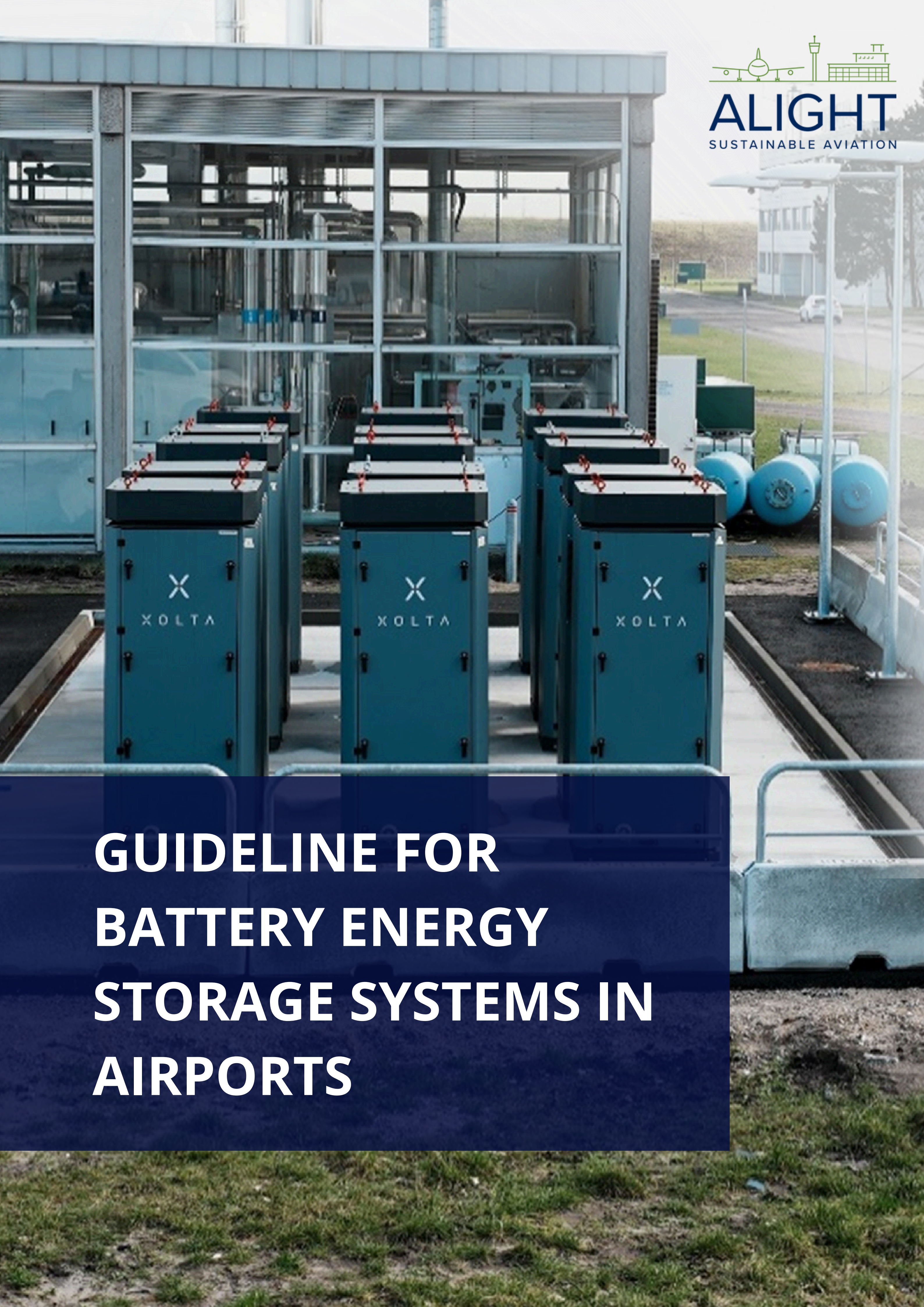
ALIGHT
SUSTAINABLE AVIATION



GUIDELINE FOR BATTERY ENERGY STORAGE SYSTEMS IN AIRPORTS

ACKNOWLEDGEMENT

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RELATED GUIDELINES

Guideline for charging infrastructure in airports

Guideline for smart energy management systems in airports

Guideline for smart charging and vehicle-to-grid in airports

Guideline for solar power plants in airports

INTRODUCTION TO ALIGHT

Alight is an EU 2020 Horizon project: A Lighthouse for the Introduction of Sustainable Aviation Solutions for the Future (ALIGHT). The consortium consists of 17 partners who have jointly committed to addressing the challenges of creating a transition in the aviation industry. Spread across 10 different European countries, the ALIGHT partners range from European airports to technology providers and knowledge institutions. The project is divided into two main focus areas: the supply, implementation, integration and smart use of Sustainable Aviation Fuel (SAF) and the development, integration and implementation of a Smart Energy system.

The smart energy section of the project addresses the full chain of system mapping, energy consumers, energy supply, including renewable energy and energy storage and energy management. For example, a Battery Energy Storage System (BESS) has been installed to gain valuable experience in, for example, the practical implementation of such a system in an airport, as well as how storage can aid in an increase in the use of renewable energy.

INTRODUCTION TO ALIGHT

INTRODUCTION TO THE GUIDELINE

This guideline provides best practices based on lessons learned in the ALIGHT project, related to implementing battery energy storage systems (BESS) in airports. The aim is to provide insights and help to overcome possible barriers related to mapping, planning, designing, and executing charging infrastructure projects in airport environments. The guideline is divided into three main pillars: mapping, planning, and implementation.

The aim of the mapping phase is to create a solid base for the later decision making through initial analyses. The aim of the planning phase is to choose the relevant technologies and to ensure a thorough foundation of data and information for the implementation and commissioning phases. The aim of the implementation phase is to ensure smooth installation of BESS.

As part of the ALIGHT project, four airports—Copenhagen, Rome, Warsaw, and Vilnius—serve as case studies for implementing smart energy solutions. These four airports are different in size, location and stage of development in the area of smart energy, offering diverse insights and learnings. Opportunities, challenges and lessons learned related to BESS from the airports are described in this guideline.

Figure 1 – Location of ALIGHT airports: Copenhagen Airports in Denmark, Aeroporti Di Roma in Italy, Lithuanian Airports in Lithuania, and Centralny Port Komunikacyjny in Poland.

INTRODUCTION TO THE GUIDELINE

ALIGHT Airports

Copenhagen Airport

Copenhagen Airport is the lighthouse airport in the ALIGHT project, meaning that it is the primary airport. Copenhagen Airport is located 8 km from the city centre of Copenhagen. In 2023, CPH served over 26 million passengers.

Rome Fiumicino “Leonardo da Vinci” Airport

Rome Fiumicino “Leonardo da Vinci” Airport (FCO) is managed by Aeroporti di Roma (ADR), and it is located 30 km from the city centre of Rome. The airport received more than 44.4 million passengers in 2023.

Centralny Port Komunikacyjny

Centralny Port Komunikacyjny (CPK) is a part of a large infrastructure project in Poland. CPK airport will be a new international airport, located around 40 km from Warsaw. It is planned to be in operation from 2028. The airport is expected to accommodate around 34 million passengers, and with the ability to expand in the future.

Vilnius International Airport

Vilnius International Airport (VNO) is part of Lithuanian Airports (LTOU) and is located 5.9 km from Vilnius. It is the largest of the three commercial airports in Lithuania including Kaunas Airport and Palanga Airport. In 2023 the Vilnius airport served around 4.4 million passengers.

INTRODUCTION TO THE GUIDELINE

Motivation

Airports are energy-intensive infrastructures, requiring innovative solutions to meet the growing need for sustainable transition. As the aviation industry transitions toward carbon neutrality, integration of smart energy technologies has become essential to continue airport operations without compromising on their environmental responsibility.

This handbook serves as a practical guide for technical project managers, offering actionable insights of planning and implementing of battery energy storage systems in an airport environment. Through practical guidelines, case studies, and lessons learned, this report provides the readers with technical insights and strategic considerations for addressing the complexities of modernising energy infrastructure in airports.

There can be many rationales for an airport to invest in renewable energy sources (RES). An important reason is the transition from fossil fuel-based energy to renewable energy in order to reduce GHG-emissions and support the airport's sustainability goals. Another important point is that the security of energy supply within the airport can be improved by having RES producing energy locally in the airport grid in combination with energy storages, as the dependency on imported electricity from the collective grid can be reduced. This is also beneficial for the collective grid, as the collective grid operator (DSO/TSO) could limit the need for reinforcements in the grid, when production and consumption are geographically located in the same place.

There can be different purposes of electricity storage and e.g., battery energy storage systems (BESS) can be used in different applications. This guideline will focus on BESS as energy storage system and the related opportunities and challenges in airports. First of all, airports can utilise BESS to store surplus local renewable energy, which can then be used later, where the demand is higher than the current local production. This can help maximizing the utilisation of installed renewable energy. The BESS can also be used for energy arbitrage, where electricity is bought when the CO_2-footprint and/or the prices are low by charging the BESS and sold (discharge the BESS to grid) when electricity is less sustainable, and prices are higher. BESS can also be utilised as power buffers for peak shaving high power loads, e.g., fast chargers to limit the load on electric infrastructure. BESS can also be used for ancillary services. These help stabilise the electricity grid through e.g. frequency containment reserves and is a way to create revenue from the BESS. A storage system is thereby an element providing a high degree of flexibility in the energy system.

SMART ENERGY SYSTEM AS A CONCEPT

The energy system is smart when it can decouple the need for simultaneity between supply and consumption, while also prioritising delivering the cheapest and/or cleanest energy to consumers. A smart energy management system is needed to monitor the energy system, make decisions and control assets. Smart energy thus encompasses how the interaction between the various energy assets and energy sectors (electricity, heating/thermal, gas, transportation, and industry) can lead to a 100% renewable energy-based system in the cheapest and most efficient way.

Therefore, cross-sectoral synergies such as flexible production, different conversion technologies, demand-side-management, and a wide range of storage technologies, are necessary in smart energy systems. The concept of a smart energy system presented in Figure 2 is focusing on the electrical aspect of smart energy, including both physical assets such as PV and batteries and control assets like energy management system (EMS). Airports have multiple reasons to invest in renewable energy sources (RES). Transitioning from fossil fuels to renewables reduces greenhouse gas emissions and supports sustainability goals, while also improving local air quality.

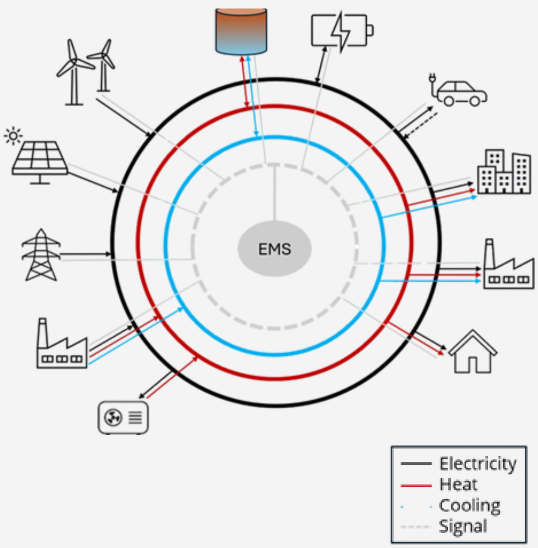

Figure 2 – Example of subsystems in a smart energy system.

Producing energy locally enhances security of supply and reduces reliance on the external grid, benefiting both the airport and the collective grid operator by limiting the need for grid reinforcements. Economic advantages include more predictable energy prices and potential cost savings. Airports may also benefit from regional or national incentives and can generate revenue by selling surplus energy, leasing land for renewables, or providing grid-support services.

The storage technologies among others can facilitate coupling between the energy sectors in an efficient and viable manner. The storage technologies cover all types of storages including electric, thermal, gas, liquid, etc. Thermal storages are often significantly cheaper than electrical storages and can advantageously be integrated into heat supply systems and thereby making the electricity demand for heat production (in e.g., a heat pump) more flexible. However, electrical storages play a pivotal role in enabling a more flexible, resilient, and renewable-based energy system, by balancing electrical generation and consumption, especially in systems with intermittent RES like solar and wind, which are intermittent. [1]

Energy Management Systems (EMS) and be used to enable flexibility in the airport energy system. It can be used to optimise energy usage, increase efficiency, and manage bottlenecks, potentially reducing costs and emissions. EMS integrates software and hardware to monitor and control energy production, storage, and consumption in real time, ensuring flexibility and maximizing value. EMS can also plan the delivery of grid services and help defer costly grid upgrades by rescheduling power flows and shifting loads, relying on controllable assets and storage.

SMART ENERGY SYSTEM AS A CONCEPT

Energy Flexibility

Flexibility is becoming more and more important with the increase of non-programmable renewable energy production, such as PV and wind turbines, necessary for energy system decarbonisation. Flexibility in energy systems can be achieved and utilised in various ways, offering numerous benefits. The adoption of smart energy technologies and the effective use of flexibility within an energy system can lead to reductions in greenhouse gas emissions, lower energy costs, and decreased reliance on expanded energy infrastructure.

As stated previously, energy storages are some of the elements that enable flexibility in the energy system [2]. Storage can be constituted by specific devices (e.g., battery energy storage or thermal energy storage) but can be found also in the thermal capacity in buildings through demand side management.When heat is provided by heat pumps, thermal storage or thermal capacity of buildings can provide flexibility in the electricity grid. This is because heat production can be adjusted to some extent without compromising indoor comfort, as thermal energy responds much slower to changes compared to electricity. This is a way of shaping the user’s energy demands. Other electrical loads may also be possible to control and shift in time to provide flexibility through demand-side-management or load-shifting.

TABLE 1

Impacts from different smart energy actions and technologies.

Aim/Goal	Smart energy actions	Method/technology
Reduce GHG-emissions of energy	Convert energy production plants from fossil fuel energy to renewable energy	Replace diesel generators for back-up power with a combination of RES and energy storage
	Optimise self-consumption from local RES	Energy storage
	Energy arbitrage based on CO_2-emissions of electricity from the grid	
	Optimise self-sufficiency from local RES	Energy storage
Reduce energy costs	Energy arbitrage based on costs	Energy storage
	Optimise self-consumption from local RES	
Reduce the need for reimbursement of energy infrastructure	Peak shaving	Energy storage to absorb and deliver power as needed
	Load-shifting	
Reduce the reliance of external energy providers	Optimise self-consumption from local RES	Electrical energy storage
	Optimise self-sufficiency from local RES	

GUIDELINE FOR BATTERY ENERGY STORAGE SYSTEMS IN AIRPORTS

This guideline focuses on guidelines for implementing batteries in airports; other storage technologies also have a pivotal role in the green transition but are not covered in these guidelines.

A Battery Energy Storage Systems (BESS) consists of three main components:

- **Batteries:** The components where the electricity is stored. Battery cells are built together to form modules/packs with voltage, current and energy ranges suitable for the application. The battery cells are electro-chemical and can have various designs, both in terms of chemical composition and physical structure.
- **Inverter** (converter): Power electronic component that handles energy conversion between the grid/RES (AC- or DC-systems) and the battery (DC-system).
- **Battery Management system (BMS):** Monitoring and controlling the operation of the battery to ensure safety, optimize performance, and prolong its lifespan.

The size of the BESS is characterized by its energy capacity, often stated in kWh or MWh. The charging and discharging power of the BESS are defined by the inverter specifications, expressed in kW or MW, combined with the battery's ability to handle charging and discharging rates relative to its energy capacity (c-rate).

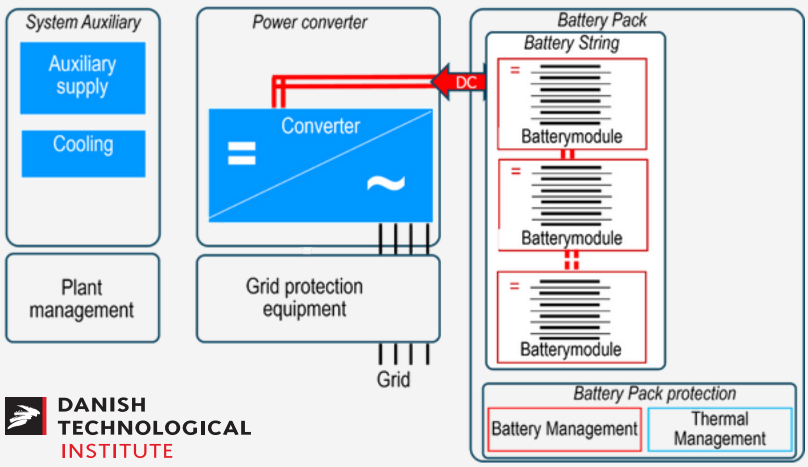

Figure 3 – A Battery Energy Storage Systems (BESS) consists of three main components.

An overview of relevant analyses in each phase and the expected outcomes in each phase for a BESS Project. The necessary analyses and assessment are site and country specific.

Overview of examples of relevant analyses

Phase	Mapping	Planning	Implementation and operation
Analyses and assessments	Initial sizing Use scenarios Initial business case Sustainability assessment	Stakeholder analysis Detailed analyses (grid, size, communication) Fire safety Implementation plan Scale-up plan Tendering and procurement	Obtain relevant permits and approvals Site preparation Installation of BESS Integration into EMS Test and commissioning Monitoring and maintenance
Outcomes	Estimations of capacity Defined use case for BESS Identification of economic break-even Identification of environmental impact	Stakeholder engagement Detailed sizing of system Electric infrastructure layout Defined safety precautions Procurement of equipment	Approvals obtained BESS installed Connection to grid and EMS Monitoring production and performance

GUIDELINE FOR BATTERY ENERGY STORAGE SYSTEMS IN AIRPORTS

Mapping

The best foundation for evaluation of whether an energy storage system will improve the energy system is to collect historic data of consumption and production. This is the case both for thermal and electrical storage systems.

The following sections focus on electrical energy storage, specifically BESS.

USE CASE SCENARIOS

Airports can utilise BESS to store surplus local renewable energy production, which can then be used later, where the demand is higher than the current local production. This can help maximizing the utilisation of installed renewable energy. The BESS can also be used for energy arbitrage, where electricity is bought when the CO_2-footprint and/or the prices are low by charging the BESS and sold (discharge the BESS to grid) when electricity is less sustainable, and prices are higher. BESS can also be utilised as power buffers for peak shaving high power loads, e.g., fast chargers to limit the load on electric infrastructure. BESS can also be used for ancillary services. These help stabilise the electricity grid through e.g. frequency containment reserves and is a way to create revenue from the BESS. A storage system is thereby an element providing a high degree of flexibility in the energy system.

CASE: ENERGY STORAGES IN FELLOW AIRPORTS

CASE: ENERGY STORAGE

The main purpose of installing a BESS would be to store surplus energy from local RES, and to do energy arbitrage by selling and buying electricity when the spot prices are attractive. Further, stabilising and supporting the electricity network near EV and transformer stations could be an advantage from the BESS. The BESS might have a capacity of 100/200 MW/MWh, however, at this stage, CPK are in touch with BESS suppliers to collect information for further investigations.

CPH CASE: PRIMARY USE CASES OF BESS

The intended use of an energy storage in CPH is to support the general building consumption together with an expected increasing number of charging stations, to serve the many different vehicles operating in the area. Moreover, the BESS is intended to support to local produced electricity from solar panel systems installed on rooftops. A local heating plant, consisting of gas boilers and heat pumps, provides district heating to the area and can use power from the installed BESS.

The BESS is intended to be a key asset to enable flexibility potential in other controllable assets and the demonstration in ALIGHT will provide insights into how future solutions should be shaped to achieve the best results in reducing GHG emissions.

The clear objective of installing a BESS as part of the ALIGHT project is to test various control and operational scenarios when connecting it to the different energy sources and consumers, to identify the optimal control paradigm for the assets.

LTOU CASE: PV PLANT AND BATTERIES

LTOU has PV panels on one terminal roof with a total capacity of 526 kWp. They are planning to install another PV plant which will also include a BESS. Currently there is no BESS at LTOU. Moreover, they are planning to install a BESS in combination with their EV charging stations.

AN OVERVIEW OF DIFFERENT USE SCENARIOS FOR BESS:

Load shifting
Energy consumption can be scheduled to avoid short-term congestion at both local installations behind the meter and at the local distribution grid.

Peak shaving
Power peaks from high demand can be reduced by either reducing the power consumption, turning off some loads (load shedding) or by utilising additional power generation facilities or storage systems to feed the demand. Load-shifting can also be used as a measure to implement peak-shaving.

Energy arbitrage based on CO_2 emissions
By importing electricity during the hours with the highest share of renewable generation in the grid it is possible to reduce the CO_2 emission of electricity used.

Energy arbitrage based on costs
Purchasing electricity when prices are low and selling when the prices are high generates a profit from the price difference.

Delivery of ancillary services
Ancillary services refer to services that help maintain grid stability and reliability often at TSO level.

Optimising self-consumption from RES
By storing energy when RES produce more energy than needed to cover the demand, or by shifting the load to meet the RES production, thus the RES will be better utilised, and a higher share of the consumption will be covered by local RES.

Figure 4 shows a simple schematic of an energy system where a BESS is used for optimising self-consumption from a PV system. Without the BESS the household in this example uses 30% of the PV power produced, the rest would have been exported to the grid. By adding a BESS, the self-consumption has been increased with an additional 30%, bringing the total self-consumption to 60%.

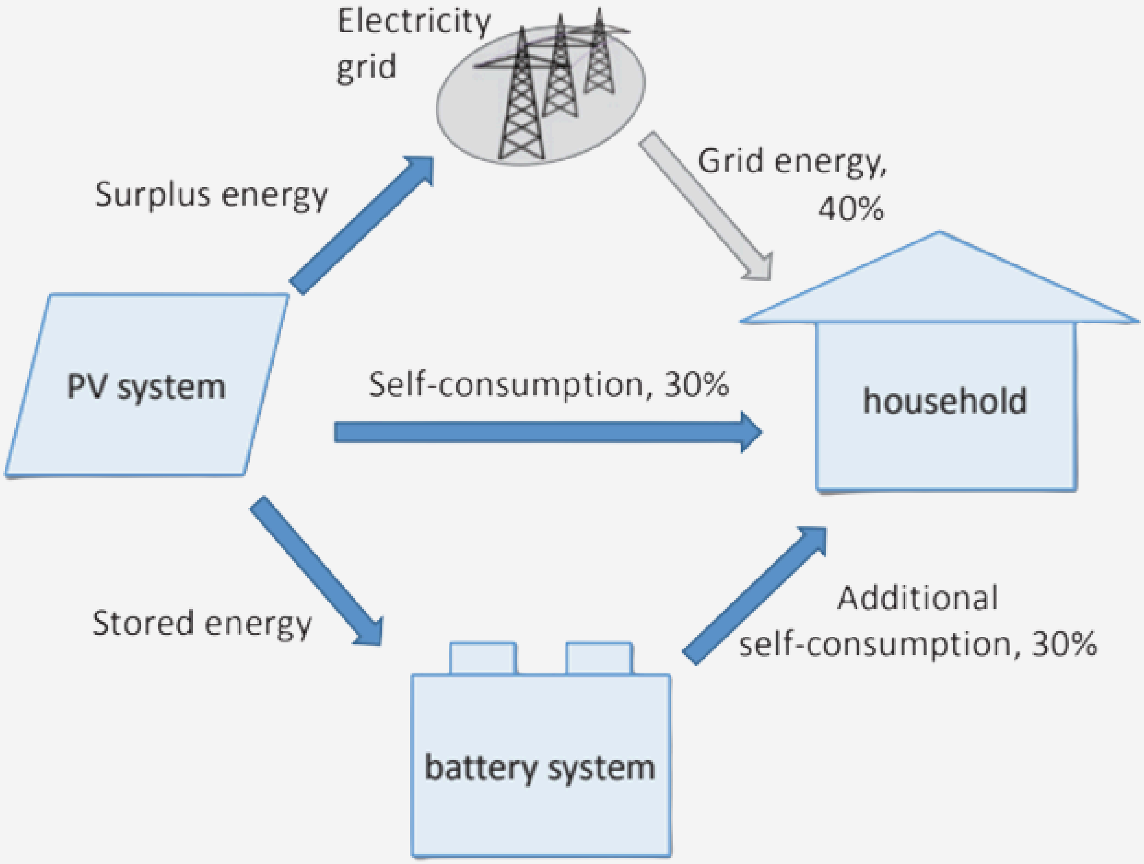

Figure 4 – Example of a battery system used for optimising self-consumption from a PV system [3].

Additional to the self-consumption it is relevant to consider the self-sufficiency, which indicates how much of the consumption is covered by local RES. The level of self-consumptions and self-sufficiency is dependent on the size of the RES and the timing between production and consumption. The self-consumption and self-sufficiency levels are relevant when dimensioning both local RES and energy storage.

INITIAL VALUE ASSESSMENT AND DIMENSIONING

An initial screening of the need for or the potential for a storage system is recommended. The screening should encompass both an initial business case evaluation and a sustainability value assessment. This can be based on generic use case scenarios for the BESS presented in the section on energy flexibility, where both intended usage, and potential usage can be included.

This initial screening also includes an initial business case taking potential cost reductions, revenues and expenses into account. Furthermore, a sustainability assessment is recommended to cover the advantages a BESS can have related to CO_2-emissions, utilisation of renewable energy and roll-out of further electrification.

Figure 5 - Iterative process of the initial screening

CASE: FEASIBILITY STUDY FOR PV AND BESS IN LTOU

For the planned PV plant, a detailed feasibility study was conducted to determine the most feasible plant size. The feasibility study investigated several scenarios including PV plants with and without batteries. Even though the investment in and installation of batteries are costly, this solution was chosen by LTOU. When the feasibility study was conducted, Lithuania experienced high electricity prices, why the purpose of batteries was initially to minimise the costs related to electricity by using the produced energy during the night and by selling excess energy to the grid in favourable hours. These prerequisites resulted in a payback period of 10-15 years.

Even though the electricity prices have now normalised, and the payback time therefore has increased significantly, the underlying objectives for LTOU have also changed: The focus is now on the volatile geopolitical situation with the neighbours to the east (Russia and Belarus). The airport is a strategic facility, both civilly and militarily, which needs to have a 24/7 power supply in case of disruptions in the city's central infrastructure.The preliminary capacity of the PV plant is 4.5 MW, and for the two storages a capacity of 2.5 MW/ 5 MWh each. The exact sizes and capacities will be determined in the design phase.

The initial business case, sustainability assessment and dimensioning will be an iterative process as their results impact each other.

The main results from the dimensioning are the optimal energy and power capacity of the BESS, when looking at the circumstances of the grid it will be integrated into.

Therefore, relevant historical data must form the basis for the calculations, such as:

- Power in point of connection (grid power, import/export)
- Power from local energy producers (e.g. PV, wind etc.)
- Electric energy consumption

The dimensioning can be based on:

- Simple calculations based on typical yearly local energy production and consumption and typical power-levels
- Simple or detailed simulations based on relevant historic time series data
- Future increase in energy demand
- Budget limitations
- Regulatory limitations
- Learning by doing, by choosing a modular and scalable solution

Designing for scalability will provide flexibility to adjust to future needs. Some solutions are storage modules built into containers that allows for extending the system energy and power capacity with additional containers. Other solutions are individual racks (smaller storage modules) which allows for even higher freedom of scalability but may have higher costs and may uptake more land area.

CASE: DIMENSIONING OF BESS IN CPH

The dimensioning of the BESS in CPH was primarily based a simulation of historic data of PV production and historic electricity consumption at the transformer station where the BESS should be installed. A simulation to size the battery and calculate the net present value (NPV) and return of investment (ROI) when assuming delivery of ancillary services were performed. The simulations showed a positive Net Present Value (NPV) for BESS within 700-1400 kWh, but that the optimal size would be above 1400 kWh.

The BESS is small compared to the airport's overall electric energy use, with a power capacity at peak equal to about one-twelfth of the airport's electric base load. Despite its scale, the installation plays a key role in advancing sustainability, optimising energy use, and managing demand-driven distribution. The system's capacity allows for testing various purposes and opportunities of the BESS, which will support decisions of potential up-scaling.

CASE: BESS CAPACITY IN ADR

ADR are at the time of writing installing a BESS with a rated power of 2.5 MW with a total capacity of 10 MWh, with a planned commissioning in beginning of 2025. The size of the BESS was determined by availability, price and technical capabilities.

The BESS in ADR is made of 2nd life car batteries, where three different suppliers are delivering the battery cells. All the batteries are produced by major car manufactures. The communication strategy must ensure a functioning and seamless operation of the batteries as a single BESS.

GUIDELINE FOR BATTERY ENERGY STORAGE SYSTEMS IN AIRPORTS

Planning

RISK ASSESSMENT AND POTENTIAL IMPACT ON AIRPORT OPERATIONS

As larger battery systems are not typical assets in airports (yet) many uncertainties will rise.

CASE: ENVIRONMENTAL CONSIDERATIONS IN CPH

A connection to the existing drainage system has been established, along with new wells for collecting water used in firefighting. During firefighting, the emergency services can close the regular drainage using a valve and connect a submersible pump to recirculate water to the affected cabinet without requiring a fire truck or hydrant for water supply.
After firefighting is complete, the water can be removed from the well and kept away from the main drainage system.

CASE: PLACEMENT OF BESS IN ADR

In the planning process of the BESS in ADR the strategic placement of the system was considered to ensure both functionality and accessibility of the BESS. The BESS is placed in containers housing both batteries and necessary auxiliary systems. The containers require a substantial area of around 3 000 m^2 which limited the possible areas resulting in the BESS being located next to an access road and surrounded by buildings. Despite the location of the system being adjacent to buildings and an access road, no specific safety distance has been planned, as the layout of the containers includes a fire protection system. The system consists of hydrants and sensors connected to a central control system. In the event of a fire, data from smoke and temperature sensors automatically activate the extinguishers, filling the containers with CO2 powder.

The risk of a fire in BESS can be a high concern internally in airport departments, by national or local fire authorities and by aviation authorities. A fire in a lithium-ion battery is difficult to fight and the smoke development are significant for batteries. As the penetration of battery systems into the market are increasing significantly, especially due to development in the electric vehicle market, the experiences with larger battery systems and fire handling are improving. Many different mitigation strategies can be chosen to minimise the risk of a fire and to minimise the consequences in case of fire, including limit smoke development and fire spread.

Fire risk-migration strategies

- **Sprinkler system** to cool and limit fire spread
- **Water filling strategies** for storage modules
- **Fire walls** to segmentate the storage system and limit fire spread
- Locating the storage system with sufficient **distance** to other critical infrastructure
- Ensuring **access roads** for firefighting equipment
- Installing **early warning systems**
- Ensuring that battery modules and battery management system (BMS) are certified to applicable **safety standards** e.g. EN 62619
- **Physical road barriers** to minimize the risk of collisions
- Ensuring that **service and maintenance procedures** are followed according to the supplier
- **Water collection** to minimise the environmental impact from firefighting
- **Sufficient training** of airport fire fighters and personnel working around the batteries including updated emergency plans

CASE: RISK ASSESSMENT

A risk assessment has been made on rack level by the supplier, Xolta, to create transparency of the system, related risks and implemented control and mitigation measures.

Many design considerations have been made to minimise the risk of a potential battery fire.

This includes, but is not limited to:

- Individual battery racks spaced with 50 cm, see Figure 8.
    - Limit a potential fire from spreading
    - Ensure easy access for fire fighter personnel
    - Allow independent operation by racks not affected by the fire
- Distance between closest battery rack and building is minimum 6 metres.
- Connector for fire hose on each rack, see Figure 6.
    - Easy access to cool down the battery and limit fire spreading inside the battery rack and to surroundings.
    - The ability to fill each rack with water will reduce the smoke development in case of a fire.
    - Water filling tests has been performed to ensure that the racks could be filled with water within 10 minutes, see Figure 7.
- Battery chemistry is LFP, which has a higher resistance to thermal runaway and therefore less tendency to catch fire.
- Batteries are tested according to EN 62619 and are UL 1642 certified to ensure a high level of safety at cell and module level.
- Professional design of enclosure, mainly consisting of steel and with individual steel cases for each battery pack inside the racks and double shelving between packs to provide thermal insulation and delay fire propagation.
- Gas relief valves to mitigate over pressure in each rack and gas and smoke sensors in each rack, that can be connected to external fire warning system.
- No outside air is circulated in the system, which prevents fresh oxygen supply.

Figure 6 – Individual battery rack from Xolta. All racks are equipped with a connector for a fire hose, so they can be filled with water in case of fire.

Figure 7 – Water filling tests has been performed to ensure sufficient design of the cabinet and sealings. The racks were required to be filled with water within 10 minutes, and the 2nd test was successful.

Figure 8 – Individual battery racks spaced with 50 cm.

STAKEHOLDERS

As part of the planning phase, it is important to identify relevant and necessary stakeholders for the coming approval phase together with construction and implementation phase.

It may be necessary to involve the following stakeholder to install and get a BESS into operation inside an airport. It will be both internal stakeholders, who belong to and work inside the airport, and external stakeholders with different responsibilities.

INTERNAL STAKEHOLDERS

- Airport fire department
- Airport master planning
- Airport asset management (e.g. responsible for electrical infrastructure)
- Airport sustainability services (e.g. project driver)

EXTERNAL STAKEHOLDERS

- Distribution system operator (DSO) (e.g. for grid connection approval)
- Municipality (e.g. for land zone permit, building permit, occupancy approval)
- National or local fire authority
- Airport specific authorisation bodies (e.g. Italian Civil Aviation Authority (ENAC))
- National or local environmental authority

REQUIREMENT SPECIFICATION FOR ENERGY STORAGE SYSTEM AND INFRASTRUCTURE

Requirements for the BESS need to be formulated including both functional and non-functional requirements. Requirements to the system can come from the end user, in this case the airport, and from external stakeholders. This can be grid connection requirements, fire safety requirements, IT security requirements among others, which need to be identified and included.

A plan for site acceptance test (SAT) shall be made together with requirement specification to make sure that the system can be validated by the customer before being put into operation.

INFRASTRUCTURE

Firstly, having the requirements for the system and its surroundings and then comparing with the existing infrastructure is necessary.

This includes investigating infrastructure for:

- **FOUNDATION ON SITE**
- **ELECTRICITY GRID AND ELECTRICAL CONNECTION**
- **ACCESS ROADS TO/FROM THE SITE**
- **SIGNS, LIGHT, DRAIN WATER SYSTEM ETC. ON SITE**
- **COMMUNICATION AND IT**

FOUNDATION ON SITE

Ensure that the site can support the weight of the BESS, which can be significant, especially for containerised systems.

Depending on the ground conditions, this may require soil reinforcement or the installation of a concrete foundation.

ELECTRICITY GRID AND ELECTRICAL CONNECTION

Regarding electrical infrastructure it is important to be aware of whether additional load and bidirectional power flow can be handled by the existing infrastructure. Both cables, transformers and switchboards need to be considered. Ensure that transformers and switchgear are scalable for future expansions and plan for cable ducts or conduits to allow for future scalability.

Consider locating the BESS close to RES or large power demands depending on the use scenario for the BESS to minimise energy losses and increase the potential impact of the BESS. Moreover, it is important to make sure that the existing grid connection agreement allows power export to the grid, if this is part of the use scenarios for the BESS. Contacting the local DSO as early as possible is recommended, as needed grid extensions can take months or years, and energy system approval processes can be extensive and have long durations as well.

ACCESS ROADS TO/FROM THE SITE

Plan for access roads to allow for the transportation of large components during installation, including cranes to lift modules or containers if needed.

Ensure that firefighting vehicles have adequate access to the site during construction and when the BESS is commissioned and in operation.

SIGNS, LIGHT, DRAIN WATER SYSTEM ETC. ON SITE

Specific signs indicating that the BESS is an electrical installation, containing batteries, not for unauthorised personnel etc. may be required by internal departments in the airport.
Moreover, specific requirements for lights on the site should be considered.
Plan for effective rainwater drainage system to prevent water pooling around the BESS installation.

Environmental authorities may require drainage systems to safely handle contaminated water from firefighting.

COMMUNICATION AND IT

Depending on how the BESS is expected to be controlled, it is important to consider how communication with the BESS is going to be implemented. If third parties are involved in the control e.g., through an energy management system, secure solutions must be developed in collaboration between the airport IT department and the energy management system operator.

Installation of a power meter and connected dashboards are recommended to ensure that the system performance can be monitored.

CPH CASE: SYSTEM DESCRIPTION

The system is located in the western part of the airport, which is designated as CPH's internal maintenance area. This area hosts numerous buildings and assets, serving various purposes such as equipment storage, workshops for both internal and external equipment, and local heat production. The installation site was selected for several reasons: primarily, it has been designated as a special demonstration area for the project, where multiple activities will take place. Additionally, this location allows for the concentration of activities in a low-traffic area, ensuring that customers are not affected by the demonstrations. The area is also suitable due to the presence of various energy producers and consumers.

After receiving bids, a system with high scalability was selected. To meet the budget a compromise on having a guaranteed energy capacity of 1000 kWh over the system lifetime were made and the system size was reduced from 18 racks to 15 racks.

TENDERING AND PROCUREMENT

There will typically be a tendering process before the purchase of a BESS is executed as it is a large investment for the airport.

When preparing the tendering material, it needs to be clear which requirements the tenders are expected to be responsible for as they may be covered by different companies, like a technology provider and an entrepreneur for the site preparation. Interfaces between these are important to define clearly. Airports may have their own procedures and requirements for tendering processes, that need to be followed. Considerations about service agreements should also be part of the tendering and procurement process.

CASE: CPH TENDERING PROCESS

In the process of getting a BESS in operation in CPH, especially the tendering process, the site preparation and the approval process has taken a long time.

Requirement specification for the BESS was formulated and incorporated into the standard form for tenders in CPH. The tendering material was sent to eight selected candidates for delivery of the BESS and a final agreement was made approximately 26 weeks later. As the standard form for tenders in the airport is extensive and requires a large amount of work from the suppliers to fill which, combined with the requested size of the BESS, limited the number of incoming bids. Many suppliers of BESS did not offer solutions smaller than a couple of MW.

IMPLEMENTATION PLAN

The planning department should establish a detailed implementation plan to ensure a structured implementation phase and to minimise costs (e.g., if cables must be installed in roads which must be reconstructed afterwards). The scope of the implementation plan shall be in line with the project size and can vary from being a simple project plan to an extensive project management plan including detailed budgets, identification and agreements with subcontractors, time schedule, logistics for construction especially important on airside and near runways.

SCALE-UP AND ROLL-OUT PLAN

For BESS it can be by dividing the optimal size determined in the mapping phase into sub-systems and implement them in stages. Choosing modular solutions gives the opportunity to extent a system with new modules along the way. By ensuring that considerations about scale-up has been part the planning process, the costs and work associated with new projects can be held at a minimum. The site and infrastructure (e.g., electrical cables, transformers, switch boards etc.) can be prepared for future upgrades either by already installing over capacity or by making cable ducts and allocate space in electrical panels.

A scale-up and roll-out plan can be made for large projects to reduce economic risks and to ensure that the system performance and impact is as expected before extending with new systems.

The plan can be reevaluated and adjusted based on experiences and results from the first stages.

GUIDELINE FOR BATTERY ENERGY STORAGE SYSTEMS IN AIRPORTS

Implementation and operation

PERMITS

In general, there is a significant need for stakeholder involvement at an early stage, prior to addressing regulatory matters. It is important to be aware of the time required to internally align on the appropriate conditions and location, as this phase can take longer than anticipated. This should be carefully considered in the overall process.

Typically, numerous approvals that must be in place before initiating any work, and the same applies to the installation of this asset.

Examples of permits needed are listed below:

- Land zone permit
- Environmental approval
- Grid connection agreement and approval
- Construction Permit
- Fire Safety approval
- Occupancy Permit

The permits needed vary from country to country and it is therefore necessary to identify national and local regulations and circumstances. The authorities responsible for issuing the permits will also differ as it is often national or local authorities. See annex for list of examples of permits and responsible authorities for Copenhagen Airport (Denmark).

SITE PREPARATION AND INSTALLATION

Site preparation may include:

- Electrical infrastructure ready for extra bi-directional power: Transformer(s), electrical switch board, cables
- Building and/or foundation for BESS: Reinforcement of existing foundation or reinforcement of ground may be needed to carry the weight of the BESS.
- Drainage of rain- and wastewater
- Establishment of communication lines and equipment
- Fire handling: Prevention, detection, alarm, protection, and extinguisher systems

If the implementation is divided into multiple stages with a pilot demonstration phase at first, it is important to consider if any of the surrounding installations shall be prepared for future up-scaling. This can be electric switch boards, cables, foundation etc.

INTEGRATION WITH EMS

For efficient energy management and utilisation, the BESS must be integrated into the airport's EMS. In order to ensure safe communication of data from the BESS and the EMS, secure protocols must be used to prevent unauthorised access or cyber-attacks on the EMS.

CASE: CONSIDERATIONS REGARDING MULTIPLE ENERGY AND BUILDING MANAGEMENT SYSTEMS IN ADR

ADR has several management systems related to different energy sectors: one for heating and cooling, one for the electrical plant, one for monitoring energy-dense assets, and so on. ADR currently monitors the consumption of various assets, which provides valuable information for the planning and execution of future projects.

There is a standalone EMS for the BESS, which can operate to minimise costs and/or CO_2 emissions. ADR plans to integrate an overall EMS that will connect PV, BESS, EVs, and consumption with the existing building management system.

CASE: THE DATA AND COMMUNICATION SOLUTION AT CPH

At the time of making the communication and data design it was deemed that the fastest and safest solution to be able to operate the BESS and the EMS was to let the BESS and EV supplier communicate with their assets, rather than letting the EMS supplier do this. A solution where the EMS have access to read-only data from the airport was chosen, since it might has resulted in delays in the project if the EMS supplier had to implement the necessary security requirements. Moreover, this solution provides only one entry point per asset, which allows better control from the airport side.

On the data sharing side, and due to the security requirements of the airport, only data coming from third party assets are shared directly with suppliers whereas any other data is pushed by the airport periodically and the airport possesses full control on what is to be shared and when.

OPERATION AND MAINTENANCE

The deployment phase begins with receival and continues with installation and commissioning. A SAT as planned in the specification phase should also be concluded. The last phase is operation where the BESS can deliver the services it is intended for. It can be integrated in a local smart energy management. During operation there is a need for periodical maintenance, which normally follows instructions from the supplier.

MONITORING AND EVALUATION

To monitor the operation of a BESS, various parameters should be considered to ensure efficient, safe, and reliable performance.

The parameters can include:

- Charge and discharge power
- State of Charge (SOC): Indicates the capacity of the battery as a percentage.
- State of Health (SOH): Reflects the overall health and aging of the battery as a percentage of its original capacity.

Energy Throughput: Tracks total energy charged and discharged over time.

Temperatures of the BESS, e.g., average temperature of each module

Safety and protection parameters such as over/under voltage alarms, overcurrent, thermal runaway detection etc.

END OF LIFE

The European Batteries Directive (Regulation (EU) 2023/1542) extents the responsibility of the producer, by requiring the battery producer to ensure and finance that the batteries can be collected for reuse or recycling. [4]

Airports buying battery energy storage systems and other applications including batteries should be aware of this and are recommended to ensure that this responsibility is taken by the producer.

The airport can also consider reuse of batteries inside the airport energy streams, as airports with large electric fleets of vehicles and GSEs will be able to collect a significant number of batteries with a second life potential. Batteries in vehicles are typical reaching end-of-life (EoL) criteria for their specific application with a higher state of health (remaining energy capacity and performance) than required for i.e. stationary applications like BESS, as illustrated in Figure 6.

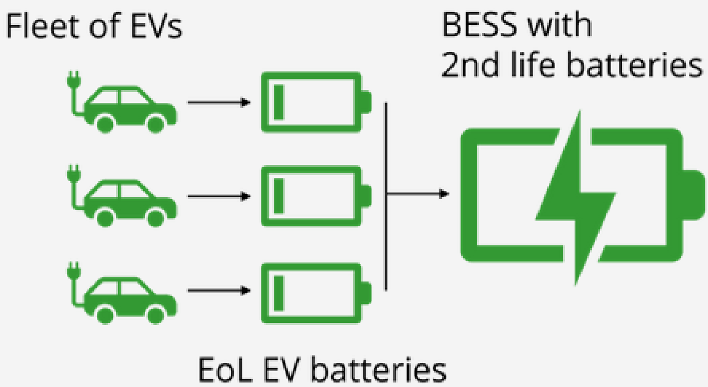

Figure 9 - Concept of reusing batteries in 2nd life applications.

OUTLOOK

The transition to more sustainable energy systems in airports presents a transformative opportunity to reduce environmental impact, enhance operational efficiency, and align with global sustainability goals. By integrating renewable energy sources, energy storage, and smart energy management systems, airports can significantly reduce their carbon footprint, enhance energy efficiency, and improve operational resilience. These solutions enable airports to better align with evolving sustainability goals and regulatory requirements, such as the EU's Renewable Energy Directive (RED III). Operationally, smart energy solutions offer flexibility, allowing airports to fit energy consumption to fluctuating renewable energy production (e.g., solar and wind) and reduce dependency on fossil fuels.

The integration of energy solutions into airport operations offers a range of benefits considering environmental, economic, operational, and social dimensions.

- **Environmental:** Energy solutions enable reductions in greenhouse gas emissions through larger shares of renewable energy. Additionally, replacing local fossil fuel-based energy production improves air quality, benefiting both airport users and surrounding communities.

- **Economic:** Airports can realize long-term cost savings through enhanced energy efficiency and reduced reliance on fossil fuel. Price stability can be achieved through power purchase agreements (PPAs) or local renewable energy sources owned by the airport, and by creating revenue from grid services.

- **Operational:** Benefits include enhanced reliability of energy systems, ensuring uninterrupted power supply for critical airport functions. These solutions also improve an airport’s resilience to disruptions, such as power outages or extreme weather events, thereby strengthening overall operational stability.

- **Social:** Adopting sustainable energy practices aligns airports with broader regional and national climate strategies. This also demonstrates the airport’s commitment to addressing climate change and sustainability goals.

While challenges such as financial constraints, technical integration, and regulatory complexity remain, airports that proactively plan, engage stakeholders, and leverage available support mechanisms can overcome these barriers. Managing a diverse portfolio of energy assets, including photovoltaic (PV) systems, battery storage, and electric vehicle (EV) chargers, requires advanced expertise and planning. Airports will need to invest in workforce training, adopt advanced energy management platforms, and collaborate with energy experts to effectively operate and maintain these systems. By implementing future-proof energy systems and scalable infrastructure, airports can adapt to increasing passenger demands, technological advancements, and evolving regulations.

NEXT STEPS

Airports are highly energy-intensive and are under increasing pressure to become sustainable. BESS is presented as a practical solution for increasing resilience, reducing greenhouse gas emissions and energy costs, enable energy flexibility, and increase utilisation of renewable energy sources such as PV. Moreover, BESS can create additional revenue for the airports by energy arbitrage (buying energy when prices are low and selling when prices are high) and thereby supplying electricity back to the grid. Operation of BESS can be optimised by considering e.g., electricity prices, CO2 intensity, and operational needs.

KEY USE CASES:

- Load shifting
- Peak shaving
- CO_2 and cost arbitrage
- Ancillary services, like frequency services
- Maximizing self-consumption from renewable energy production

IF YOU ARE CONSIDERING INSTALLING A BESS, YOU CAN START YOUR WORK WITH THE FOLLOWING STEPS:

1. Engage stakeholders and address IT and cyber security at an early stage
2. Initiate a detailed mapping and feasibility study incl. defining use cases for the BESS
3. Define requirement specification for the BESS
4. Plan and execute pilot projects

Mapping: Key questions

- What are the main use scenarios for implementing a BESS at this airport, and how will these scenarios support local renewable energy integration, cost savings, and/or grid flexibility?
- What is the optimal size (energy and power capacity) of the BESS, and which considerations have been done when settling on the chosen size?
- Which impact/outcomes will the BESS have on the airport (Technical, economic, and sustainability)?

Planning: Key questions

- Which internal and external stakeholders must be involved in the phases of BESS project?
- Have relevant risks and mitigation measures been addressed?
- Have all relevant functional and non-functional requirements been specified and validated?
- Does the existing infrastructure need to be adapted/upgraded to support the BESS project?

Implementation: Key questions

- Are all permits and regulatory approvals obtained?
- Is the site prepared to ensure a safe and compliant installation/operation of the BESS?
- How shall the BESS be integrated into the overall EMS of the airport?
- Have sufficient maintenance and monitoring been defined?

ABBREVIATIONS

Abbreviation	Explanation
ADR	Aeroporti Di Roma (fellow airport in ALIGHT located in Italy)
BESS	Battery energy storage system
BMS	Battery management systems
BoL	Beginning of life
CPH	Copenhagen Airports
CPK	Centralny Port Komunikacyjny (fellow airport in ALIGHT located in Poland)
DSO	Distribution System Operator
EMS	Energy management system
ENAC	Italian Civil Aviation Authority
EoL	End-of-Life
EV	Electric vehicle
Fellow airports	Referring to airport partners in ALIGHT: ADR, CPK and LTOU
GSE	Ground Support Equipment
Lighthouse airport	Referring to main demonstration airport in ALIGHT: Copenhagen Airports
LTOU	Lithuanian Airports (fellow airport in ALIGHT located in Lithuania)
NPV	Net Present Value
PV	Photovoltaic
RE	Renewable energy
RES	Renewable energy sources

ABBREVIATIONS

ROI	Return of investment
TSO	Transmission System Operator
SAT	Site Acceptance Test
SoC	State-of-Charge
SoH	State-of-Health
VNO	Vilnius International Airport

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