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### Summary
The deliverable covers (1) the benefits of the rSOC technology in comparison to other electrical energy storage technologies, (2) a statement on research policy and funding and (3) recommendation to accelerate the deployment of sector coupling technologies.

### Key words
Power-to-gas technologies, reversible SOC technology, sector coupling, EU/national/regional research programmes and budgets, strategic energy technologies, energy transition
TABLE OF CONTENTS
1. Benefits of rSOC technology ................................................................. 4
2. Statement on research policy and funding ........................................ 8
3. Recommended actions to support the deployment of sector coupling technology ......................... 9
1. BENEFITS OF RSOC TECHNOLOGY

1.1. Relative positioning of rsoc technology compared to competitive technology

The share of variable renewable electricity source is expected to increase, which increases the demand for electrical energy storage. Various technologies can provide this service and rsoc technology is one of them. Authors from the BALANCE project published an in-depth discussion of the potential of rsoc technology for Electrical Energy Storage compared to competitive technology, which is summarised below.

The main competing energy storage technologies with rsoc based energy storage systems are:

i. PHS (Pumped Hydro Storage)
ii. CAES (Compressed Air Energy Storage) and
iii. Batteries (mainly flow batteries)

The reasons as to why the above energy storage technologies are considered as competitors to rsoc technology is as follows:

- PHS, CAES and flow batteries are all meant for seasonal energy storage where energy can be stored to cater to a long-term demand and not for short bursts or impulses.

- These energy storage technologies (of course depending on plant size and capacity) can either supply the electrical power requirements (to meet the load demand) on their own or can supplement a conventional power plant by adding electrical power to the grid.

- These can also be used for absorbing excess electrical power from the grid, thereby assisting in grid balancing.

All these technologies are quite mature and have been commercialised but have their own drawbacks. Due to thermal inertia of high temperature heat exchangers, rsoc based systems are not suitable for the most demanding frequency regulation services such as Frequency controlled disturbance reserve (FCR-D), which needs to be activated in less than a minute. However, it could possibly participate in service that requires activation of 15 min or more (manual frequency restoration reserves, replacement reserves). rsoc based system are very suitable for energy management, load levelling, peak shaving and seasonal energy storage. The above three competing energy storage technologies are active players in these categories as well however they cannot be deployed at any location with the exception of batteries with poor economic scaling (volume and weight increases linearly with increase in scale of the energy storage). rsoc systems are envisaged to be deployed almost anywhere – in both grid dependent and independent areas. In places where the rsoc is connected with the grid, it will assist in grid stability and load levelling and in grid independent areas, the rsoc can be directly coupled with the renewable energy sources but this will be a challenge from a control and electrical point of view and will warrant a sophisticated energy management strategy.

Energy storage based on rsoc technology has the following advantages when compared to other conventional energy storage technologies:

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- **Flexibility** - Flexibility here can be defined in two ways, one with regard to system size and the other with regard to use of different fuels. rSOC systems can easily be scaled up or down without loss in thermodynamic performance. This is because unlike conventional thermodynamic devices such as steam and gas turbines, which are usually more efficient at a large scale, electro-chemical performance of the rSOC is not affected by size. Indeed, the overall system efficiency is also affected by heat loss and efficiency of auxiliaries, which are often size dependant. They are also able to operate on different types of carbonaceous fuels (during the fuel cell mode)

- **Adaptability** - The system can easily be integrated (electrically, thermally or chemically) with other renewable energy technologies, certain industries and a host of different applications, thereby making it adaptable to any situation

- **Capability** - Power sizing and energy capacity can be done independently for the two modes of operation in rSOC. The power sizing is given by the surface of cell area, which is stacked in the system, and the energy capacity is given by the amount of fuel storage volume. This gives rSOC systems an edge over other storage technologies. The operational times between the fuel cell mode and the electrolyser mode can be tailored independently and this along with a robust system control mechanism makes energy storage systems based on rSOC extremely capable of catering to different power and energy storage capacities.

- **High efficiency** - Not only the US DOE (United States Department of Energy) but also the European Association for Storage of Energy have set an ambitious target of 80% round trip (RT) efficiency for grid energy storage\(^2\). It is envisaged that EES (Electrical Energy Storage) systems based on rSOC can achieve up to 60% roundtrip efficiency (albeit with a specific set of operating conditions). This is similar or superior to CAES, but lower compared to some other technologies like PHS, however, PHS is limited by geographical limitations. Altogether, the good round-trip efficiency combined with the advantages described above makes rSOC a high potential candidate for energy storage.

One of the most important challenges for any energy storage system is to store energy at a large scale and be able to meet the energy demand for a relatively long period of time. Therefore, key aspects that have to be met by any energy storage technology include: cost, efficiency, storage capacity and widespread availability. Out of these four aspects, rSOC technology scores high on the last three aspects and that is why it is predicted to be an important contributor in the energy storage field. The only point where rSOC technology does not have an advantage over the other three technologies is the category of affordability. This is mainly for two reasons – cost of manufacturing of the SOC stack and the fuel source needed at the fuel electrode side. The capital cost of rSOC is relatively high, due to the early stage commercialisation of the solid oxide cell stack; however, it is predicted that the stack cost can be largely reduced once massive production is established and economics of scale are achieved. The cost of fuel source can be brought down if the rSOC stack is able to produce its own fuel (while operating in electrolysis mode) from low-cost electricity. However, fuel storage cost will need to be taken into consideration since the storage price varies significantly depending on the fuel type.

Heat integration is crucial for rSOC systems to achieve high efficiency in the electrolysis mode. The major improvement in terms of efficiency comes from accessing a waste source of low-grade steam (100-150°C). If this is not available, thermal storage can be added to rSOC system to store the waste heat produced in fuel cell mode to be used later in electrolysis mode, however, the capex of the thermal storage should be taken into account.

\(^2\) C.H. Wendel, P. Kazempoor, R.J. Braun, Novel electrical energy storage system based on reversible solid oxide cells: system design and operating conditions, J. Power Sources, 276 (2015), pp. 133-144

European Energy Storage Technology Development Roadmap towards 2030- Update.
The main characteristics of different energy storage technologies is shown in Table 1. A clear advantage of rSOC technology is the high energy amount that can be stored in large tank, underground storage or piping network.

<table>
<thead>
<tr>
<th>System</th>
<th>Energy storage capacity</th>
<th>Energy density (Wh/L)</th>
<th>Daily-self discharge (%)</th>
<th>Response time</th>
<th>Life time (years)</th>
<th>Cycle life (thousands cycles)</th>
<th>Round-trip efficiency</th>
<th>Initial investment cost (USD/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHS</td>
<td>&lt;12 GWh</td>
<td>0.5-2</td>
<td>0</td>
<td>3-6 min</td>
<td>30-60</td>
<td>10-30</td>
<td>70-85%</td>
<td>500-4600</td>
</tr>
<tr>
<td>CAES</td>
<td>&lt;30 GWh</td>
<td>2-6</td>
<td>&lt;0.3</td>
<td>3-6 min</td>
<td>20-40</td>
<td>8-12</td>
<td>42-55%</td>
<td>500-1500</td>
</tr>
<tr>
<td>FES</td>
<td>&lt;1 MWh</td>
<td>20-80</td>
<td>&gt;20% /h</td>
<td>&lt;4 s</td>
<td>20-30</td>
<td>&gt;20</td>
<td>85-90%</td>
<td>130-500</td>
</tr>
<tr>
<td>Battery Li-ion</td>
<td>&lt;0.8 GWh</td>
<td>200-500</td>
<td>0.1-0.3</td>
<td>&lt;1 s</td>
<td>5-15</td>
<td>1-20</td>
<td>90-95%</td>
<td>300-3500</td>
</tr>
<tr>
<td>SMES</td>
<td>&lt;20 kWh</td>
<td>0.2-2.5</td>
<td>10-15</td>
<td>&lt;1 s</td>
<td>20-30</td>
<td>20</td>
<td>&lt;95%</td>
<td>13-515</td>
</tr>
<tr>
<td>TES</td>
<td>&lt;7.2 GWh</td>
<td>80-500-500-3000</td>
<td>Almost zero</td>
<td>&lt;15 min</td>
<td>15-20</td>
<td>1-20</td>
<td>40-60%</td>
<td>500-1000</td>
</tr>
<tr>
<td>rSOC</td>
<td>&lt;170 GWh</td>
<td>16-35</td>
<td>Almost zero</td>
<td>&lt;5 min</td>
<td>13-30</td>
<td>12</td>
<td>84%</td>
<td>130-515</td>
</tr>
<tr>
<td>Flow batteries</td>
<td>&lt;1 GWh</td>
<td>16-35</td>
<td>Almost zero</td>
<td>&lt;1 s</td>
<td>15-20</td>
<td>1-20</td>
<td>40-60%</td>
<td>500-1000</td>
</tr>
<tr>
<td>Super capacitors</td>
<td>&lt;20 kWh</td>
<td>10-30</td>
<td>&lt;1 s</td>
<td>5-15</td>
<td>1-20</td>
<td>&gt;100</td>
<td>&lt;95%</td>
<td>130-515</td>
</tr>
</tbody>
</table>

Table 1 Comparison of main characteristics of different energy storage technologies. SMES=superconducting magnetic energy storage, TES= thermal energy storage and FES= flywheel energy storage. Adapted from Venkataraman et al.3 and 4

A key advantage of rSOC systems over other energy storage technologies is that chemicals/ hydrocarbon fuels can be produced from renewable hydrogen, which in turn may be produced by renewable electricity. In that case, the production of these fuels/chemicals takes place in a more sustainable way. rSOC systems working on hydrogen and synthetic methane can use the existing gas grids (which are present in almost all European countries) for storage as well as a source of fuel if the generated hydrogen is used for different purposes. This allows easy deployment of this technology in Europe. Such an existing grid storage is not an option for other energy storage technologies, which again gives rSOC systems an edge over other energy storage technologies.

rSOC systems can play a significant role in absorbing excess renewable power, thereby converting it to hydrogen or other chemicals downstream (in combination with other feedstocks). This way the hydrogen is definitely produced in a sustainable way but the same cannot be said for the downstream chemicals because that would depend on the other feedstocks. It is however envisaged that the emissions from production processes of downstream chemicals will be minimised due to the fact that at least hydrogen is produced from renewable source.

All these points position rSOC systems as a flexible energy conversion and storage technology when compared to conventional systems.

Even within electrochemical electrolyser technologies, SOC technology is potentially superior to alkaline and PEM based electrolysers5. This is because high-temperature electrolysis leads to reduced overpotentials at

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4 Tomas Díaz de la Rubia, Florian Klein, Budd Shaffer, Nathan Kim, Goran Lovric. Energy storage: Tracking the technologies that will transform the power sector. Deloitte 2015
5 P. Kazempoor, R.J. Braun, Hydrogen and synthetic fuel production using high temperature solid oxide electrolysis cells (SOECs), Int. J. Hydrogen Energy, 40 (2015), pp. 3599-3612
low current densities and also part of the energy required for electrolysis can be met by low-grade waste heat from industrial processes for the steam generation. These results in considerable savings in input energy required for the whole electrolysis process. Co-electrolysis, which is using CO\text{2} and H\text{2}O(g) to generate syngas, is an option only in high temperature electrolysers and not in low temperature electrolysers. The generated syngas can have various H\text{2}/CO compositions, which can then be used in Fischer-Tropsch processes to generate synthetic fuels.

The comparison of rSOC with the main competing energy storage technologies for a set of crucial characteristics is mentioned in Table 2.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>PHS</th>
<th>CAES</th>
<th>Batteries (Li-ion)</th>
<th>rSOC based energy storage system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>Limited</td>
<td>Limited</td>
<td>Can be deployed anywhere</td>
<td>Can be deployed anywhere</td>
</tr>
<tr>
<td>Scale</td>
<td>MW</td>
<td>MW</td>
<td>MW</td>
<td>100 kW, scalable to MW after technology maturation</td>
</tr>
<tr>
<td>Lifetime</td>
<td>&gt; 30 years</td>
<td>&gt; 20 years</td>
<td>10 years</td>
<td>&gt; 10 years</td>
</tr>
<tr>
<td>RT cycle efficiency</td>
<td>85 % max</td>
<td>85 % max</td>
<td>95 % max</td>
<td>60 % max(^6)</td>
</tr>
<tr>
<td>Storage duration</td>
<td>Hours/months</td>
<td>Hours/Days</td>
<td>Minutes/Days</td>
<td>Hours/months</td>
</tr>
<tr>
<td>Power-commodity-power capability</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

Table 2 Comparison of rSOC based energy storage system with other competing energy storage technologies.

1.2. Summary of techno-economic evaluation performed in BALANCE

An extensive techno-economic evaluation was performed in the BALANCE project and is detailed in the Deliverable 5.3 with is public and accessible on BALANCE website\(^7\).

In BALANCE, we have evaluated in detail the process chains of H\text{2}, CH\text{4} (both by steam- and co-electrolysis), syngas and methanol (both by steam- and co-electrolysis) with respect to three objective functions i.e., round-trip efficiency, SOFC-mode power density (i.e. considering the total power of the fuel consumed, in LHV terms, W/cm\(^2\)) and SOEC-mode power density (i.e. taking into consideration the power stored inside the synthesised product, in LHV terms W/cm\(^2\)). Application-independent databases for the optimal designs of each process chain are created. Three case studies of small-scale (50-400 kW) and large-scale (40 MW) applications for residential complexes to wind farm area are defined to evaluate which process chains are beneficial for which applications. For each case study, the design database is screened to optimally match the plant design and application scenario. The major conclusions from the techno-economic evaluation are given below:

\(^6\) Deliverable 5.3 from the BALANCE project (Results from the techno-economic analysis comparison between the possible process chains and environmental impact analyses)

\(^7\) https://www.balance-project.org/
Thermodynamic performance of the process chains considered

The process chains considered in the following paragraphs are six. Taking into account the product synthesized and the type of electrolysis, these are: (i) hydrogen via electrolysis, (ii) methane via steam electrolysis, (iii) methane via co-electrolysis, (iv) syngas via co-electrolysis, (v) methanol via steam electrolysis and (vi) methanol via co-electrolysis. The different fuel storages are located on the rSOC system site. Due to internal reforming/methanation, the P-CH4-P achieve high round-trip efficiency (45–60%, with no heat loss considered) and also high power density. There is no big difference between steam electrolysis and co-electrolysis. P-H-P process chain shows less round-trip efficiency (35–43%, assuming no heat loss) and power density. P-SYN-P’s round-trip efficiency (40–53%, no heat loss) and power density are in between. The P-MeOH-P has a broader efficiency range (up to 53%), comparable to P-SYN-P.

Case study observation

All three case studies are existing and practical, representing the current application scenario. For all cases, it is observed that the electricity demand is much larger than the variable renewable power production (which may change in the future, towards larger renewable’s installations), the case study thus requires either connecting to the grid or using a power generator. In such circumstances, the battery is not applicable for all case studies. This shows also the advantage of the rSOC system (wider application range), compared with battery. However, the rSOC system will also be operated at almost only one mode (SOFC mode).

Small-scale application highlights

The results of both small-scale applications, a smart grid area (60 kW) and a university building (300 kW), were similar. Regarding only the economic preference, the process chains are ranked as H2 > syngas > methanol >> methane. The difference between H2 and syngas systems are not large. The methane is less preferred due to the substantial methanator CAPEX at low capacities (which might be due to the uncertainty of cost functions extrapolated to such small capacities).

Large-scale application highlights

The results of 40 MW wind farm area showed that the economic preference is methane = syngas > hydrogen > methanol. There is no substantial difference among different process chains. Thus, for large-scale applications, there are more technological and design choices.

2. STATEMENT ON RESEARCH POLICY AND FUNDING

The EU-wide share of renewable energy use is rapidly and steadily increasing, to 20% by 2020, and a targeted 32% by 2030. Newly installed renewables capacity and investment in ‘new renewables’ dominate the assets being added to the energy infrastructure every year. By the mid-2020s, building a new wind farm is expected to become cheaper than running an existing gas plant, and by 2040, projections indicate that renewable energy sources will represent 60% of the European electricity mix.

One of the most critical aspects in this trajectory will be to ensure that the massive penetration of fluctuating and non-dispatchable renewables (in particular wind and solar) does not encounter bottlenecks in the distribution and utilization of the energy generated. New and crucial roles are therefore to be played by intelligent demand and grid management, by linking and integrating traditionally independent energy infrastructures, and by energy storage.

Solid Oxide Cells (SOC) in general, and reversible SOCs (rSOC or ReSOC) in particular, are devices that exchange energy between electrical and chemical form, at particularly high efficiencies and without polluting emissions. The potential of this technology lies precisely in this capacity to either generate electricity from fuel or store electricity into a fuel or chemical. The possibility to store renewable, clean power as a fuel or
substance that is easily stored and transported is a game-changing asset, allowing the electrical and natural gas grids to exchange energy, promoting zero-emission mobility and opening up to the opportunity of radically “greening” industrial and refinery sectors. Converting fuels back to power with near-zero emissions closes the loop and places rSOC technology flexibly in an increasingly circular economy.

As such, rSOCs can contribute directly to three out of ten Key Actions of the SET Plan, increasing efficiency in industry (Key Action 6), favouring efficient and flexible energy storage (Key Action 7) and scaling up the production of renewable, alternative fuels (Key Action 8). The BALANCE project has carried out a survey of funding instruments and availability in the European Member States to assess the potential for rSOC deployment by 2030. The survey integrated technology stakeholders’ views with focused desk research.

For SOC technology to adequately contribute to these Actions, considering a progress from TRL 4 to 7 and based on estimates by Hydrogen Europe and the European Energy Research Alliance, development of SOC technology should need around 240 M€ from here to 2030. Making power-to-X more efficient and better integrated with industrial processes, it is expected that rSOCs can then contribute to accommodate an additional 20-40 GW of renewable generation by 2030, resulting in the transfer of 70-140 TWh of Europe's renewable energy to other sectors, generating both energy storage and innovation capacity.

Above all, the public funds required to achieve this objective are already in circulation, considering EU Regional funds alone, addressing the Thematic Objectives Research and Innovation (TO1), Low-carbon economy (TO4) and Transport and energy networks (TO7), and earmarking 1% of the budget dedicated to these areas. This 1% is derived from conservative estimates of the contribution rSOCs could realistically make – by increasing power-to-gas efficiency, added value and flexibility – towards the achievement of 60% renewable electricity in the EU by 2030, the integration of infrastructural networks and EU technological competitiveness, as well as taking into consideration other forms of surplus renewable energy storage and other electrolysis technologies. This quota of EU Regional funds then amounts to around 500M€ for the eighth Framework Programme, Horizon 2020. This is double the amount needed, as derived by the authors and based on estimates of sector specialists (240 M€), showing that the public funds and policy instruments are already accessible, they just need to be adequately rationalised and focused to generate the required innovation to accommodate massive penetration of renewables, transferring clean and sustainable energy to the industrial, energy and transport sectors, and thereby pave the way to the ultimate achievement of a future-ready, resilient Energy Union.

An extensive analysis of funding available for the Solid Oxide Cell technology can be found in the deliverable 2.5 (Stakeholder and activity catalogue – Update and policy recommendations).

3. RECOMMENDED ACTIONS TO SUPPORT THE DEPLOYMENT OF SECTOR COUPLING TECHNOLOGY

This chapter recommends actions to support the deployment of sector coupling technology, the so-called Power-to-X technologies.

The reversible SOC (rSOC) technology is currently at TRL 5, lower than single-direction power-to-X technology, for instance Solid Oxide Electrolyzer, Proton-Exchange Membrane Electrolyzer and Alkaline Electrolyzer, which is taken into account in the recommendation actions below. The rSOC technology has the specific advantage that it is also capable of the reverse operation (fuel cell mode) and is often referred as a Power-to-X-to-Power technology, “X” standing for hydrogen or possibly other intermediates like methane, methanol and ammonia among others.
Several organisations have published recommendations concerning the deployment of electrolyzers as sector coupling technologies, such as IEA with their report “the Future of Hydrogen” in 2019. The FCH JU published the “Hydrogen Roadmap Europe: a sustainable pathway for the European Energy transition” in 2019. NOW GmbH (National Organisation Hydrogen and Fuel Cell Technology) coordinated a report on the “Industrialisation of water electrolysis in Germany: opportunities and challenges for sustainable hydrogen for transport, electricity and heat” in 2018. The recommendations below are in line with these advisory documents.

The following market activation measures are suggested:

- Remove or decrease tax and levies on renewable electricity used by water/steam electrolyzer. The rationale for this measure is that Power-to-X technologies can alleviate constraints placed on the grid by the addition of Variable Renewable Electricity Sources (wind and solar). Therefore, tax and levies presently discourage the implementation of sector coupling or electrical energy storage. In the worst case, power is taxed two times in an electrical energy storage plant making it difficult to compete with a rapidly dispatchable fossil fuel alternative.

- Set mandates for renewables shares in key industries using a large consumption of hydrogen, such as oil refineries and ammonia production plants. These two applications consume yearly 280 TWh of hydrogen, about 80% of hydrogen produced in Europe today. This creates a market for certified renewable hydrogen by guaranteeing demand. Oil refineries are already covered by the Renewable Energy Directive II where it is stated that renewable hydrogen used in fuel processing can be included in the share of renewables in transportation fuel. However, ammonia production is not included in that directive. This measure would enable to bring the CAPEX of electrolyzers down by supporting production volume, strengthening the supply chain, scaling up production lines and increasing the degree of automation in manufacturing, quality assurance and testing.

- The gas grid could be progressively decarbonized by a binding target of renewable content in the gas grid. Favouring the injection of renewable hydrogen would support a scale up of electrolyzer capacity and effectively link the electrical grid with the gas grid. Hydrogen can be blended with natural gas up to 20% without requiring technical adjustment in the grid and most appliances. However, regulation concerning hydrogen blending should be harmonized throughout Europe. It is also straightforward to convert renewable hydrogen into synthetic methane to increase the share of renewables bypassing regulation limits on hydrogen content in the natural gas mixture. Harnessing the capacity of the natural gas grid leverages existing infrastructure and can mobilise vast amounts of stored renewable energy.

- Creation of a system for certified renewable hydrogen which is flexible in sourcing renewable electricity, meaning that guarantee of origin would be acceptable as renewable electricity. This

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8 https://www.iea.org/publications/reports/thefutureofhydrogen/
10 https://www.now-gmbh.de/content/service/3-publikationen/1-nip-wasserstoff-und-brennstoffzellentechnologie/181204_bro_a4_indwede-studie_kurzfassung_en_v03.pdf
11 Hydrogen Roadmap Europe, FCH JU, 2019
12 DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources
14 https://www.netbeheernederland.nl/_upload/Files/Toekomstbestendige_gasdistributienetten_133.pdf
Grant agreement number: 731224.

A measure would greatly extend the number of annual operation hours, bringing the specific CAPEX down. This action is supported by the FCH JU with the Certifhy project\textsuperscript{15}. The aim of Certifhy is to create the path forward for an actionable Guarantee of Origin (GO) scheme with a pilot demonstration of the hydrogen GO scheme and the creation of a Stakeholder Platform to give the scheme its legitimacy. The project will define the scheme’s governance, as well as its processes and procedures over the entire GO life cycle: from auditing hydrogen production plants, certification of Green or Low Carbon hydrogen production batches, through issuing and trading to “usage” of GOs. It is recommended that this certification should be extend for synthetic fuel produced from renewable hydrogen and renewable CO\textsubscript{2}.

- CAPEX subsidies are suggested for first-of-a-kind applications and new technology introduction to the market. CAPEX subsidies have actually a smaller impact on the price of the hydrogen compared to the extension of operating hours with the use of renewable guarantee of origin as stated in the previous point. However, first-movers will face high initial investment and the highest risk in the deployment curve and should be supported.

Support measures for market activation are the following:

- Standardisation of approval procedures for the deployment of power-to-hydrogen or power-to-gas plants. The mapping of approval procedures in Europe is being documented in the Hylaw project\textsuperscript{16}, supported by the FCH JU. The Hylaw project maintains an extensive database as regards legal and administrative procedures and barriers in Europe for the deployment of hydrogen technologies.

- Standardisation of test procedures for electrolysis technology. There is a lack of widely accepted test procedure standards for electrolysers, especially for Solid Oxide Electrolysers. In the ISO standard for low temperature electrolysers\textsuperscript{17} Solid Oxide Electrolysers are excluded. Triggered by the European FCH JU-supported project SOCTESQA\textsuperscript{18}, the IEC has initiated a standardisation project for fuel cell systems operating in reverse mode for energy storage, which is very relevant for Solid Oxide Electrolysers\textsuperscript{19}, being the only truly reversible technology.

- R&D funding to support development of technology performance (efficiency, durability, capital cost) and manufacturing processes to prepare for the next generation of the technology and maintain competitive advantage from overseas (in particular China, Japan, Canada and USA).

- International cooperation is needed in order to track progress of the different countries but also for cross-border infrastructures and sharing best practices.

\textsuperscript{15} https://www.certifhy.eu/
\textsuperscript{16} https://www.hylaw.eu/
\textsuperscript{17} ISO 22734:2019 Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications
\textsuperscript{18} http://www.soctesqa.eu/project
\textsuperscript{19} Fuel cell technologies - Energy storage systems using fuel cell modules in reverse mode (preparing IEC 62282-8-101, -102, -201)