European Commission

# ENTEC

Energy Transition Expertise Centre

## Terms of Reference

Energy storage

# Terms of Reference – Energy storage


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## Disclaimer

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# 1 Initial request of the EC from 11 Oct. 2021/research questions

Energy storage, together with other technologies, is one of the candidates to provide flexibility to the electricity system, facilitating the integration of renewables, lowering electricity prices during peak times, facilitating the electrification of the economy and increasing the security of the electricity system.

There are different energy storage technologies with different capabilities and maturity levels. Nevertheless, energy storage technologies and capacities should be market-driven on a level playing field.

We are interested in the current costs and trends for the different storage technologies, as well as the market opportunities in different Member States. In particular, we would like to:

1) update the information we have[1] as regard CAPEX, OPEX and other technology features of the different storage technologies (chemical, electrochemical, electrical, mechanical and thermal) and, if possible, their trends for the coming years.

2) assess the market opportunities for energy storage. In particular:
   - assess competitiveness and any possible added value of energy storage compared to other flexibility sources, such as power flexibility, interconnections or demand response.
   - assess the current market value of energy stored in different MSs through their possible revenue streams (i.e. from the day-ahead and intraday markets, balancing markets, ancillary services markets/procurement - if present per Member State, etc).
   - Qualitatively assess any possible gap between the identified costs and revenues.

[1] EC study: Energy Storage Study - Contribution to the security of electricity supply in Europe - EASE technology fiches: Technologies | EASE

# 2 Task structure

## 2.1 Task 1 with focus on current situation and potential development till 2030

### 2.1.1 Database of storage technologies

**Objective**: This sub-task aims to characterise **potential technologies** that could be used for storage in the electricity sector (sector coupling), giving a brief description on their main features as well as updating specific techno-economic parameters. This is done by reviewing and updating the database of the 2020 study on energy storage commissioned by DG ENER.[2]

Based on the definition of energy storage[3], the storage types to be included will cover mechanical, electro-chemical, electrical, chemical and thermal storage forms. The focus will be on storage technologies which can provide storage or other services to the electricity system (as opposed to storage services to gas or heat systems, unless there are significant interaction with the electricity system), including stand-alone, behind-the-meter storage and combined with RES.

**Forms of stored energy**
- Chemical
- Electro-chemical
- Electrical
- Mechanical
- Thermal

The specific technologies focused in the study should be a sub-set of the ones in the 2020 database. At the beginning of the study we will identify the most relevant technologies with a focus on those, which play a significant role in EU modelling exercises (such as the storage study, the MIX scenarios and others) and/or which have seen significant cost improvements in the last years. Taken into account that energy storage future capacity is mainly driven by batteries and hydrogen technologies, the study will also assess why other storage technologies may be necessary for the future energy system

The technologies will be characterised by the following aspects:

- Technology Readiness Level (TRL)
- Round-trip/conversion efficiency
- Timescale (duration of storage ranging from minutes to days and storage cycles)
- Response time
- Energy capacity
- Power capacity
- Applications: mobile and/or stationary
- Services provided (see below)
- Capex and Opex
- Lifetime
- Use of critical raw materials
- Other capabilities (inertia and virtual inertia, reactive power control, black start capability, …)

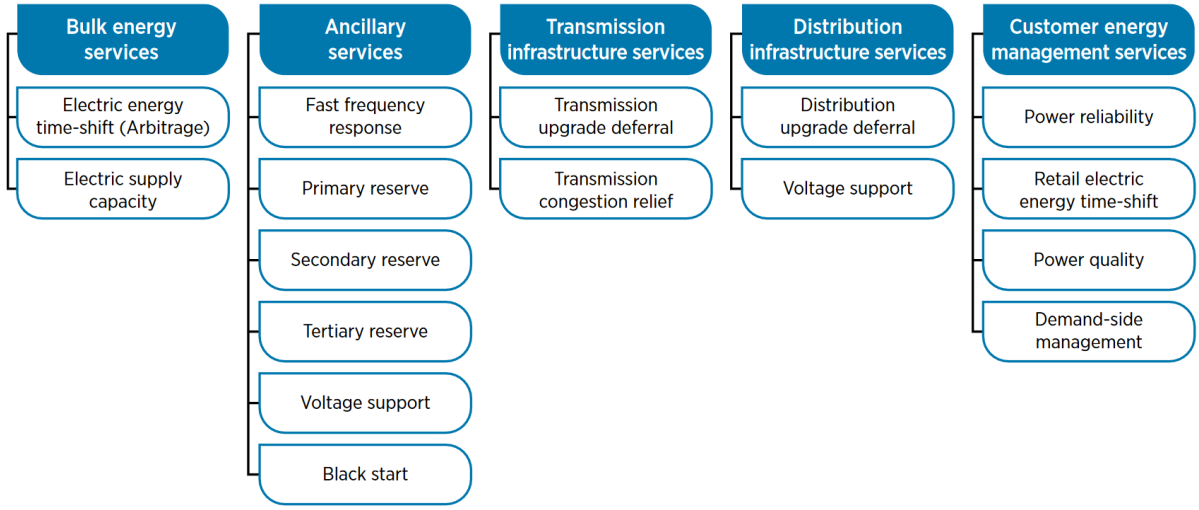
The update of the storage technologies characteristics will be mainly based on literature review, given the need to updated quantitative techno-economic parameters. Moreover, analysis of the technical characteristics of the technologies will allow to fill-in more qualitative characteristics such as the potential electricity storage services.

[2] https://ec.europa.eu/energy/studies_main/final_studies/study-energy-storage_en

[3] Article 2 (59) of Directive (EU) 2019/944

The classification of storage services will be standardised for all storage technologies throughout all planned working task in the study. We suggest to use IRENA's classification of storage services shown below with revisions if needed (in particular with EASE's classification of energy storage applications).

**Figure 1 Electricity storage services**




Source: IRENA (2020) Electricity storage valuation framework

Although it will not be possible to calculate the total cost of ownership (TCO) for the technologies, as it is highly system-dependent and requires especially assumptions regarding use profiles and other use case specific parameters, a short description of what to take into account for the calculation of TCO for storage projects will be provided.

The study will provide EU global figures for cumulative energy storage in the EU (and latest annual installations); at least for the dominant storage technology types (e.g. PHS, thermal storage and batteries, including EVs) in GW and GWh.

### 2.1.2 Technologies and use cases

**Objective**: Outline of **use cases** along three dimensions: technologies, actors and markets. Use cases are defined as the combination of selected technologies, the potential services/markets where they could be used and the different actors such as grid operators, energy consumers (industrial/commercial/residential), aggregators, utilities and other market operators. Thus, one technology could be used in different markets/services, or in one market/service but by different actors.

To identify all potential use cases, we will set-up a matrix between technologies and services/markets. Table 1 illustrates such a matrix. For each service, we will detail the potential actor types which could make use of the suitable technologies.

In order to fill-out the matrix, we will define the minimum technical characteristics, which a technology needs to have in order to provide a certain service. For example, only technologies with an appropriate response time could provide FCR balancing services, which would serve to exclude some technologies from providing these services. Some technical elements are defined by national legislation. A short overview will be given for these.

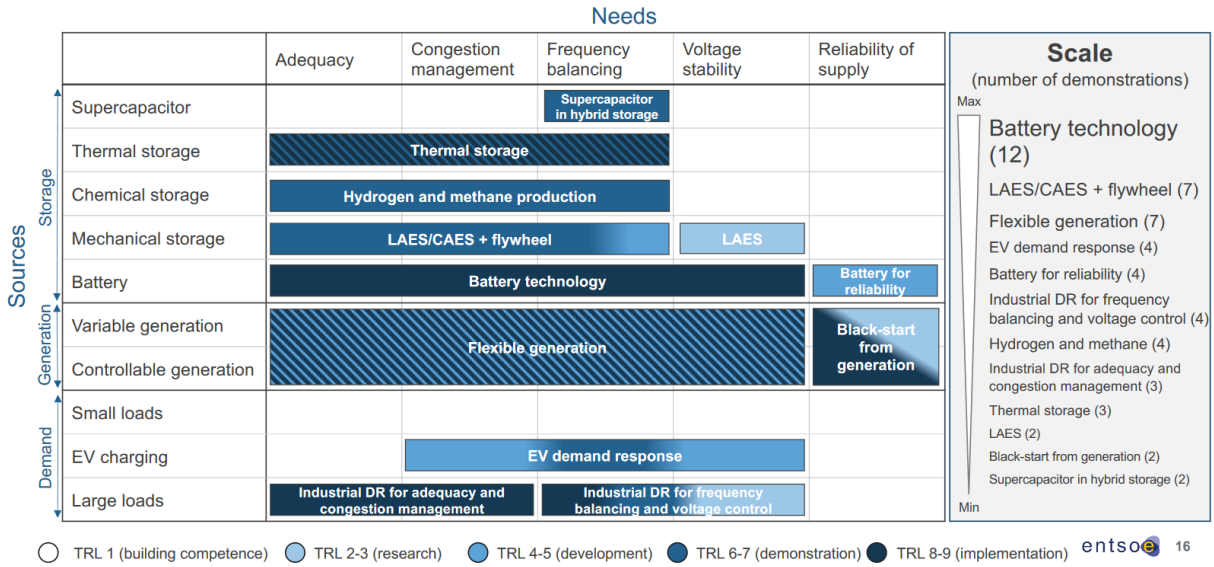
The population of the matrix will be based on literature review (including previous studies and outputs from expert groups funded by the EU), expert knowledge as well as identification of existing applications.

**Table 1 Examples of use cases defined by technology and markets/services**

| Market/Service<br>Technology | Day ahead | Intra day | Balancing | Congestion management | Other AS | Transmission/distribution expansion deferral | Capacity mechanisms |
|---|---|---|---|---|---|---|---|
| Batteries (vehicle-to-grid) | | | Use case1 actor a<br>Use case1 actor b | | | | |
| Hydro-pumped storage | | Use case2 actor a<br>Use case2 actor c… | | | | | Use case 3… |
| …. | … | | … | | | | |

An example of a similar table is ENTSO-E's flexibility presentation.

**Figure 2 ENTSO-E mapping on technical flexibility solutions**




Source: Hofmann in ENTSO-E (2019) Webinar on Flexibility Framework & Mapping

### 2.1.3 Alternative flexibility solutions

**Objective**: Comparison of storage technologies with other solutions to provide flexibility to the system. We will look at other options that could provide flexibility and compare these flexibility options with storage options. The key question is: What are the competing flexibility options and how do they compare to the storage technologies, technically and economically?

Using a similar approach as on the previous EnTEC in-depth study on digitalisation, we will identify and compare flexibility use cases that show similar features as the respective storage use case.

**Alternative sources of flexibility**

- **Supply-side**: RES generation management, geographical/portfolio smoothing
- **Interconnections**
- **Demand-side**
  - **DSM through sector coupling (HP, e-mob)**
  - **DR through industry load shifting/shedding**
  - **DR through HH with smart electricity use**

A special focus is on DSM through sector coupling (heat pumps, e-mobility if not a use case in the sub-task above), smart electricity consumption of households, and load shifting or shedding in industry as well as RES generation management.

The contribution to the system of the flexibility solutions will be assessed in terms of their timescale and flexibility capacity. The focus of the analysis will be mainly on the capabilities of the alternative flexibility solutions, and not on their costs (which may be only assessed qualitatively).

## 2.2 Task 2 - Market value of stored electricity and cost gaps

The market opportunities and related market value of storage technologies will be analysed and cost gaps will be qualitatively assessed. However, a quantitative assessment of the market values entails detailed market data of each market and country at high granularity (at least hourly) for the future. Therefore, we have decided to use a qualitative approach and gave only indications for a quantitative assessment.

### 2.2.1 Market values

The objective of this sub-task is to assess the value for energy storage, i.e. assess the opportunities from potential revenue streams of the use cases in different markets and non-market applications of storage (such as wholesale markets, balancing markets, non-frequency ancillary services, congestions management or behind-the-meter storage with solar PV).

#### Approach

Data availability is key for this analysis. To derive charging and discharging profiles for storage technologies, data on market prices (traded volumes?) are needed. But access to market data or prices at an hourly resolution in all member states and all different markets in the respective member states as well as the aggregation and analysis of all markets is extremely challenging. Further, since storage options in one market affects prices of this respective market and the adjacent markets, assumptions are needed on storage types and capacities and their impact on prices. Ideally scenarios could reflect such developments and interactions. As a full scenario analysis of the EU electricity system is not foreseen in the planned time frame of the study, we will rely on existing scenario analysis and historical market data (summarized in a dashboard) as well as on expert views for future market developments and related revenue streams (based on a questionnaire to relevant stakeholders).

### Opportunities dashboard

The main output of the sub-task will be a 'storage opportunities dashboard', indicating for each market/application the relevant drivers (represented by indicators) which influence the revenues stream. The dashboard will not quantify the revenue streams per se but aims to provide quantitative data on the drivers as much as possible.

As the opportunities are related to the market/applications and not specifically to the technologies, the opportunity dashboard will focus on the analysis per technology, market/application and Member State. In order to facilitate data collection, we will focus on transversal data sources as much as possible (i.e. covering the EU27) instead of realising MS-specific data collection. Any data gaps for specific Member States will be clearly documented.

A literature and data availability review at the start of the task will be conducted to agree with ENER the dashboard indicators and the (transversal) data sources to be employed.

The aim is to collect data for the most recent year available. As certain markets/applications will not exist in every MS (for example, certain balancing markets may still not be operational in certain Member States), this will provide a preliminary input to task 3 regarding storage barriers and/or drivers. However, it is not the main objective of the present task to assess barriers to storage, but rather the opportunities. Therefore, aspects such as entry barriers to electricity markets will be covered in Task 3, if not addressed in the Energy Storage Study already (e.g. too high procurement lead times, uncontracted balancing energy bids not being accepted in certain balancing markets). Market design aspects which provide an incentive to storage (e.g. time-of-use retail tariffs) may be included.

In case the data collection efforts or its review indicates data processing or availability issues, a subset of Member States to agree with ENER may be chosen with sufficient diversity of geography, market and other characteristics.

An example of the output is the following.

**Table 2 Examples of the revenue opportunities dashboard**

| Market/non-market opportunity | Drivers / indicators | Potential data sources |
|---|---|---|
| **RES variability management** | Cost of capital for RES | Trinomics et al. study on Macroeconomic of the Energy Union |
| **Forward** | Summer/winter or other seasonal high/low price differentials | ENTSO-E TP |
| **Day-ahead** | Average daily price differentials | ENTSO-E TP |
| **Intra-day** | DA-ID price differentials | ENTSO-E TP |
| **Balancing** | Balancing energy average prices | ACER MMR |
| | Balancing energy procurement volumes | ENTSO-E TP |
| | Balancing capacity average prices | ACER MMR |
| | Balancing capacity procurement volumes | ENTSO-E TP |
| **Congestion management** | Re-dispatching volumes | ACER MMR |
| | Re-dispatching costs per EUR/MWh | ACER MMR |
| **BtM storage + RES** | Residential energy prices | Eurostat |
| | % of households with time-differentiated retail tariffs | CEER |
| **…** | | |

For some use cases such as residential storage + solar PV, non-market applications like cost savings (e.g. related to solar PV capex savings or reduced energy bills) will constitute the main revenue stream. Therefore, the drivers/indicators for these non-market applications will focus on the aspects which increase these cost savings, such as high energy prices for households (including taxes and charges + network tariffs) or use of dynamic / time-of-use retail tariffs. However, revenue streams from participation in different electricity markets should also be considered, with the appropriate drivers/indicators.

The analysis of the dashboard should provide a high-level overview of the current opportunities for storage, making a link to the Task 1 mapping of technologies and use cases to provide an indication of which technologies could be potentially most profitable in certain regions.

It should be discussed with ENER how future developments of the EU energy system and markets will be considered in the task and how they would affect the opportunities. Future developments regarding market design (e.g. implementation of the Electricity Target Model and consequent market coupling of day-ahead, intra-day and balancing markets -especially balancing energy) will be addressed in Task 3 but may be used here.

**Questionnaire**

Through a questionnaire we will approach storage technology providers, project developers, utilities and DSO/TSO to make an inventory of:

- Dominant applications of energy storage now and in the near future (e.g. 2025-2030)
- Typical stacking of revenues in existing projects
- Expected stacking of revenues in future projects
- Expected market values with highest growth in the future
- Market and system values not yet monetized by revenues

An inventory of most important barriers and drivers for developing sustainable business cases now and in the near future will be set-up (also relevant for task 3).

We propose to use the segmentation of energy storage applications from Task 1. We will approach the EASE network (50+ members) for filling in the questionnaire (note: this has not yet been discussed with EASE for approval), for additional insights on heat and hydrogen storage we suggest to approach the representative IEA tasks and dedicated networks (FCH JU, EGEC, EUROHEAT & Power etc.). The questionnaire will be shared with ENER in advance.

### 2.2.2 Cost gaps

Based on the results of Task 2.1 and Task 1 we provide indications of cost gaps for the selected use cases. With the proposed approach of the opportunities dashboard, it will not be possible to quantify revenues, and thus also not to quantify cost gaps. However, the analysis of the dashboard as well as of questionnaire responses should allow to conduct a qualitative gap analysis of the different opportunities and possibilities for revenue stacking, which improve the business case of the storage technologies.

## 2.3 Task 3 Regulatory frameworks

Objective: this task aims to provide regulatory recommendations on storage to support the Commission identifying key EU actions for the development of storage in the EU. This would complement the 2020 storage study and update its country fiches (potentially focusing on the most important barriers to match project resources), not to repeat recommendations. Furthermore, the ACER 2020 market monitoring report recently released also contains an analysis of barriers for small and new market players in the different MSs.

The analysis could build on that by focusing on the following **new elements**:

- MS intentions regarding targets and a regulatory framework facilitating the deployment of storage
- Market design affecting each of the relevant revenue markets/streams (day-ahead, intraday, balancing, congestion management, etc. + passive storage utilisation), as a separate analysis per market has not been done yet. It would focus on intra-day, day-ahead, balancing, other ancillary services and capacity mechanism design.
    - Including an analysis of Electricity Target Model and expected remaining barriers once network codes and guidelines (especially the market guidelines) are fully implemented
- Guarantees of origin / certification of renewable energy, temporal requirements for additionally and storage
- Incentivising long-term storage through the different revenue streams
- Double taxation issues for behind-the-meter storage applications
- Non-discriminatory network planning and procurement of distribution flexibility services in order to defer network investments and minimise system costs

The work should be highly coordinated with the work in Task 2 in what concerns the identification of the barriers.

Given the complexity and diversity of the topics above, each will be treated separately, with a dedicated (sub)chapter for analysis of the barriers. A (sub)chapter can then provide the recommendations.

The **approach** for the study will be to:

- Identify the barriers for the development of storage per MS on the topics above
- Analyse which barriers affect each use case. The barriers will be linked (at a high-level, not per Member State) to the use cases surveyed in Task 1 to highlight which storage technologies and use cases is affected by which barrier.
- Collect data on the barriers for EU27, from transversal sources (i.e. sources covering all MS, not individual MSs)
- Recommendations for fostering storage considering:
    - Current status and further implementation of CEP and electricity market guidelines provisions
    - Current status and further implementation of Electricity Target Model and consequent expected integration of forward, day-ahead, intraday and balancing markets
- Analyse the international landscape, in particular those countries where energy storage is rapidly developing (e.g. US, UK, Australia, …).

# 3 Deliverables and meetings

For the purpose of this specific study, the following deliverables will be produced and meetings held.

For efficiency, we propose not to provide revised versions for the interim deliverables, and rather to address the Commission's comments individually in case further agreement is needed, or on the following deliverable otherwise.

Further meetings will be needed for each task in order to discuss specific issues – thus only the main project management meetings are indicated below.

**Table 3 Deliverables and project meetings**

| Deliverable/ meeting | Contents | Date | Outputs |
|---|---|---|---|
| **M1** | Kick-off for all tasks | Mid-January | pptx |
| **D1** | T1.1 Template of database of storage technologies | End of January | Excel |
| **D2** | T1.1 Draft database of storage technologies<br>T1.2 Draft mapping of technologies and use cases<br>T2.1 Indicator dashboard template + corresponding sources agreed on with EC<br>T2.2 Questionnaire template<br>T3 Regulatory barriers list and template for data collection | End of February | Word docx + Excel |
| **M2** | Discussion of T1 draft outputs<br>Discussion of T2 and T3 templates | Early March | pptx |
| **D3** | T1.3 Draft analysis of alternative flexibility solutions<br>T2.1 Draft dashboard (indicators quantified in a draft version) + preliminary cost gap evaluation<br>T3 Draft regulatory barrier analysis | End of April | Word docx + Excel |
| **M3** | Discussion of T1 and T2 draft outputs | Early May | pptx |
| **D4** | Draft report with revised version for all tasks | End of May | Word docx + Excel |
| **M4** | Final meeting | End of May | pptx |
| **D5** | Final report | Early June | Word docx + Excel |

The deadlines of draft and interim deliverables were made under the assumption of a 1-week feedback period by the Commission after delivery of the draft documents.

# 4 Time and work planning

**Start of the project and kick-off meeting: Mid-January 2022**

**Interim project meeting #1: Early March 2022**

**Interim project meeting #2: Early May 2022**

**Final project meeting: End of May 2022**

**Final Stakeholder Workshop: June 2022**

**Table 4 Lead, contribution, start and completion date per task**

| Deliverables | Start | Completion | Lead | Contribution |
|---|---|---|---|---|
| Project coordination | Jan 2022 | June 2022 | Trinomics | |
| Task 1 | Jan 2022 | End of April 2022 (draft) | ISE | ISI, IEE |
| Task 2 | Jan 2022 | End of May 2022 (draft) | ISI | TNO, IEE, ISE |
| Task 3 | Jan 2022 | End of May 2022 (draft) | Trinomics | IEE, ISE |

# 5 Resources

**Table 5 The following table shows the planned resources by task**

| Task/Resource | Resource needs in days | Share of total resources in percent |
|---|---|---|
| Project coordination | 24 | 10% |
| Task 1 Focus on current situation | 56 | 25% |
| Task 2 Market value and cost gaps | 80 | 33% |
| Task 3 Regulatory frameworks | 80 | 33% |
| **Total** | **240** | **100%** |

# 6 List of Tables

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