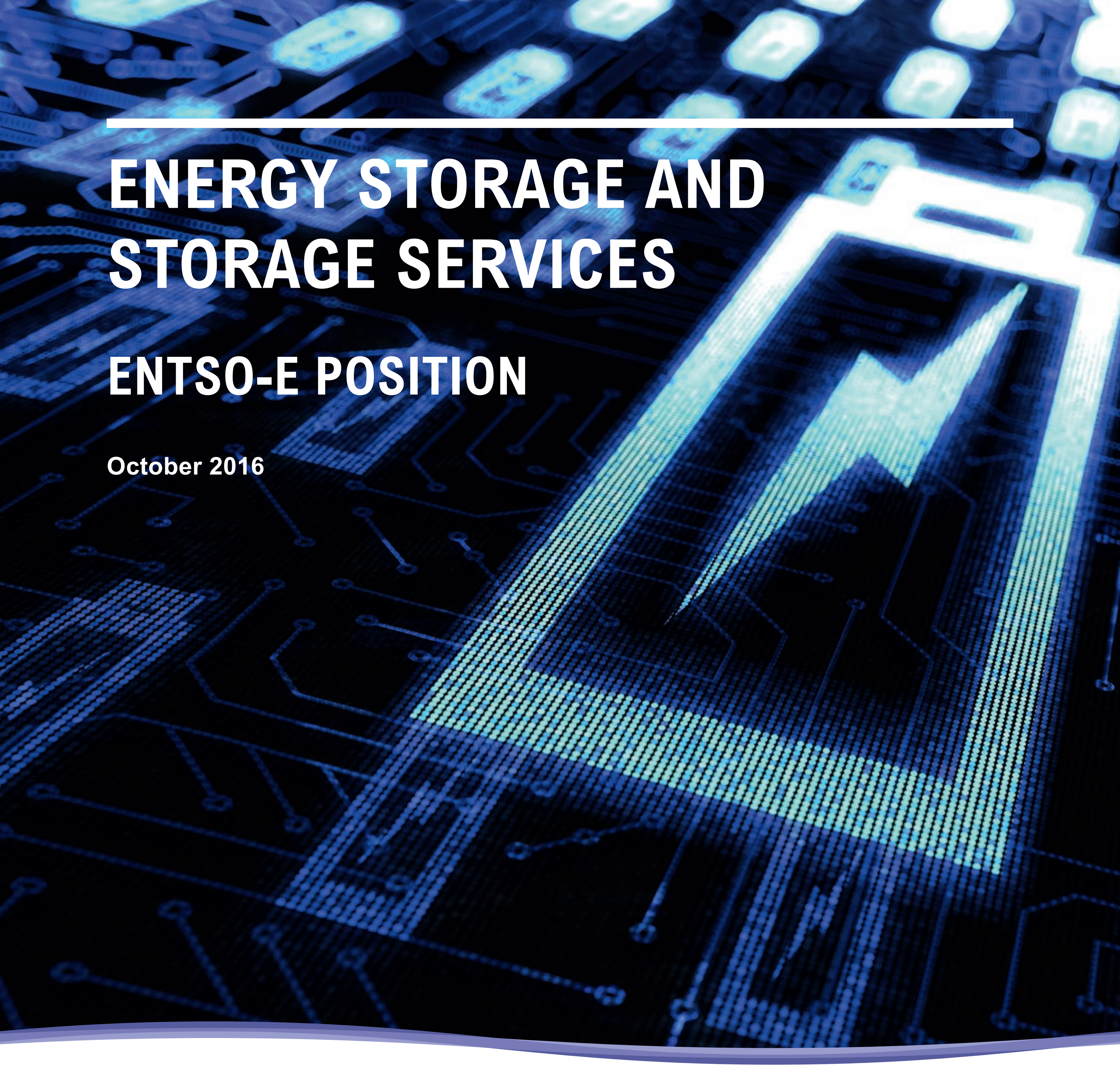

ENERGY STORAGE AND STORAGE SERVICES

ENTSO-E POSITION

October 2016

Variable renewable generation requires the power system to become more flexible to respond to the variability and uncertainty of operational conditions at various timeframes. Storage is one of the promising options to provide more flexibility to the system. This paper assesses the services that storage could provide and gives recommendations on how to maximise the benefits of storage in the most competitive manner in both the short and long term.

European Network of
Transmission System Operators
for Electricity

entsoe

EXECUTIVE SUMMARY

The high deployment of variable[1] renewable generation requires changes in the operation and development of the power system. The power system must become **more flexible** to respond to the variability and uncertainty of operational conditions at various timeframes.

As storage is one of the promising options to provide more flexibility to the system, **this paper assesses the services that storage could provide** and gives recommendations on how to maximise the benefits of storage in the most competitive manner in both the short and long term.

Developments in advanced storage technologies are able to offer capabilities and deployment possibilities that support the long-term EU energy policy objectives. The cost effectiveness of storage technologies is increasing. With the advancement of new technologies, it is possible to build, locate, and operate concentrated electrical storage anywhere in the network. Small-scale devices can be aggregated to ensure large-scale deployment.

The emergence of storage technologies is now challenging all actors in the electricity value chain to see how, when, and where storage could be used and how it could be managed. This is especially relevant as storage technology has features that fit within the remit of both regulated and market parties. As such, ENTSO-E agrees with the European Commission's view[2] that storage is neither generation nor demand.

As an overarching principle, one of the main roles for transmission system operators (TSOs) and ENTSO-E is being neutral market facilitators. In the context of this paper, we assess the potential of storage – as one tool in the tool box – in providing the necessary flexibility to the system.

[1] Volatile or non dispatchable/intermittent RES.
[2] https://ec.europa.eu/energy/en/topics/technology-and-innovation/energy-storage

SOME GENERIC PRINCIPLES SHOULD GUIDE THE FUTURE INVESTMENT FRAMEWORK FOR STORAGE:

- There is a need for a European legal and regulatory framework regarding general principles for storage;
- Storage should compete on a level playing field with other technologies, and the tariff structures should ensure neutrality of storage;
- Storage devices should not be restricted to a single service, as this would not be economically efficient;
- The TSOs should have access to data for central and distributed storage facilities for system security for all timeframes.

The application of these principles depends on the type of service provided, as explained in the following paragraphs. This distinction is based on the assumption that, for each storage application, the primary business case is identifiable, even if the same application could provide different services to different markets.

STORAGE USED TO OPTIMISE THE INTEGRATION OF RENEWABLE ENERGY SOURCES IN THE ENERGY MARKET

Storage could improve the efficiency of the market and facilitate the integration of renewable energy sources (RES) by managing their variability not only on a daily basis but also on a more seasonal basis. There is, however, evidence that investments on this basis are becoming increasingly difficult in an environment with more uncertainty in planning permissions and in wholesale electricity prices.

Typically, TSOs would not invest in storage technologies for this purpose, as these investments should be primarily driven by the market. As the current market environment is difficult, the market design should ensure a price signal that is predictable and sufficient to stimulate investments. This, however, will take time to develop. Depending on the specific conditions of a country, the market could be stimulated by allowing TSOs to organise tenders (e.g., procuring a certain quantity of MW with long-term regulated contracts) to contribute partially to the business case or by allowing TSOs to make a regulated investment and auction the associated capacity to the market on equal and transparent terms, as TSOs do today with the capacity for interconnectors.

STORAGE DELIVERING EXISTING AND FUTURE SYSTEM SERVICES

The integration of variable RESs and the security of supply is a challenge for TSOs. It is highly unlikely that system service arrangements designed for a system based on the conventional generation will fit the needs of a system based on high-variable renewable generation. The TSOs should thus facilitate the associated market by establishing clear technical and market requirements for new and existing system[3] service procurements. Nevertheless, ENTSO-E also recognises that it is not possible to develop competitive markets for all the required system services within all balancing areas of the EU. This particularly relates to locally bound system services, such as reactive power and system services in (parts of) TSO balancing areas with insufficient competition. In those circumstances, a TSO could own and operate a storage facility.

[3] In this document, both the delivery of system services and the procurement of ancillary and other services are generically referred to as system services.

STORAGE ENABLING EFFICIENT GRID DEVELOPMENT

The integration of RES requires significant additional flexibility and capacity of the transmission system. Any technology alternative that adds such flexibility and provides capacity should be investigated. With further technological development, storage has features to enable more efficient grid development in specific circumstances, for instance with intermittent congestions and could serve as a complement to the lines. If storage would have positive technical properties and a positive cost benefit analysis, then TSOs should be able to own and operate a storage facility for this purpose. The development of storage as part of the transmission system requires a framework to ensure that the effect is transparent and minimal on the market. The figure below provides the relevant illustration.

Advanced Storage Technologies …	… are multi-purpose	… and require a healthy investment environment
	**Integration of RES in the energy market**	**Competitive investment target** Regulated investment may be relevant as a starter/transition policy, with auctioning of the regulated capacity to competitive players.
	Existing and future system services	**Competitive else regulated investment** TSOs invest only if competition is not relevant or efficient, especially for locally bound services or areas with insufficient competition.
	Enabling efficient grid development	**Regulated investment**

Fig. 1: Graphical illustration of services delivered by storage

INTRODUCTION

The EU has defined ambitious energy policy goals with respect to competitiveness, security of supply, and sustainability. These policy goals are defined for an electricity system that is **in transition towards high penetration of variable renewable energy.** As a consequence, the system will become more complex and more decentralised. Furthermore, it is expected that the electrification of European society will further continue, and the customer will be more and more empowered through and offer its flexibility, also thanks to increasing digitalisation. This transition will result in new technological and economic needs and opportunities.

A wide range of energy storage technologies exists, which could deliver services to meet these needs. The technologies have different maturity levels and different technologies can be used for different types of services. Presently, the energy storage capacity connected to the grid is higher than 50 GW (around 95 % is in pumped hydro storage [PHS] installations). The share of energy storage other than PHS is increasing with growth rates of more than 10 % in 2015 (IEA 2015).

Electrochemical and thermal storage technologies, as grid-connected storage, are growing in importance in Europe. The high potential improvement and cost reduction for lithium-ION batteries and redox flow batteries allow these technologies to grow faster than other battery technologies. Growth for compressed air energy storage (CAES) and flywheel energy storage (FES) is low.

Certain storage technologies could meet some of the needs of the system as soon as these technologies become mature and their cost sufficiently declines. For example, batteries are becoming more and more attractive, and costs are expected to halve in the period 2020–2030.

Hence, it is important that a clear legal and regulatory framework for general principles that are applicable to storage is established to ensure a common European approach. Current practice without a clear European framework leads to different and not harmonised national interpretations.

STORAGE USED TO OPTIMISE THE INTEGRATION OF RES IN THE ENERGY MARKET

The implementation of an **appropriate market design** is the best way to ensure the most 'efficient' allocation of resources. However, in itself, the target model will probably not deliver on the RES policy objectives nor facilitate enough associated investment, including in complementary technologies, such as storage and demand-side management. The discussions regarding the future market design should ensure a level playing field for different technologies. Furthermore, the transmission and distribution tariff structures should be assessed in order to avoid unequal treatment of different technologies.

When considering the market environment, it is important to acknowledge that there is a fundamental shift in the cost structure of electricity generation. The costs of the future generation capacity of renewable energy sources are mostly fixed, with high upfront investment (capital costs) and low or zero operational costs. These renewable energy resources require flexibility solutions to handle their intermittent nature. Some flexibility options, such as storage, have similar cost structures as renewables (i.e., mostly fixed costs).

The paradox of the current market situation, however, is that the business case for storage facilities to match supply and consumption (energy arbitrage) has been eroded due to the effect of the RES on price formation (i.e., the spread between high and low wholesale prices is too unpredictable and, in many cases, too flat to accommodate the investment decision). Given the policy targets and the requirements of the market for flexibility, it makes sense to use all the electricity that variable RES can produce.

There is the need for a more integrated system approach, given the challenging environment. The TSOs should be involved in defining the European needs for different flexibility service levels to be provided by the market. These options should provide the system with a clear framework for investment in order to remove existing barriers and to minimise the risks.

When markets do not provide the right price signals for investment decisions in flexibility services, one way to push these investments for a limited time would be to procure part of the capacity with a long-term regulated contract to support the business case. This would secure the investment by a fixed revenue stream for part of the capacity. These costs would then be included in the regulated costs of the TSO, which effectively makes the contract regulated without actually regulating the returns of the party who invests in the storage facility.

Another way to push forward the market could be for a TSO to own a storage facility as a regulated asset and auction its capacity to the market[4] for all relevant timeframes (intraday, day-ahead, month-ahead, and year-ahead) as TSOs are doing today with the capacity of interconnectors. This option is in line with the unbundling principle that ensures that TSOs are not actively engaged in trading. This would also facilitate market parties, as it alleviates barriers to entry for new market entrants that require access to flexibility but do not have the resources to invest in it on their own.

Recommendations

- Improve market design to ensure adequate price signals for storage;
- Transmission and distribution tariff structures should ensure technology neutrality;
- The market could be stimulated either by regulated contracts or by regulated investments of the TSO, whichever is regarded as more effective by the relevant policy makers; and
- If operated as a regulated asset by the TSO, the capacity of the investment could be auctioned to the market participants on equal and transparent terms as TSOs do with the capacity of interconnectors.

[4] For example, to facilitate balancing supplying parties to optimise their balance.

SERVICES THAT STORAGE COULD PROVIDE TO THE POWER SYSTEM

STORAGE AS A PROVIDER OF EXISTING AND NEW SYSTEM SERVICES

System services are of paramount importance for the operation of power systems.[5] They play a decisive role in providing security for system operation and in remedial actions to restore normal operation in the case of deteriorated operation conditions in the system, including blackouts.

Constant growth of variable renewable energy generation increases the complexity of the power system operation. In order to manage these changes, TSOs require an increased level of system services that will meet higher quality standards (i.e., response time and flexibility range).

The current service providers, whose primary activity is not the provision of system services but the production of electricity, are facing strong competition in the energy market, which influences their participation in the market for system services. Consequently, there is a risk that some power systems could be faced with a scarcity of conventional generation sources that provide system services.

The current developments require an appropriate market design of system services that goes beyond the presently established models allowing all types of flexibility, such as demand-side response or storage to participate. In this sense, some energy storage technologies have reached a level of maturity sufficient to make them eligible for the provision of system services.

Thus, the potential of different storage technologies to provide system services and to compete with other conventional technologies on the market of system services primarily depends on:

- The type of system service and the technical capabilities of the storage technology in terms of energy storage capacity, power range, response time, etc., and
- Legislation that encourages markets to develop, including the access of distributed storage to the market for system services.

However, not all services are expected to be delivered by a functioning competitive market due to limitations in the scale of the market or because they are bound by location. To facilitate the integration of storage into the market of system services, TSOs will have to define technical requirements for the delivery of the services.

[3] According to the ENTSO-E paper published in the Energy Union context, Markets and Innovation Deliver: 'system services', are defined as services that TSOs need to keep the power system stable and reliable at all times. These include not only ancillary services such as black start capability (the ability to restart a grid following a blackout), frequency response (to maintain system frequency with automatic and very fast responses), and fast reserve (which can provide additional energy when needed) but also the provision of reactive power for voltage stability, transient and dynamic stability, inertia, fault levels, power flow limits, (n-1) security, etc.

On the longer term, yet within the 2030 horizon, high-variable RES penetration will require new system services regarding core synchronisation of the network: i) provision for inertia and ii) provision for short circuit power. It is likely that storage could be used for the provision of both of these services.

Furthermore, it is of considerable importance that the reliability of the system can be monitored and supervised by the TSO. This would imply that the TSO should have access to the data of central and distributed storage facilities for system security in all relevant timeframes, as defined by the System Operation Guidelines. This is especially important, as not all storage assets would be directly connected to the transmission grid.

Recommendations

- The TSOs could facilitate market integration of storage by establishing clear technical and market requirements for its participation in the procurement of system services.
- Markets should value flexibility according to system needs, as this will enable the participation of storage in the provision of system services.
- When competitive markets do not exist, a TSO could make a regulated investment or engage in long-term contracts.
- For research on future system services, TSOs could experiment the advanced use of storage technologies.
- The TSO should receive the data for the required supervision of central and distributed storage facilities for system security in all timeframes.

STORAGE ENABLING EFFICIENT GRID DEVELOPMENT

Network development is exposed to increasing uncertainties on consumption (uncertain consumption patterns and unclear when and at what pace transport/heat will electrify) and on production (volumes localisation and pace of RES development).

This requires more flexible tools for system operation and network planning. Storage is one source of flexibility for the grid among others, such as:

- Dynamic monitoring of assets, enabling to operate them in real-time limits;
- Dynamic grid configuration, such as phase shifters;
- Flexibility of consumption and of generation.

The TSO should evaluate all possible technologies when making investments. Moreover, ENTSO-E anticipates that energy storage technologies will gain importance due to increasing performance and decreasing costs of new storage solutions; hence, this alternative should be investigated further.

Electrical energy storage allows handling intermittent congestions. By simultaneous charging and discharging, the power flow in lines can be changed without affecting the overall system and market balance (as shown in the figure below). The example does not take into account the effect of losses.

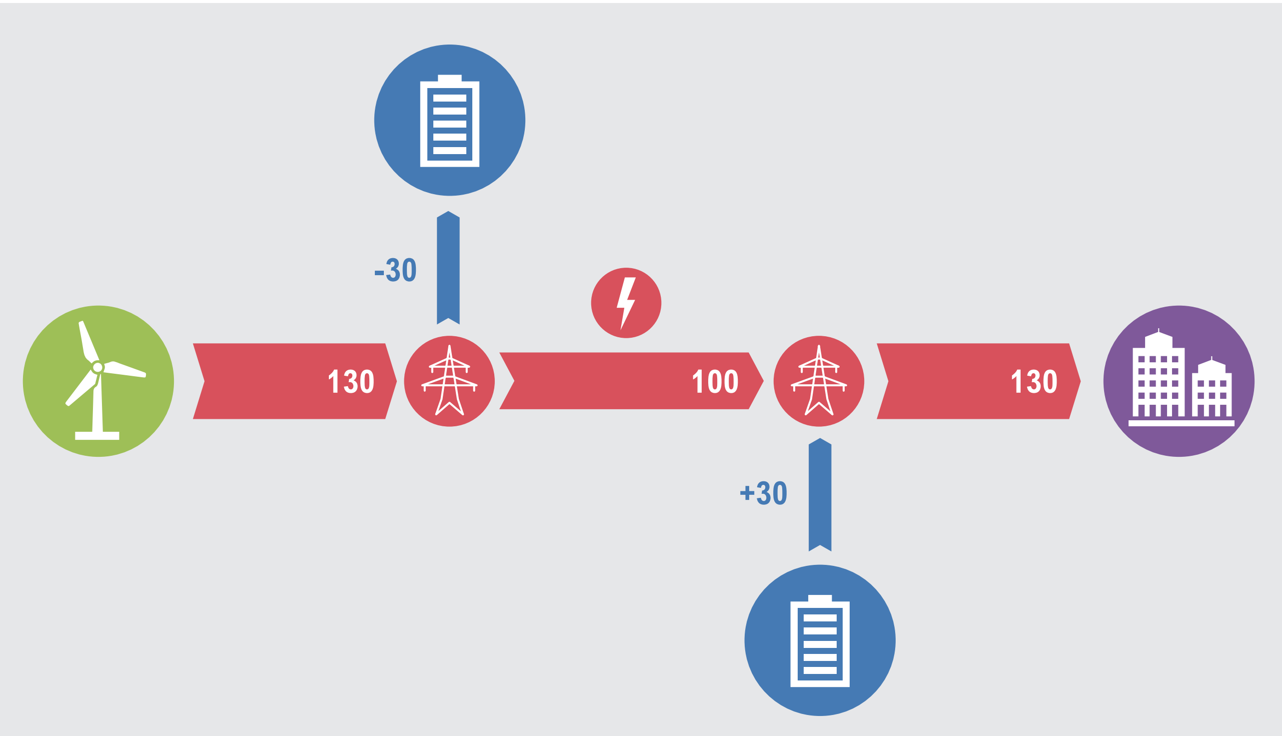

Fig. 2: Simplified example of neutral use of storage for congestion management

The location of storage units, the installed available power, and the size of the storage units (energy) are key to achieve this effect. A fleet of storage units may be operated at zero overall balance by the TSO (see illustration above), and hence with a pure transmission effect. This will require additional technological development. Therefore, research and innovation is needed to ensure that future networks can also leverage technological developments of storage. The storage asset would then be treated as other regulated assets. The transmission capacity would be made available to the market like the availability of a power line. The framework for settlement of losses occurring in the storage facility should be further developed.

The example above demonstrates that storage can be used for different purposes in the network. It could be used as a complement to increase the flexibility in the network, or it can be used as a temporary measure to avoid the curtailment of RES while waiting for the required grid expansion. This extension would then serve as a permanent solution, which is required when RES shares are expected to increase, and would result in the permanent need for transportation capacity.

Provided the technical and economical properties are favourable (CBA[6)]), electrical energy storage, together with other sources of flexibility, may help in optimising the whole network development plan, including lowering the costs of RES integration to the electrical system and supporting the ability to cope with public acceptability challenges.

Recommendations

- The TSOs should assess storage as a possible additional resource for grid development in the future.
- To ensure a transparent operation and minimal impact on the market, a framework for storage as part of the regulated network system is required.

[6)] Cost benefit analysis.

ABBREVIATIONS

CAES	Compressed Air Energy Storage
CBA	Cost Benefit Analysis
EC	European Commission
ENTSO-E	European Association of Transmission System Operators for Electricity
FES	Flywheel Energy Storage
PHS	Pumped Hydro Storage
RES	Renewable Energy Sources
TSO	Transmission System Operator

CONTACT

ENTSO-E AISBL
Avenue de Cortenbergh 100 · 1000 Brussels – Belgium
Tel +32 2 741 09 50 · Fax +32 2 741 09 51
info@entsoe.eu · www.entsoe.eu