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SET Plan Secretariat

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"Become competitive in the global battery sector to drive e-mobility forward"

Purpose of this document

This document[1] is intended to progress the implementation of the actions contained in the SET-Plan Communication [1] and specifically one of the two actions concerned with the priority "Diversify and strengthen energy options for sustainable transport". It is part of a series of Issues Papers jointly prepared by the services of the European Commission and discussed with the representatives of EU member states and countries part of the SET Plan, working together in the SET Plan Steering Group.

The Issues Papers propose to stakeholders strategic targets in different areas of the transport and energy sector. The input from, and positions of stakeholders will be used to come to an agreement on targets in a dedicated meeting of the SET Plan Steering Group with a representation of key stakeholders.

Stakeholders are invited to take position on the proposed targets in accordance with the guidelines set out in the paper ***The SET Plan actions: implementation process and expected outcomes*** and submit their positions to SET-PLAN-SECRETARIAT@ec.europa.eu by **25/05/2016** at the latest. All relevant documents and material are available on the SETIS website https://setis.ec.europa.eu/.

Introduction

The Energy Union strategy [2], adopted by the European Commission and endorsed by the Council, is built on the ambition to achieve a fundamental cost-effective transformation of Europe's energy system. This will be achieved by moving to more flexible, more decentralized, more integrated and therefore smarter, more sustainable, secure and competitive ways of delivering energy to consumers. One of the core priorities of the Energy Union strategy is to speed up energy efficiency and decarbonisation of transport through Research and Innovation (R&I) in e-mobility. The strategy will put the EU at the forefront of the next generation of clean transport technologies and energy storage solutions with the aim of turning these into a motor for growth, jobs and competitiveness. Within the fifth dimension of the

[1] This document is a working document of the European Commission services for consultation and does not prejudge the final form of any future decisions by the Commission.

Energy Union strategy dealing with Research, Innovation and Competitiveness, the integrated SET-Plan will steer European energy R&I designed to accelerate the energy system transformation.

E-mobility facilitates the reduction of greenhouse gas (GHG) emissions through the electrification and consequent decarbonisation of transport. Road transport accounts for some 80% of all GHG emissions related to transport [3] and so electrification in this sector has massive potential for decarbonisation. At the same time e-mobility provides an opportunity for enhancing EU industrial competitiveness, a major enabler of future economic growth and job creation, in addition to providing benefits in terms of energy security, health and environmental protection.

Traction batteries are considered a Key Enabling Technology in electric vehicle (EV) drive trains [4]. Current traction batteries are to a large extent based on lithium-ion (Li-ion) chemistry, however in the future other lithium (Li) and non-Li based chemistries are expected to gain ground. In recent years the development of hybrid electric vehicle (HEV) batteries has yielded a relatively mature generation of vehicles (nearly 2 million HEVs had been sold worldwide by 2014 [5]). More recently the focus of battery development has shifted towards higher energy systems specifically suited for Plug-In Hybrid Vehicles (PHEV) and Battery Electric Vehicles (BEV). Since BEVs are more demanding in terms of energy density and power requirements, development of batteries for BEVs drives R&I in the field. Such developments are nonetheless beneficial for different vehicle categories, chiefly passenger light duty vehicles, as well as 2-3 wheelers, quadricycles, SUVs, minivans, short range heavy duty vehicles (buses and trucks), and fuel cell electric vehicles (FCEV).

As important as they are, technology improvements achieved through R&I are not sufficient to drive EU competitiveness in the battery sector, which is explicitly targeted in this Key Action. Competitiveness in this sector also hinges on having a stable and secure battery manufacturing base. The EU has a leading position in the lead-acid battery industry with well-developed battery producing capacities. Furthermore the EU maintains a strong position in lithium-ion cells and other chemistries (sodium nickel chloride, i.e. "Zebra") for niche applications (e.g. aviation/space/military). However unlike in Asia, a significant European automotive cell manufacturing capacity does not exist for mainstream traction battery cells, especially Li-ion and NiMH. This despite the EU's strong car manufacturing industry which is expected to maintain its strong position also in EV production, although arguably their actions to date have not been aggressive enough compared with some newcomers who have less legacy investments to protect.

The lack of an EU automotive battery cell manufacturing base leads to a dependence on battery cells imported from Asia, forcing EU's car manufacturing industry to purchase ‘off the shelf’ cells. This endangers OEM's competitive advantage because of security of supply chain issues, increased costs due to transportation, loss of part of the value, time delays, relinquished control on quality and limitations on design options. It also raises concerns related to the potential loss of Europe's knowledge base [4, 7]. Initiatives have been triggered to address this situation. As an example, at least one Member State has recently started discussions to set up a national or even European cell production capacity. This can be seen in the context of a prospective alliance between certain OEMs to manufacture next-generation batteries. Another approach is to stimulate foreign investment by way of establishing foreign manufacturing plants in the EU – as Japanese and Korean companies already did. The US also followed this approach. Still, establishing a European battery cell manufacturing base is not a panacea since dependencies related to the supply of raw materials will remain [8-11].

Manufacturing capacities should however be considered over the whole battery value chain – from powder to power - including advanced materials development and production technologies, cell manufacturing, pack assembly and system integration for current lithium-ion technologies and also for emerging and future technologies. Although EU industry has a good knowledge and has some production

base in all segments of the battery value chain, it is far from being self-sufficient (and hence is relying on imports) particularly for basic materials and battery cells. EU industry is however active in the production and supply of some basic materials, in cell integration and packaging, in battery control, power electronics, in battery plant manufacturing, cell integration and pack assembly, battery recycling, and system integration. In addition the EU has globally recognised academic and research institutions in the field with good links with OEMs and battery manufacturers.

To ensure EU competitiveness in the global battery sector in a strategic and cost-effective manner a holistic approach covering different aspects is needed:

- Potential uses for batteries beyond e-mobility applications need to be exploited. Examples include the use of battery energy storage systems in households (either standalone battery systems or EV batteries in vehicle-to-home configurations) or as utility scale grid connected assets, relevant to Key Actions 3 and 4 of the SET Plan [1], respectively. Exploitation of R&I synergies between these applications would facilitate the achievement of increased battery systems performance and safety while decreasing production costs. There is also a need to establish a manufacturing chain for these different applications, which could lead to a much needed critical mass in the size of the first-use Li-ion battery market. It also opens a potentially interesting "second life" market for automotive batteries.
- Widespread deployment of any innovative, disruptive technology requires significant transformations of the product value chain, development cycles and associated technologies and services. Acknowledging this, the SET Plan [1] underpins the importance of promoting new investments at all stages of the innovation chain. For battery technologies and systems, such investments are to be done in a coordinated way to leverage European public and private investments, thereby covering the expected high cost of R&I and the upscaling of manufacturing processes to mass production scale for Li- and future non-Li based batteries, primarily for automotive but also for selected energy storage applications.
- It is important to take into account barriers such as different Member States' approaches on industrial policy, lack of fit-for-purpose standards, chronic difficulties for incubation (e.g. access to finance), the lack of skilled and educated workforce, and specifically uncoordinated and incompatible regulatory and legal frameworks. Concerning the latter, adoption of global regulatory safety requirements for e-vehicles under development by UNECE will guarantee more regulatory stability and thereby facilitate economies of scale.
- The business case for batteries – particularly batteries for e-mobility – needs to be supported. This can be achieved through policy-pull measures, as for instance with Directive 2014/94/EU which requires the deployment of a certain level of charging infrastructure in Member States. In fact, sales of e-vehicles are picking up in some countries such as the Netherlands and Norway which could effectively act as pioneers and lead the way to a quicker rate of e-vehicle uptake in other countries. This of course will be crucial to ensure the profitability of EU battery manufacturing capabilities once they are created or enlarged. While market uptake aspects fall outside the scope of the SET Plan, they will be addressed by the Strategic Transport Research and Innovation Agenda (STRIA) – which, along with the
  SET Plan, will feed the Energy Union Integrated Strategy on Research, Innovation and Competitiveness (EURICS).
- It is also critical to reinforce existing and build new strategic alliances between public and private stakeholders to promote energy storage in the transport, power, gas and residential sectors. This may include initiatives to establish new business and market models and exchange knowledge to avoid duplication of efforts. Stakeholders include battery manufacturers, core materials suppliers, automakers, power electronics, battery management system (BMS) specialists,

distribution systems operators (DSOs) and the general supplier industries, as well as factory builders and research and standardization bodies.

Targets

As an overarching objective, R&I related to Key Action 7 of the SET Plan will aim at developing and demonstrating technologies, manufacturing processes, science-based standards and regulations, to increase performance and safety and reduce overall cost of battery systems used for storage purposes in the transport and other sectors. The R&I effort will cover materials, cells, packs and systems with a focus on high energy and resource efficiency, modularity and re-configurability, while also taking into account second life and recycling. In terms of chemistries, the core focus is on Li-ion batteries, while attention and a certain support may be given to post-Li-ion.

To guide the discussion with SET Plan countries and stakeholders on the prioritisation of the required activities to be implemented at regional, national and European level, targets identified below are proposed by the Commission. Their values are based on a number of sources [5, 6, 12-30] and have been subjected to internal Commission review and consensus. The set of targets should guide coordination of EU and Member States funding in areas of materials research, nanotechnology, electrochemistry, manufacturing processes and manufacturing technologies. Achievement of the targets will require coordination of R&I activities, with responsibilities and efforts shared between different stakeholders during the implementation phase.

Targets are not relevant to batteries for portable/electronic equipment which falls outside the scope of this Issues Paper. Targets are differentiated into performance, cost and manufacturing targets. Considering the expected dominance of Li-ion chemistry in the coming decades for electrochemical energy storage, barring unexpected but possible breakthroughs, the performance and cost targets defined are application-specific and based on technology improvements deemed achievable for Liion batteries up to 2030. Targets may be exceeded through developments in other advanced technologies.

a) Performance targets

Successful deployment of batteries for automotive applications requires meeting a number of performance criteria:

Table a

		Current (2014/ 2015)	2020	2030
Performance targets for automotive applications				
1	Gravimetric energy density [Wh/kg]			
	pack level	85-135	250	> 250
	cell level	90-235	400	> 400
2	Volumetric energy density [Wh/l]			
	pack level	95-220	500	> 500
	cell level	200-630	750	> 750
3	Gravimetric power density [W/kg]			
	pack level	330-400	470	> 470

Comment [1]: - For batteries in the automotive field, the key parameters to follow are, in order of importance:
o safety
o cost (€ / kWh),
o volumetric energy density (Wh / l),
o reliability
o durability (cycling and calendar life)
- Concerning the cost :
o the current values in 2016 are around 400 kWh for a pack.
o This cost in 2020 could be around 15 200 €/kWh
o In 2030, the cost could reach 120 €/kWh.
- Concerning the density :
o The energy density could be multiplie by 1.5 by 2020 and double by 2030
So, batteries at EV pack level with such targets in 2030 (120-150 € / kWh, 250W kg, 500Wh / l, 5000 cycles, 15-20 years) would be a real asset for the developme of electric mobility.

	cell level		700	> 700
4	Volumetric power density [W/l]			
	pack level	350-550	1.000	> 1.000
	cell level		1.500	> 1.500
5	Fast recharge time [min] (70-80% ΔSOC)	30	15	3
6	Battery life time			
	Cycle life to 80% DOD [cycles]		1.000	5.000
	Calendar life [years]	8-10	15	20

b) Cost targets

Table b

TARGETS		Current (2014/ 2015)	2020	2030
Cost target				
1	Battery pack cost for automotive applications [€/kWh]	180-285	90	75

Automotive sector is leading Li batteries development and as result Li batteries have shown a significant cost reduction during last years. Li batteries for grid connected stationary applications have different requirements, however they can highly benefit from the automotive sector achievements. The Levelized Cost of Energy (LCOE) of the services provided by stationary batteries to the Power System will decrease thanks to the progress in the EV sector.

c) Manufacturing targets

Table c

TARGETS		Actual (2014/ 2015)	2020	2030
Manufacturing targets				
1	Automotive (Li-ion and next generation post-lithium) battery cell production in EU [GWh/year][2] (% supporting EU PHEV+BEV production)	nearly 0	5 (50% = 0.25 M of 20 kWh)	50 (50% = 1 M of 50 kWh)

[2] Two assumptions were made when defining this target value, based on projected global sales for PHEV+BEV in 2020 and 2030 of 2.5M and 5 M vehicles respectively: (a) the percentage for EU OEMs production of PHEV+BEVs is assumed to be maintained at the current level of 20% for both 2020 (with an average energy capacity of 20 kWh) and 2030 (with an average energy capacity of 50 kWh); (b) EU battery manufacturers will supply half of the cells needed for the PHEVs+BEVs produced by EU OEMs.

Comment [2]: This could also be valid f stationary storage, but the table only discusses automotive storage. We shou explicitly mention this.

Comment [3]: These numbers are low f stationary applications where the added value is lower than for automotive ones. We would propose for the case of stationary Li-Ion batteries :
- 2014/2015 1000-3000 (estimation)
- 2020: 3000-5000 (estimation)
- 2030: 10000 (taken from European energy storage technology development roadmap towards 2030)

For other battery chemistries these valu could be different.

Comment [4]: The cost of the inverter a control system are equally important for the total cost of the storage system.

Comment [5]: Text added

Comment [6]: The ETP storage suppor manufacturing targets, as they include a certain 'learning curve' in handling technology. The targets itself are quite ambitious.

Comment [7]: Li-ion could be replaced 'Li-based' batteries.

Comment [8]: The ETP Storage considers that the focus of this paper is too much concentrated on only Li-ion. Other technologies (Metal-air,...) exist w large potential to contribute to the mentioned targets.

Comment [9]: Levelized cost of energy an important parameter as well

2	Utility Storage (Li-ion and next generation post-lithium) battery cell production in EU [GWh/year]		2.2	10
3	Recycling			
	Battery collection rate	45% (Sept 2016)	60%	75%
	Recycling efficiency (by average weight)	50%	50%	50%
	Economy of recycling	Not economically viable	Break even	Economically viable
4	Second Life	Not developed	Developed	Fully established

Comment [10]: Utility storage targets ar mentioned here, but no cost or performance targets for these applicatio are given

For stationary energy storage the SET-Plan R&I will aim at developing and demonstrating technology, manufacturing processes, standards and systems, which have the potential of driving high-efficiency (>90%) battery based energy storage system cost **below €150/kWh** (for a 100kW reference system) and a lifetime of thousands of cycles by 2030 to enable them to play an important role in smart grids. Technologies will include materials, cells, modules but with a focus on battery systems targeting modularity and re-configurability and considering as well second life and recycling aspects.

Comment [11]: It is really important, for stationary storage systems, to precise a distinguish the target costs for the two main components :
- cost of electrochemical modules (in €/kWh)
- cost of the inverters / power electronics (in €/kW)
The cost of installation/integration (in €) also an important one to have in mind.

In addition to the targets above, there are other requirements for which it is more difficult to set SMART targets and that will be addressed by the EURICS expected by the end of the year. Such requirements include safety, manufacturing process for advanced battery materials/components production (including its efficiency, environmental footprint and impact), reduction in the use of critical materials, interoperability and system integration at pack level, standardization, workforce and education – as outlined e.g. in [21, 23, 26, 28, 31].

Next steps

Stakeholders are requested to provide their feedback and take position on the proposed targets in accordance with the guidelines set out in the paper "*The SET Plan actions: implementation process and expected outcomes*". Stakeholders should submit their positions to SET-PLANSECRETARIAT@ec.europa.eu by **25/05/2016** at the latest. Stakeholders' positions will be used to come to an agreement on targets in a dedicated meeting of the SET Plan Steering Group with a representation of key stakeholders.
Subsequently the parties involved will undertake to agree on an Implementation Plan for the delivery of the agreed R&I targets. In doing so factors of a technological, socio-economic, regulatory, financial, or other nature, which may be of relevance in achieving these targets, have to be considered.

Proposed actions

The annex below reproduces actions which were identified in the document 'Towards an Integrated Roadmap: Research & Innovation Challenges and Needs of the EU Energy System' (https://setis.ec.europa.eu/set-plan-process/integrated-roadmap-and-action-plan). These actions can be used in the preparation of the Implementation Plan but are in no way restricted to these suggestions.

Annex: Relevant actions of the 'Towards an Integrated Roadmap' document of the SET Plan

Part II **Competitive, Efficient, Secure, Sustainable and Flexible Energy System**

HEADING 2 ***Ensuring Energy System Integration***

Challenge 1 Energy Grids

ADVANCED RESEARCH PROGRAMME

Action 5: Research and development of tools development to support new market designs at PanEuropean and regional levels

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 5: Demonstration of novel tools to prepare recommendations for novel market designs

Challenge 2 Storage (Heat and Cold, Electricity, Power to Gas or other energy Vectors)

ADVANCED RESEARCH PROGRAMME

Action 1: Enhanced Storage materials

Action 2: New Technologies for Next Generation Central and De-central Storage Technologies of any scale

Action 3: Improved second generation technologies for Next Generation Central and De-central Storage Technologies of any scale

Action 4: Storage System interfaces

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Storage System Integration and Benefit Assessment via Simulation of System Embedding

Action 2: Central and De-central Storage Technology Demonstration of any scale

Action 3: Storage System integration Demonstration

Action 4: Storage Manufacturing Processes

Action 5: Storage Recycling

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Storage Standardisation

Action 2: Storage Business Case Evaluation in global market environment/systems

Action 3: Storage Business Cases in local market environment/systems

Action 4: Soft Aspects and Society Acceptance

Action 5: Closed storage material loop

Challenge 5 Cross-technology Options

ADVANCED RESEARCH PROGRAMME

Action 1: Cross-Sector Chemical Storage Technologies

Action 6: Energy Systems Integration – Testing and Evaluation of Integrated Energy Systems

Part III **Fostering Innovation in Real Environments and Through a Market -Driven Framework**

HEADING 3 ***Fostering Sustainable Transportation***

Challenge 1 Fuel and fleet diversification

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstrate the usage of waste brake energy through batteries in buses (B1) Action 2: Electrification of buses and captive fleets in urban areas (B4)

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Accelerating the electro-mobility deployment for passenger cars (A1)

Challenge 2 Energy performance of transportation systems

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Increase Information Data Management for Electric Transport Infrastructure to enable smart services and improve logistics (C1)

Action 2: Develop smart charging as a way to better integrate electric vehicles into the grid and promote renewables i.e. real time control of charging power of an electric vehicle according to the user needs, the availability of network capacity, the cost of energy and its sourcing (A3)

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Promote the "Human Factor" (B2); Promote more sustainable mobility choices.

Part IV **Cross-cutting Aspects**

HEADING 4 ***Advancing higher education and lifelong learning and fostering the link between education and training institutions, business and research institutes***

Action 1: Develop networks of higher education institutions with links to business and research

Action 2: Develop networks among training institutions, business and research institutes for lifelong learning

Action 4: Develop a quality assurance framework for higher education and lifelong learning programmes on energy

Action 5: Development of energy-related education programmes for decision-makers

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