





EUROBAT

BATTERY ENERGY STORAGE FOR SMART GRID APPLICATIONS



EUROBAT, the Association of European Automotive and Industrial Battery Manufacturers, acts as a unified voice in promoting the interests of the European automotive, industrial and special battery industries of all battery chemistries to the EU institutions, national governments, customers and the media. With over 40 members comprising over 90% of the automotive and industrial battery industry in Europe, EUROBAT also works with stakeholders to help develop a vision of future battery solutions to issues of public interest in areas like e-mobility and renewable energy storage.

This paper was prepared by the Smart Grids Task Force of EUROBAT's Industrial Battery Committee:

- Rainer Bussar, Exide Technologies, Chairman
- Michael Lippert, Saft
- Géry Bonduelle, EnerSys EMEA
- René Linke, Hoppecke Batterien
- Giorgio Crugnola, FIAMM
- Joseph Cilia, Abertax Technologies
- Klaus-Dieter Merz, Abertax Technologies
- Chris Heron, EUROBAT Secretariat
- Erwin Marckx, EUROBAT Secretariat

Disclaimer

This publication contains the current state of knowledge about the topics addressed in it. It was prepared by the EUROBAT office in collaboration with members of the Association. Neither EUROBAT nor any other member of the organization can accept any responsibility for loss occasioned to any person acting or refraining from action as a result of any material in this publication.

BATTERY ENERGY STORAGE FOR SMART GRID APPLICATIONS TABLE OF CONTENTS

1.	INTR	RODUCTION	p. 4
2.	NEW	/ MARKETS FOR ON-GRID BATTERY ENERGY STORAGE	p. 6
3.		ENTRALISED BATTERY ENERGY STORAGE FOR GRID IAGEMENT	p. 9
	3.1.	Battery Energy Storage in a smartening Electricity sector	p. 9
	3.2.	Services and Functions of Battery Energy Storage for Grid Operators	p. 10
4.	BATT	TERY ENERGY STORAGE FOR HOMES AND BUILDINGS	p. 11
	4.1.	Battery Energy Storage at a customer level	p. 11
	4.2.	Functions of BES in End-user applications	p. 12
5.	OVE	RVIEW OF BATTERY TECHNOLOGIES	p. 14
	5.1.	Lead-based batteries	p. 14
	5.2.	Lithium-based batteries	p. 15
	5.3.	Nickel-based batteries	p. 16
	5.4.	Sodium-based batteries	p. 17
6.	CON	CLUSION AND RECOMMENDATIONS	p. 18

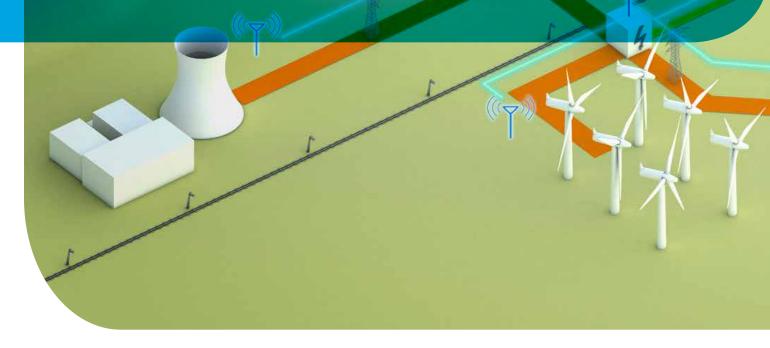
INTRODUCTION



EUROBAT, the Association of European Automotive and Industrial Battery Manufacturers, welcomes the European Commission's January 2013 Working Paper "The future role and challenges of Energy Storage", which is valuable in its prioritisation of all energy storage technologies and its commitment to address them more effectively in EU energy policies.

EUROBAT has actively contributed to the followup work of EASE, the European Association for the Storage of Energy, and EERA, the European Energy Research Alliance, to develop the crossindustry "European Energy Storage Technology Development Roadmap towards 2030". The collective industry vision provides invaluable information on what is required to develop supportive market conditions for Energy Storage in the period towards 2020-2030. This complimentary EUROBAT paper has been compiled to provide information on the specific advantages of utilising Battery Energy Storage (BES) solutions to support Europe's future Smart Grid. It aims to enhance knowledge about batteries and how they can contribute to society in the context of the European Union's long-term climate and energy policies, in which "Smart Grids will be the backbone of the future decarbonised power system".

This paper acts as a reference document explaining the potential contribution of battery energy storage at all levels of the electricity grid: generation, transmission, distribution and customer. The paper also gives an overview of the four main battery technologies commercially available for energy storage – Lead, Lithium, Nickel and Sodium-based batteries – and makes a series of recommendation for how their mass-market utilisation can be facilitated at a European level.





6 EUROBAT

NEW MARKETS FOR ON-GRID BATTERY ENERGY STORAGE (BES)

Energy Storage (ES) is expected to play a major role in Europe's future Smart Grid. The European Commission's 2012 Communication "Renewable Energy: a Major Player in the European Energy Market" states that "electricity storage is a clear key technology priority for the development of the European power system of 2020 and beyond, in the light of the increasing market share of renewable and distributed generation and the growing limitations of the energy grid". The Commission's Working Paper "The future role and challenges of Energy Storage" more specifically states:

nergy Storage can supply more flexibility and balancing to the grid, providing a back-up to intermittent renewable energy. Locally, it can improve the management of distribution networks, reducing costs and improving efficiency. In this way, it can ease the market introduction of renewables, accelerate the decarbonisation of the electricity grid, improve the security and efficiency of electricity transmission and distribution, stabilise market prices for electricity, while also ensuring a higher security of energy supply.

These various functions ensure that demand for energy storage technologies will increase in line with Europe's decarbonisation. From a current capacity of 100GW, the International Energy Agency (IEA) has projected that the necessary amount of EES in the world in 2050 will double or triple to between 189GW or 305GW, corresponding to an output variation rate of renewable energies of 15% or 30% respectively.¹ RWTH Aachen has further calculated that an optimised European Electricity System with close to 100% renewable generation will require short-term hourly storage of 2000GWh.²

The European Battery Industry welcomes this impetus, and continues its work to optimise the technological and economical competitiveness of Battery Energy Storage systems for grid support.

BES systems range anywhere from 2kW (5 kWh – 20 kWh) up to 50MW (MWh), and are set apart by

their fast response, mobility, and flexibility to be fitted to either high power or high energy applications. Batteries have the unique potential to provide energy storage services at all levels of the grid – generation, transmission, distribution or customer – while also providing several ancillary functions to their different users.

Traditionally, large-scale Pumped Hydro Storage Systems (PHS) have provided almost 99% of worldwide storage capacity, chiefly fulfilling the function of demand

Storage applications at the diffe



- 1 "Prospects for Large-Scale Energy Storage in Decarbonised Power Grids" In
- 2 "Technology Overview of Energy Storage: Overview on the potential and or

STORAGE APPLICATIONS AT THE DIFFERENT LEVELS OF THE ELECTRICAL SYSTEM

- 1. Generation level: Arbritage, capacity firming, curtailment reductions
- 2. Transmission level: frequency and voltage control, investment deferral, curtailment reduction, black starting
- 3. Distribution level: voltage control, capacity support, curtailment reduction
- 4. Customer level: peak shaving, time of use cost management, off-grid supply

levelling at a transmission level. As Renewable Energy Sources (RES) integration into Europe's electricity sector increases, additional smaller-scale and more flexible storage technologies are required at all levels (see pg. 9).

Batteries provide mobile and highly flexible storage capacity, and can be placed at several different places of the grid to ensure efficiency, including:

- Connection to a feeder of RES (photovoltaic, wind etc.)
- Connection to High Voltage/Medium Voltage or Medium Voltage/Low Voltage Substations
- Connection to any point in the Low Voltage grid
- Connection to RES in homes and buildings

rent levels of the Electrical System







Within this wide range of potential applications, the European Battery Industry has prioritised two areas in which the versatility and fast response of BES is most valuable in the short term:

1. Decentralised energy storage for Grid Management At a distribution level, BES can 'smooth out' electricity supply from variable RES to the low- and medium- voltage grid to match with demand, by controlling the power flow, mitigating congestion and maintaining voltage in an appropriate range.



1. Energy management in homes and building
At a customer level, residential homes and small/
medium-sized enterprises are expected to become
actively involved in modifing their energy spending
patterns by monitoring their actual consumption
in real time. BES will enable customers to store
electricity when it is not needed and discharge it
when needed.



For the purposes of this paper, EUROBAT will focus specifically on these priority areas, where battery technologies are already commercially available to competitively provide a portfolio of energy storage functions to grid operators or end-users.



In the longer-term, as their cost and performance continues to improve, batteries are also expected to become increasingly competitive for centralised energy storage on generation and transmission levels. Several projects have already been initiated to implement large-scale battery energy storage on the transmission level.

DECENTRALISED BATTERY ENERGY STORAGE FOR GRID MANAGEMENT



Europe's distribution networks will need to accommodate an increasing number of local Renewable Energy Sources

Battery Energy Storage in a smartening electricity sector

Batteries and other energy storage technologies are necessary for the successful incorporation of increased levels of Renewable Energy Sources into the EU's electricity grid. By 2020, RES is expected to represent 17% of the EU's total electricity consumption, already demanding substantial restructuring of the electricity system. While the proliferation of large-scale renewable generation sources such as offshore wind parks will need to be supported by investments into the transmission grid, Europe's low and medium voltage distribution networks will also be required to accommodate an increasing number of small or medium-scale local sources.

The role of Distribution Service Operators (DSOs) will change significantly in line with these developments, as they become responsible for the smart management of the electricity flowing within their grids, by dynamically managing distributed generation and demand. Power will no longer only flow in one direction from power sector to consumers, who will be encouraged to actively manage their energy demand. This evolution will only be possible through significant investment. The IFA has estimated that distribution networks will demand €480bn total

investment by 2035, which according to the European Commission will be 4-5 greater than that needed to develop Europe's transmission grid.³

This investment is necessary to develop commercial solutions to overcome the challenges that DSOs face in integrating RES into their networks: higher peak loads, more severe power requirements, and the challenge to continue matching supply and demand. Battery energy storage is an optimum solution for DSOs to maintain grid stability and flexibility in spite of these challenges, and demonstration projects have been underway for several years to prove the potential of different battery technologies in this capacity.

Decentralised BES has dynamic behaviour with fast and powerful response times enabling for compensation of fluctuating renewable generation. Large scale BES is also an efficient and emission-free solution to a number of ancillary services and to compensate for the different up- and downwards ramp rates of wind and solar generators compared to fossil fuel based power plants.

Battery Energy Storage is an optimum solution for DSOs to maintain grid stability and flexibility



Services and Functions of Battery Energy Storage for Grid Operators

BES offers a wide range of primary and ancillary services and functions for grid operators. These include (non-exhaustive):

Peak shaving in low voltage gridTypical duration is 2 hours, with 1 to 2 cycles per day

BES can store energy in periods of low demand, and release that energy at periods of high demand. This reduces peak demand in low voltage (LV) electricity grids, and allows grid operators to defer investment into upgrading their network capacity.

Load levelling in LV grid

Typical duration would be up to 8 hours

BES can help grid operators to avoid a fatal overload in power of grid devices, by shifting load from peak to base load periods in order to reduce the maximum currents flowing from the high voltage grid through constrained grid assets.

Integration of renewable energy into the grid *Numerous small cycles per day*

BES can provide control power to limit fluctuations of feed-in electric power into the low voltage grid, and potentially also for large photovoltaic farms in the middle voltage grid. It can also shave off renewable peak generation in times of high production and low consumption, minimising grid congestion and/or RES curtailment. This function also provides voltage support on distribution feeder lines. This may allow for the deferral of any necessary grid upgrade or extension.

Frequency regulation

Numerous small cycles per day, quick response time

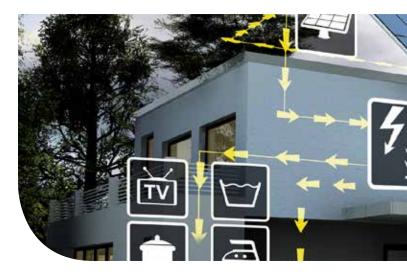
BES can store energy or feed in energy in order to balance a grid area with high frequency instabilities. This defers the need for grid upgrade or extension.

BES can also provide primary reserve capabilities to wind and solar generators, which is crucial in grids with high renewable penetration and subsequent low intertia due to a lack of conventional generation. BES can also optimise reserve power generation from conventional generators.

Voltage control

Numerous small cycles per day, quick response time

BES can help to maintain the voltage profile within a defined range, with the aim to guarantee standard of supply. BES achieves this by storing energy when the voltage is high, and feeding in when voltage is low.



BATTERY ENERGY STORAGE FOR HOMES AND BUILDINGS

Battery Energy Storage at a customer level

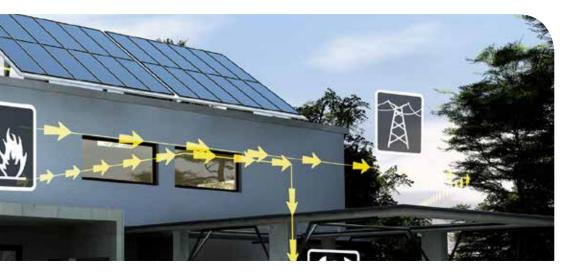
As the EU's electricity sector develops towards smarter transmission and distribution, consumers will also be encouraged to actively manage their energy demand. Added responsiveness at a customer level will save costs and avoid over-sized distribution grids, increasing overall flexibility for DSOs and improving the economic situation of consumers.

BES in homes and residential buildings allows users to store electricity from local generation (PV panels, small wind turbines etc.) when it is not needed and discharge it when needed. This can increase the percentage of selfconsumed electricity from a maximum 30% without storage to around 70%, optimising efficiency and reducing the amount of additional power needed from the grid. A typical battery to

be used in for households is 2 kWh per installed kWp PV (depending on climate).

In the future, customer-level BES systems have the potential to be aggregated and provide active grid support. This potential will be facilitated by the implementation of International or European connection and communication standards. It will also require further IT improvement, with pooled virtual storage having the potential to be influenced or directed by the real time situation of the grid.

BES allows customers to store energy from local generation and discharge when needed



Copyright: Siemens AG

Functions of BES in End-user applications

Small and medium-size users (i.e. households, industry) which use tailored BES as a component in their smart system can benefit in the following ways (non-exhaustive list):

Time-shift for self-consumption

Typical duration is 1-6 hours, with typically 1 cycle a day

BES can provide power during RES non-generation hours, allowing the household or building to increase independency from the electrical-grid. In the mid-term, this could reduce the overall electricity price by smart-metering, where stored energy is discharged during peak load hours when electricity prices are high. The primary renewable energy source will be Photovoltaic

Time-shift for feed-in

Typical duration is 1-6 hours, with 1 cycle a day

BES can provide power when renewable energy source supply is below demand or in non-generating hours. It can create economic value through electrical energy trading to (for example) the local utility industry via "storing-selling-consumption". The primary renewable energy source will be Photovoltaic.

Smoothing of RES feed-in

Typical duration ranges from milliseconds to a few minutes, with numerous small cycles per day

BES has the capacity to smooth RES feed-in by providing, absorbing and delivering power to limit fluctuations of feed-in electricity in the low voltage grid. This will improve overall grid conditions, with higher shares of renewable energy employed. Appropriate energy sources are photovoltaic and wind energy.

Uninterruptible Power Supply (UPS)Typical duration is 15 minutes to 1 hour, with the number of cycles depending on the grid stability

BES allows for increased power safety in areas with weaker low voltage grids. It has the capacity to provide backup power through the entirety of a power outage period. The number of cycles is dependent on overall grid stability (e.g. in Germany there are only a few minutes of grid failure per year).



Improving the short-term business case: German Storage Subsidy Programme

n May 2013, Germany introduced a €25 million storage subsidy programme, providing financial support to all photovoltaic systems containing BES that are installed in Germany in 2013 (with a maximum capacity of 30kW). The programme gives subsidies via low-interest loans from state-owned KfW bank and principal grants from the Environment Ministry. The subsidies amount to €660/kW of solar power for each system, improving the economic logic for BES take-up in the residential and commercial sector.

EUROBAT welcomes the introduction of storage incentive schemes as a short-term stimulus to encourage increased take-up of BES in renewable energy systems during a difficult financial period; especially in those countries where PV has already reached a high deployment level. Such mechanisms provide a valuable platform for the initial market introduction of BES on distribution and customer levels, already helping utilities to manage with the effects of RES integration.

However, in the long-term, EUROBAT considers that a level playing field should be established to allow for free and fair competition between all storage technologies and other flexibility options. To ensure future sustainability, battery-integrated PV systems must become fully market competitive in their own right, and make economic sense for PV system owners without subsidisation.

6

OVERVIEW OF BATTERY TECHNOLOGIES

EUROBAT emphasises that all four battery technologies – Lead-based, Lithium-based, Nickel-based and Sodium-based batteries - can provide distinctive and important functions to grid operators. In addition, each technology has potential for significant further technological and economic improvement in the short to medium-term.



Lead-based Batteries

Lead-based batteries have been well established in industrial applications for over 100 years, and are well-fitted in several on-grid applications for grid operators and end-users. At present, approximately 80% of the total installed capacity of industrial batteries (for stationary and motive applications) is based on lead-acid technology.

Different designs of Lead-based batteries are available, with an important choice to be made between flooded (vented) Lead-acid batteries requiring maintenance, or maintenance-free valve-regulated Lead-acid (VRLA) batteries.

Lead-based batteries for on-grid BES feature the following performance characteristics:

- Capacity 1 Ah up to 16,000 Ah
- Energy density 25-50 Wh/kg (60-40 Wh/l)
- Energy Efficiency Higher than 85%
- Calendar life 20 years
- Cycle life >2,000 cycles @ 80% depth of discharge (state of the art)
- Operation temperature range --30°C up to +50°C

Lead acid cells are robust and less sensitive to application conditions. They can be connected in large battery arrangements without sophisticated management systems. They are further differentiated by a low cost per kWh (typical about 120 to 200 €) to install and low cost per kWh electricity throughput (typical range: 0.1 to 0.15€ per kWh turn over for battery only). In Europe, over 95% of Lead-based batteries are collected and recycled in a closed loop system by the Battery Industry.

Further Development

For grid applications, advanced Leadbased batteries (for example AGM or enhanced flooded and VRLA batteries) continue to be developed in order to provide increased cycle life, charge acceptance, discharge performance, and cost reduction. Their specific power will be improved with advanced additives to the active materials and lower internal resistance designs; while cycle life will be lengthened through design enhancements such as corrosion-resistant Lead alloy materials and a more intelligent battery operation mode

Lithium-based Batteries

Commercialised since the beginning of the 90s, Lithium-ion batteries took over 50% of the small portable market in a few years, and since 2000 have successfully begun to enter industrial markets.

Existing in different chemistries with specific power vs. energy characteristics, Lithium-ion batteries feature:

- High energy density (150-200 kWh/m3, 140 kWh/ton at battery level)
- High efficiency (near 100%)
- Long cycle life (>5,000 cycles @ 80% depth of discharge) combined with long calendar life of 20 years+
- Maintenance-free design
- Versatility: electrodes can be optimized for different power / energy patterns
- SOC & SOH indication (state of charge, state of health

A major advantage of Li-ion technology is its versatility: highly scalable, it can be adapted to practically any voltage, power and energy requirement, with power to energy ratios ranging from very high power (i.e. 10kW / kWh) to very high energy. Li-ion batteries require sophisticated control electronics, which makes the technology somewhat complex on the one hand, but offers precise management and state of

charge control in "smart" applications on the other.

The implementation of Li-ion batteries in the stationary field has significantly increased since 2010 and has benefited from the extensive experience gained in the development of batteries for electric and hybrid vehicles. About 100MW of stationary Li-ion batteries are operating worldwide in grid connected installations. Systems in association with distributed renewable generators from a few kW to several MW, as well as for grid support with voltages up to 6000V have been designed and successfully tested. Recycling processes and installations are in place achieving a recycling efficiency well above 50%.

Further Development

Technology improvements will further increase energy density, cycle and calendar life. Building up of industrial capacity for mass production of industrial size cells and batteries, driven by automotive, energy storage and other mass markets, is poised to reduce system cost in the future. Increased market volume will drive a greater differentiation of system solution offerings for different application fields, along with a strong integration of segment specific system functions.

OVERVIEW OF BATTERY TECHNOLOGIES



Nickel-based Batteries

Nickel-based batteries (Nickelcadmium, Nickel-metal hydride, Nickelhydrogen and Nickel-zinc) are the second most used electrochemical energy storage after Lead-based batteries. They serve special markets where energy must be stored in extreme climate or cycling or fast charging conditions. Different designs are available: pocket, sintered, plastic-bonded, nickel foam, and fiber electrodes. Cells are prismatic or spiral wound cells, flooded (vented) or valveregulated (maintenance free). Alkaline cells can be connected in series and parallel to build battery systems with the desired voltage, energy and power characteristics.

Nickel-cadmium and nickel-metal hydride are the most applied alkaline industrial battery systems. The feature the following performance characteristics:

- Capacity- 0.5 Ah 2,000 Ah
- Nominal energy density From 20-80Wh/kg (50-300 Wh/l)
- Energy efficiency >90% (dependent on application)
- Calendar Life 25 years
- Cycle Life >3,000 cycles (of

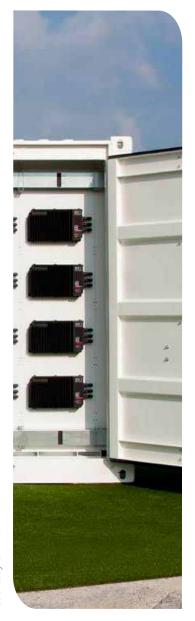
nominal capacity)

Operating temperature range - -40°C to +60°C

Alkaline cells are very robust and well suited for operation in critical environments. They can be connected in large strings without need for sophisticated management systems. Their costs range from 250 to 1,000 € per kWh to install. Collection and recycling of used industrial alkaline batteries is close to 100% in Europe.

Further Development

Future development will focus on increasing cycle life, extending temperature range and reducing self-discharge and costs. Active materials, collector materials, additive materials, and production methods will be subject of R&D. Because of their performance, reliability, operational safety and durability against adverse environmental influences, alkaline batteries will continue to be irreplaceable in their establish applications.



Sodium-based Batteries

Sodium Nickel Chloride (NaNiCl₂) batteries are a relatively new technology, and were originally introduced in the market for Electric and Hybrid-Electric Vehicles. A wider range of products is now available for stationary back up, railway back up and on-grid/off-grid energy storage.

Several pilot projects have been initiated globally over the last two years (in Europe, the US, Brazil, Korea and Africa) to improve familiarity with the technology and encourage further advancements. Complete turnkey energy storage systems with a power rate up to the MW size and 3 to 6 hours energy are being developed and are currently under test, with the first MW class delivery expected for Summer 2014.

NaNiCl₂- batteries are marked by high specific energy, a constant performance and cycle life in harsh operating environments, and low maintenance requirement. They feature the following performance characteristics:

Cell capacity- 380v 40Ah

- Nominal energy density 120 Wh/ Kg / 140 Wh/I (battery level)
- Energy efficiency 92% at C/4 rate
- Calendar Life 10+ years in stationary float applications at any ambient temperature
- Cycle Life > 4500 cycles @ 80%
 DOD (SOC 10% to 90%)
- Operating temperature range --30°C to +60°C without power reduction.

Further Development

After only 15 years in use, there is still extensive potential for further technological improvement. The specific power of NaNiCl₂ batteries is being improved, with advanced additives introduced for the positive active materials and lower resistance of ceramics in the solid electrolyte. Other R&D focuses on improving the recharge power, and on increasing cycle life through design enhancements. Further cost reductions are being realised by automation and process improvement in the manufacturing process, as well as economies of scale from increased production volumes.

18 EUROBAT

CONCLUSION AND RECOMMENDATIONS

EUROBAT emphasises that batteries of all technologies – Lead, Lithium, Nickel and Sodium – are already available on the market to address the storage needs of TSOs, DSOs and customers at each level of the electricity grid. Decentralised BES provides a mobile and scalable solution to answer specific local problems raised by RES integration at the distribution level of the grid. BES also has a high potential to create interest and momentum at the customer level for endusers. Batteries of all technologies can be implemented in low-risk and environmentally friendly conditions, with high political acceptance

Ithough continued R&D is needed to further reduce prices and improve performance, each battery technology can be implemented to provide on-grid storage today. Their market introduction and further development should therefore be given immediate support by policy makers and standardisation bodies.

Additionally, to facilitate the shortterm market introduction of BES, especially at distribution and customer levels, EUROBAT makes several recommendations:

Decentralised energy storage must be seen as an integral part of the

development of Europe's future

Smart Grid.

As the responsibilities of DSOs evolvefrom the straightfoward management of downstream energy distribution towards the balancing of multi-directional power flows from local RES generation and local demand - decentralised energy storage at distribution and customer levels will quickly become an integral flexibility mechanism to ensure the stability of electricity supply. EUROBAT therefore considers that as new markets emerge for smarter distributed generation, a level playing field should be implemented to allow energy storage technologies to fairly compete with other flexibility solutions.

A market framework for energy storage should be developed at an EU level

An EU-level market framework for energy storage would allow for the value streams of BES and other storage technologies to be quantified for all actors. Official definitions of energy storage should be included in network codes and relevant EU legislation, and targeted regulatory initiatives should be introduced to minimise market distortions hampering the development and fair competition of storage technologies.

Flexibility should be allowed for individual, but undistortive national approaches.

Key recommendations for developing the European BES market



Member States should evaluate the specific potential for deployment of energy storage technologies at all levels of their electricity system.

In order to successfully plan for the progressive decarbonisation of their electricity system, Member States will need to evaluate the specific potential for deployment of energy storage technologies within their territory. This potential should be estimated at all levels (generation, transmission, distribution, customer), and for all technologies.

These national analyses can be employed at a European level to more accurately quantify the role that energy storage will need to play in the EU's long-term transition towards a decarbonised power sector.

The further development of Battery Energy Storage should be prioritised in all EU-level R&D initiatives, at both cell and system levels.

On-grid BES installations are already reaching the European market. Horizon 2020, the European Commission's Framework Programme for Research and Innovation, should include a specific focus on storage technologies to encourage their continued development. Cell-level and systems-level research into all battery technologies will improve the business case for BES at all levels of the grid, and large-scale demonstration projects are necessary to evaluate how BES can best

respond to market needs and the value streams for different actors.

EUROBAT also considers that support for energy storage should be maintained in existing R&D initiatives, including the SET-plan, the European Electricity Grid Initiative (EEGI) and the European Energy Research Alliance (EERA).

Efforts to develop a European market for energy storage should recognise the existing strengths of Europe's manufacturing base

Although further research and innovation into new and untested storage concepts is undeniably important, EUROBAT advocates that ongoing efforts to develop a European market for energy storage also capitalise on the existing strengths of Europe's manufacturing base.

Lead-based, Lithium-based, Nickel-based and Sodium-based batteries are well established on the European market for different industrial stationary and motive applications, and are all already capable of providing a portfolio of services to grid operators and end users.

In the short and medium-term, the continued technological and economic improvement of these battery technologies should be prioritised to allow for their adaptation to the changing requirements of on-grid energy storage, and immediate integration into on-grid systems.

