M€/year. After removing flexibility costs, the net value[10] lies between 11 and 18 M€/year.

These estimates are for the medium run (2020 or 2030, depending on cases) for continental France.

2 The gross value of flexibility is positive in all five configurations; the net value (once flexibility costs are removed) is positive in only four, whereas is it is negative in the configuration with medium / low voltage transformers, which is cast aside.

The **net value is close to zero** in the configuration **with medium / low voltage transformers**. For flexibility services to be profitable in this configuration would require specific conditions: high cost of hardware reinforcement, less than three sites offering flexibility, flexibility used for several years. These requirements stem from the small size and low cost of hardware in this configuration (a few thousand euros), which limit the possibility for flexibility to be a cheaper alternative. Therefore, this configuration is cast aside for the time being. In the long run, technology breakthroughs may improve its economics, especially through cheaper flexibility instrumentation and controls.

Analyzed configurations	Gross value	Net value	Occurrences	Level of interest for flexibility
1 Injection constraints on high/medium voltage transformers	5-10 M€/yr	1-3 M€/yr	15-30 occ./yr	• Significant net value • Limited number of local cases • Priority configuration for the implementation of a market design
2 Withdrawal constraints on high/medium voltage transformers	0 à 18 M€/yr *Middle hypothesis at 8M€/yr* →	1,5-4 M€/yr	~15 occ./yr	• Net value subject to high uncertainty • High unit value • Need to assess the maturity of flexibility on other cases before going into this configuration
3 Injection constraints on medium-voltage network	> 5M€/yr (2030 outlook)	~5 M€/yr (2030 outlook)	~15 à 20 occ./yr (2030 outlook)	• Significant net value • Limited number of local cases • Priority field for the implementation of a market design
4 Constraints on medium/low voltage transformers	9-20 M€/an *(maximum)*	~0 M€/yr →Positive value only under specific conditions	Potential of ~2000 occ./yr →Unknown portion of cases with positive net value	• Close to zero net value • Profitability subject to specific conditions • High number of cases • Least priority configuration
5 Outages due to: Incidents	~3M€/yr	~3M€/yr	~1000 occ./yr	• High total net value but low unit value because of the high number of cases • Opportunistic approach could be developed • Way to experiment on cases with low unit value with lower risk than if differing investment
5 Outages due to: Work on the grid	1-5 M€/yr	1-3 M€/yr	2000–6000 occ./yr	

Figure 1 – Gross and net values of flexibility for the management of electrical distribution grids on the five analyzed configurations

anticipate under degraded circumstances (because there are a large number of possible incidents), while sources of flexibility are useful only if in the right location on the grid.

[9] Gross value is the benefit from using flexibility, either through postponement or avoidance of investment, or through faster reconnection after outages or lower probability of occurrence of outages

[10] Net value is the difference between the gross value of flexibility and the cost of flexibility

3 **For each of the four selected configurations, the net value ranges from 1 to 5 M€/year. Well-located sources of flexibility could be used several dozen times per year, except for the configuration with value for operation (in case of outage) which could occur up to several thousand times per year, making the unit value very low[11].**

Using flexibility to address **injection constraints on high/medium voltage transformers** or on the **medium-voltage grid** could create significant net value (**1 to 3 M€/year** for high/medium voltage transformers, about **5 M€/year** for the medium-voltage grid) with a limited number of occurrences (~15 to 30 per year for each type of hardware). Flexibility is most easily implemented in these configurations because flexibility is available (since it is also the cause of the constraint) and the impact on stakeholders is limited (no change needed in the way energy is used). The implementation is essentially limited to compensating producers for the amount of energy they could not inject. These configurations hold the most promise for the definition and implementation of rules to promote the use of flexibility.

The net value of the configuration with **withdrawal constraints on high / medium voltage transformers** lies from **1.5 to 4 M€/year**. Both the gross and net value are subject to high uncertainties, because they depend on the location of constraints and sources of flexibility. Withdrawal constraints are more complex to address than injection constraints because they appear mainly when the grid is not fully operational. However, it could be interesting to implement a market design for flexibility for this configuration because of the low number of occurrences with a possibly high unit value (tens of thousands of euros per case).

The net value of the configuration with **outages due to work on the grid or incidents** lies between **4 and 6 M€/year**. The number of occurrences is higher than for the other configurations (it is in the thousands), but the unit value is low, which the framework for use and valuation of flexibility will have to take into account. This framework is likely to be based on an opportunistic approach, with DSOs occasionally using existing sources of flexibility which were developed for and are used on other mechanisms providing better visibility for developers. DSOs could use flexibility for grid operation rather than for planning to experiment on cases with lower unit value, because the costs and possible consequences of a pilot will be more limited in case of failure.

Phase 2: Mechanisms for the use and valuation of flexibility on a local scale

The following nine mechanisms for the use and valuation of flexibility were investigated. They define possible terms of agreement between flexibility providers and distribution system operators.

[11] Furthermore, this configuration requires appropriately located sources of flexibility.

INJECTION CONSTRAINT

Smart grid connection solutions – *injection*

Alternative grid connection solution including an option for the DSO to restrict injection during a set number of hours per year in exchange for lower grid connection costs

Alternative ratio in the S3REnR

Lower (or even negative) ratio of costs to be borne in the framework of the S3REnR, in exchange for flexibility services

WITHDRAWAL CONSTRAINT

Smart grid connection solutions – *withdrawal*

Alternative grid connection solution including an option for the DSO to activate the flexibility during a set number of hours per year in exchange for lower grid connection costs

"TURPE pointe mobile" (Critical Peak Pricing)

Price signal activated by the DSO, according to terms defined in the "TURPE pointe mobile" tariff (frequency, duration, location)

Direct contracting of flexibility by the DSO

DSO contracts flexibility from the market. Various patterns are possible: tender, competitive dialogue, call for expression of interest

Opportunistic use of flexibility by the DSO ("DSO option")

Call for existing flexibility to participate in network management, without commitment.

Regulated feed-in tariff for flexibility

Regulated (and flat) feed-in tariffs to remunerate flexibility for as long as it is activated

Local intraday or day-ahead market

Equivalent to a balancing mechanism on a local scale

Investment and management by the DSO

Figure 2 – Mechanisms for the use and valuation of flexibility to address injection and withdrawal constraints[12]

These mechanisms have been assessed and ranked using criteria of techno-economic and operational efficiency[13].

4 The focus should be on the four mechanisms that came out ahead of the assessment: "smart grid connection solutions" for injection, "alternative ratio" in the S3REnR, "direct contracting" of flexibility, and the "DSO option" to use existing flexibility in an opportunistic way. These mechanisms cover all the positive-value configurations.

The **smart grid connection solutions, for injection constraints**, are currently being reviewed by French DSOs. They use an existing framework (technical and financial proposal, connection contract) and act directly on the root of the constraints (i.e newly connected power generation units). However, the scope of this mechanism is limited[14] to injection constraints caused by new connections[15] on the medium-voltage grid.

The **alternative ratio in the S3REnR**[16] is complementary to smart grid connection solutions. It relies on already existing S3REnR (that would need to be updated to make them compliant with this mechanism) and offers future sources of flexibility a possibility to be used for injection constraints on high / medium voltage transformers.

The **direct contracting of flexibility by the DSO** enables all sources of flexibility to compete, whether or not they are newly connected, and whatever the technology. This mechanism is more complex than

[12] TURPE: Tariff of public electrical grids (*Tarif d'Utilisation des Réseaux Publics d'Electricité*); S3REnR: local framework for the connection of renewable power to electrical grids (*Schémas Régionaux de Raccordement au Réseau des Énergies Renouvelables*).
[13] Criteria: large techno-economic flexibility potential, low transaction costs, visibility for stakeholders, control of the risk of failure, ease of implementation, controllability, compliance and impartiality of mechanisms. All are further down in this document.
[14] Sources of flexibility designed to relieve constraints on high / medium voltage transformers cannot participate in this mechanism because they are already dealt with in the framework of the S3REnR. Already-connected sources of flexibility cannot participate either, because this mechanism requires a new connection contract with the DSO.
[15] Sources of flexibility with a new connection contract.
[16] The aim of the S3REnR is to program the grid reinforcements required to connect renewable power sources and to split the cost of these reinforcements between all newly-connected power sources using locally defined ratios.

the previous two because it requires the DSO to run an analysis and issue specifications, to interact with flexibility providers, and to more tightly monitor and verify the offered flexibility (for withdrawal constraints). Hence, this mechanism should be earmarked for cases and areas with high unit values and where it is relevant to introduce competition (i.e supply must sufficient). This makes it suitable mainly for constraints on high / medium voltage transformers.

The **opportunistic use of flexibility by the DSO (« DSO option »)**, is appropriate for the purpose of handling grid operation in an agile manner under unforeseen circumstances. This mechanism consists in activating existing flexibility sources, without any commitment from flexibility providers to offer flexibility nor from DSOs to call on it. It is easy to implement, and does not generate any risk for stakeholders. However, it is strictly limited to grid operation, because DSOs do not have any guarantee regarding the availability of flexibility, which is the trade-off for agility.

These four mechanisms cover all the previously identified positive-value configurations:

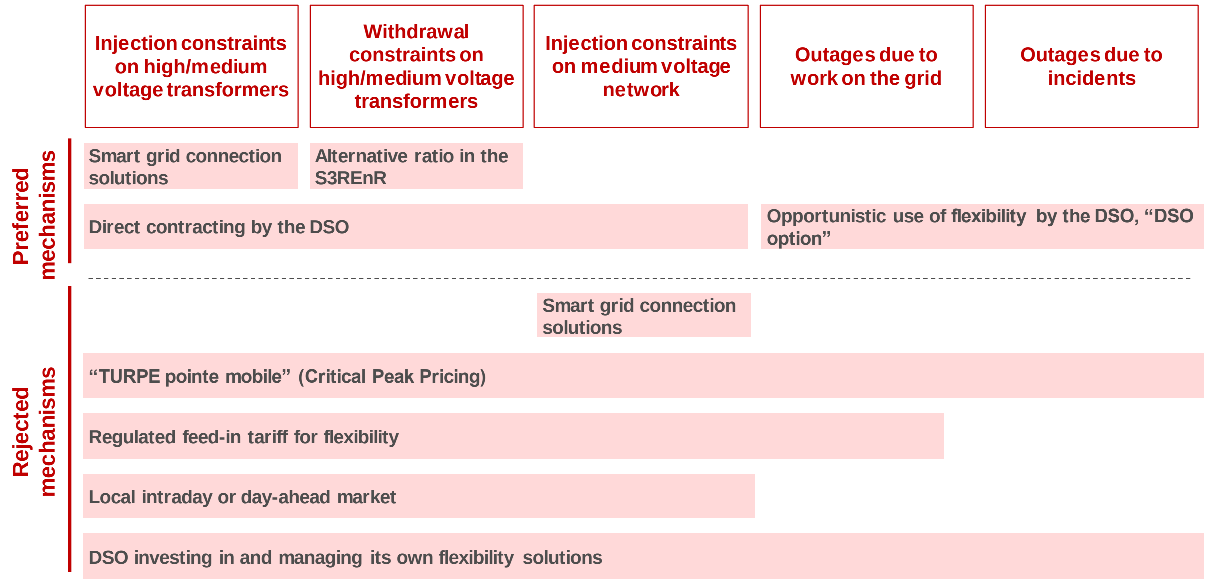

Figure 3 – Mechanisms for flexibility use and valuation on a local scale

5 **The other five mechanisms have been rejected for several reasons: complexity of implementation, low efficiency or incompatibility with the position of DSO.**

The **“TURPE pointe mobile” (Critical Peak Pricing)** mechanism would create locally inefficient situations, by triggering a system-wide price signal impacting thousands of devices on the grid for the purpose of using flexibility only in a few dozen cases per year. Besides, without significant practical feedback, the visibility and commitment of participants are too weak for the DSO to defer investments.

The **smart grid connection solutions** are not suitable for withdrawal constraints: withdrawal units differ from injection units regarding load profiles, constraints and variability over time. Indeed, there can be a wide and non-constant gap between actual maximum withdrawal capacity and the contracted capacity. Besides, this mechanism would not be compatible with the position of DSO, because it could be considered a way for the DSO to enter the competitive curtailment market.

A **regulated feed-in tariff for flexibility** would be complex to implement because as an open-ended subsidy, it would not provide enough visibility on flexibility volumes for the DSO to assess the value of flexibility.

A **local intraday or day-ahead market** would be cumbersome and would not offer enough visibility to stakeholders. The development of efficient tools could make it possible in the medium run, provided that they almost completely automate the process (as with smart contracts[17]).

[17] Contracts between two entities allowing for digital, decentralized, automated and controlled transactions, without any third party in the process.

Allowing the DSO to invest in and manage its own flexibility solutions does not seem appropriate in most cases. Because of its regulatory status, the DSO would not be able to use its battery for other purposes than its own flexibility mechanism, which would decrease the profitability of this solution, and make it less competitive than services purchased from a third party. This mechanism could be considered only in case of market failure (inability of the market to provide) or if the use of a flexibility solution exclusive for the DSO's needs were justified.

Phase 3: Coordination of local flexibility services with the existing national mechanisms, and possible windfalls from those services

Several issues can be anticipated regarding the operational implementation of the 4 selected mechanisms. In particular, it is necessary to coordinate these local mechanisms with existing national ones, in order to maximize the value generated by flexibility services and thus to reduce their overall cost. It is also necessary to make sure that the implementation of local mechanisms does not create windfalls.

Nine issues were identified and distributed in four categories:

(i) Management of a subset of sources of flexibility within an aggregated portfolio

- **A** Activation (or exclusion from activation) of a local subset of flexibilities within a portfolio

(ii) Collateral effects of local flexibility activation on the national scale (and conversely):

- **B** Intensification of constraints on one scale (national or local) by the activation of flexibility sources on the other scale (local or national)
- **C** Imbalance on the portfolio of a balancing responsible party because of the activation of local flexibility

(iii) Activation conflicts due to the overlapping of different mechanisms:

- **D** Non-coordinated management of flexibility sources between the different mechanisms
- **E** Conflicting and simultaneous activations on the local and national scales
- **F** Local activation reducing the dynamic activation potential of flexibilities on the national scale

(iv) Windfalls for stakeholders:

- **G** Double remuneration of a flexibility answering to only one need
- **H** Remuneration of a non-existing flexibility (ghost flexibility)
- **I** Artificial creation of a constraint and provision of a source of flexibility by stakeholders seeking to earn the difference between remuneration and socialized cost

Figure 4 – Issues associated with using flexibility on a local scale

6 **A debate is in progress on how to coordinate the use of sources of flexibility on a local scale which were initially developed for the transmission network. So far, a list of focal points between stakeholders has been established, the key issues have been articulated, and some options have been defined. The debate must carry on for stakeholders to reach agreements on the best solutions, which the result of pilot projects will contribute to shaping.**

Discussions are in progress between DSOs and the TSO regarding the coordination of flexibility mechanisms. Their aim is to:

- Enable each source of flexibility to participate in several mechanisms, as long as it contributes to social welfare, and makes it possible to split the costs between mechanisms;
- Minimize the social cost of conflicts: conflicts can be addressed in different ways, and that which will be selected must be optimal with respect to social costs;
- Define and allocate the extra costs generated by these conflicts: conflicts create extra costs, hence the need to clearly define which stakeholders are to bear them. The aim of efficient coordination is to avoid these extra costs.
- Limit transaction costs for flexibility providers: the participation in several mechanisms generates additional transaction costs.

However, the debate on these issues is still ongoing. Participants will have to define the governance to define and enforce coordination rules and how deeply TSO and DSO operational systems are to be integrated.

7 Regarding coordination, we have analyzed the three most difficult issues: (i) the management of a subset of sources of flexibility within an aggregated portfolio, (ii) the emergence of collateral effects on one scale upon the activation of flexibility on the other scale, (iii) flexibility activation conflicts due to the overlapping of different mechanisms.

(i) – The simultaneous participation of a source of flexibility in local and national mechanisms raises **the question of activating or excluding subsets from aggregated flexibility portfolios**, which were initially designed for use on the transmission grid. Local activation of a subset of these portfolios would interfere with the currently business of aggregators, which build up portfolios for flexibility needs defined on a national scale. It would impact the value of aggregating portfolios comprised of multiple sources of generation and flexibility. However, such activation – or exclusion from activation – restricted to a local subset of the portfolio would enable sources of flexibility to participate on both the local and the national scale while minimizing conflicts. The rules for restricted participation or exclusion would have to be defined jointly by DSOs and the TSO in order to manage these conflicts as well as possible.

Two option to implement these rules are currently being investigated: have all network operators use a central platform, or coordinate separate mechanisms.

The French balancing mechanism[18], currently managed by the TSO, was designed for the purpose of addressing both balancing needs and constraints on the transmission grid. Because of this latter purpose, it structurally takes into account the location of sources of flexibility. Thus, one option would be to extend this platform to resources and constraints on the distribution grid. However, there are several hurdles to this project: at the moment, the platform is not able to integrate distribution-level constraints and sources of flexibility[19]; besides, such an integration would require the implementation of business rules regarding local activations and restrictions by DSOs; finally, governance issues would have to be solved to allow for DSO participation in this balancing mechanism.

Alternatively, an *ad hoc* mechanism for local sources of flexibility, coordinated with the transmission system, could be implemented and operated by DSOs. This option would limit conflicts and the associated consequences, but would require flexibility providers to use two distinct mechanisms, possibly making their work more complicated. However, it would bring greater agility to the management of local flexibility, and keep the interests of each grid operator more clear.

The coordination and communication functions between the TSO, the DSOs and aggregators will have to be defined prior to choosing the option to be implemented, whatever it is. The principle of a single point of contact must be maintained to enable each flexibility provider to interact solely with the grid operator to which it is connected.

(ii) – Any flexibility activation on the local grid can have collateral effects on the national scale (and conversely):

- For instance, flexibility activation on national mechanisms can **intensify the constraints on a local grid**;

[18] *Mécanisme d'ajustement*.
[19] Information at the scale of the distribution grid is not needed to manage constraints on the transmission grid.

- Conversely, local flexibility activation can generate **unexpected imbalances on the portfolio of balancing responsible parties,** which will necessarily impact the balancing management at the national scale.

(iii) – When a source of flexibility participates in several mechanisms, **activation conflicts** can occur:

- The **management of flexibility resources** can generate incompatibilities between the different mechanisms (e.g following activation on one mechanism, the availability of a flexibility can be impaired for an activation closely afterwards on another mechanism);
- **Simultaneous and conflicting activations** of one source of flexibility on two distinct mechanisms can also generate activation conflicts;
- Even when they are both upward or both downward, two simultaneous activations can also cause issues. Indeed, for some mechanisms, **the exact moment of activation matters,** because the load variation matters more than the amount of energy activated. In this specific case, a source of flexibility activated shortly beforehand on another mechanism cannot provide any more value.

8 **This study highlights that two critical issues stand out: (i) the management of a subset of sources of flexibility within an aggregated portfolio and (ii) activation conflicts – because of higher probability of occurrence and resulting risks in case of failure. The mechanism causing the most issues is the direct contracting of sources of flexibility by DSOs which would generate the most conflicts because it causes the most impact.**

The criticality level of these issues depends on three parameters: the **type of product activated through the mechanism** (which can either be “service”[20] or “energy”[21]), the **timing of activation** (before or during the gate closure time) and the **level of commitment** of the mechanisms.

A mechanism to activate “service” products transfers more responsibility onto flexibility providers than with “energy” products, which ultimately minimizes potential conflicts. **In the first stages of using flexibility on the distribution grid, “service” products would be best suited to most configurations**.

Similarly, a source of flexibility participating in mechanisms without commitment (such as the “DSO option”) does not face the “critical” conflicts arising from participation in several mechanisms with commitment. This is why **contracting is the mechanism with the highest potential for conflicts,** whereas the “DSO option” on existing sources of flexibility minimizes this risk.

Besides, **activation conflicts caused by the participation of sources of flexibility in several mechanisms with commitment** (for instance: contracting on the one hand, and demand response tender[22] issued by the TSO on the other hand) could become critical once flexibility volumes are significant.

Finally, the analysis of the three **windfalls for stakeholders** **(iv)** shows that there several options can be used to neutralize them when designing flexibility use and valuation mechanisms.

[20] When a flexibility provider commits to keeping the amount of power injected or withdrawn below or above a set limit, in order to help relieve constraints, in a process separate from purchasing or selling energy (the management of energy injected or withdrawn remains the sole responsibility of the balancing responsible party, not the grid operator).
[21] When a flexibility provider sells or purchases energy in accordance with conditions set by a contract (duration, notice period, supply period…).
[22] *Appel d’offres effacement*.

9 **In any case, the priority measures to prevent and solve conflicts have to include well-calibrated penalties, efficient governance and communication between stakeholders (TSO, DSOs and flexibility providers) and robust monitoring and verification processes.**

Whatever the governance and the level of integration eventually selected, solving these issues will require:

- **Efficient communication between flexibility providers and distribution and transmission grid operators** to prevent conflicts or make their resolution easier;
- **Priority rules** in case of conflict to opt for the best option in terms of social cost;
- **Well-calibrated penalties** to prevent fraud without deterring players from participating and to direct choices towards the social optimum;
- **Monitoring and verification of registered sources of flexibility by the TSO** (regular flexibility tests, verification of actual load variation …);
- **Efficient governance**.

Although a number of issues were identified, volumes and probabilities of occurrence are low, especially as long as local flexibility is emergent. The solutions to all these issues can be gradually improved using feedback from implementation.

The actions of each stakeholder will have to be communicated in order to optimize the management of sources of flexibility on the national and local scale. Monitoring and verification processes will be key to ensure the viability of mechanisms, especially regarding actual load variation and possible windfalls.

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