



EPS Contribution to the Interim Evaluation of Horizon 2020

This document is the contribution of the European Physical Society (EPS) to the Interim Evaluation of Horizon 2020 with a specific focus on the Societal Challenge 'Clean, Safe and Efficient Energy'.

Horizon 2020

As with previous framework programmes, Horizon 2020 is an essential pillar of the European research system for it is the most accessible source of funding for trans-border collaborations in Europe. In addition, thousands of young researchers have benefited from the various mobility programmes supported by the European Commission. The European Research Council (ERC) has become the flagship of European research and serves as a reference for national and international programmes. Hence, framework programmes are truly the backbone of the European Research Area. Horizon 2020, by introducing the grand challenge approach, has provided the visibility and necessary impetus to bring Research and Technological Development (RTD) closer to the needs and expectations of the citizens and to provide answers to them.

The EPS therefore urges the European Commission to maintain the budget for Horizon 2020, and to further sustain and expand research funding in future framework programmes. Due to its expertise on scientific issues EPS will only discuss here the following aspect.

Societal Challenge 'Clean, Safe and Efficient Energy'

EPS fully endorses the Horizon 2020 objective to aim for competitive, low carbon energy systems and reduced energy consumption to tackle the societal challenge 'Clean, Safe and Efficient Energy'. In this context, EPS sees merit in the activities supported so far under Horizon 2020. However, these activities seem to focus overwhelmingly on short-term, technological issues. The EPS would like to highlight that a long term approach to these issues is necessary, to explore new areas and generate new knowledge. Notably, an efficient expansion of renewable energy sources requires solutions for intermittency and storage which still require extensive research and development.

The current philosophy of Horizon 2020's Work Programmes therefore needs to be adapted to make room for long-term, blue-sky research.

Recommendations for research areas in the field of energy

As discussed in the EPS Energy Group Position Paper ‘European Energy Policy’ [1], substantial CO₂ reductions imply a vast transformation of the existing power supply system into either renewable or nuclear power or some combination thereof. Already at the present level of penetration of renewable energy sources (~23% of the EU electricity production), solutions are urgently needed to adequately tackle the problem of intermittency of the energy supply. This will demand a combination of high capacity non-intermittent (e.g. nuclear, oil and coal fired) and flexible backup plants (e.g. gas, hydropower), large electrical energy storage capacities and substantial expansion of electricity distribution grids, including smart grids. The integration of this variable electricity supply is expected to become even more difficult as its percentage rises to above 30-40%. The expected substantial changes in the electricity sector present major technological issues requiring long-term perspectives and sustained investment in research and development.

In this context, EPS recommends to develop and strengthen research activities in all areas of electrical energy storage, which notably encompasses thermal storage, graphene-based technologies, and Power-To-X, energy vectors.

The rationale for this recommendation is provided in the Annex.

Concluding remarks

This paper includes recommendations for research areas which are essential for addressing the energy challenge of our time. The EPS urges the European Commission to take into consideration these recommendations during the definition of the final Horizon 2020 Work Programme (2018-2020). Moreover, the EPS recommends that these issues be included in future framework programmes as well. The EPS and the EPS Energy Group are willing to provide further input and expertise whenever needed or appropriate.

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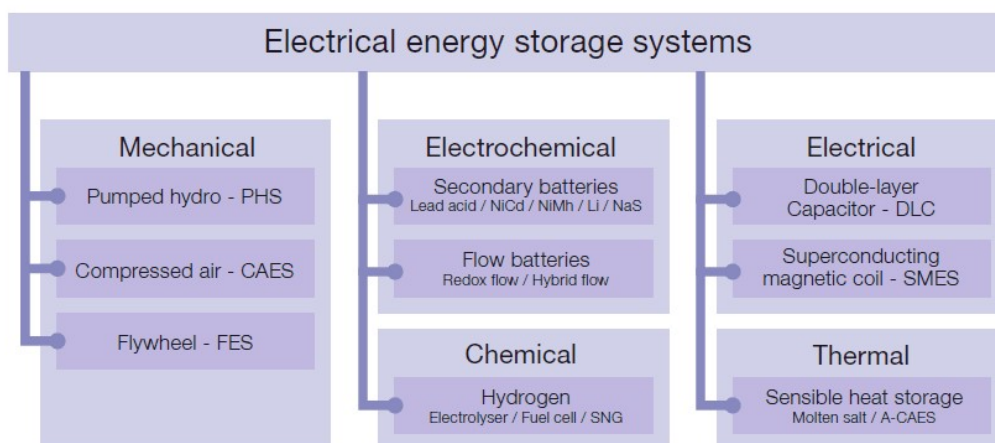
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Annex

Rationale for the recommendation on research areas to be fostered to address the Horizon 2020 Societal Challenge 'Clean, Safe and Efficient Energy'

As depicted in the figure below, there are various systems to store electrical energy.



Excerpt from the International Electrotechnical Commission (IEC) White Paper 'Electrical Energy Storage' [2]

EPS recommends to focus particularly on thermal storage, graphene-based technologies and Power-To-X, energy vectors. The rationale for this recommendation is presented below.

1. Thermal storage

Thermal storage technologies play a very important role in achieving the European targets for renewable energy and energy efficiency. It enables a larger fraction of renewable energy to be usefully consumed as the overall efficiency is improved by balancing the availability and the demand. The potential of thermal storage is very high, as 49 % of all the primary energy in Europe is used for heating purposes. An efficient thermal storage technology will automatically lead to a more efficient energy supply as a whole.

There are four main options for thermal storage: sensible, latent, sorptive and chemical heat storage. Sorptive and chemical heat storage technologies belong to the class of thermochemical energy storage techniques.

State of the art solar thermal systems for combined hot water generation and space heating cover between 15% and 40% of the heat demand of small domestic systems and of larger solar assisted district heating systems. The fraction of usefully consumed solar thermal energy can only be substantially increased if new storage systems are

developed that can efficiently cope with seasonal storage. At the highest efficiencies, the volume of seasonal storage needed for a single family house is 120 m³ for a sensible, 60 m³ for a latent and 12 m³ for a chemical heat storage system.

A large fraction of the potential of solar thermal energy can be realised with already existing sensible heat storage, mostly in combination with heat pumps. These water-based systems become more economical with increasing size, e.g. storage for a large number of houses or a district. For decentralised demand of heat, compact solutions need to be found, with reduced volume for both energy storage and thermal insulation.

In the case of solid sorption heat storage, solar heat is used to remove moist from the active storage material, e.g. a zeolite. When heat is needed, water vapour is led through the material, the water vapour is adsorbed and the released heat of adsorption can be used for space heating or domestic hot water preparation. Solid sorptive materials have the ability to store thermal energy in a nearly loss freeway over longer periods of time (weeks, months) or for nearly indefinite periods if the dried material is hermetically sealed from any moisture. For the generation of water vapour, low temperature heat sources can be used. The theoretical maximum energy density of solid sorption storage is over 170 kWh/m³, but strongly depends on the type of sorption material used.

In the charging phase of liquid sorption storage, a diluted mixture (e.g. sodium hydroxide, also called sodium lye) and water is concentrated by evaporating the water. The concentrated lye can then be stored for indefinite periods, without any loss of the stored energy. To generate heat, water vapour is added to the liquid using two reactors, one diluting the concentration and the other one generating the heat. The first reactor produces low temperature heat for space heating, the second high temperature heat e.g. for hot tap water. The energy density of liquid storage materials is between 170 and 400 kWh/m³, depending on the charging and discharging parameters.

2. Graphene-based technologies

Since its discovery in 2004, graphene has become one of the hottest topics in the field of materials science. Its highly appealing properties have led to a plethora of scientific papers. Graphene promises a revolution in electrical and chemical engineering. It is a potent conductor, extremely lightweight, chemically inert and flexible over large surface areas.

Among the many areas of materials science affected by "graphene fever" is the field of electrochemical energy-storage devices. Much more research is needed before graphene can contribute to improved electricity storage but the potential is large. The most recent applications of graphene range from lithium-ion batteries and electrochemical capacitors to emerging technologies such as metal-air and magnesium-ion batteries. Soon after the discovery of graphene, early research already showed that lithium batteries with graphene based electrodes had a greater storage

capacity and lifespan than standard designs. It could be a very important factor in the development of high capacity electricity storage by reducing the weight of batteries and increase their lifetime.

Another focus is graphene-based supercapacitors, which demonstrate a higher power capability and longer life cycle albeit with a smaller electricity storage capacity than standard batteries. Nevertheless, they hold a large promise as a complement to batteries as part of an integrated storage solution. A combination of graphene batteries and supercapacitors could be very important in the development of electric cars. Today these green vehicles run on batteries that weigh 200 kg. By reducing the weight of electrical storage, graphene could improve vehicle efficiency and thus increase the driving range of electric cars, a limitation that currently hampers their popularity.

Graphene-based storage is not limited to transport applications alone. It also could play a major role in the future of the power grid as Europe relies increasingly on renewable electricity. If Europe can bring high capacity electrical storage to maturity, it would also allow operators to store large amounts of electrical energy for times of insufficient power generation.

3. Power-To-X, energy vectors

The need for storage of surplus renewable electricity arises from the fact that supply and demand are ill-matched both geographically and temporarily. This already causes problems of overcapacity and grid congestion in countries where the fraction of renewable electricity exceeds 20%. A systematic approach is needed, which focusses not only on the energy source, but encompasses conversion, storage, transport, distribution and use. Furthermore, there is a need for more flexibility in the energy system. Rather than relying on purely electrical storage, integration with other energy systems, for example the gas network, would yield an electricity supply that is less vulnerable to failure and better adapted to the demand.

Power-To-X (or P2X) identifies technologies that transform surplus renewable energy into material energy storage, energy carriers, and energy-intensive chemical products. Surplus energy from renewable sources can then be used in the form of tailor-made fuels for vehicles or improved plastics and chemical products with greater added value. The X in the terminology refers to different entities like chemicals, liquids, gas, power, heat, mobility, etc.

With Power-To-X technologies power will first be electrochemically transformed into a material substance; the focus is on chemicals other than hydrogen, taking advantage of the higher volumetric energy density of hydrocarbons (e.g. carbon monoxide, methane, methanol and synthesis gas). These material resources must then be efficiently stored, distributed and then transformed into end products. To accomplish this, innovative solutions are needed, which should lead to ecological, economical and

societal advantages. In doing so, Power-To-X could contribute to decarbonizing the electricity system and to simultaneously decrease the percentage of fossil resources in the important markets of transport, commerce, and chemistry.

To illustrate this, let us consider to overcome the intermittency of renewable electricity generation by coupling the electricity net to the gas distribution network; if we consider methane with an approximate 3.5 times higher volumetric energy density than hydrogen then the Dutch gas network alone has a storage capacity of 552 TWh, sufficient to cover the entire EU energy demand for over a month. More importantly, this also shows the use of the existing gas infrastructure for energy storage, transport and distribution. In addition surplus renewable electricity converted via the Power to Gas (P2G) scheme, into synthetic methane or by using feedstock CO₂ and H₂O for the synthesis of syngas, a mixture of CO and H₂, it could play a central role in the synthesis of a range of hydrocarbon products, including methane, diesel and dimethyl ether.

Another interesting example for a massive reduction in fossil fuel burning are carbon-based solar liquid fuels such as methanol for energy storage. A new interesting concept consists in marine-based, rotatable, artificial islands, on which intermediate-concentration reflectors focus sunlight onto high-efficiency photovoltaic cells and where the resulting electrical, and perhaps thermal, energy is used to produce H₂ and to extract CO₂ from seawater. These gases are then catalytically reacted to form liquid methanol, which is stored at the island and collected by tanker ship. Methanol, CH₃OH or MeOH, is the simplest carbon-based hydrogen carrier which is liquid at normal ambient conditions. With approximately half the energy density of gasoline (15.6 MJ/L vs. 32.4 MJ/L), it can be used in existing gas turbines, modified diesel engines, and direct methanol fuel cells. The technology, installation and operating costs of solar methanol islands, as well as their location should be carefully assessed as they could have a significant long-term impact on the earth's climate. All alternative methods of recycling CO₂ between the atmosphere and combustible liquid fuel should therefore be investigated. It should be noted that 'methanol islands' is a policy option recommended in the STOA Briefing '*Methanol: a future transport fuel based on hydrogen and carbon dioxide?*' [3].

References

1. <http://www.eps.org/resource/resmgr/policy/eps-pp-EuropeanEnergyPol2015.pdf>
2. <http://www.iec.ch/whitepaper/energystorage/>
3. [http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/527377/IPOL-JOIN_ET\(2014\)527377\(SUM01\)_EN.pdf](http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/527377/IPOL-JOIN_ET(2014)527377(SUM01)_EN.pdf)