United Nations ECE/ENERGY/GE.6/2023/6

Economic and Social Council

Distr.: General
25 August 2023

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Group of Experts on Energy Efficiency

Tenth session
Geneva, 5-6 October 2023
Item 8 of the provisional agenda
Improving energy efficiency in industry

Advancing energy resilience and decarbonization across the United Nations Economic Commission for Europe region: unleashing the potential of energy storage and demand-side flexibility*

Note by the secretariat

Summary

The Committee on Sustainable Energy and its subsidiary bodies highlight a broad range of actions (ECE/ENERGY/146) and technical recommendations (CSE-31/2022/INF.2) for building resilient energy systems in the region of the United Nations Economic Commission for Europe.

Energy storage is referred to as an important option amid scaling intermittent renewable energy resources that requires vast energy storage solutions to make best use of low carbon resources and maintain energy security. Interconnected energy systems as well as energy storage on system and end-use level, are enablers for resilience, as well as catalysts for overcoming many energy-related challenges. There is not one technology, but instead a mix of technologies for any specific situation, context, and aim.

Development of support resources related to energy storage, to increase understanding of potentials, requirements, and other aspects, is therefore a part of the Work Plan of the United Nations Economic Commission for Europe (ECE) Platform on Resilient Energy Systems. The present document lays the ground for future research on the subject.

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* This document was scheduled for publication after the standard publication date owing to circumstances beyond the submitter’s control.

I. Introduction

1. Energy storage has the potential to be a key enabler of achieving multiple goals, including reliable access to clean energy sources, leveling imbalances of supply and demand, reducing impact of energy costs, shaving peak demands, etc. As the goals, needs and motivations vary, as well as the types, forms, and shapes of energy storage, it is necessary to create a foundation that empowers stakeholders to make informed decisions on meeting the desired outcomes while harnessing their potentials without creating lock-in effects. This includes awareness about aspects that need to be considered, and the types of storage that are suitable in particular contexts.

2. To identify fitting technologies, it is necessary to understand the strengths and weaknesses, the opportunities and threats of each type of storage in view of use cases or desired outcomes and which aspects are of relevance to assess these. Such aspects of an energy storage option can include energy density, memory effect, durability, acquisition costs, space requirements, discharge time, power output, temperature, required materials (critical or alternative), repair- and recyclability, environmental footprint. To make informed decisions on energy storage, it is further important to understand the required loads, time patterns, and other key or limiting factors to adjust the technology mix and to dimension the energy storage solutions adequately to meet economic viability criteria.

3. Energy storage can only meet its full potential if considered in a wider context and in combination with demand-side flexibility approaches for different end-use sectors. Therefore, harnessing the potentials of energy storage and demand-side flexibility necessitates linking across all ECE areas of work on sustainable energy (energy efficiency, renewable energy, cleaner electricity systems, gas, coal mine methane and just transition, resource management) and such thematic areas as Transport, Urban Development, Housing and Land Management, and Environment.

4. The present document contains an overview of what energy storage is, what forms and shapes it can take, what forms of energy it can store, and in what context it stands to demand-side flexibility.

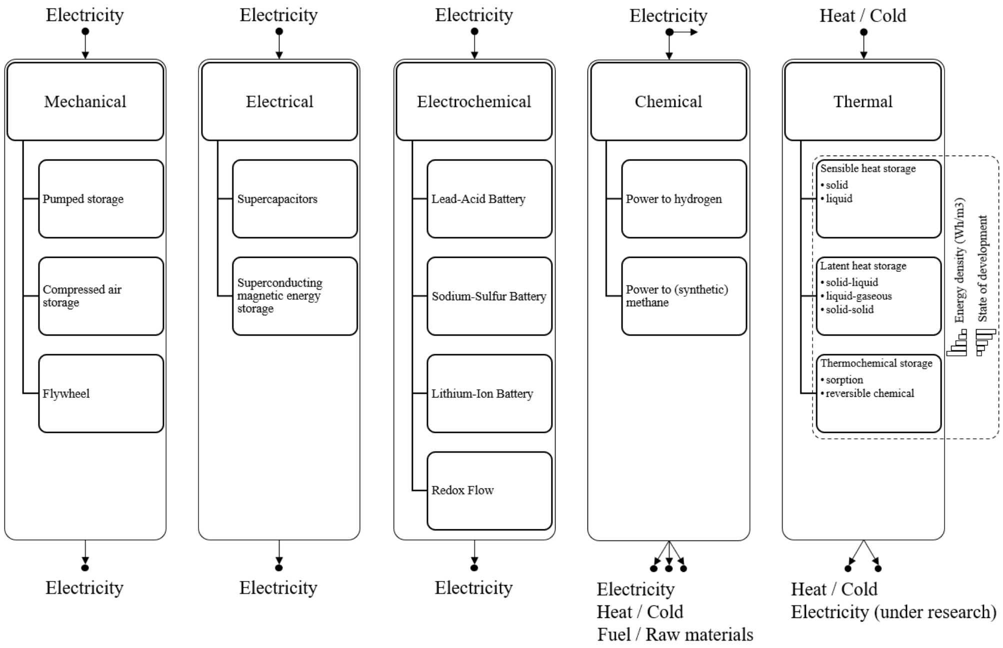
II. Energy Storage

5. Energy storage stores energy that is currently available but not required, for later use. Storage is accompanied by a conversion of the form of energy, and implies energy losses during both storage and energy conversion. This underlines the need to find fitting solutions that result in the best systemic efficiency, meaning the best overall energy performance.

Categorization by type of energy

6. Facilities for energy storage are categorized based on the type of energy that is stored (the primary form). However, frequently while charging or discharging the storage unit, a different type of energy is utilized (Figure I).

Figure I
Overview of energy storage technologies



Source: adapted from Michael Sterner and Ingo Stadler, “Energiespeicher im Wandel der Zeit”, Energiespeicher - Bedarf, Technologien, Integration, Michael Sterner and Ingo Stadler, eds. (Springer Vieweg, Berlin, Heidelberg, 2017); Emde, “Techno-oekonomische Bewertung von energietraegeruebergreifenden hybriden Energiespeichern” (2023); BVES.

Categorization by storage duration

7. Energy storage can be divided into short-term and long-term storage based on the storage period (Figure II). Depending on the timescale considered, different technologies are used, whereby the following time windows can be identified:

(a) Range up to a few minutes (feed-in fluctuations);

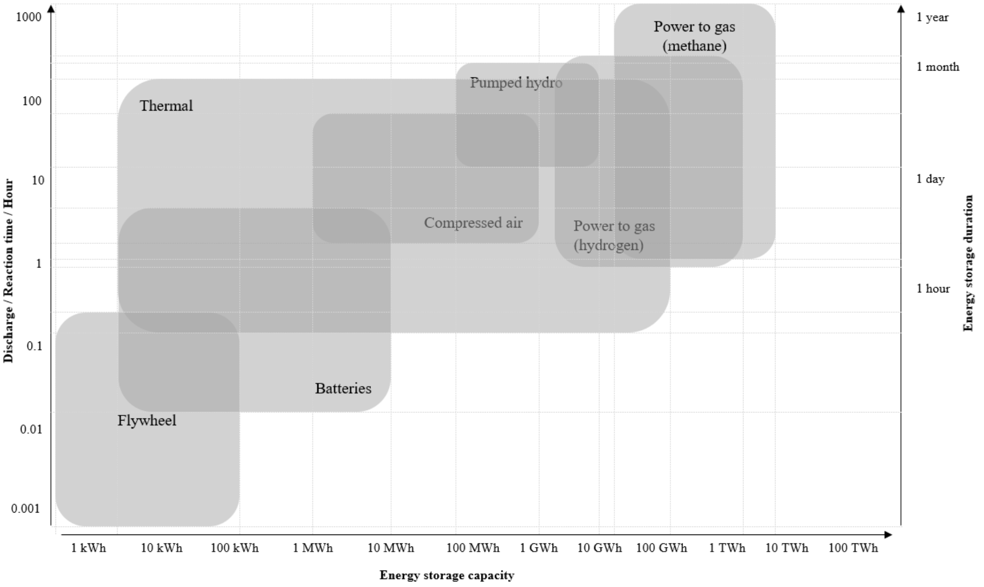
(b) Up to one day (e.g., PV daily patterns);

(c) Up to three days (random fluctuations);

(d) One to two weeks (sustained periods of strong or weak winds);

(e) Seasonal balancing.

Figure II
Comparison of discharge time and capacity of some energy storage technologies



Source: adapted from Bahman Shabani and Jason Moore, "A Critical Study of Stationary Energy Storage Polices in Australia in an International Context: The Role of Hydrogen and Battery Technologies", Energies, 9(9):674 (August 2016).

8. Awareness of additional determinants facilitates narrowing down feasible types of storage for the desired use cases and forms of energy available and forms of energy output needed: maximum power output (MW), lifespan in charging cycles, efficiency (per cent), self-discharge (per cent per hour), investment cost per kWh of storage capacity, cost per stored kWh, specific energy (Wh/kg), energy density (Wh/m^3), typical time of discharge for usual size, system-related capacity limit, flammability, toxicity, raw materials needed, repairability and recyclability, etc.

9. The useful type of storage is largely constrained by the intended area of application within which different sets of the aforementioned determinants have a priority or are a limiting factor. In essence, these can be subdivided by system level storage (infrastructure (including autonomous or off-grid streetlights), energy generation (store surplus generation of wind, tidal, solar, combustion, etc. plants), energy system (grid stability,) and end-use level storage (buildings, industrial facilities, vehicles).

10. The objectives for using energy storage are diverse:

(a) On a system level, they include avoiding losing surplus renewable energy that cannot be absorbed by the grid (curtailment), avoiding energy bottleneck and regional shortages, as well as stabilizing the grid (i.e., reducing the need for baseload reserve power plants and levelling out the volatility of renewable generation);

(b) From energy suppliers' perspective, they include avoiding selling energy at a loss, being able to provide additional energy to bridge brief periods of scarcity, and for local suppliers and end-users to store surplus electricity or heat;

(c) Objectives of industry and most other end-use can be categorized into optimization (load shifting through energy trading; consumption optimization; recuperation; peak shaving; integration of renewable energy resources; use of energy flexibility for cost optimization), security of energy supply (reduce dependency from external energy supply; process stabilization; ensuring uninterrupted energy supply), and generating additional revenues (load shedding and load increase; provision of balancing power or disconnectable loads).

11. Taking the types of (externally obtained, or otherwise wasted) energies available, the desired outcome (i.e., certain temperature, air pressure, lifting a certain weight, a certain

brightness), the objectives and limitations of technologies and use-cases into consideration, systemic efficiency is achieved for that constellation of types of energy, necessary conversion, storage types meeting the requirements and equipment ensuring the technical side of the outcome that requires least energy overall, and simultaneously meets the objectives.

III. Demand-side energy flexibility

12. To effectively pursue energy resilience and decarbonization, it is essential to look beyond energy generation and transmission and storage of surpluses. Energy flexibility measures on the demand-side help to reach the respective goals faster by undertaking measures adjusting to a volatile, intermittent, insufficient, or price-sensitive energy supply. This can be done by adjusting the energy demand in four principal forms:

(a) Time adjustment of consumption (shifting consumption at times of high renewable energy production);

(b) Incentivizing capacity limitation (reduction of consumption at peak load times);

(c) Incentivizing consumption increase (increase in consumption at off-peak times);

(d) Small changes for grid stabilization (short-term change of the load curve).

13. Many of the below demand side energy flexibility examples from industry, are transferrable to other stationary energy use cases:

(a) Dynamic change of energy source: depending on the energy availability or price of several available energy sources;

(b) Variable energy price related process interruption (pause): if the energy price (independent of source) exceeds a defined level, process can be paused for energy cost optimization (if delivery time and workload allow);

(c) Reorder production sequence: sequence of production steps is swapped for energy cost optimization;

(d) Reschedule production start;

(e) Reorder machine loading: at price peaks, focus on production of parts that require less energy.

(f) Energy storage: charging and depleting depending on the interday energy cost fluctuations;

(g) Virtual storage: storing energy in the ongoing processes (e.g., electrolysis, cold rooms).

(h) Adjust process parameters to the energy-optimal load profile.

(i) Adjust shift times: scheduling production to take place or increase when lower energy prices are expected (e.g., forecast of surplus wind or solar energy or off-peak tariffs).

(j) Adjust break times to energy price peaks or supply shortage (can be applied only for short peaks or at highly automated facilities).

14. The aspirations of energy resilience and decarbonization can be most effectively achieved by combining demand-side energy flexibility measures with both local, and system level storage options, power-to-X applications, systemic approaches and policy measures for the energy system and end-users.

15. Looking at the clean energy resources available across the ECE region, there is less of an energy problem but more a problem of distribution and making use of clean energy and on-site energy efficiency potentials.

16. An increasing amount of renewable energy in the energy system will increase the demand for energy storage on the various levels and types, across the ECE region and its multiple time zones that also represent a range of energy use patterns. Storage solutions, a robust energy system design with sufficient interconnectors and multiple redundancies, and digital solutions can help level these issues out.

17. The challenge at hand is to understand feasibility of options under various conditions, from technical, financial, climate, resource, and skills perspectives. In conclusion, storage of energy brings flexibility, which in turn increases resilience as it helps to level out volatility, avoid losing surplus energy, bridge times of scarcity, and thus reduce need for fossil base-load capacity and enable reduction of carbon footprint of the energy sector.

IV. Recommendations

18. To harness the potential of energy storage in advancing energy system resilience and decarbonization, it is deemed advisable to explore:

(a) How different types and levels of storage can support and increase the energy system resilience;

(b) How energy storage technologies can help expedite and reduce cost of decarbonization of transport;

(c) How energy storage and demand-side flexibility options can ensure making best use of intermittent renewable energy, including the energy that is best suited to store renewable energy and leads to the highest systemic efficiency;

(d) Supportive policy frameworks and regulatory mechanisms that are needed to incentivize adoption and integration of energy storage technologies;

(e) The means, including possible business models, that are needed to ensure that energy system participants can identify fitting energy storage technologies, evaluate their benefits and challenges, and implement applicable solutions;

(f) Questions related to affordability, integration with other technologies, and the impact on energy efficiency;

(g) Environmental implications of energy storage technologies from extraction to disposal, recyclability, circularity, as well as alternative materials and access to critical raw materials;

(h) Access to, and affordability of energy storage technologies across the ECE region, along with identifying possible financial mechanisms that can facilitate a broader roll-out and adoption of system-, local-, and micro-level energy storage;

(i) How digitalization can help optimize energy storage and enable demand-side flexibility;

19. To drive these efforts, establishment of a dedicated task force may be proposed for consideration;

20. The need to embrace technological diversity, continuous knowledge dissemination, and adoption of circularity principles, is also underscored.