European Commission

STUDY ON MISSION-ORIENTED R&I

ENERGY STORAGE
TO SPEED UP THE ENERGY TRANSITION

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ABSTRACT

The overall purpose of this study is to increase understanding on how a technology-driven mission, in this case energy storage, can be designed and how such a mission in the field of energy storage could look like. The methodology used in this study combines literature research with expert knowledge and expert interviews. The study summarizes present EU policy on energy storage, gives examples of missions from various companies and institutions and presents key findings of recent roadmaps on energy storage. Together with expert interviews on mission-oriented R&I this information serves as a background to propose two missions on energy storage. Firstly, a so-called transformer mission is proposed as "Develop an interconnected, carbon-neutral and reliable Pan-European Energy System by 2030". This mission transforms the whole energy system in Europe, while the second proposal accelerates the technical development of Post-Li-Ion batteries. This so-called accelerator mission is proposed as "Develop more powerful and clean European Post-Li-Ion batteries for electromobility available on the market by 2030". Finally, an evaluation and monitoring scheme for both missions is developed.

EXECUTIVE SUMMARY

A massive increase in renewable energy generation and upcoming electric vehicle networks are both accelerating the need for new energy storage solutions. Worldwide power generation from renewable energy sources is expected to nearly triple between 2010 and 2035, reaching a 31 % share.

The overall purpose of this study is to increase understanding on how a technology-driven mission, in this case concerning energy storage, can be designed and how such a mission in the field of energy storage could look like. The aim of the study is to give a more in-depth and tangible idea of how a mission-oriented R&I could look like, how it could be designed, managed and operationalised.

The methodology used in this study combines literature research with expert knowledge and expert interviews. As a starting point recent EU policy on energy was reviewed and main findings were summarized. Based on an extensive web and literature research summaries on recent missions on energy storage and key findings of recent roadmaps on energy storage are given. A survey with key questions for a mission-oriented R&I was set up and interviews were taken to acquire and incorporate expert opinions. Finally, two mission proposals were given with targets and detailed milestones.

The main general findings of this study can be summarized as follows:

- Several EU policy papers on energy union, energy systems and on energy storage recognize the importance of energy storage for future energy systems with increased electromobility. Focus for R&D in battery storage should be given to post Li-ion generation.
- The existing missions in energy storage are general but diverse and reflect the interests of the stakeholders. Many missions consider electricity systems only.
- There are many recent roadmaps on energy storage and their political and general recommendations can be classified in the following four areas: 1) Stimulate and support markets, 2) Harmonize regulation, 3) Setting standards, 4) Preserve environment and safety.

The proposed Transformer Mission is "**Develop an interconnected, carbon-neutral and reliable Pan-European Energy System by 2030**". The main targets on the way to fulfill the mission are:

- Develop and agree on interconnected European energy system development plan
- Support energy technology R&D and system integration

- Decrease greenhouse gas emissions in the energy sector
- Raise awareness and understanding in society of the future interconnected energy grid

The main impact is that Europe will have a reliable, secure, economical and ecological system which respects the geography of all European countries aiming at carbon emission neutrality and that there will be a larger geopolitical independence from non-EU countries.

The proposed Accelerator Mission is "**Develop more powerful and clean European Post-Li-Ion batteries for electromobility available on the market by 2030**". The main targets on the way to fulfill the mission are:

- Improve energy density of Post Li-ion batteries
- Develop powerful and reliable battery systems
- Reduce battery system life-cycle cost

The main impact is the accelerated development of a European local competitive battery manufacturing industry for electromobility. This would make Europe more resilient against external factors affecting the foreign battery supply chain and making electromobility more affordable to citizens. In addition, decreasing the environmental impact by reducing emissions in general and CO_2 in particular.

It can be concluded that major challenges for energy storage R&I are improving the cost performance ratio of energy storage, adapting regulatory framework and building manufacturing capacity for batteries in Europe. The most important measures to speed up the integration of energy storage are in good agreement with the challenges. Finally, a mission in energy storage shall consider all energy storage technologies at multiple time scales. Mission development should involve all relevant stakeholders and missions need a detailed roadmap with clear objectives and milestones.

1. Motivation, Background and Scope

A massive increase in renewable energy generation and upcoming electric vehicle networks are both accelerating the need for new energy storage solutions. Worldwide power generation from renewable energy sources is expected to nearly triple between 2010 and 2035, reaching a 31 % share. For Europe this figure will be even higher. For example, Germany's "Energiewende" assumes a share of renewables of at least 50 % of electricity consumption by 2030, and 80 % by 2050.

In this context energy storage is a pivotal technology and its importance is already reflected upon at EU level in many policy papers and in two of the ten integrated SET Plan actions. Action 4 deals with „Integrated and flexible energy systems" and action 7 is related to „Become competitive in the global battery sector to drive e-mobility and stationary storage forward".

The overall aim of the study is to increase understanding on how a technology-driven mission, in this case one concerning energy storage, can be designed and how such a mission in the field of energy storage could look like. The aim of this study is to give a more in-depth and tangible idea of what a mission-oriented R&I could look like, how it could be designed, managed and operationalised. The underlying questions to be explored include e.g. what technologies and other innovation instruments should be mobilised and combined, and how this process should be organised.

To answer these questions, this study is divided in six main chapters. At the beginning a short description of background and scope of the study is given. Chapter 2 summarizes recent EU policy related to energy storage. Chapter 3 summarizes examples of energy storage missions and lists major energy storage roadmaps and case studies and summarizes their main findings. In addition, chapter three contains the main results of expert interviews that where related to mission-oriented R&D in energy storage. Chapter 4 contains proposals for two examples of energy storage missions. In the annex the detailed interviews and all evaluated roadmaps and studies are given. The methodology used in this study combines literature research with expert knowledge and expert interviews.

As an example of the complexity of R&I in energy storage, Figures 1.1 and 1.2 demonstrate the main challenges in the development of new and advanced electrochemical energy storage. In a first step new material classes as seen in Fig. 1.1 must be found and developed to considerably enhance the volumetric and gravimetric energy density in comparison to present Li-ion batteries. Secondly, the material needs to be integrated in cells and batteries which can be more or less seen as an engineering challenge (Fig. 1.2). From this example, it is clear that the whole value chain for energy storage technologies needs to be considered and this involves multiple disciplines.

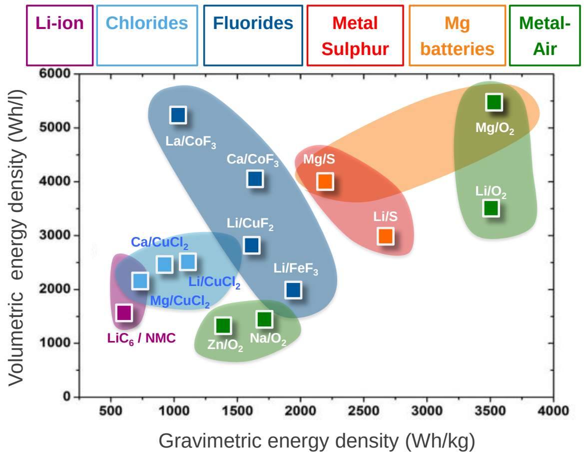

Figure 1.1: Volumetric and gravimetric energy density of Li-ion and post Li-ion materials (Courtesy: M. Fichtner, Helmholtz Institute Ulm)

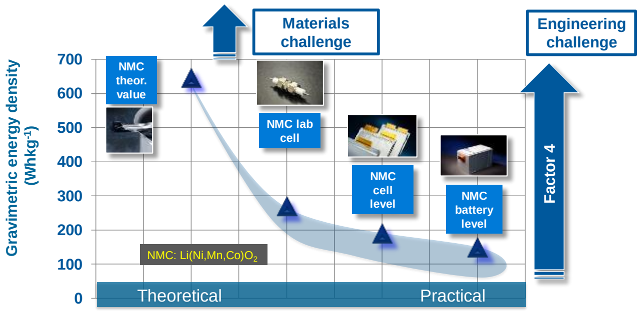

Figure 1.2: Gravimetric energy density of Li-ion cells from theoretical material value to practical batteries (Courtesy: M. Fichtner, Helmholtz Institute Ulm)

2. EU POLICIES

Summary

Several EU policy papers on the energy union, energy systems and on energy storage have recognized the importance of energy storage for future energy systems with increased electromobility. Focus for R&D in battery storage should be given to post Li-ion generation.

In this chapter a short summary of recent EU policy papers on energy storage is given. The importance of Energy Storage is already reflected in many recent European policy and science papers. Among them:

- EC, Commission staff working document „**Energy storage – the role of electricity**", Brussels, 1.2.2017 SWD(2017) 61 final
- EC, Communication from the commission to the European Parliament, the Council, the European economic and social committee, the committee of the regions and the European Investment Bank „**Third Report on the State of the Energy Union**", Brussels, 23.11.2017 COM(2017) 688 final
- EC DG R&I „**Batteries - a major opportunity for a sustainable society**", Research & Innovation Pro-jects for Policy 2017
- EC, „**Transforming the European Energy System through Innovation**" Integrated SET Plan Progress in 2016
- Integrated SET-Plan Action 7 ~ Implementation Plan ~ „**Become competitive in the global battery sector to drive e-mobility and stationary storage forward**".
- JRC Science for policy report, "**EU Competitiveness in Advanced Li-ion Batteries for E-Mobility and Stationary Storage Applications –Opportunities and Actions**", 2017

Not only the importance of energy storage for future energy systems based on renewables is underlined, also the need for a non-discriminatory way by the regulatory framework is mentioned and priority should be given to electrochemical energy storage.

The main statements address important market and regulatory issues and are summarized below.

<u>Recommendations and main statements in European Energy Storage Policies</u>

EC, COMMISSION STAFF WORKING DOCUMENT „**Energy storage – the role of electricity**", Brussels, 1.2.2017 SWD (2017) 61 final

- Energy storage should be allowed to participate fully in electricity markets.
- The cost-efficient use of decentralised storage and its integration into the system should be enabled in a non-discriminatory way by the regulatory framework.
- Energy storage as an enabler of higher amount of variable RESs could contribute to energy security and decarbonisation of the electricity system or of other economic sectors.

EC, Communication from the commission to the European Parliament, the Council, the European economic and social committee, the committee of the regions and the European Investment Bank „**Third Report on the State of the Energy Union**", Brussels, 23.11.2017 COM(2017) 688 final

- While Horizon 2020 will deploy over €2 billion in the period 2018-2020, focusing on four key energy and climate priorities: storage, renewables, buildings and (urban) e-mobility. Accounting for bottom-up activities, the total amount may even rise to €3 billion.
- Batteries are a strategic part of the innovation priorities defined last November. With increasing performance and falling costs, batteries will be an essential enabling technology for reaching the Energy Union objectives, in particular through applications in electro-mobility and electricity storage.
- This complements regulatory action to remove disincentives to energy storage and promote electro-mobility.

EC DG R&I „**Batteries - a major opportunity for a sustainable society**", Research & Innovation Projects for Policy 2017

- Establish a common infrastructure for fast-charging electric vehicles.
- Harmonise vehicle charging protocols and billing systems in Europe (interoperability).
- Support the transition to electricity production from renewable sources.
- Stimulate recycling of automotive and industrial batteries.
- Facilitate the reuse of batteries for new purposes.
- Develop fit for-purpose performance and safety assessment standards.
- Support European battery cell production.
- Promote research on new battery materials and chemistries.

EC, „**Transforming the European Energy System through Innovation**" Integrated SET Plan Progress in 2016

Action 4: Integrated and flexible energy systems

- This calls for high levels of observability and controllability of the grid, increased storage capabilities, stronger interactions with other energy networks (e.g. via power-to-heat, power-to-gas/fuel, electric vehicles) and an optimised integration of consumers and prosumers via innovative and attractive demand-response schemes.

Action 7: Batteries for E-mobility and stationary storage

Integrated SET-Plan Action 7 ~ Implementation Plan ~ „**Become competitive in the global battery sector to drive e-mobility and stationary storage forward**".

- …, the proposals for Research and Innovation (R&I) activities issued by the TWG Action 7 are of high importance and can play a key role in a European strategy on batteries.

JRC Science for policy report, "**EU Competitiveness in Advanced Li-ion Batteries for E-Mobility and Stationary Storage Applications – Opportunities and Actions**", 2017

- Considerations on EU competitiveness in LIB cell manufacturing should target innovation in cell chemistries, formats and manufacturing technologies/processes.
- Efforts for establishing LIB cell manufacturing capacity in the EU should primarily target LIB cells of generation-2b and beyond and should focus on production stages which are critical for LIB quality, performance and safety.
- Competing with non-EU LIB cell producers on cost-only basis is unlikely to be successful. A competitive EU LIB cell production should offer added value beyond cost, in terms of enhanced sustainability, safety and performance.

3. EVIDENCE

Summary

The existing missions in energy storage are general but diverse and reflect the purpose of the stakeholders. Many missions consider electricity systems only.

There are many recent roadmaps on energy storage and their political and general recommendations can be classified in the four areas: 1) Stimulate and support markets 2) Harmonize regulation 3) Setting standards 4) Preserve environment and safety.

3.1 Examples of Energy Storage Missions

Table 3.1 summarizes existing missions on energy storage. These missions were obtained by searching the World Wide Web with specific search items several times and by looking directly at important companies and associations. Therefore, this overview cannot be complete but still covers a wide range of countries and associations.

It can be seen, that the missions are rather general and that clear milestones shall be given in additional working papers, roadmaps or internal strategy papers. For example, the Helmholtz Association developed a 5-year plan for the funding period from 2015-2019 with clear milestones each year.

Furthermore, mission statements on energy storage are rather short and easy to understand. Seven out of the seventeen missions restrict energy storage to electricity storage only.

Table 3.1: Example of missions on Energy Storage

Organisation	Mission
Energy Storage Integration Council (ESIC) – EPRI (USA)[1]	To advance the integration of energy storage systems through open, technical collaboration: guided by the vision of universally accessible safe, secure, reliable, affordable, environmentally-responsible, electricity.
Joint Center for Energy Storage Research	To create game-changing, next-generation battery technologies that will transform transportation and the electricity grid the way lithium-ion batteries transformed personal electronics.

[1] https://www.epri.com/#/pages/sa/epri_energy_storage_integration_council_(esic)

(JCESR) – Department of Energy (USA)[2]	
Energy Storage Association (ESA)[3]	To promote the adoption of competitive and reliable energy storage systems for electric service.
US Department of Energy (USA)[4]	To facilitate development, adoption, and deployment of energy storage devices and systems that can meet future electric grid and consumer needs.
National Renewable Energy Laboratory NREL (USA)[5]	To advance the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.
Joint Center for Energy Storage Research (USA)[6]	To overcome critical scientific and technical barriers and create transformative battery technology for transportation and the electric grid. JCESR's research focuses exclusively on the development of next-generation, beyond-lithium-ion batteries.
Research Field Energy - Helmholtz Association (DE)[7]	To develop solutions to secure an economically, ecologically and socially sustainable supply of energy by replacing fossil and nuclear fuels with sustainable climate-neutral energy sources.
Program Storage and Cross-linked Infrastructures (DE)[8]	To develop economically efficient energy storage systems and to design and link important infrastructures for energy transmission and distribution.
Energy Conservation and Energy Storage (IEA-TCP) [9]	To facilitate integral research, development, implementation and integration of energy-storage technologies to optimise the energy efficiency of all kinds of energy system and to enable the increasing use of renewable energy instead of fossil fuels.
European Association for Energy Storage (EASE)[10]	EASE actively supports the deployment of energy storage as an indispensable instrument in order to improve the flexibility of and to deliver services to the energy system with respect to EU energy and climate policy.
European Energy Research Alliance (EERA)[11]	To accelerate the development and market uptake of new energy technologies by coordinating energy research

2 https://www.jcesr.org/
3 http://energystorage.org/
4 https://energy.gov/
5 https://www.nrel.gov/
6 https://www.jcesr.org/
7 https://www.helmholtz.de/en/research/energy/
8 https://www.sci.kit.edu/
9 https://iea-eces.org/
10 http://ease-storage.eu/
11 https://www.eera-set.eu/

Tesla (USA)[12]	To accelerate the world's transition to sustainable energy through increasingly affordable electric vehicles and renewable energy generation and storage.
Tiankan[13]	To design, develop and to produce game-changing new technology that empowers the next generations with a smart way to manage power & energy.
India Energy Storage Alliance[14]	To make the energy sector in India more competitive and efficient by creating awareness among various stakeholders in the industry and by promoting information exchange with the end users.
China Energy Storage Alliance[15]	We believe that energy storage is the key to China's transition to a cleaner, more resilient economy.
The Electricity Storage Network (UK)[16]	Electricity storage is essential to the delivery of a secure, low carbon and low cost electricity system.
Green Energy Storage (IT)[17]	We develop solutions for a sustainable world, where energy is available, renewable, safe and affordable for everyone.
AKU-BAT CZ (Czech Republic)[18]	The goal of AKU-BAT CZ is to promote favorable conditions for the development of the utilization of electric power stored in batteries.

The mission statements mentioned above are very different depending on the organization developing the mission, i.e. national departments of energy are rather political and thus general described, while private companies are aimed at consumer, etc. For this study we selected the missions of nine associations, where we added additional content details and further instruments concerning governance and management (see Annex 5.1).

3.2 Overview on recent Roadmaps on Energy Storage

A review on energy storage roadmaps was done and Table 3.2 summarizes energy storage roadmaps and strategic papers published since 2011. In total 23 papers were reviewed and major recommendations are summarized below (Annex 5.2). Only seven of them covered all energy storage technologies and six focused on the applications without referring to specific technologies.

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[12] https://www.tesla.com/
[13] http://www.tiankangbattery.com/mission
[14] http://indiaesa.info/about-iesa
[15] http://en.cnesa.org/
[16] http://www.electricitystorage.co.uk/
[17] www.greenenergystorage.eu/en/mission/
[18] https://www.aku-bat.cz/

Table 2.2: Recent Roadmaps on Energy Storage used for Studies

Nr.	Institution	Year	Title
1	EERA/EASE	2017	Joint EASE/EERA recommendations for a European Energy Storage Technology Development Roadmap – 2017 Update
2	Roland Berger (DE)	2017	Business Models in Energy Storage
3	Standards Australia (AU)	2017	A Roadmap for Energy Storage Standards
4	Clean Energy Council (AU)	2017	Charging Forward: Policy and regulatory reforms to unlock the potential of Energy Storage in Australia
5	World Energy Council	2016	World Energy Resources: E-storage: Shifting from cost to value - Wind and solar applications
6	NY Battery and Energy Storage Technology Consortium (USA)	2016	Energy Storage Roadmap for New Yorks´s Electric Grid
7	Agora Energiewende (DE)	2015	The European Power System in 2030: Flexibility Challenges and Integration Benefits
8	IRENA	2015	Renewables and Electricity Storage – A Technology Roadmap for REmap 2030
9	TNO (NL)	2015	Towards a future proof energy system – Flexibility and value
10	DNV (NL)	2015	Energy Storage NL 2030 – System Integration and the role of energy storage
11	Agora Energiewende (DE)	2014	Electricity Storage in the German Energy Transition
12	International Energy Agency	2014	Technology Roadmap Energy Storage
13	California ISO (USA)	2014	Advancing and Maximizing the Value of Energy Storage Technology – A California Roadmap
14	Ecofys (DE)	2014	Flexibility Options in Electricity Systems
15	DTU (DK)	2013	International Energy Report 2013 – Energy Storage Options for future sustainable Energy Systems
16	SBC Energy Institute	2013	Energy Storage
17	Fraunhofer ISI (DE)	2013	Technology Roadmap for Energy Storage for Electric Mobility 2030

18	USDRIVE (USA)	2013	Electrochemical Energy Storage Technical Team Roadmap
19	Centre for Low Carbon Futures (UK)	2012	Pathways for Energy Storage in the UK
20	NASA (USA)	2012	Space Power and Energy Storage Roadmap
21	California Energy Commission (USA)	2011	2020 Strategic Analysis of Energy Storage in California
22	IEC	2011	White Paper – Electrical Energy Storage
23	Boston Consulting Group	2011	Revisiting Energy Storage – There is a business case

3.3 Recommendations from Roadmaps

The main recommendations of the roadmaps listed in Table 3.2 can be classified in the following main categories:

- Stimulate and support markets
- Harmonize regulation
- Setting standards
- Preserve environment and safety

To stimulate and support markets it is recommended to establish clarity on the rules under which energy storage can access the market and that the procurement of energy storage and energy storage services is market based. These rules must ensure that energy storage receives equal access to flexibility markets. Furthermore, it is favoured to introduce incentives rather than more regulations. Examples for incentives could be to support investments in research and development for early stage energy storage technologies including technology breakthroughs and to support targeted demonstration projects for more mature, but not yet widely deployed, energy storage technologies to document system performance and safety ratings.

To harmonize regulation two major recommendations can be found. Firstly, regulatory barriers should be removed. These are for example barriers to demonstration projects, barriers in the legislation and market model or the elimination of double charging. Secondly, regulation should be introduced to ease energy storage deployment. This could be for example to establish policy support and an enabling regulatory framework to facilitate further commercial deployment of storage technologies. Another specific recommendation is to support future sector coupling a regulatory setting should be developed to favour the effective coupling of the power, heat and gas infrastructures.

Setting standards at least on the European level is defined as a key recommendation to accelerate energy storage deployment. A key aspect is to establish a definition of energy storage in the EU regulatory framework and to establish a comprehensive set of international standards in a manner that allows for incremental revisions as energy storage technologies mature. Future standards should support the roll-out of energy storage and should focus on the installation of systems, product safety and performance standards. To ease seeting up standards alignment and stronger engagement with the International Electrotechnical Commission (IEC) committee structures is recommended to leverage existing knowledge bases and accelerate numbers of compliant products.

To preserve environment and safety is an important aspect in all energy storage devices. Therefore, recycling rules and guidelines should be developed by incorporating industry and other relevant stakeholders. Especially for batteries an approach towards the reuse, recycling or disposal of batteries at the end of their useful life should be developed. For battery installations safety regulations should require that all installations must be performed by a qualified installer.

A detailed summary of all recommendations is given in Annex 5.3.

3.4 Examples of mission oriented institutions

3.4.1 Helmholtz Association, Germany

One example of a mission oriented research funding is the German Helmholtz Association (www.helmholtz.de), which is described in detail in the following.

For the “programme-oriented funding”, research activities performed by the Helmholtz Centres are divided up into research fields and programmes. Still, there is an adequate scope for taking up new research approaches and ideas which are not considered in original forward planning. The research fields and programmes get their shape and structure from a process of inter-centre competition and networking, are externally evaluated and receive funding within the scope of a reliable medium-term framework.

The program-orientated funding is based on a two-step system: the first step is a scientific evaluation of the centers and the existing programs at the level of the individual centers. The second step is a strategic evaluation of the programs planned for the future at the level of the areas of research, see Figure 3.1.

The scientific evaluation is focused on scientific quality. The results serve to provide a review of the performance of both the Helmholtz Center and the individual, usually cross-center programs. Both aspects are equally important. In the programmes, the insights and findings are combined and system solutions are developed.

The focus of the strategic evaluation is on the programme proposals prepared for the coming funding period in terms of the research policy objectives: To what extent do they address the challenges, formulate objectives to solve these challenges, and indicate ways to achieve these objectives? How do the centers combine their expertise and incorporate the recommendations of the scientific evaluation? And in what way does a program contribute towards implementing the strategy of the area of research?

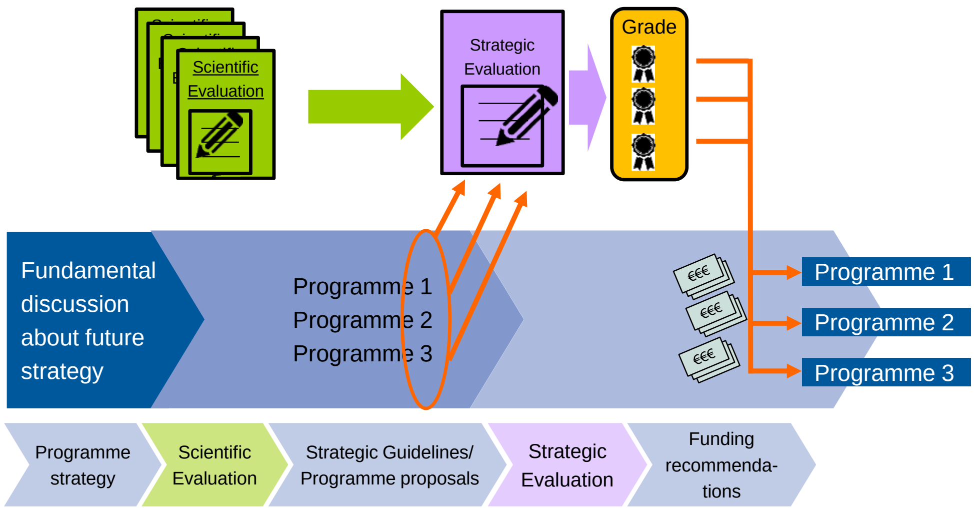

Figure 3.1: Helmholtz Evaluation and mission oriented R&D approach

The Helmholtz-Gemeinschaft is a registered association. Its members are 18 Research Centres, which are legally independent bodies. The activities of the Helmholtz Association are governed by its statutes. A full-time President heads the Helmholtz Association. The President is responsible for implementing the programme-oriented funding system. The President works with the Helmholtz Centres to develop the association's general strategy and represents the association internally and externally.

The institutions associated within the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren pursue the long-term research goals of the state and society, including basic research, in scientific autonomy.

The reports provided by international and independent experts form the basis for the Helmholtz Senate's recommendation on the extent to which the federal government and the federal states should fund the research programs and how the funding should be apportioned. Furthermore, recommendations also emerge as to how the programs and areas of research can be further developed.

The central decision-making bodies at the Helmholtz Association are the Assembly of Members, made up of internal members of the association, and the Senate, made up of external members. The members of the Assembly of Members are the directors of the Helmholtz Centres, the members of the Senate are representatives of Federal and Länder government, as well as representatives of science and research, business and industry, and other research organisations. The Senate commissions the evaluation of research programmes by independent, internationally-acknowledged experts and receives their review reports. These evaluations serve as a basis for the funding recommendations which the Senate makes to the association's financial sponsors i.e. Federal and Länder government on how much support funding the individual research programmes and core topic areas will receive. A Senate Commission prepares all Senate resolutions on the subject of "Evaluation and Programme-oriented Funding".

The Senate which is made up of external members performs the important role within the Helmholtz Association of making recommendations to the financial sponsors on thematic priorities and funding for research programmes. The Senate reaches these recommendations by first discussing the structure and strategies of the research fields within the scope of the relevant research policy requirements. It then commissions the research programme evaluations by independent, internationally-distinguished experts. Finally, the Senate discusses their review reports before adopting funding recommendations for the financial sponsors. The Senate convenes at least once a year.

The Senate established a Senate Commission which prepares its deliberations on the results of the programme evaluations. The Senate Commission is made up of permanent as well as - depending on the research field under discussion - alternating members.

3.4.2 Austrian Institute of Technology, Austria

Austrian Institute of Technology (AIT, www.ait.ac.at) sees its position as a key player in the Austrian and European innovation system by performing applied research for and enabling the market exploitation of innovative infrastructure related solutions. The functionality of “bridging the gap" between research and technology commercialisation is a key aspect of developing new technologies and enabling an economic boom.

Unlike universities that are focusing on basic research and addressing short-term exploitation, AIT covers the entire spectrum from taking up emerging technologies, first proof of concepts, and applied research to transferring these emerging technologies into specific applications up to demonstrators and prototyping.

The Strategic Research Advisory Board (SRAB) is a panel advising the AIT Supervisory Board. Its main responsibilities include providing comments, statements and recommendations concerning AIT’s strategic orientation and its 4-year research programme as well as formulating recommendations to the Supervisory Board.

Moreover, it provides advice and guidance to the Supervisory Board on issues connected with AIT's research strategy. Upon request by the Supervisory Board, the SRAB reviews questions of general strategic nature and helps set the course for AIT in science and technology policy issues.

The Strategic Research Advisory Board consists of five members of international esteem in the science and research arena. The members are appointed for the same term as the Supervisory Board members (a maximum of two terms).

3.5 Expert Interviews

Nowadays the expert interview is considered as a method of qualitative empirical research designed to explore expert knowledge. In this study the experts were selected to have a good mixture of active scientists working in the R&D of energy storage, of directors that are responsible for research institutions in the field of energy and energy storage and of managers that work for associations in energy storage or that are used to working in institutions with mission oriented R&D programs in energy. Nearly all have more than 10 years hands-on experience in the field of energy or energy storage (see Annex 5.4).

The questionnaire was developed to gain an accurate view on mission oriented research in the field of energy storage (e.g. challenges, technological developments and system integration, management and monitoring, enablers and barriers, involvement of end users etc). In addition the experts were asked to formulate a specific mission in the field of energy storage.

The main results of the interviews are summarized below. In addition, a detailed analysis of all interviews is given in Annex 5.5.

<u>Energy storage</u> (challenges, technological developments and system integration)

The challenges on energy storage can be sorted in three categories. Firstly, general challenges without time frame, secondly present challenges and thirdly challenges in 5 years. According to the feedback major challenges include, improving cost performance ratio of energy storage, establishing cell and battery manufacturing in Europe, establishing regulations to foster energy storage development and applications and setting up recycling facilities.

There is a clear tendency that at present Li-ion batteries are considered most important technology and it is common understanding that Li-ion batteries are the work horse for energy storage for the next years. The measures that are needed to speed up the integration of energy storage are closely related to the main challenges. Most often mentioned measures are changing the regulatory framework, decreasing levelised costs of storage, improving material properties and new materials and battery production.

<u>Mission oriented research</u> (benefits, management and monitoring)

According to the experts, the advantages of a mission oriented research in the energy sector are following:

1. Systemic: no technology can be analysed in isolation, but rather as the resulting impact it has on the whole energy system. It encompasses a wide range of different technologies very contrasted in nature, level of complexity and level of maturity.
2. Multi-sectorial: energy cuts across housing, transportation, industry, and power sector.
3. Multidisciplinary: as the transition involves changing policies, market design, regulatory frameworks and people consumption behaviours and patterns.
4. Societal: as it will profoundly affect the relationship of every citizen to the energy (e.g. the prosumer) and will require a profound transformation of behaviours and lifestyles.
5. Global and highly political: as energy underpins social and economic development.

For monitoring a group of different stakeholders is the most common proposal and as key performance indicators the levelised cost of energy storage and the installed amount is recommended. It is essential that KPI’s are clearly defined that can be computed or evaluated and are directly reflecting part or all of the end objective of the mission. As a mission by definition supposes a rather long timeframe, KPI’s should allow to track intermediate progress.

There is no common scheme proposed to manage different stakeholders in energy storage but it is mentioned twice that new alliances seem important to improve communication between stakeholders.

The role of bigger firms in influencing the business ecosystem appeared to be critical. It seems to be numerous examples where industrial interests are favoured vs. the general public interest. It is recommended that for key strategic stakes such as Energy Storage, specific instruments and initiatives should be developed that clearly unite, in a transparent and open way, assets from across sectors and member states to create a true industrial critical mass and leadership in Europe.

Mission proposal

Most of the missions proposed by the experts are rather general emphasizing new regulatory frameworks and business models that enable energy storage technologies penetrate the market. It is also mentioned that an energy storage mission should face two main issues: decrease the cost of energy storage systems and promote the deployment of technologies.

Post Li-ion batteries in terms of more energy density, more power density, more sustainability and more safety is pointed out as main mission for electromobility by 2035. For instance, sodium-sulphur (Na-S) batteries with a minimum 85% of thermodynamically efficiency.

It is recommended to treat energy storage as a true pan European issue. The European Energy System should be considered and treated as an integrated energy market. For instance, establish (smart) grids that are capable of integrating decentralized “prosumers”.

4. Proposal on Energy Storage Missions

Summary

Based on study of roadmaps, the different missions and the interviews in this chapter we propose each one transformer and one accelerator mission. For both, the transformer and the accelerator mission a governance, management and monitoring is described individually.

Our proposed Transformer Mission is “**Develop an interconnected, carbon-neutral and reliable European Energy System by 2030**“.
The impact: A reliable, secure, economically and ecologically system which respects the geographical of all European countries aiming at carbon emission neutrality. A larger geopolitical independence from non-EU countries.

Our proposed Accelerator Mission is “**Develop more powerful and clean European Post-Li-Ion batteries for electromobility available on the market by 2030**”.
The impact: Accelerated development of a European local competitive battery manufacturing industry for electromobility. Thus making Europe more resilient against external factors affecting the foreign battery supply chain and making electromobility more affordable to the citizens. In addition, decreasing the environmental impact by reducing emissions.

Recommendations

Mission development should involve all relevant stakeholders and missions need a roadmap with objectives and milestones.

Based on study of roadmaps, the different missions and the interviews in this chapter we propose each one transformer and one accelerator mission. For both, the transformer and the accelerator mission a governance, management and monitoring is described individually.

4.1 Missions

What is a mission? A mission aligned along on opportunities of the solving societal challenges connected to the implementation of the energy transition with special focus on the role of energy storage. Thereby the proposed missions are narrowly defined package of measures and activities that can deliver a verifiable result on a planned timescale that represents clear progress against the societal challenge. Thus each mission aims to achieve a specific result and is expressed in a quantitative target, which is easily measurable, also for citizens and policy makers. Especially in terms of achieving the energy transition a change of paradigm is necessary, which needs technical breakthroughs on large-scale.

In the frame of the study two kind of mission are proposed: an accelerator mission and a transformer mission.

The accelerator missions focus on concrete solutions, identified from the outset but flexible and adaptable. The focus on the development and deployment of key innovations, covering the entire research and innovation chain in a re-iterative manner.

However, the transformer mission is to *transform* an entire economic or socio-technical system in a set direction. Transformer missions address rather complex and systemic challenges, as paradigm change, which needs measures rather on a broader scope of sectors, policies and actors. In this manner the transformer mission also includes not only the technological, but also regulatory as well as societal measures and investments.

4.1.1 Transformer Mission, Targets, Milestones and Impact

Our proposed Transformer Mission is "**Develop an interconnected, carbon-neutral and reliable Pan-European Energy System by 2030"**.

The current implementation of the "Energiewende" as adopted by the German Federal Government already shows exemplarily for Europe that, for its success, increasingly systemic aspects have to be considered. The Pan-European energy system consists of a range of components and stakeholders like producers, conversion systems, storage systems, transport systems, consumers, and multimodal forms of energy (e.g. electricity, gas, heat, fuels).

Implementation of the necessary European energy turn in 2050 needs to be able to answer the question of how can the energy system be redesigned according to a carbon neutral system being based on renewable sources on a faster time scale. In this light, the European geography and its respective yield of renewable energy have to be considered in order to form a Pan-European system.

The specifically systemic approach of this mission addresses the interaction of these individual components in a system from both the technical and the economic points of view. In current and future scenarios, the above individual components are coupled physically and by information technologies as well as via the actors and their behaviours.

Energy systems design and operation are of high importance in order to develop holistic approaches that merge the individual parts of the systems. Additionally, the interfaces of the system have to be considered:

- Added value chains for various multimodal forms of energy: generation, conversion, storage, transport, and use;
- Timelines for the generation of scenarios: today, tomorrow (until 2035 and 2050), and on the longer term (after 2050);
- Interactions with the "environment": society, economy, physical environment, materials, and technologies development.

The systemic and, hence, trans-technological approaches pursued consist of the analysis and optimisation of selected added value chains and sustainability paths that also consider technologies studied throughout Europe with real data sets. Long-term analysis of integrated systems additionally requires further information on its elements, such as on energy efficiency of infrastructures. Technological options will be related to the manifold views of our society ("sociotechnical arrangements"). From this, auspicious innovation paths will be derived and investigated.

Interactions within the energy system are represented by models, simulated in a variety of scenarios, and verified by real data sets. Modelling from the component level to the process level to the energy system level will lead to in-depth knowledge and applicable tools.

The following targets are proposed on the way to the mission:

- Develop and agree on interconnected Pan-European energy system development plan
- Support energy technology R&D on energy storage, sector coupling and system integration
- Decrease greenhouse gas emissions in the energy sector
- Raise awareness and understanding in society for the future interconnected energy grid

Closely related to these targets are the following milestones:

- Agree on an interconnected Pan-European energy system development plan by 2020
- Achieve a rate of 25 % of renewables in EU energy generation by 2025 and 50 % by 2030
- Achieve a rate of 30 % of electricity generation that is coupled to other sectors (heat, mobility, fuels) by 2030
- Reduce greenhouse gas emissions in the energy sector in the EU by at least 60 % by 2030 (from 1990 levels)

We assume that due to the low cost of renewables and fast decreasing cost of energy storage the present target of at least 27% of renewables in EU energy generation by 2030[19] can be increased to 50% in 2030. By consequently supporting and adding renewable energy sources and sector coupling we further assume that the present target of 40% greenhouse gas emission reduction by 2030[21] can be increased to about 60%.

Management, control, and optimisation of the entire system as well as of individual sub-systems will decisively determine stability and availability (robustness & resilience), economic efficiency, and ecology. For this purpose, new grid structures covering various forms of energy will be developed. Both the European and global contexts will be considered and the relationship of centralised and decentralised components will be resolved. In this context, the reorganisation of the energy markets will also be addressed.

The integration of the energy system in a sustainable circular economy is an important subset of the larger challenge: the dynamic management of resources including energy, materials, and the natural environment. All these natural and industrially processed resources are connected into a multidimensional system of networks, storage, and conversion processes. With respect to materials, the basic industrial sectors metallurgy, cement, and petro-chemistry, which use highly complex processing, storage, and transport networks, are of particular importance. The final goal, a viable, stable, and resource efficient energy system, cannot be described by singular objectives, such as low-energy consumption, grid stability or low resource intensity, since all of these goals compete with each other and, ultimately, are connected via the systems entropy.

The transformer targets can be checked with clear key performance indicators (KPIs) and have main enablers and barriers as summarized below.

Transformer-Target 1 ´Develop and agree on interconnected Pan-European energy system development plan`

- KPI: Adopt European energy system development plan by 2025.
- Enabler: Further develop existing structures like the ENTSOE network and the Energy Union.
- Barrier: Different national energy policies.

Transformer-Target 2 ´ Support energy technology R&D on energy storage, sector coupling and system integration`

- KPI: Provide by sector coupling and energy storage more than 30% peak power and full daily flexibility by 2030.

[19] EU, A policy framework for climate and energy in the period from 2020 to 2030, Brussels, 22.1.2014

- Enabler: Intensify R&D on sector coupling and energy storage. Introduce a clear definition of energy storage.
- Barrier: No clear standards and regulations for system integration of new technology. No clear definition of interfaces of different energy carriers.

Transformer-Target 3 ´Decrease greenhouse gas emissions in the energy sector`

- KPI: Achieve reduction of more than 40% of CO_2 emissions in the energy sector by 2030
- Enabler: More electricity usage and clean energy generation by renewables. Clean fuel generation with power to x technologies or fuel cells and hydrogen.
- Barrier: Low cost of CO_2 certificates and low cost of fossil fuels.

Transformer Target 4 ´Raise awareness and understanding in society for the future interconnected energy grid`

- KPI: A large majority of European citizens and all governments support the interconnected European energy system development plan by 2030.
- Enabler: EU fostering market policies.
- Barrier: European adverse market policies.

Impact
A reliable, secure, economically and ecologically system which respects the geographical of all European countries aiming at carbon emission neutrality. A larger geopolitical independence from non-EU countries.

4.1.2 Accelerator Mission, Targets, Milestones and Impact

Our proposed Accelerator Mission is "**Develop more powerful and clean European batteries for electromobility[20] available on the market by 2030**".

As proposed by several of our interview partners for this accelerator mission we rely on "Implementation Plan of the integrated SET-Plan – Action 7"[21]

Current traction batteries are to a large extent based on lithium-ion (Li-ion) chemistry which is expected to remain the technology of choice for still many years but their maximum energy density will be limited to approximately 350- 400 Wh/kg. Higher performance needs the gradual introduction of new generation batteries (post Li-ion) based on the development of a series of novel Advanced Materials.

[20] *electromobility covering a wide range of applications: passenger cars, buses, trains, heavy duty, forklifts, maritime, etc.
[21] https://setis.ec.europa.eu/sites/default/files/set_plan_batteries_implementation_plan.pdf

With the focus on Post Li-ion batteries, the technologies offering the best chances of success are Na-Ion, Li-S and metal (Li or Fe or Zn)- air, but depending on the system, performance issues including poor cycle life, low power, low efficiencies and limited safety need to be addressed and solutions brought first from today TRL levels 3 to successful prototypes in TRL level 7. To achieve this the main general objectives towards the mission are:

- Improve energy density of Post Li-ion batteries
- Develop powerful and reliable battery systems
- Reduce battery system life cycle cost

Within the temporary working group 7 of the "Implementation Plan of the integrated SET-Plan – Action 7", the experts assume that by 2030 a TRL 7 and by 2035 a TRL 9 can be achieved for Post Li-ion batteries with a performance data of at least 400 Wh/kg, 750 Wh/l and 2000 cycles at 80% DoD with a cost of less than 100 €/kWh[22]. With a mission-oriented approach it seems very likely that this development can be accelerated by approximately five years. Instead of the proposed budget of 55 Mio. € an estimated budget of about 100 Mio. € is rather appropriate.

To achieve the mission, the following milestones are proposed:

- Achieve TRL 7 for post-Li battery for electromoblity at cell level with at least 400 Wh/kg, 750 Wh/l and 2000 cycles at 80% DoD with a cost of less than 100 €/kWh by 2025
- Achieve TRL 9 for post-Li battery for electromoblity at cell level with at least 400 Wh/kg, 750 Wh/l and 2000 cycles at 80% DoD with a cost of less than 100 €/kWh by 2030

Pushing technology development from TRL 7 to TRL 9 involves for example reproducible material development in large quantities, setting up a large scale manufacturing route including recycling and ensuring all safety and performance standards for the complete life cycle. Therefore, we assume that this could be not faster than within 5 years.

Methodologies for large-scale new materials manufacturing processes, environmentally friendly, need to be developed in order to reduce the battery system cost. Taking into account the rather fundamental character of most technical drawbacks of post-Li ion systems, a good understanding of the cell reactions (cathode, anode...) is required. The cell development needs to be accompanied by appropriated sensing, monitoring, thermal management and safety systems.

The accelerator targets can be checked with clear key performance indicators (KPIs) and have main enablers and barriers as summarized below.

Accelerator Target 1 ´Improve energy density of Post Li-ion batteries`

- KPI: Achieve energy density of at least 400 Wh/kg by 2030 at cell level.
- Enabler: Material- and battery producing pilot plants on medium scale level up to 10 kg.
- Barrier: Uncertain pay back period of investment in battery manufacturing.

Accelerator Target 2 ´Develop powerful and reliable battery systems`

- KPI: Achieve power density of at least 700 W/kg with more than 2000 cycles by 2030.
- Enabler: Material- and battery producing pilot plants on medium scale level up to 10 kg.
- Barrier: Uncertain payback period of investment in battery manufacturing.

Accelerator Target 3 ´Reduce battery system life cycle cost`

- KPI: Develop batteries for e-mobility with ~ 100 €/kWh by 2030 at cell level.
- Enabler: Support large scale manufacturing of post Li-ion plants.
- Barrier: Uncertainty of development of different types of post Li-ion batteries.

Impact

The main impact is the accelerated development of a European local competitive battery manufacturing industry for electromobility. Thus making Europe more resilient against external factors affecting the foreign battery supply chain and making e-mobility more affordable to the citizens.

In addition, decreasing the environmental impact by reducing emissions in general and carbon in particular. The potential environmental impacts of a large scale market penetration of electric vehicles in the EU, focusing on passenger cars and light commercial vehicles have been investigated.[22] For instance, the main impacts of different scenarios using EV are estimated as follows:

- Total transport fuel consumption decreases significantly, especially in long term, i.e. petrol and diesel used in passenger cars (12-20% by 2030) and consequently results in low exhaust CO_2 emissions (15%-27% by 2030) from passenger cars.

[22] https://www.ecologic.eu/sites/files/publication/2013/4058_SummaryreportHvESD.pdf

- The increase in overall electricity demand is relatively small (about 5% by 2030).
- Investments in charging infrastructure are significant and amount roughly 30 to 150 billion Euro in total in the EU till 2030.
- The net impact on tax revenues is likely to be negative (18-38 billion Euro by 2030).

4.1.3 Governance & Management

For the governance and management of both transformer and accelerator mission it is important to establish long lasting expert consortia representing all groups, e.g. citizens, firms or city councils. These consortia should be independent of economic and personal interests. Still experts from industry and research must certainly must provide the expertise and propose the needed knowledge about new breakthrough technologies and developments.

Transformer Governance & Management

The Dialogue Platform is a high level strategic discussion and political end-user consortium, exchanging about future energy goals and political frame conditions of the European countries as well as present technologies. Members of the dialogue platform represent citizens, consumers and companies (MEMS as well as big firms rather as users than producers), who have major interest in the success of the mission. The dialogue platform is advised by international relevant stakeholders, reporting on the present national political challenges and promising R&I developments.

The Management Board is a high level expert consortium. This could be members from research and industry as well as government, ministries, research institutions and industry and of existing European exchange platforms e.g. EASE and EERA as well as market and consumer experts. In order to keep the collaborations and consortia efficient, the consortia should be not too large. The management board develops transformer mission drafts based on promising and revolutionary developments in fundamental and applied science, which are "evaluated" or rather reviewed in the dialogue platform. Those transformer missions selected to be relevant according to the end-user needs in the dialogue platform will be followed up by the EC for a European transformer missions. Other proposed mission drafts will be dropped or given back to the management board for review and further development in terms of end-user needs. This way these missions are defined rather independently of fundamental research, but include general overall transformer targets with respect to the end-user needs. Also within the dialogue platform ideas of transformer mission could be elaborated and given to the management board for expert evaluation.

Based on these transformer missions 5-year project programmes are developed in more focused target groups. For assuring a flexibility, the 5-

year research programmes should be evaluated by international experts after 3 years according to the set KPIs – as proposed in the interviews - and the two more promising projects keep funding for the last two years while dropping the other project. The evaluation could be done by members of the dialogue platform and management board. In that way the competitiveness can be increased but also synergies will be used. This management structure is illustrated in Figure 4.1.

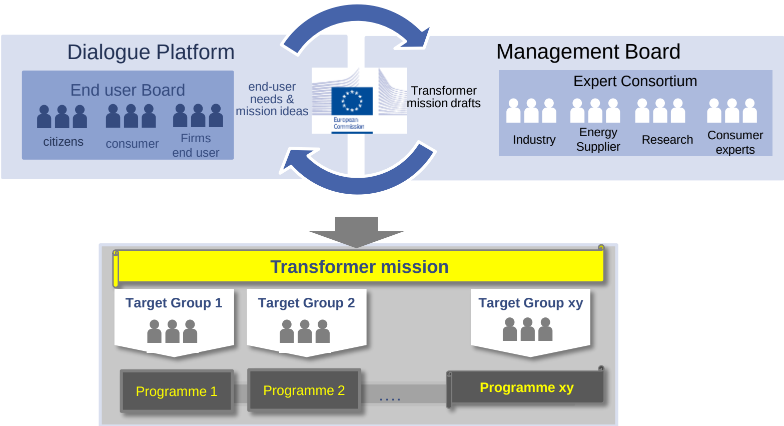

Figure 4.1: Governance structure of transformer mission

The challenge of mission oriented research and innovation on European level is to take into consideration the numerous fields of national perspectives, including national political developments, regulations and energy specific peculiarity of each European nation. In that manner for the end-user and the management boards on European level the selection of members providing a brought overview of research, regulations and political developments are essential for thoughtful management.

We propose to build up a core group of leading European research organization together with a selected members of the end-user board within the target so that a long lasting framework for research exchange is established between the leading research institutions in Europe. The involvement of the end-user board shall avoid, that the core group follows exclusively their interests. In that manner the strategy and research results of the different research organisations and different nations are brought together so that a common understanding of research and research goals is achieved across Europe while keeping the end-user in focus of the mission.

For the transformer mission a high level governance needs to be established including all relevant stakeholders, which are

- Member states representatives
- National agencies
- Industry
    - EU Original Equipment Manufacturer
    - EU Battery producer

    - EU Advanced material producer
    - SMEs
- Consumers and end-users
    - Citizens
    - City council as end-user of future technology
    - Companies as end-user of future technology
- Research institutions and universities
- Representatives of Networking platform, e.g. EERA, EASE
- Regulation experts.

It is essential to gather representatives from different disciplines to receive a reflected, holistic view on the research results.

New promising, developments, which e.g. are generated in the dialogue platform, can be taken into consideration in the periodical reviews evaluating the relevance in comparison to the existing targets. If they are evaluated to be relevant, they are included in the process by creating drafts for Accelerator Missions. These drafts are passed to working groups, see Figure 4.3, for evaluating its relevance and if applicable developing accelerator missions. This is especially important for recognizing e.g. promising post Lithium materials or storage technologies.

Accelerator Governance & Management

The governance and management of the accelerator mission will be rather traditional and project oriented. Still especially for the field of energy storage, which has been a very dynamic developing research field since the start of the energy transition, it is important to keep the balance between a target-oriented research aligned to the mission, the defined goals and the possibility of enabling flexibility for unforeseeable changes, e.g. price dumping of Li ion batteries from China.

For the accelerator mission a governance and management composed of experts including all relevant stakeholders, which are

- National agencies
- EU Industry
    - Original Equipment Manufacturer
    - Battery producer
    - Advanced material producer
    - SMEs
- EU Consumers
- EU Research institutions and universities
- Representatives of EU Networking platforms, e.g. EERA, EASE, EMIRI, EUROBAT, Recharge…
- EU Regulation experts.

Output targets should be demonstrated at cell level in a Consortium comprehending a European Battery Manufacturer and OEM in a 4-year research and innovation programme. Potential for upscaling and recyclability must be addressed in the development.

Based on interview results we propose to define certain amount of budget for research programme on high TRL that encourages domestic small businesses to engage in systems or technologies that have the potential for commersialisation. Each project should involve at least three of the above mentioned stakeholder groups, e.g. SMEs, researchers and consumer, in order to cover the whole value chain. The US Small Business Innovation Research (SBIR)[23] programme is a good example how to create competitive opportunities for small business. Through a competitive awards-based program, SBIR enables small businesses to explore their technological potential and provides the incentive to profit from its commercialization. By including qualified small businesses in the nation's R&D arena, high-tech innovation is stimulated and the United States gains entrepreneurial spirit as it meets its specific research and development needs.

4.2 Evaluation and Monitoring

Overall guidelines for monitoring are transparency and efficiency. It shall be obvious that transformer missions and accelerators missions are monitored on different levels and that they need different monitoring schemes. A proposal for the monitoring is given in Fig. 4.2.

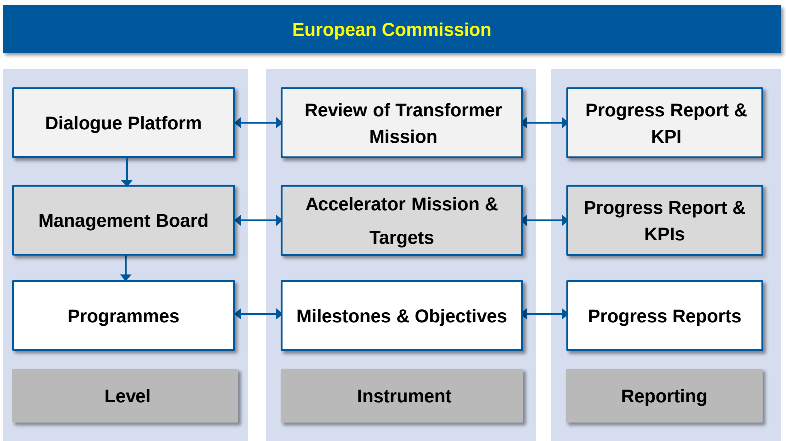

Figure 4.2: Monitoring of mission-oriented R&D program at different levels and with different instruments

Monitoring of transformer missions can be done efficiently by defining relevant key performance indicators and are to be addressed in the yearly progress report. This could be for example the number of different energy

[23] https://www.sbir.gov/about/about-sbir

storage applications. Members of the dialogue platform shall monitor the progress in adequate time spans. Usually, once or twice a year seems a reasonable number of meetings. Members of the dialogue platform also prepare a yearly report for the commission on the progress of the transformer missions. Based on the progress and a recommendation of the dialogue platform, the Commission decides on further general funding of the transformer missions.

Accelerator missions should be defined in more detail and should be combined with clear milestones and objectives along the well selected KPIs. As formulated in one of the interviews "*KPI's are clearly defined that can be computed or evaluated and are directly reflecting part or all of the end objective of the Mission. As a Mission by definition supposes a rather long timeframe, KPI's should allow to track intermediate progress.*"

Members of the management board shall monitor the progress continuously or at the time of the relevant milestones. They report yearly to the Commission and the Dialogue platform members. If milestones and objectives cannot be reached the funding needs to be adjusted.

All reporting on progress and milestones has to be done via an open access platform.

The exchange of knowledge on new technologies, business models etc. of the future energy systems should be fostered also mobility scheme on students/PhD, so that the next generation is highly qualified for the future energy system across Europe. Existing structures and research platforms and cooperation structures as set up by EERA could be used for these exchange programs. Thus the future generation is equipped with the necessary knowledge of the fast changing and developing field of energy storage. Furthermore, the exchange and transfer best practices of the various business cases of storage integration coming up across Europe are crucial for further increasing the share of renewables

Research organisations need to work together to gather the high level research expertise of all European countries and use successful research results on national level; each institutions representing its discipline and their field of expertise.

4.2.1 Transformer: Evaluation and Monitoring

Each transformer mission receives a certain amount of budget which is fixed by the management board decision periodically (5-years term) via the strategic evaluation. The strategic programmes of each target groups are jointly prepared and proposed by the leading European research organisation and elaborated in workshops.

The budget should be divided up into resources for infrastructures, application oriented research (TRL >5) and knowledge transfer/cooperation activities, e.g. mobility scheme. A certain amount of budget should be reserved for new and innovative, not foreseeable technologies/innovations. The infrastructure projects could be prototype living labs build up at universities and research organisations for research and teaching, e.g. Energy Lab 2.0[24], but also decentral, regional microgrid models should be supported, e.g. Regenkibo[25], where innovative technologies and market models are investigated. For these kind of projects apart the integration of SMEs could be obligatory so that the European industry is included and fostered. In that manner – as proposed in the interviews - a large living lab (model city), in which stationary and mobile storage devices will be integrated, tested and optimised in a real-life renewable ecosystem on European level could be realized. These projects on small and medium scale and thus proof of concept models can initiate changes on larger scale are achievable.

The funding system needs to take into account that research funding resources needs to be distributed independently of this core-group/consortium. Concerning an equal and fair funding across large and small research organisations should be addressed. Otherwise the danger occurs that only the large research institutions are strengthened and small institutions are not included.

As done before the financing should be combined with a certain amount of national funding as it is common up to rely on existing results. In that manner the national and European research and development efforts go hand-in-hand. In the field of energy transition also the jointly financing and use of infrastructures (combined with national funding) and pilot plant and technology solutions combined with best practice business models would foster the implementation of innovative technologies.

4.2.2 Accelerator: Evaluation and Monitoring

The Governance and Management of the accelerator mission are rather project oriented and based on flat hierarchies. Drafts and ideas for accelerator mission are developed in working groups and evaluated by the European Commission together with an international advisory board, which selects the most relevant accelerator missions. As described above, the accelerator mission alternatively can be initiated by the dialogue platform, further developed and evaluated according to relevance elaborated in the management board. Once the accelerator mission is defined, the target group develops accelerator targets which define a concrete time frame including milestones and key performance indicators. Project proposals within the accelerator mission directly address these targets and are

[24] https://www.elab2.kit.edu/

[25] http://forschung-stromnetze.info/en/projects/regional-power-consumption-helps-avoid-grid-expansion/

evaluated to the given key performance indicators and milestones, Figure 4.3.

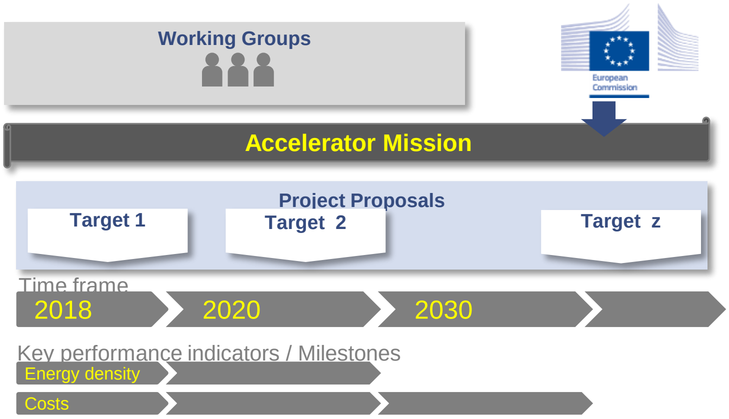

Figure 4.3: Monitoring of accelerator missions

Within the targets several research project programmes dealing with different materials systems for e.g. 5 years. After 3 years the three projects are evaluated according to the key performance indicators and the two most promising systems are selected to keep on funding, while dropping the other projects. The left budget can be invested in new ideas and systems. In that way the competitiveness can be increased but also synergies would be used.

Flexibility

Dependency and development on the markets outside of Europe, e.g. China as happened with Lithium batteries or PV industry. The instruments for reporting stay similar to present reporting tools and periods. Yearly reporting of present status, summary of results and reporting of KPIs (publications, third party funding, dissemination activities, and measurable milestones). KPIs need to be specifically defined to use them for evaluation.

Also, results and consortia within the clusters should be gathered in platforms in a long-term view, as it is practiced by e.g. the BRIDGE-initiative (https://www.h2020-bridge.eu/) to bring results and best practices together and learn from each other’s experiences.

KPI’s are clearly defined that can be computed or evaluated and are directly reflecting part or all of the end objective of the Mission. As a Mission by definition supposes a rather long timeframe, KPI’s should allow to track intermediate progress.

5. Annexes

1) Descriptions of missions in energy storage (see Table 3.1)
2) Copy of energy storage roadmaps (see Table 3.2)
3) Summary of recommendations from roadmaps (listed in Table 3.2)
4) Expert interviews
5) Analysis of expert interviews

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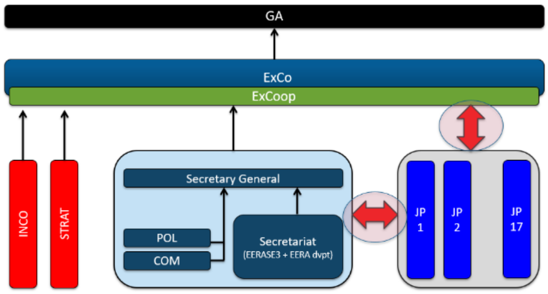
Annex 5.1: Descriptions of missions in energy storage

Program Storage and Cross-linked Infrastructures (DE)	
Mission	To develop economically efficient energy storage systems and to design and link important infrastructures for energy transmission and distribution.
Timeframe	5 Year Periods
Targets	Technology based
Governance	See chapter 3.4.1
Implementation	Lab scale, in selected areas large scale infrastructures close to industry level
Monitoring	Yearly report on content and Key Performance Indicators, which are presented at Helmholtz Senate
Evaluation	By external review board, Midterm evaluation after 3 years back
European Energy Research Alliance (EERA AISBL)	
Mission	To accelerate the development and market uptake of new energy technologies by coordinating energy research.
Timeframe	EERA was founded in 2008. **The EERA has evolved into a legal entity named "EERA AISBL"** since April 2014.
Targets	EERA aligns bottom-up activities of the scientific community, organised in Joint Programmes, with the directions set out by the Strategic Energy Technology Plan (SET-Plan), which aims to better align public and private, European and national R&I agendas.
Governance	It is governed respectively by the **General Assembly** composed of representatives of all the Members and by the **Executive Committee**. Everyone is entitled to speak in the **General Assembly** but only full Members have the right to vote. The General Assembly meets at least once a year and is the supreme governing body of the EERA, notably on the decisions concerning the approval of the budget, the membership fees, the annual report of activities, the determination of the Executive Committee, the change of the Internal Rules, etc. The **Executive Committee** is the main governing body of EERA. It provides guidance to the Alliance, takes the decisions on its functioning and approves new Joint Programmes. The Executive Committee is supported by the Personal Representatives and the EERA secretariat. The Personal Representatives meet prior to the Executive Committee meetings to prepare these. The secretariat serves as point of contact between the Executive Committee and the EERA Joint Programmes and provides support to the Executive Committee.

	
Monitoring	The Joint Programmes are at the core of EERA´s activities. Active in diverse areas, such as wind energy, bioenergy, smart grids, nuclear and energy storage, the Joint Programmes develop research activities based on shared priorities between research centres and universities. Through the Joint Programmes, EERA supports the Member States in their efforts to coordinate their long-term energy research activities by contributing to deliver faster on the European goals. Since 2010, 17 Joint Programmes have been launched. EERA works in close collaboration with industry and other stakeholders to define and align research and innovation priorities. Collaboration with industry is implemented through joint projects, both within the framework of the EERA Joint Programmes and bilaterally between single institutions and industry.
Evaluation	Periodic evaluation of the JP trhought the EERA Executive Committee (4 years).
Energy Storage Integration Council (ESIC) – EPRI (USA)	
Mission	To advance the integration of energy storage systems through open, technical collaboration: guided by the vision of universally accessible safe, secure, reliable, affordable, environmentally-responsible, electricity.
Timeframe	In 2013 the Energy Storage Program at EPRI, in collaboration with utilities, vendors, National labs, and industry experts created the Energy Storage Integration Council (ESIC)
Targets	ESIC collects and shares information on leading practices that support effective energy storage integration and develops and publishes a variety of guides. • The Grid Services and Analysis Working Group (WG1) determines the requirements of energy storage with respect to grid needs and value. It develops guidelines and definitions for evaluating energy storage system value and power system impacts. • The Testing and Characterization Working Group (WG2) characterizes and standardizes technical parameters of fully-integrated energy storage products with respect to utility requirements. It works to improve industry standards for energy storage by developing common metrics and establishing performance standards and test protocols.

	• The Grid Integration Working Group (WG3) provides practical guidance for implementing energy storage in the field.
Governance	ESIC is an open and active venue, executed via a combination of in-person meetings, webcasts, and teleconferences, for identifying key gaps and common approaches for the integration of energy storage across key technical topic areas. ESIC is organized in topic focused working groups that meet on a bi-monthly basis. Work product focused subgroups meet more frequently, typically every 1-2 weeks to make progress on more specific deliverables These three working groups are all coordinating to define common approaches to the development and use of safe, reliable, cost-effective energy storage. Cross-group coordination is facilitated by ESIC Working Group Chairs and EPRI technical staff.
Management & Monitoring	ESIC's working process: • Identify gaps in understanding of utility technical requirements for energy storage systems, along with current deployment concerns. • Define work products to address the gaps. These can include handbooks, guidelines, software, or others. • Task forces work collaboratively with ESIC to develop tools, guidelines, etc. These are published and distributed to provide common understanding among utilities, solution providers, and other stakeholders. They are updated as new information becomes available. 
Energy Conservation and Energy Storage (IEA-TCP)	
Mission	To facilitate integral research, development, implementation and integration of energy-storage technologies to optimise the energy efficiency of all kinds of energy system and to enable the increasing use of renewable energy instead of fossil fuels.
Timeframe	The IEA was founded in 1974 to help countries collectively respond to oil supply disruptions. One year later, the IEA Technology Collaboration Programmes were created.
Targets	Storage technologies are a central component in energy-efficient systems. Since energy storage is a cross-cutting issue, expert knowledge of many

	disciplines (energy supply and all end-use sectors, as well as distribution) must be taken into account. Depending on the form of energy which needs to be balanced and the required storage period, there are different types of energy storages such as • Thermal storage • Electrical energy storages • Material storage systems
Governance	ECES is one of 39 Technical Collaboration Programs (TCP's) within the International Energy Agency (IEA). The research projects are organized in annexes. The IEA is an autonomous body within the OECD framework. The Governing Board is the main decision-making body of the IEA, composed of energy ministers or their senior representatives from each member country. Through the IEA Ministerial meeting that takes place every two years, the IEA Secretariat develops ideas for existing or new work programmes, which are then discussed with member countries in various IEA committees and ultimately presented to the Governing Board for approval. In addition to the Governing Board, the IEA has several Standing Groups, Committees and Working Parties made up of member country government officials, which meet several times a year. In addition to the Governing Board, the IEA has several Standing Committees (also known as Standing Groups), made up of member country government officials, which meet several times a year. The Committee on Energy Research and Technology (CERT) is part of the IEA energy technology network. At the core of this network of senior energy technology experts are a number of IEA Technology Collaboration Programmes (TCPs). These enable governments, businesses, industries, international organisations and non-governmental organisations to share research on breakthrough technologies, to fill existing research gaps, build pilot plants and carry out deployment or demonstration programmes.
Management & Monitoring (IEA)	Every two years, ministers from member countries gather for the IEA Ministerial meeting. The high-level ministerial meeting sets broad strategic priorities for the IEA. Although ministers may instruct the IEA to focus on a specific issue, the direction they provide also comes through the discussions that ensue at these meetings. Through the IEA Ministerial, the Secretariat develops ideas for existing or new work programmes, which are then discussed with member countries in various IEA committees and ultimately presented to the Governing Board for approval.
Joint Center for Energy Storage Research (JCESR) – Department of Energy (USA)	
Mission	To create game-changing, next-generation battery technologies that will transform transportation and the electricity grid the way lithium-ion batteries transformed personal electronics.
Timeframe	The Center was established by the Department of Energy as an Energy Innovation Hub in 2012 and is led by Argonne National Laboratory.
Targets	JCESR intends to leave three legacies: • a library of fundamental science of the materials and phenomena of energy storage at atomic and molecular levels,

	• two prototypes, one for transportation and one for the grid, that when scaled to manufacturing are capable of meeting JCESR's aggressive performance and cost targets, and • a new paradigm for battery research and development that integrates discovery science, battery design, research prototyping, and manufacturing collaboration in a single highly interactive organization.
Governance	JCESR brings together high-powered scientists and engineers from ten universities, five national laboratories, and five industrial firms, and provides them with the tools and institutional backing needed to discover new materials, understand their basic science, accelerate technology development, and commercialize revolutionary energy storage technologies. The team's combined expertise spans the full innovation ecosystem – mission-driven basic research, innovative engineering, technology development, entrepreneurial experience, and commercialization. In addition, JCESR's industrial partners have the resources and market reach to swiftly commercialize revolutionary energy storage technologies. To supplement the 20 partner organizations, JCESR has created an affiliate program that brings together small and large businesses, non-profits, universities, and national laboratories to further promote public-private partnerships.
Management & Monitoring	As part of our strategy, we also continue to emphasize exploratory or "divergent" research on alternative approaches for prototypes. Experience with lithium ion and other battery concepts has shown that many excellent ideas fail, often because of competing side reactions that inevitably occur at electrochemical interfaces. JCESR intentionally maintains a strategic portfolio of alternative approaches that we can quickly move into the mainstream.
Energy Storage Association (ESA)	
Mission	to accelerate the widespread use of competitive and reliable energy storage systems in North America
Target	The Energy Storage Association is the leading national voice that advocates and advances the energy storage industry to realize its 35 GW by 2025 goal, resulting in a better world through a more resilient, efficient, sustainable, and affordable electricity grid.
Governance	**ESA builds strategic relationships with other leading organizations to help build a strong energy storage industry. Partners include state and regional associations; business, energy and legal organizations; universities, research and nonprofit entities; and more.**
Implementation	To achieve this mission, ESA will educate stakeholders, advocate for public policies, accelerate market growth, and deliver direct member value.
Management & Monitoring	Our Discussion Forums are the heart of our organization and some of the most meaningful ways for you and your company to derive value from membership. The Discussion Forums provide you with valuable educational and networking opportunities to advance your business goals. • Markets and Models Discussion Forum: Provide monthly webinars on various issues related to the development of markets structures topics that promote the inclusion of energy storage.

	• Technical Discussion Forum: Provide quarterly webinars on technical issues in energy storage including lessons learned from implementations. • Policy Discussion Forum: Provide monthly webinars on current policy and advocacy activities of the organization and their impact on members and the industry.
National Renewable Energy Laboratory NREL (USA)	
Mission	To advance the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.
Timeframe	In 2017, NREL celebrated 40 years of driving advanced energy research.
Targets	• Sustainable Transportation (Vehicle Technologies, Hydrogen, Biofuels) • Energy Productivity (Residential Buildings, Commercial Buildings) • Renewable Electricity (Solar, Wind, Water Power, Geothermal) • Systems Integration (Grid Integration, Distributed Energy Systems, Batteries and Thermal Storage, Energy Analysis)
Governance	The National Renewable Energy Laboratory is managed for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy by the Alliance for Sustainable Energy, LLC, a partnership between Battelle and MRIGlobal.
Implementation	Through partnerships and licensing of its intellectual property rights, NREL seeks to reduce private sector risk in early stage technologies, enable investment in the adoption of renewable energy and energy efficiency technologies, reduce U.S. reliance on foreign energy sources, reduce carbon emissions, and increase U.S. industrial competitiveness.
India Energy Storage Alliance	
Mission	To make the energy sector in India more competitive and efficient by creating awareness among various stakeholders in the industry and by promoting information exchange with the end users.
Timeframe	Launch: May 2012
Target	To make India a global leader in energy storage and microgrids, and a hub for manufacturing of these emerging technologies by 2020, by facilitating technology adoption
Governance	In order to further facilitate steady growth of the energy industry, the India Energy Storage Alliance has announced the formation of its Leadership Council (LC). Individual representatives from Leadership member companies constitute the Leadership Council and aim to lead different IESA working groups and drive IESA towards its priorities with a focus on policy. They will take on a lead role to create a platform for Indian and foreign companies to exchange and collaborate technology development, trade negotiations and investments. Presently, the council consists of five members representing five leading companies in this space. These leaders will work together on the overall policy and programme direction for India Energy Storage Alliance (IESA), developing the Indian Energy storage industry beyond individual company business.

The Electricity Storage Network (UK)	
Mission	Electricity storage is essential to the delivery of a secure, reliable and sustainable electricity network, strong enough to meet rising demand.
Timeframe	The Electricity Storage Network was established in 2008 as an informal group of manufacturers, developers, network operators and others interested in storage. Working closely with the Electricity Storage Association (ESA), a number of successful meetings and conferences were held, prior to the groups formal establishment at the beginning of 2010. We now have a leading position in bringing together all those interested in electricity storage in Government, the Regulatory bodies, industry and academia.
Target	To connect research, market and government with regular meetings, discussions and conferences.
Management & Monitoring	Representatives from The Electricity Storage Network attend discussion meetings at both the regional, national and international levels in order to present the case for electrical energy storage. Members will continue to be represented at national and international standards and regulation meetings and other industry groups with interests in electricity storage and continue to receive expert advice and timely information on current topics of relevance to electricity storage, especially on system services, regulatory reform and national and international initiatives, through our member only meetings and regular newsletters. The Electricity Storage Network holds an annual symposium each year bringing together experts from across industry, research, business and policy, providing their views on the deployment of electricity storage in the power system, from consumer and community level to the larger projects on major distribution and transmission connected site.

Annex 5.2 Copy of energy storage roadmaps

Link: https://gigamove.rz.rwth-aachen.de/d/id/sK73eKcwrRLcsm

Annex 5.3 Summary of recommendations from roadmaps

In the following the political and general recommendations that were evaluated in the several roadmaps (listed in table 3.3) are summarized. In the frame of our study one main finding is that these recommendations can be classified in the following four main categories.

- **Target 1 (blue): Stimulate and support markets.**
- **Target 2 (brown): Harmonize regulation.**
- **Target 3 (black): Setting standards.**
- **Target 4 (green): Preserve environment and safety.**

The relevant recommendation according to these categories are marked in the above colours. The number of the study corresponds to the listing in table 3.3.

Study 1

- **Remove regulatory barriers to demonstration projects.**
- **Establish a definition of energy storage in the EU regulatory framework. (e.g. an amendment to the Electricity Directive).**
- **Establish clarity on the rules under which energy storage can access markets – in particular, the perceived inability of transmission system operators (TSOs) and distribution system operators (DSOs) to own and operate energy storage.**
- **Eliminate unwarranted/double charging in a coordinated approach at European level. Whether and to what extent storage should finally contribute to grid costs merits a dedicated debate at European level.**
- **Ensure the procurement of all energy and ancillary services is market-based, subject to a Cost-Benefit Analysis (CBA).**

Study 2

- Energy stakeholders need to prepare today to capture the business opportunities in energy storage and develop their own business models.

Study 3

- **Standards that support the roll-out of electrical energy storage in Australia must initially focus on the installation of systems, product safety and performance standards.**
- **Alignment and stronger engagement with the International Electrotechnical Commission (IEC) committee structures is recommended to leverage existing knowledge bases and accelerate numbers of compliant products.**
- **Recycling rules and guidelines should be developed by industry bodies such as the Australian Battery Recycling Initiative (ABRI) and the Clean Energy Council (CEC).**
- **Handling and transport rules and guidance should be incorporated into existing documents, rather than new standards.**

Study 4

- **Reform the current energy market settlement regime to adopt a five-minute market settlement approach that provides a more effective market signal for energy.**

- **Reform the frequency control regime to enable fast acting devices to assist with frequency control and system security support by rapidly responding to emergency frequency events with Fast Frequency Response capability.**
- **The Australian Energy Market Commission (AEMC) should review options to address electricity market rules that distort investment away from network services and towards poles and wires.**
- Distribution businesses should publish better data on impending network constraints that could be addressed by incremental investments in on-grid energy storage. The AEMC and Australian Energy Regulator (AER) should change the requirements on distribution businesses regarding the Distribution Annual Planning Report to transition from a report-based approach to a geographic information system (GIS)-driven portal, to enable better market access and usability of data.
- The AEMC should significantly lower the RIT-D threshold from the current $5 million level and encourage approaches such as Ergon Energy's 'Optimal Incremental Pricing', which allow for smaller increments of investment while reducing the administrative burden on distribution businesses.
- Distribution businesses should follow Energy Queensland's example, making it easier to obtain approval for grid connection when adding a battery to an existing solar PV system.
- **State and territory governments should support benefit-reflective feed-in tariffs (as adopted by the Victorian Government) in order to ensure the full value of energy storage is recognised.**
- **In states where customers continue to receive premium feed-in tariffs (PFiTs), governments should consider the feasibility of programs to allow the value of the PFiTs to be traded in exchange for a subsidy for a battery.**
- **The Australian Energy Regulator (AER) should support the transition to demand-based tariffs and empower consumers by updating its online tariff comparison tool to include demand charges.**
- **State government safety regulators should require that all battery installations must be performed by a qualified installer with the demonstrated competency in battery.**
- There should be a legally enforceable Australian Standard for the product safety of lithium ion batteries. Until then, State government safety regulators should mandate that batteries installed in their jurisdiction be required to demonstrate compliance with best practice international product standards for battery safety, such as IEC 62619:2017.
- Governments that provide rebates or conduct reverse auctions for 'behind the meter' battery storage systems should specify tender conditions that either: require use of retailers that are signatories to the Solar Retailer Code of Conduct; or that can demonstrate compliance with standards at least as stringent as those of the Solar Retailer Code of Conduct.
- **Industry and all levels of government should work together to develop an agreed approach toward the reuse, recycling or disposal of batteries at the end of their useful life.**

Study 5

- To focus less on an investment cost only approach for storage technology assessment, where only technologies with the lowest levelised cost of storage (LCOS) are rewarded. Cheapest is not always best, or possible.
- To examine storage through holistic case studies within a specific context, rather than place faith in generic cost estimations.

- **To accelerate the development of flexible markets, working with transmission and distribution system operators and regulators to help quantify and realise the true potential value of increasing system flexibility.**
- **To establish policy support and an enabling regulatory framework to facilitate further commercial deployment of storage technologies.**
- To consider storage as a key component when planning for grid expansion or extension.

Study 6

- No specific recommendations

Study 7

- Wind and solar PV drive power system development.
- Regional European power system integration mitigates flexibility needs from increasing shares of wind and solar.
- Cross-border exchange minimises surplus renewables generation.
- Conventional power plants need to be flexible partners of wind and solar output.

Study 8

- This means electricity storage systems cannot be addressed with a single policy covering the different possible locations and services.
- Instead, dedicated policies are needed for each of these application areas. At the same time, policies need to ensure consistency and consider the broad scope of regulatory options for electricity storage systems (including grid codes, pricing mechanisms and the creation of new markets).

Study 9

- **Adaptations in the design of the energy market, which should migrate from one based on centralized, stable supply to one based on flexibility with value. This requires the admission of new market participants, market transparency, and fluctuating prices.**
- Dynamic modelling of flexibility in the energy system. To protect the affordability of our energy production, more insight is required into the way the various sources of flexibility influence price.
- Portfolio analysis of flexibility sources. A key conclusion of this Study is that a combination of flexibility sources is required in order to facilitate flexibility at various levels in the system. These sources require further investigation.
- Economic opportunities: Value model for players. Flexibility can acquire an economic value in an energy market in which electricity prices are variable and external costs are discounted in the price. Further Study is necessary to explore the contribution that aggregators might make here.
- Learning by doing: Practical experiments and living labs. Uncertainty is inherent in any transition process, and parties who are prepared to experiment with the development of the necessary flexibility in the energy system should be given ample opportunity to do so.

Study 10

- Stimulate and support research and development
- **Remove barriers in the legislation and market model and adapt the legislation to the desired situation.**

Study 11

- The expansion of renewable energy does not have to wait for electricity storage. In the next 10 to 20 years the flexibility required in the power system can be provided for by other, more cost-effective technologies such as flexible power plants, demand side management. New storage is required only at very high shares of renewable energies.
- The market for new storage technologies will grow dynamically. New markets for battery storage and power to gas technologies are expected to emerge, especially in the transport and chemical sector. Storage developed in these sectors can enable further flexibility for the electricity system as an additional service. Research and development as well as market incentive programs should maximize the system-supporting contribution of new storage technologies.
- **Storage must receive equal access to markets for flexibility. Storage can already today deliver several ancillary services at competitive costs. Flexibility markets – such as the ancillary services or future capacity markets – should therefore be designed such that they are technology-neutral.**
- Storage should become a tool in the toolbox of distribution system operators. In specific cases, storage that is used to support a grid can help to avoid grid expansion in the low-voltage distribution grid. The regulatory framework should enable such cost-efficient decisions.

Study 12

- Determine where near-term cost effective niche markets exist and support deployment in these areas, sharing lessons learned to support long term development.
- **Incentivise the retrofit of existing storage facilities to improve efficiency and flexibility.**
- **Develop marketplaces and regulatory environments that enable accelerated deployment, in part through eliminating price distortions and enabling benefits-stacking for energy storage systems, allowing these technologies to be compensated for providing multiple services over their lifetime.**
- **Support targeted demonstration projects for more mature, but not yet widely deployed, energy storage technologies to document system performance and safety ratings. Share information collected including lessons learned widely through storage stakeholder groups.**
- **Support investments in research and development for early stage energy storage technologies including technology breakthroughs in high-temperature thermal storage systems and scalable battery technologies, and systems that incorporate the use of both electricity and thermal energy storage (i.e. hybrid systems) to maximise resource use efficiency.**
- **Establish a comprehensive set of international standards in a manner that allows for incremental revisions as energy storage technologies mature.**
- Evaluate and broadly disseminate the learning and experience from established installations. Information should include data on both technical aspects (e.g. generation, cost, and performance) and contextual details (e.g. market conditions, energy pricing structures) specific to a region/market.
- Establish international and national data co-operation to foster research, monitor progress and assess the research and development (R&D) bottlenecks. Complete analysis in support of regional assessments to quantify the value of energy storage in specific regions and energy markets, and promote the development and adoption of tools devoted

Study 13

- Expanding revenue opportunities
- Reducing costs of integrating and connecting to the grid

- **Streamlining and spelling out policies and processes to increase certainty.**

Study 14

- A flexibility gap is created by the shift towards high-VRES systems.
- New flexibility options in demand and storage require control and communication infrastructure.
- VRES control is unavoidable for higher RES shares.
- Changing the market for reducing the flexibility gap.
- Incentives and systems for demand management are needed.
- Extending the market size is a no regret solution.

Study 15

- Since energy storage must be expected to be a cornerstone of future renewable energy systems, it should be supported as a separate field of research.
- Strong and focused support for materials R&D relevant to energy storage technologies should be prioritised.
- In the longer term, to realise a future 100% renewable based energy system, research and innovation must ensure development of the flexibility and associated solutions needed to ensure a reliable and economic energy system.
- The increased research efforts should be accompanied by demonstration projects in grid integration of energy storage, thermal management and industrial waste heat storage, grid-connected battery storage, and heat storage (including underground technology).
- Demonstration of connections between grids, such as the power-to-gas concept in which electricity is converted to synthetic methane or hydrogen.
- **Design of market terms for integrating energy storage in electricity markets.**
- **Development of a market-based approach to the allocation of flexibility so as to provide flexibility in an economical manner.**
- Sizing and positioning of storage in power systems should account for the variability and predictability of stochastic power generation, network topology and network usage, and the economics of storage operations.
- **Regulatory settings should be developed to favour the effective coupling of the power, heat and gas infrastructures.**

Study 16

- The features of storage technologies must match application requirements
- With the exception of pumped hydro storage, the deployment of electricity storage is at an embryonic stage
- Research, Development & Demonstration is making inroads into solving technological obstacles
- The business cases for electricity storage are very complex and rarely viable under current market conditions and existing regulatory frameworks
- Environmental and social impacts vary according to the technology and might hinder development in some cases

Study 17

- No specific recommendations

Study 18

- No specific recommendations

Study 19

- Increased electricity generation from variable renewable sources, such as wind, combined with the electrification of heat in homes are two of the most important factors likely to drive the deployment of energy storage.
- There are many different technologies for heat or electrical storage at different stages of maturity and with a wide range of characteristics. It is unlikely that a single solution will emerge in the future given the wide variations in possible applications.
- Energy storage currently faces a **number of regulatory and market barriers.**
- Public attitudes towards energy storage could be crucial in determining its role in the energy system, but to date little or no work has been undertaken in this area.

Study 20

- No specific recommendations

Study 21

- Implement energy storage procurement targets under AB 2514.
- **Ensure the Self-Generation Incentive Program covers energy storage resources, providing potentially crucial financial incentives for energy storage investment.**
- **Refine its Resource Adequacy (RA) program, which ensures that California ISO has access to sufficient resources to operate the grid safely and reliably and promotes the siting and construction of new resources needed for future reliability. All load-serving entities (LSE) within the CPUC's jurisdiction are subject to the determined RA requirements. The CPUC could promulgate rules to allow certain categories of energy storage procurement to count toward an LSE's RA obligations.**
- Use existing proceedings related to the development of the smart grid, permanent load shifting, demand response, long-term procurement process, and alternative-fueled vehicles to explore the cost-effective promotion of energy storage technologies as they relate to these proceedings.
- Implement real-time pricing and strong price differentials between peak and off-peak rates to boost the market for peak-load shaving technologies.
- Encourage the California ISO and FERC to open markets to competition from energy storage.
- Develop a valuation methodology for energy storage that accounts for its costs and benefits to ratepayers and the public, given the state's energy and environmental goals. This method could value technologies based on the most promising applications and ensure that benefits to additional applications are appropriately counted. This report identifies three potentially promising applications for energy storage: frequency regulation, integrating variable renewable energy, and developing community or distributed energy storage systems.

Study 22

- **Public support for development of conventional storage.**
- Long-term storage, on the order of months.
- **Cooperation between energy sectors; coherent regulations.**
- **Incentives for development and operation of storage.**
- **Public policy for and investment in storage research.**
- Potential barriers to the introduction of microgrids.
- **Regulations for the safety of new storage technologies.**

- **Environmental regulations for new storage technologies.**

Study 23

- No specific recommendations

Annex 5.4 Expert interviews

Link: https://gigamove.rz.rwth-aachen.de/d/id/9qPzxnzh7tSpsx

Annex 5.5 Analysis of expert interviews

1 Experts Background

The experts were selected to have a good mixture of active scientists working in the R&D of energy storage, of directors that are responsible for research institutions in the field of energy and energy storage and of managers that work for asscociations in energy storage or that are used to work in institutions with mission oriented R&D programs in energy. Nearly all experts as listed in table 3.4 have more than 10 years hands-on experience in the field of energy or energy storage.

Table: Interviews towards Mission oriented R&I programs (in alphabetical order)

Name	Institution	Country	Role/Position	Date
Christian Brennig	German Association of Energy Storage www.bves.de	Germany	Referent Technology and Standards	29.11.2017
Dr. Patrick Clerens	European Association for Storage of Energy	EU	Manager EASE	14.12.2017
Dr. Adel El Gammal	European Energy Research Alliance	EU	Manager EERA	15.01.2018
Prof. Max Fichtner	Helmholtz Institute Ulm	Germany	Director of Helmholtz Institute Ulm	15.12.2017
Prof. Dr. Joachim Knebel	Karlsruhe Institute of Technology	Germany	Head of Division Mechanical and Electrical Engineering	14.12.2017
Dr. Marcos Lafoz	CIEMAT	Spain	Leader of Electric Power System Unit (Department of Energy) and EERA Mechanical Energy Storage	22.12.2018
Dr. Frank Meinke-Huberny	VITO Energyville	Belgium	Leader of Energy System and Implementation Unit	15.12.2017
Dr. Edel Sheridan	SINTEF	Norway	Researcher and EERA Electrochemical Energy Storage	7.12.2017

Dr. Tobias Sontheimer	Helmholtz Association	Germany	Coordinator Research Field Energy	4.12.2017
Prof. Petr Vanýsek	Brno University / Northern Illinois University	Czech Republic / USA	Professor	12.01.2018

2 Guiding Questions

1) Introduction
    a. Could you please briefly introduce yourself. What is your background?
    b. What is your position in the organization?
    c. What are your main tasks?
    d. Which areas of energy storage are closely related to your R&I activities?
    e. What exactly is the focus of your work?
2) Challenges
    a. What are the main challenges in energy storage today and in 5 years from now?
3) Technologies and system integration
    a. What energy storage technology is today most important for you?
    b. What is needed to speed up the integration of energy storage?
4) Is your organisation using mission oriented R&I programs?
    a. Yes. In which specific research field?
    b. Yes. Which process?
5) Do you have practical experience with mission oriented R&I programs?
    a. Yes. What kind of experience?
    b. Yes. What are the benefits?
6) Management and Monitoring
    a. How should progress be measured and monitored towards milestones and the final target of 2030?
    b. What is an effective scheme to manage many different stakeholders in energy storage?
7) How would you formulate a specific mission in the field of energy storage?
    a. Please formulate a specific mission for 2nd generation batteries
    b. Please formulate a specific mission for pan European Grid.
    c. What would you need for the implementation (Ressources, Regulation, Infrastructure, etc.) of the mission?
    d. How would you involve end-users (national governments, cities/regions, private foundations) in the governance of the mission?
8) How would you perceive the role of bigger firms in influencing the business ecosystem in your mission area?
9) Any information or question that you have to us?

In bold extensions of the guiding questions after the first three interviews.

3 Evaluation and Analysis of the Expert Interviews

The evaluation was done in such a way that along the guiding questions all answers were summarized. If an answer was mentioned more than one time, the authors summarized it and it is highlighted in bold. A short summary is given for most of the questions.

1) Background of experts

The selection of experts includes active scientists, leading scientists, directors and managers. Nearly all experts have more than 10 years hands-on experience in the field of energy or energy storage.

2) Challenges

The challenges on energy storage are sorted in three categories. Firstly, general challenges without time frame, secondly present challenges and thirdly challenges in 5 years. Challenges in bold were mentioned more than only once. According to the feedback major challenges include, improving cost performance ratio of energy storage, establishing cell and battery manufacturing in Europe, establishing regulations to foster energy storage development and applications and setting up recycling facilities.

General

- Changing the regulatory framework to get the right legal classification of storage systems.
- Changing the understanding of the decision makers that storages are usual and relevant elements in energy systems.
- Politics: National governments should be aware of the need of energy storage now and in the future. They should think more forward than they actually do.
- **Decreasing levelised cost of energy storage** to compete with other flexibility options.
- Up-scaling of medium and long-term storage until 2030.
- Where are the attractive application cases and scenarios for energy storage?
- What are the relevant technical requirements and boundary conditions for energy storage: E.g.: long-term – short-term. Energy storage capacity. Response time?
- Storage concepts should be analysed with a systemic perspective, when considering the different applications such as security of supply, reliability, grid stability, heavy duty transport, marine and aviation, off grid applications etc…

Today

- **Higher energy density storage systems needed**
- **Regulatory framework challenge: business cases sometimes cannot succeed because of regulations**
- Improve communication across EU (e.g. difficulties to find partners in EU projects not dealing with Li-ion batteries…) and align policy between member states.
- **Establishment of cell and battery manufacturing in Europe**
- Raw materials: availability in Europe. Also finding other suitable elements/materials for batteries.
- New battery systems: finding suitable chemistries (e.g. sodium-sulphur).
- Solid state electrolytes: for solid state batteries

5 Years

- **Facilitation of pilot lines for new chemistries beyond Li-ion**
- **Adequate recycling, facilities available**
- Cheaper and kind-environmental materials that allow suitable chemistries for batteries

- To improve materials in chemical, electrochemical and mechanical storage, in order to achieve higher energy and power densities.
- To improve power electronics and control to increase flexibility, time response and reliability

3) Technologies and system integration

There is a clear tendency that at present Li-ion batteries are considered most important and it is common understanding that Li-ion batteries are the work horse for energy storage for the next years.

The measures that are needed to speed up the integration of energy storage are closely related to the main challenges of question 2. Most often mentioned measures are changing the regulatory framework, decreasing levelised costs of storage, improving material properties and new materials and battery production.

a. What energy storage technology is today most important for you?

- **Lithium ion batteries**
- Fuel cells
- Stationary energy storage for stability.
- All energy storage technologies are relevant depending on the application (e.g. flywheels, capacitors, hydro, ALES, CAES, hydrogen and for mobility batteries and fuel cells…).
- A storage technology which allows to transform surplus renewable electricity into long-term storable chemical energy carrier such as synthetic fuels and gases (CH4, hydrogen). These energy carriers can also be "rückverstromt"; even under long overall efficiency.
- High capacity / short duration power storage for grid management/continuity of supply
- e-Mobility for light weight transport
- **Power to Clean fuel for heavy transport, marine, aviation, conversion technologies (Power to X)**
- Pumped Hydro ES

b. What is needed to speed up the integration of energy storage?

- **Changing the regulatory framework**
- Changing the understanding of the decision makers that storages are usual and relevant elements in energy systems.
- Establish a definition of energy storage in the EU regulatory framework; analysing energy storage, not as a set of technologies, but as a separate key function/component of the entire energy system.
- **Decreasing levelised costs of storage**
- **Improvement of material properties and new materials**
- Energy generation in large scale
- Business models integrating energy systems together with generation
- **Battery production**
- Recycling in EU
- Business models for decentralized consumption
  - More potential for consumer market participation, e.g. pricing structure to reflect electricity demand peaks
  - Setting up new business models
- Demand side management (by aggregators) in cooperation with industry which add large scale batteries to a complement portfolio
- Ease demonstration projects by better regulatory boundary conditions and support.

- Infield demonstration of storage integration in the scale of 50.000 inhabitant model region; based on lab-scale development and validation. Communication and with the relevant stakeholders and the citizens in the model region.
- Better energy system modeling - scenarios
- Market design supporting energy storage for long term contracts or specific system services supporting new products
- Better market model/pricing model properly incentivizing energy storage
- Provide better visibility from a time perspective on how the cost of different storage technologies is likely to evolve under various technical and market development scenarios
- Strategic partnerships with industry in an early phase of the innovation process to ensure that their requirements are taken into account.
- Incentivize market development to ensure scale effect

4) Is your organisation using mission oriented R&I programs?

- No IIII
- Yes IIIII

a. Yes. In which specific research field?

- **In energy and energy storage**

b. Yes. Which process?

5) Do you have practical experience with mission oriented R&I programs?

Seven out of ten experts have practical experience with mission oriented R&I programs. The experience covers project work or participation in Helmholtz programs at different levels. The main benefit is not coherent but it is mentioned that it is easier to find targets, formulate objectives and work with many different stakeholders across disciplines and organisations.

a. Yes. What kind of experience?

- Yes IIIIIII
- No III
- Worked on photovoltaic roadmap for Solarverband since 2012
- Worked in large EU projects
- Smaller projects with industry by fixing one specific issue
- Helmholtz research is purely and firstly mission oriented: We work on the grand challenges of our society, such as energy, mobility, built environment and climate. The challenge is the combination of these challenges to one united mission.
- The program-oriented funding of the Helmholtz association is mission-based. Various research centers cooperate in strategic long-term R&D programs on the most pressing challenges of the energy transition.
- National R&I Programmes, i.e. Retos Collaboration (industry cooperation research)

b. Yes. What are the benefits?

- Target driven
- Companies can focus their activities
- Masterplan for a new energy system in Germany and realization of this masterplan. Possibility to discuss this development with European Member States, possible adaptation of suitable modules by European Member States
- Setting up large consortia finance and fortune community
- Ease of research exchange and collaboration
- Possibility to work on broad topics where multidisciplinary is needed

- **To find synergies with other research centres as well as with the industry to develop technologies to be transfered to the market**
- Strategic process across different organisations
- Peer review enables fast feedback and fast adjustment
- It encompasses a wide range of different technologies very contrasted in nature, level of complexity and level of maturity.

6) Management and Monitoring

For monitoring a group of different stakeholders is the most common proposal and as key performance indicators the levelised cost of energy storage and the installed amount is recommended.

There is no common scheme proposed to manage different stakeholders in energy storage but it is mentioned twice that new alliances seem important to improve communication between stakeholders.

a. How should progress be measured and monitored towards milestones and the final target of 2030?

- Define research programmes for 5 years dealing with different systems. After 3 years select the two more promising systems and keep on funding them while dropping the other. In that way the competitiveness can be increased but also synergies would be used
- KPI's are clearly defined that can be computed or evaluated and are directly reflecting part or all of the end objective of the Mission. As a Mission by definition supposes a rather long timeframe, KPI's should allow to track intermediate progress.
- The one and only indicator is the levelised cost of stored energy and this needs to be evaluated. This is coupled with the amount of MW of energy storage installations at the grid
- The progress could be monitored by the national government on the pilot plants, i.e. governments should monitor what came out from the pilot plants. It is the successful projects and a higher technology readiness level that should be included.
- Monitor: Review process with international experts
- Monitor: External super- and advisory board (independent scientists, industry, political and strategic management experience)
- Monitoring activities in the field and interviewing non involved market experts

b. What is an effective scheme to manage many different stakeholders in energy storage?

- Policy should give clear guidelines only
- Governments can manage individual storage plants by taxation, tax discounts or incentives
- Market need clear objectives and boundaries
- Research projects with industry involvement covering the whole value chain
- **New alliances on energy storage (e.g. new EU Battery Alliance) to improve communication between stakeholders Integration of different stakeholders is important**
- Local, national and international government as well as consumers need to be involved in research and application research
- Important is to bridge fundamental and applied research

- Effective rather in smaller units with a clear defined goal, big consortia must be divided in smaller units
- Management with technical expertise is needed and which is aware of goals of the partners
- Clearly defined sub goals coordinated by management
- Too large groups are not effective
- Gather all energy storage activities under one programme instead of cutting it into pieces in different actions
- Firstly, look at needs and formulate requirements for R&D
- Secondly, which technology is needed at what time?
- Thirdly, define and sort stakeholders in categories. Develop a comprehensive roadmap.
- Need for an effective exchange concept of stakeholders.

7) How would you formulate a specific mission in the field of energy storage?

- Energy storage technologies shall move from R&D to market
- From a game changer to a stabilizing element in energy systems
- Provide long-term, large-capacity energy storage technology which is capable to make up for long term periods without much renewable generation
- An energy storage mission should face two main issues:
  - decrease the cost of energy storage systems
  - promote the deployment of technologies
- In Implementation Plan of the integrated SET-Plan TWG 7 („Become competitive in the global battery sector to drive e-mobility and stationary storage forward") have been defined 5 missions for e-mobility (materials, manufacturing, fast charge, second-use, recycling)
- Reduce the overall energy needs in Europe by at least 1.5% per year, through better design, planning and behavior, aiming at greater efficiency gains:
- Supply the different types of energy services with the most efficient mix of carbon free and, whenever possible, renewable energy sources; develop new energy
- Solutions that have the potential to provide carbon-free energy production, distribution, and storage by 2050.
- Target the complete decarbonisation of the transport sector, with focus on the required technological advancements, integration and new business models such as shared mobility, seamless mobility and trans active mobility concepts.
- Propose new regulatory frameworks, business models, services and applications that enable a mass behavioral shift towards a proactive and sustainable relation of the prosumer to energy; propose and develop lighthouse and pilot projects at various community levels that are replicable and scalable and that contribute to the overall system design.
- From a resource perspective, develop and implement new concepts of circular economy in both the material and immaterial cycles.

a. Please formulate a specific mission for 2nd generation batteries

- Post Li ion batteries for e-mobility by 2035
- A sodium-sulphur (Na-S) battery with a minimum 85% of thermodynamically efficiency
- More energy density, more safety, less cost, more power, more sustainability

b. Please formulate a specific mission for pan European Grid

- Combine country specific technologies (water dams in Norway, pumped hydro in CH and A) and different energy carriers (hydrogen close to wind parks, …), usage of underground reservoirs (heat, chill, gas). Nuclear in France as base load and back up capacity.
- European policy should regard and treat energy storage as a true pan European issue. The European Energy System must be considered and treated as an integrated energy market. All European Member States have to jointly work on the solution of the energy challenge.
- Establish (smart) grids that are capable of integrating decentralized "prosumers"

c. What would you need for the implementation (Resources, Regulation, Infrastructure, etc.) of the mission?

- Commitments of industry and considerable involvement of companies to building cells and batteries, recycling and electric cars
- Abolition of special regulations for storage (no special regulations for storage)
- Same rules for all market participants and CO2 pricing and internalization of external effects in the energy sector
- Market pull has priority
- More focus on hybridization systems (combination of high energy density and high power density)
- Fast charging of batteries in order to be competitive and to increase the uptake (charging infrastructure needed)
- Continue to fund fundamental and applied research, batteries, new materials. Testing is needed for assumption how technologies, stakeholders can interact.
- Legal framework need to be adjusted so that free energy market in Europe can be realized. Not complete deregulations, but legislation needs to be renewed to enable new business models.
- Enable user-friendly consumer participation in the market. E.g. by allowing aggregation of decentralized storage systems on private household levels
- Remove regulatory barriers to enable demonstration projects to study the technical feasibility and market applications of energy storage systems
- Set up a regulatory framework that allows the market uptake, for instance by allowing investments
- Incentives, in terms of taxes, to build pilot or power plants with new systems (e.g. 2nd generation batteries)
- In Germany ~ 200 Mio.€ per year for R&D on electrochemical energy storage
- Infrastructure for up-scaling and manufacturing to cover the way from R&D to market
- A large living lab (model city), in which stationary and mobile storage devices will be integrated, tested and optimized in a real-life renewable ecosystem. This requires a tailored regulatory framework (for this particular project).
- An improved connection from R&D to market.

d. How would you involve end-users (national governments, cities/regions, private foundations) in the governance of the mission?

- Alignment between LOCAL/REGIONAL GOVERNMENT (politicians) – RESEARCH INSTITUTIONS (researches) – SMALL ENTERPRISES (industry) at regional level. For example:
  - USA: Small Business Innovation Research grants (SBIR)
  - Czech Rep: Joint grants for research institutions and small enterprises through the Technology Agency of the Czech Republic

- Demonstration projects with real implementation of the technologies developed are essential for the confidence of the end-users in the missions

8) How would you perceive the role of bigger firms in influencing the business ecosystem in your mission area?

- There are numerous examples where industrial interests are favoured vs. the general public interest, and this is simply unacceptable and widely damageable to the public perception of the Union of its core values and finally of democracy. Specific instruments and initiatives should be developed that clearly unite, in a transparent and open way, assets from across sectors and member states to create a true industrial critical mass and leadership in Europe, as was done for the "Airbus Mission".
- Big firms are already involved and need to stay involved as owners and operators of essential infrastructure
- At the same time new market players need also encouragement to participate in the energy transitions to foster innovative business models
- Big firms have the decisive influence. Without big firms no realization.
- We must remain at any time extremely cautious that industrial and financial interests do not dictate public strategy as it is often the case, but that on the contrary, public interest is clearly recognized as the overarching priority that private interest must eventually support.
- The bigger the firm gets, the more separated to the influence from outside. They have their own mission and therefore it is difficult to support small research.

9**) Any information or question that you have to us?**

- Electrical Infrastructure for charging e-vehicles is and will remain a big a challenge in Europe.
- Better management of resources by prevent the use of non-abundant raw materials for stationary applications (for instance, cobalt for Li-ion batteries in stationary applications).

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This is one of a series of simulation studies developed to support mission-oriented research and innovation policy at EU level.

The overall purpose of this study is to increase understanding on how a technology-driven mission, in this case energy storage, can be designed and how such a mission in the field of energy storage could look like. The methodology used in this study combines literature research with expert knowledge and expert interviews. The study summarizes present EU policy on energy storage, gives examples of missions from various companies and institutions and presents key findings of recent roadmaps on energy storage. Together with expert interviews on mission-oriented R&I this information serves as a background to propose two missions on energy storage. Firstly, a so-called transformer mission is proposed as "Develop an interconnected, carbon-neutral and reliable Pan-European Energy System by 2030". This mission transforms the whole energy system in Europe, while the second proposal accelerates the technical development of Post-Li-Ion batteries. This so-called accelerator mission is proposed as "Develop more powerful and clean European Post-Li-Ion batteries for electromobility available on the market by 2030". Finally, an evaluation and monitoring scheme for both missions is developed.