Technology Collaboration Programme (TCP) on Energy Storage (ES)

energy storage
IEA Technology Collaboration Programme

Strategic Plan: March 2026 – February 2031

Overview of the status of the respective technology field and key policy and research R&DD challenges (beyond the TCP)

1. Technology Area and Relevance to Energy Transition

Stationary energy storage encompasses thermal, electrochemical, mechanical and chemical technologies that play a crucial role in the global energy transition. These technologies are pivotal for integrating renewable energy (RE) sources, enhancing grid reliability, reducing congestion and curtailment, and improving energy efficiency. Thermal energy storage (TES) involves capturing heat or cold for later use, which is particularly relevant for balancing supply and demand in district heating, cooling systems, and industrial processes. Electrochemical energy storage (EES), through batteries, supports e.g. grid stability by storing electricity generated from intermittent RE sources such as wind and solar. Mechanical storage can occur as flywheels, compressed air energy storage or (pumped) hydropower storage, while a chemical energy storage system uses RE to drive a chemical reactor that produce any type of fuel.

The relevance of these technologies to the energy transition cannot be overstated. They reduce the cost of integrating renewables and, thus, enable higher penetration of all renewables (offering flexibility), reduce dependency on fossil fuels and help in achieving carbon neutrality goals. By facilitating peak shaving and load shifting, they contribute to more efficient and resilient energy systems helping the electrification of the energy system and the decarbonisation of the industry.

This supports the IEA's commitment to advancing energy transition, ensuring energy security, promoting clean energy and diversifying sources to achieve global net zero emissions by 2050.

2. Progress in Technology Over the Past 5 Years

The stationary energy storage sector has seen significant technological advancements:

- Battery Technology: Lithium-ion batteries have dominated the market due to their high energy density and decreasing costs. Innovations in solid-state batteries, which promise higher safety and energy capacity, are gaining traction, although they are not yet commercialized at scale. Flow batteries and other chemistries, such as sodium-ion and zinc-air, are being developed to provide cost-effective and scalable alternatives.
- Thermal Energy Storage: TES technologies have advanced with improved materials and system designs that increase efficiency and reduce costs. Next to sensible heat storage, which is an inexpensive and proven technology, phase change materials and thermochemical storage systems have been explored for their potential to store large amounts of energy with minimal losses. Concentrated solar power plants with integrated TES are becoming more prevalent, enhancing the dispatchability of solar energy.
- Integration and Management: Smart grid technologies and advanced energy management systems have been developed to optimize the integration of storage solutions – not only into the grid but also related to flexible sector coupling (demand side response). Together with AI and machine learning tools, these systems enable better forecasting, real-time monitoring, and automated control, which are essential for maximizing the benefits of energy storage.

3. Policy and Research Challenges

Despite these advancements, several challenges remain:

- Policy Frameworks: Many countries lack comprehensive policies that incentivize the deployment of energy storage systems. Regulatory uncertainty, especially regarding ownership and market participation, poses a significant barrier. Clear policies are needed to define the roles of storage in energy markets and to provide financial incentives for their adoption.

- Cost and Financing: Although costs have been decreasing, initial investment for energy storage technologies remains high. Governments and financial institutions need to develop innovative financing models to support widespread deployment. This includes subsidies, tax incentives, and public-private partnerships. In this context, assessing the value of energy storage is a challenge itself.
- Research and Development: Continued R&D is crucial to overcome technical limitations such as energy density, lifecycle, and safety concerns. Investments in research are needed to develop next-generation storage technologies and to scale up manufacturing processes.
- Grid Integration and Standards: The integration of storage systems into existing grid infrastructures poses technical challenges. Developing universal standards and protocols for interoperability and safety is essential for widespread adoption.
- Environmental and Social Considerations: The lifecycle environmental impact of battery production and disposal is a growing concern. Policies promoting re-use, repurposing or recycling and sustainable material sourcing are necessary. Additionally, social acceptance and community engagement in storage projects are vital for successful implementation.

4. Future Outlook

Over the next 5 to 10 years, addressing these challenges will be critical for the global affordable energy transition. The deployment of stationary energy storage will likely accelerate as countries recognize its importance in achieving energy security and sustainability goals. Collaborative efforts between governments, industry, and academia will be essential to drive innovation and policy development, ensuring that energy storage plays a central role in the future energy landscape.

TCP introduction

- *Our Vision*: The share of renewable energy is growing rapidly in energy systems around the world. Flexibility will be key. Within this energy system, energy storage is/will be crucial to make energy from renewables available when needed and to realize an affordable, efficient and resilient energy system.
- *Our mission*: Our Energy Storage TCP ensures that energy storage becomes a strategic element in the energy system of the future by fostering research, development and pre-standardisation work of energy storage technologies and the integration in the energy system. We disseminate the results to policy makers, society and industry.
- *Definition of Energy Storage*: An energy storage system can take up energy and deliver it at another point in time. The storage process itself consist of three stages: charging, storage and discharging. After the discharging step, a storage system can be charged again.

Since 1975, our TCP is focused on storage technologies and the integration of storage into the energy system. Since energy storage is a cross-cutting issue, expert knowledge of many disciplines (energy supply and all end-use sectors, spatial-temporal energy planning, as well as energy transmission and distribution) must be considered (we don’t deal with energy storage in relation to 1 energy source, but treats the entire energy system in an integrated way (our USP)). To use this widespread experience efficiently and gain benefits from the resulting synergies, coordination is needed to develop suitable working plans and research goals. ES TCP is responsible for fulfilling this important task. ES TCP’s strategic plan therefore includes research activities, as well as coordination activities.

The main ES TCP policy messages are:

- Energy storage in general has a significant economic and technical value as major contributor to the overall energy transition (no efficient and affordable energy transition without energy storage).
- Thermal energy storage should receive more balanced attention in analyses by policy makers, considering the contribution this technology will have for a successful energy transition, specially related to the decarbonisation of the industry. In buildings (including HVAC systems), TES support energy conservation and reduced heat pump capacities.
- There is a need to establish an analytical regime of metrics for valuing energy storage across energy technologies, end use profiles, and jurisdictions.
- There is a need to solve economic-regulatory hurdles (market access, taxation, security of investment, public private partnership, etc.).

- Improved communication efforts are needed, such as better visualization, successful demonstration projects and show case applications, simpler language, and communication of results of ES TCP work to speed up the deployment of energy storages.

Strategic Objectives

Depending on the required form of energy and storage period, various technologies, such as thermal, electrochemical, mechanical or chemical storages, are suited and available. Energy storage technologies can be differentiated according to their storage duration (short, medium, and long duration energy storage) and their positioning in the energy system (e.g. behind/front the meter, grid storage). The energy transition will require each of these types to be deployed in appropriate quantities, but there are different challenges associated with adoption and deployment of each – technological innovation, market design and regulatory regimes, etc.

The TCP addresses some of these challenges, through the following four priority areas:

1. System integration: Energy storage enabling flexibility and sector coupling, including bi-directional applications and focus on more integrated system packages.
2. Electrical Energy Storage (EES): Focus on system aspects of electrical storage and new and innovative storage concepts.
3. Thermal Energy Storage (TES): Focus on thermochemical energy storage, phase change materials, sensible thermal storage (at all temperatures ranges and serving various applications).
4. Chemical Energy Storage (CES): Focus on power to gas (within boundaries of gas/H2 as energy storage and carrier serving system integration) and conversion technologies/efficiencies.

High-level overview of programme of work

Tasks in progress:

- Task 41 “Economics of Energy Storage”. For the economic evaluation of energy storage systems, technical benefits of energy storage should be translated into economic values and finally enable valid business cases. Main outcomes of Task 41 for decision makers in politics & industry and financial sector representatives will be a collection of economics evaluation methods and best practice examples. Final report expected to be published in 2026.
- Task 42 “System flexibility from Medium-Duration Energy Storage (MDES)”. The main goal is to establish the rightful place of MDES technologies within the array of technologies that are available to support transition to Net Zero electricity grids. Although any electricity grid could technically operate without realising any MDES technologies at all, this is invariably far from being cost optimal and it is vital that policy-makers and grid-operators understand this crucial point. Final report expected to be published in 2027.
- Task 43 “Standardized use of building mass as storage for renewables and grid flexibility”. Thermal component activation uses existing structural masses in buildings (e.g. concrete elements) for heating and cooling purposes. The main goal of Task 43 is to prepare the storage technology for widespread integration on an international level, harnessing the benefits of this storage on local, quarter and city level respectively. Final report expected to be published in 2026.
- Task 44 “Power-to-heat integrated Carnot Batteries for zero-Carbon (industrial) heat”. Objectives: Identify the main roles of the storage supported Power-to-Heat and heat-integrated Carnot batteries solutions and map the design configurations to the use cases; raise awareness of the stakeholders by creating common understanding of the (role of) Power-to-Heat technologies and heat-integrated Carnot batteries; facilitate technology entrance to market through the identification of best Go Opportunities; provide information to policy makers to create suited regulatory frameworks and support schemes to further the market uptake. Final report expected to be published in 2027.
- Task 45 “Accelerating the uptake of Large Thermal Energy Storage (LTES)”. Objectives: Further improvement of numerical simulation to have better tools for system design, integration in district heating systems and optimisation; broadened LTES materials database and materials test methods; setting a basis for future standards and performance checks for LTES systems; targeted information and training material for decision makers, implementers and developers; inventory of improved concepts and technologies. Final report expected to be published in 2027.

New Tasks/ Task ideas:

- Task 46 “Application-oriented energy storage selection”
- Task 47 “Components for Thermal Energy Storage”
- Task 48 “Thermal energy storage materials”
- “Energy storage and artificial intelligence” (Task 49*) (* tentative Task number, Task not yet approved)

Special attention will be given to new Tasks to actively stimulate industry involvement to increase and accelerate the deployment of innovative energy storage developments.

The following table illustrates how the Tasks address the four priority areas. Consequently, EES and CES should receive extra emphasis in new Tasks in the next term.

		Priority Areas			
Task	Title/Topic	System Integration	EES	TES	CES
41	Economics of Energy Storage	++	+	+	+
42	System flexibility from Medium-Duration Energy Storage	++	+	+	+
43	Standardized use of building mass as storage for renewables and grid flexibility	++		++	
44	Power-to-heat integrated Carnot Batteries for zero-Carbon (industrial) heat	++		++	
45	Accelerating the uptake of Large TES	+		++	
46	Application-oriented energy storage selection	++	+	+	+
47	Components for TES	+		++	
48	TES materials			++	
49*	Energy storage and artificial intelligence	++	+	+	+
	Extra emphasis for scope in new Tasks in next term		■		■

Operations, finance and management

- All Contracting Parties and Sponsors make an annual financial contribution to the common fund used for ES TCP general, administration, and communication matters. The overall budget is EUR 88,040 in 2025. ES TCP Tasks are Task-shared (not cost-shared).
- Management: Chair: Bert Gysen, VITO, Belgium; Vice Chairs: Christian Fink, AEE INTEC, Austria, Abhishek Somani, PNNL, USA; Secretary: Christoph Rathgeber, ZAE Bayern, Germany.
- Two meetings of the ExCo per year, monthly meetings of Chair and Secretary, and regular meetings of the Chair and Vice-Chairs to work towards the goals of ES TCP's Strategic Plan.
- Two reviewers are appointed for each Task. They monitor progress and take a more focused, critical look at the extent to which the objectives (overall and Task-related) are being achieved.
- A Communication Working Group with ES TCP Chair, Secretary, and a group of ExCo delegates guides the implementation of the communication plan.
- Ad hoc working groups.

Membership and outreach

- Our participating countries (21): Austria, Belgium, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Israel, Italy, Japan, South Korea, the Netherlands, Norway, Slovenia, Sweden, Switzerland, Turkey, United Kingdom, USA.
- Our sponsors (3): BVES – German Energy Storage Systems Association, Germany; University of Seville, Spain; CIC energiGUNE, Spain
- Our limited sponsors (4): University of Valladolid, Spain; University of the Basque Country, Spain; University of Melbourne, Australia; Centre for Renewable Energy Sources, Greece
- Outreach: Contact to the European Commission and Spain as new contracting parties. Further interest for limited sponsorships from institutions in Poland, Portugal, and Spain.
- In 2026-2027, the ES TCP will come up with a shortlist of missing countries based on certain criteria (to be discussed). Based on this shortlist, we will contact the CERT/REWP delegates for further action (passing on contact persons) so that we can expand the number of participating countries.

Collaboration

- TCP Coordination Groups (ES TCP co-leads Energy System Flexibility Coordination Group)
- Joint Tasks (47, 48) on thermal energy storage materials and components with SHC TCP
- ES TCP was presented within the IEA (CERT, EUWP, REWP).

- Partnerships with other international bodies (e.g. UN, World bank, MI, CEM, IDO, CEN) and affiliated initiatives (like other TCP's) are encouraged by the ExCo, also at Task level.
- ES TCP started an academic exchange platform for PhD and post-doc topics/vacancies.
- In 2026-2031, our ES TCP will cooperate more intensively with other TCP's: first contacts have been made with IETS, ISGAN, Hydro, and PVPS.

Communication

Efforts will be made to increase the dissemination of the TCP work results. Results will be open source and shared through public media.

- Further working towards becoming a leading international source for energy storage information through a database of energy storage fact sheets on our website.
- Sharing information about statistics on energy storage markets, R&D funding programmes and pilot installations through country reports from ES TCP member countries on the website.
- The tri-annual scientific energy storage conferences *Enerstock* continues to be the platform for sharing latest results in the energy storage community. We will use and promote the ES TCP and Enerstock brand for better recognition. Other communication efforts are directed to support our policy messages and to increase the active participation of experts from the energy storage community in symposia, workshops, webinar events, etc. to present the latest developments and innovations on energy storage. Enerstock 2024 took place in Lyon, France. Next Enerstock will be in Bilbao, Spain, in the first half of October 2027.
- The first Enerstock online "Decarbonisation Now – What can we expect from Energy Storage" was launched in February 2023. Invited presentations on energy storage from different perspectives and stakeholders made up the conference program: Energy storage R&D, energy storage manufacturers, policy, education & society, and finance & markets. *Enerstock online* is organized as an *in between* of the tri annual (physical) Enerstock scientific conferences with the aim to support the scientific energy storage community. The second *Enerstock online* is planned for 10–11 February 2026 and will focus on the topic of flexibility provided by energy storage.
- In 2022, ES TCP started online seminars – *OnSeminar* – to discuss and disseminate up to date RD&D activities related to energy storage. *OnSeminars* includes one to three presentations followed by a Q&A session. The recordings are shared via ES TCP's YouTube Channel.
- LinkedIn page to announce ES TCP events, inform about Tasks and publications, and interact with international energy and energy storage community.
- Quarterly ES TCP newsletter sent to approx. 1,500 subscribed contacts with energy storage success stories, updates on ES TCP Tasks and their expert meetings, and energy storage conferences. Subscription for newsletter through ES TCP website.

Additional activities in 2025:

- Animated movie to explain the function, role, and necessity of energy storage to transform our energy system. Briefly introduce ES-TCP as an international research platform, committed to provide workable solutions. Audience: Policy makers dealing with energy transition issues like regulations, stimulation programmes, funding of research; journalists and media people who need an explanation of the role of energy storage; non-scientific people with little previous technical knowledge. (Released on 1 Sep. 2025.)
- 100th Executive Committee Meeting & 50th Anniversary with symposium in Rotterdam on 13 Nov. 2025 with IEA representatives and Dutch government invited.

From 2026 onwards, the introduction of metrics for assessing the impact of communication is planned.

Gender equality and diversity

Status quo:

- Geographic diversity: Participating countries are from Europa, North America, and Asia.
- 15 out of 46 ExCo (alternate) delegates and 1 out of 6 Task Managers are women.

As a step towards gender equality and increased diversity, the ES TCP plans to raise the awareness of its members of this status quo.