IEA Technology Collaboration Programme

International Energy Agency

Technology Collaboration Programme on Energy Storage

(ES TCP)

Task 39 - Large Thermal Energy Storages for District Heating

Subtask A: Application Scenarios, Assessment of Concepts, Integration aspects

Deliverable A1: Method to carry an LTES project, important questions & KPIs - Synthesis

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Introduction

Large Thermal Energy Storages (LTES) offer various advantages for District Heating Networks (DHN), such as providing more flexibility in the network (improved control, expanded energy mix, etc.), increasing the share of renewables and waste heat recovery, peak power shaving, or enhancing power-to-heat (P2H) potential (stabilization of the power grid thanks to P2H).

The four main LTES technologies used in DHN are: Tank (**TTES**), Pit (**PTES**), Borehole (**BTES**), and Aquifer (**ATES**) Thermal Energy Storages, illustrated in Figure 1.

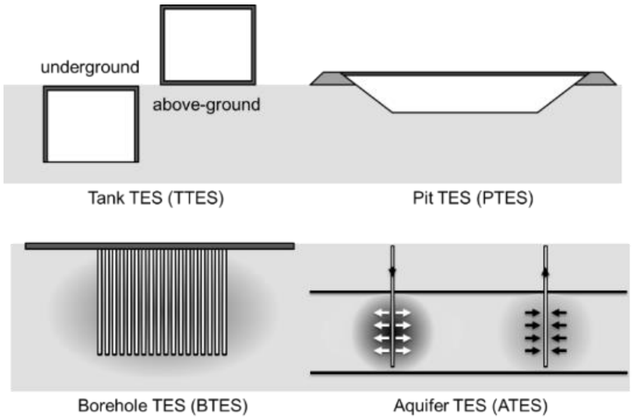


FIGURE 1 THE FOUR LTES TECHNOLOGIES CONSIDERED IN IEA-ES TASK 39 (SOURCE: SOLITES).

An LTES project can be subdivided in four essential stages: Opportunity, Design, Tender, and Implementation & Operation. The main stakeholders involved during each step are presented in Figure 2.

This leaflet presents each project phases' main objectives, main indicators of interest for the stakeholders involved, common challenges faced, and tools available to carry out each activity while guaranteeing the best control and quality of the project. It is aimed at project owners and initiators or any actor who wishes to contribute to LTES development, by providing a global vision and a method to master project development. It is a condensed version of the main deliverable of Subtask A entitled "Method to carry out an LTES project, important questions & KPIs – Report", which goes into more details regarding the work to conduct at each stage and the main indicators investigated.

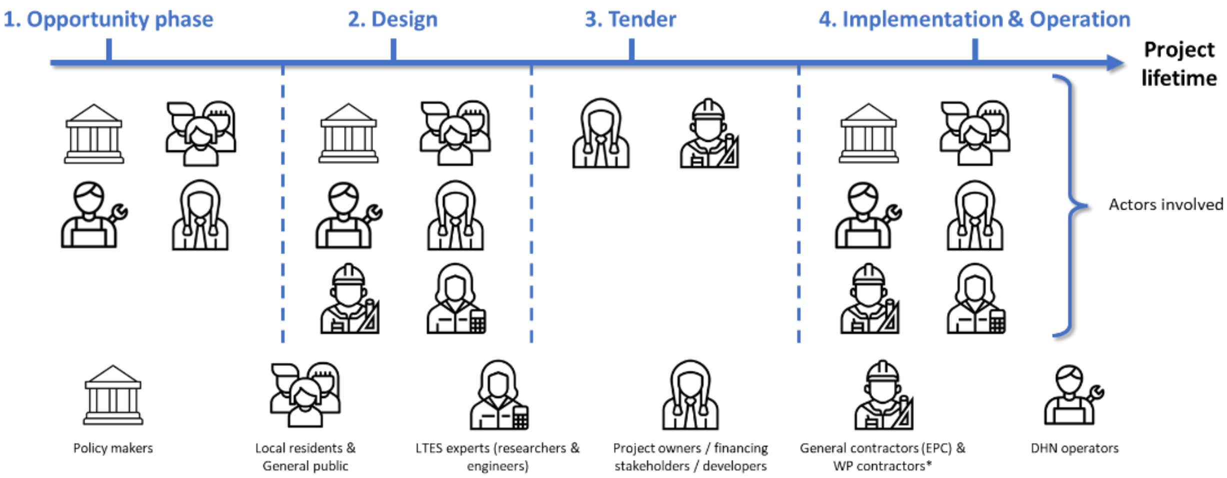


FIGURE 2: STAGES OF AN LTES FOR DHN PROJECT AND ACTORS INVOLVED.

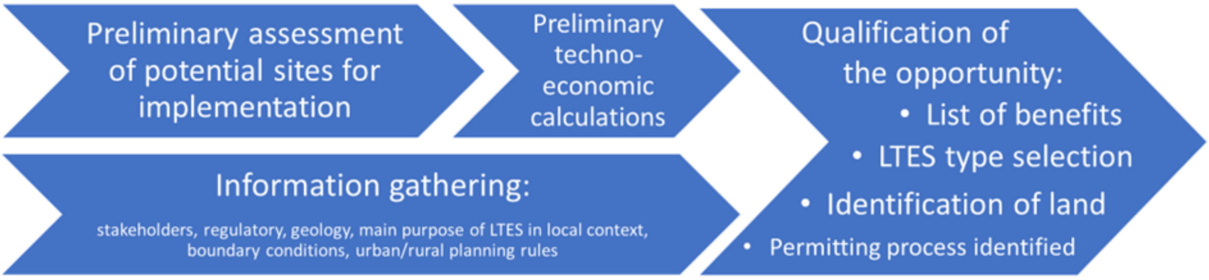
1. Opportunity

Objective

This phase aims at establishing the potential for LTES in a given context. Project developers carry out the first techno-economic feasibility studies to investigate the relevance of LTES, the appropriate type of LTES is chosen, and potential risks and showstoppers are investigated.

Activities

- Identification of potential installation sites,
- Collecting and listing the techno-economic boundary conditions of the site including the considered DHN,
- Initial guess and analysis on energetic and economic benefits and risks,
- Preliminary underground investigations for underground LTES systems,
- Identification of main available constraints (topology, groundwater presence, urban planning rules, expansion of living area…),
- Selection of the most suitable technology adapted to the need/context.



Common challenges

- Access to the actual heat load and heat sources available: data from customer / DHN operator,
- Land availability and competition with other public projects (development of economic activities or housing for example),
- Superficial knowledge or information on the underground (i.e., soil and aquifer) characteristics for the chosen site,
- Uncertainty on prerequisites for approval, due to lack of regulations which are dedicated to High Temperature (HT) Underground Thermal Energy Storage or existing HT-LTES systems within the same administrative area.

Tools

- Pre-feasibility simplified modelling tools (energetic, thermohydraulic approaches),
- Simplified/simulated boundary conditions to initiate computations,
- Business plan,
- Existing literature on the nature of soils and environmental constraints,
- Urban planning documents,
- Open data for presence of groundwater, topology, weather conditions etc,
- Best practices bibliography/references for the different technologies of LTES.

Indicators

Actor	Technical indicator	Economic indicator	Environmental indicator
 Policy makers	- Technology - Location / land area required - Heat transfer fluid and storage medium - Size of the DHN / heat demand / number of households impacted - Storage lifetime / project start date - Heat source energy fractions with or without LTES & percentage of renewables	- DHN weighted marginal heat price with or without LTES	- Type of impacts to foresee (environment / local residents) - Energy specific CO_2 emissions with or without LTES
 Local residents & General public	- Technology - Location / land area required - LTES volume (compared to concrete values) - Size of the DHN / heat demand / number of households impacted - Storage lifetime / project start date - Heat source energy fractions with or without LTES & percentage of renewables	- DHN weighted marginal heat price with or without LTES	
 DHN operators	- Technology - Location / land area required / distance to integration point - LTES volume - Operation temperature range (Heat transfer fluid AND storage medium) - Heat source energy fractions with or without LTES & percentage of renewables - Identification of post-heating technologies for boosting the discharged temperature	- DHN weighted marginal heat price with or without LTES - Heat generation cost	
 Project owners / financing stakeholders / developers	- Technology - Location / land area required / distance to integration point - LTES volume - Heat source energy fractions with or without LTES & percentage of renewables - Modelled charged and discharged heat - Surplus energy available and targeted heat from the DHN to be addressed - Design storage capacity - Storage lifetime / project start date - Heat source energy fractions with or without LTES & percentage of renewables	- DHN weighted marginal heat price with or without LTES - Heat generation cost	

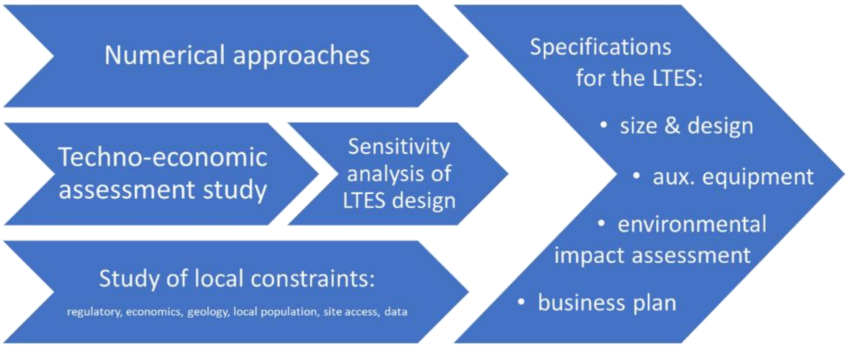
2. Design

Objective

The design phase spans between the end of the opportunity and the start of the implementation. Its purpose is to remove barriers and de-risk the project to be able to implement it in a later stage. It includes all the studies (technical, economic, regulatory, etc.) required to be able to implement the project. The clarification of all those specific constraints can have a decisive impact on the LTES design and its technical and economic relevance. The LTES optimal type, size and geometry are established in this phase.

Activities

- Thermohydraulic behaviour and performance modelling,
- Permitting (environmental impact assessment),
- Soil analysis / detailed local constraints identifications (existing buried network, etc.),
- Sensitivity analysis of main parameters / variables for optimum sizing and performance check,
- Technical specifications (geometry / materials / sizing) & Construction method,
- Land securing,
- Economic viability & Public financing support estimation / securing.



Common challenges

- Permitting delays (absence of specific regulatory framework in some countries, lack of experience in the permitting process from administration),
- Instruction delays for subsidy instruction process,
- Modification of input data and boundary conditions along the process → new calculations / simulations,
- Define and explore new control strategies taking advantage of the flexibility offered by the LTES,
- Availability of suitable topping solutions for high grid supply temperatures, to make the storage a secured capacity especially under extreme cold weather,
- Technical difficulties due to soil quality / groundwater presence and flow,
- Local opposition to the project (lack of knowledge about its advantages or lack of involvement).

Means & Tools

- Detailed study tools, divided into the two following categories, LTES specific and system design tools:
  - Environmental impact assessment study,
  - Detailed modelling tools (energetic, thermohydraulic approaches) leading to technical specifications (e.g. maximum flowrate of the pumps, size of the thermal storage, expected thermal losses, etc.),
  - Geotechnical specification,
  - Estimated pricing of the LTES allowing to define the more suitable design for the project.
- Business plan

Indicators

The design phase is a follow up of the opportunity phase, thus the indicators introduced in the previous part are still relevant in this part and only additional indicators are introduced in the following table.

Actor	Technical indicator	Economic indicator	Environmental indicator
 Policy makers		- CAPEX & OPEX	- Hydrogeological effects - Thermal effects and extent of the heating zone - Changes in groundwater chemistry - Changes in microbial population - Reduction in CO2-emissions
 Local residents & General public	- Share of renewables in heat generation portfolio - Share of stored heat in annual heat supply	- Increase/reduction in heat supply tariff	- Hydrogeological effects - Changes in groundwater chemistry - Reduction in CO2-emissions
 DHN operators	- Modelled charged and discharged heat - Number of heat storage cycles per year	- Expected cost of backup heating unit to lift the temperature to the one of DHN	- Hydrogeological effects (i.e. groundwater/ground temperature)
 Project owners / financing stakeholders / developers	- Storage losses - Energy efficiency - Number of heat storage cycles per year - Annual refill volume - Soil characteristics - Slope & depth	- Cost of the energy used to charge the LTES - CAPEX & OPEX	- Hydrogeological effects - Thermal effects and extent of the heating zone - Changes in groundwater chemistry - Changes in microbial population
 General contractors (EPC) & WP contractors	- Design parameters of the corresponding work package LTES components - Performance indicators of the corresponding work package LTES components	- CAPEX & OPEX	
 LTES experts (researchers & engineers)	- All design parameters - Modelled charged and discharged heat - Storage losses - Energy efficiency - Number of heat storage cycles per year	- DHN weighted marginal heat price with or without LTES	

3. Tender

Objective

During this phase, the general contractor or the different sub-contractors are chosen based on a defined scope of work. The different offers need to be compared thanks to different KPIs listed below. Contracts need to correctly balance the role and responsibilities of each party based on their knowhow, experience and size compared to the work to be done to make the project ready to be financed. The tender process usually starts during the design phase to test the market and get updated prices.

Activities

- Work Package (WP) distribution established, interfaces clarified and listing of requirements for each WP
- Specification of the need and listing of the requirements,
- Negotiation,
- Selection of the best offer considering specific criteria to be defined by the project owner,
- Contractualization based on a clear and balanced distribution of responsibilities.

Common challenges

- Increased interest rate leading to an increase in heat price compared to the assumptions of the previous stages,
- Definition of contractual commitments and clear associated penalties for:
  - Price
  - Delay
  - Durability
  - Performance (global or specific adapted to the scope of work requested)
- Project WP structuration to adapt to limit the interface risk while preserving competitivity.

Tools

- Comparative table of offers,
- Business plan,
- Tender documents.

Indicators

Actor	Technical indicator	Economic indicator	Environmental indicator
 Project owners / financing stakeholders / developers	- Key performance indicators of the corresponding work package LTES components	- Updated DHN weighted marginal heat price with or without LTES - CAPEX of the project - OPEX estimations Typically, you can express each Work Package in €/m3 or €/m² to easier compare different offers.	Any environmental restriction (and its related KPI) imposed by the administration in the permits obtained needs to be requested
 General contractors (EPC) & WP contractors	- Key performance indicators of the corresponding work package LTES components	- CAPEX of the package	Any environmental restriction (and its related KPI) imposed by the administration in the permits obtained needs to be ensured

4. Implementation / Operation

Objective

During the implementation phase, the LTES is built and connected to the district heating network, and later commissioned. It is then operated for the duration of the project.

Activities

- Construction work,
- Component manufacturing & assembly,
- Quality insurance of the work (during assembly/construction),
- Financing scheme finalization (Subsidies / Equity / Debt),
- System commissioning,
- Performance tests measurements,
- Compliance to specifications,
- Creation of digital twins,
- System operation and maintenance during the LTES expected lifetime.

Common challenges

- Bad weather conditions during the implementation (wind, rain, frost/snow),
- Availability of water for filling,
- Low quality implementation (not enough quality insurance) leading to leakages, broken equipment/components, and delays,
- Geological conditions different than expected (stone instead of soil in the underground for example),
- Storage operation modes and heat loads different from design hypotheses,
- LTES performance sensitivity to operational conditions,
- Storage service lifetime and maintenance effort.

Tools

- Instrumentation,
- Supervision & quality assurance (including extraction and analysis of data periodically),
- Proper hydro chemical concept,
- Engineering team design and modelling tools,
- Operation & maintenance planning and work.

Indicators

Actor	Technical indicator	Economic indicator	Environmental indicator
 Policy makers			- Environmental indicators from the KPI list to control according to regulation
 Local residents & General public		- DHN weighted marginal heat price with or without LTES	- Local area impact during and after implementation (visual, acoustic, traffic disturbance…) - Changes in groundwater chemistry - Ground temperature increase
 DHN operators	- Annual charged and discharge heat - Heat losses - Efficiency - Number of heat storage cycles per year - Auxiliary power consumption	- DHN weighted marginal heat price with or without LTES	- Environmental indicators from the KPI list to control according to regulation
 Project owners / financing stakeholders / developers	- Annual charged and discharge heat - Heat losses - Efficiency - Number of heat storage cycles per year - Auxiliary power consumption - Stratification indicators	- DHN weighted marginal heat price with or without LTES - Evolution of CAPEX & OPEX	- Environmental indicators from the KPI list to control according to regulation - Changes in groundwater chemistry - Ground temperature increase
 General contractors (EPC) & WP contractors	- Performance indicators of the corresponding work package LTES components - Auxiliary power consumption of the corresponding work package LTES components	- Evolution of CAPEX & OPEX	
 LTES experts (researchers & engineers)	- Measurements from the various sensors of the project - Stratification indicators - Efficiency		- Environmental indicators from the KPI list to control according to regulation - Changes in groundwater chemistry - Changes in microbial population

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