Disclaimer: this document reflects the work of the Electrolyser Partnership set-up in the context of the European Clean Hydrogen Alliance. The input identified does not necessarily represent the position of the European Commission nor the position of individual members of the Alliance.
Foreword

Electrolysers are electrochemical devices that, with the input of electricity, split water into hydrogen and oxygen. Although electrolysis currently contributes to only a small portion of hydrogen production (approximately 4%), its market share is anticipated to experience significant growth. Together with fuel cells, they will be two key pieces of equipment required for the hydrogen economy, thereby playing a central role to decarbonizing energy systems.

According to the Electrolyser Partnership Declaration in 2021, reaching REPowerEU objectives of 10 million tons of domestic clean hydrogen production by 2030 would require around 100GW of installed electrolyser capacity in Europe. In order to achieve such benchmarks, the Electrolyser Partnership is working together to make the European and international market for electrolysers a reality.

During the 2nd Electrolyser Summit of June 2023, the State of Play of the European value chain for electrolysers highlighted that Europe has today approximately 3.1GW/y of manufacturing capacity, with several companies planning to increase this to 21GW/y by 2025, in line with the expected demand outlook in Europe and globally. The expansion plans are remarkable, with a compound annual growth rate of 88% in the next three years.

However, there are challenges related to building and expanding integrated supply chains and the availability of raw materials at the required scale. Critical raw materials are only one part of the puzzle: basic chemical components and high-end performance materials will also be essential for electrolysers. All these advanced materials, engineered via specialized processing and synthesis technology, will play a critical role in the nascent hydrogen economy.

To address these challenges, the European Commission published a Green Deal Industrial Plan in February 2023. This plan includes two complementary pieces of legislation, the Net-Zero Industry Act (NZIA) and the Critical Raw Materials Act (CRMA), which together aim to develop a solid regulatory framework for sustainable supply chains for hydrogen technologies and their raw materials.

While NZIA demonstrates a commitment to bolstering the European clean tech manufacturing value chain by facilitating access to funding, expediting permitting procedures, and offering strategic labelling for net-zero technologies and particularly hydrogen, the CRMA is not providing to hydrogen technologies the same level of attention in the current trilogue negotiations. This could potentially leave their needs somewhat neglected.

While echoing the commitment of European Commission President Ursula von der Leyen that “the future of our clean tech industry has to be made in Europe”, it is essential to maximise the growth potential of the Green Deal and ensure a compelling business case for clean energy supply chains in Europe, from the raw material to the end product.

Therefore, the Electrolyser Partnership is urging EU institutions and other relevant stakeholders to keep electrolyser technologies and their critical raw and advanced materials as priorities when developing the legislative frameworks of the CRMA and NZIA. This will directly contribute to strengthening European industrial leadership by ensuring safe, resilient, and sustainable hydrogen supply chains.
Which raw and advanced materials are needed for electrolysis technologies?

There are four main electrolyser technologies: PEM (proton exchange membrane), AWE (alkaline), AEM (anion exchange) and SOEC (solid oxide). The first two technologies have already achieved significant market adoption, whereas the latter two are in advanced stages of development although with a lower technology readiness level (TRL).

By 2050, PEM and AWE technologies are expected to represent more than 75% of installed electrolysers globally (43% for AWE, 33% for PEM). Because of this increase, the main inputs for these technologies will experience increased pressure, for instance on Platinum (Pt) but especially Iridium (Ir), which are both Platinum Group Metals (PGMs).

Demand for Platinum is expected to reach 9 to 34 tons globally by 2050, and for electrolysers the estimates assume that a range between 3 – 9 tons will be dedicated to those manufactured in Europe. Fewer concerns are however expected with Platinum current availability in the global market, due to stable supply chains and expected increased recycling and thrifting.

Concerning Iridium, demand today is around 1 ton globally, but it is expected to grow to the 5 – 17 ton range by 2030. 17 tons would already represent above 200% of the global available supply of Iridium in 2020. In the absence of a strong reduction in materials usage and/or catalyst loading per power unit (compared to estimate of 0.2 – 0.25 ton per GW), the demand is expected to jump to the 9 – 34 ton range globally by 2050 with the EU accounting for up to 25% of global demand.

Along with raw materials, other advanced materials such as fluoropolymers and electrocatalysts should also be monitored. Without advanced materials, key strategic net-zero technology applications cannot operate at scale, including electrolysers. The manufacturing and regulatory constraints in Europe of such materials could lead to additional market uncertainties in the forthcoming years.

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1 JRC, Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, Publications Office of the European Union, Luxembourg, (2023)
2 Joint briefing note IEA
3 Ibid
4 Ibid
5 The Electrolyser Partnership reserves the right to consider the list as incomplete and possibly not fully representative of its members’ current usage of critical raw materials, as listed by the JRC.
Which raw and advanced materials are likely to be bottlenecks for the hydrogen industry?

When it comes to the supply chain for electrolysers, it is essential for the EU to pay attention to the raw materials aspect, especially when compared to China and Africa. In the case of various electrolysis technologies, such as PEM technology, the EU holds only 1% of the supply of its most relevant CRMs. On the other hand, the EU is performing admirably when it comes to advanced materials, and it is worth noting that China is always a close competitor in this regard.

The intensities of the top-10 critical raw materials for electrolysis technologies could be weighed down by the materials needed by fuel cells, which are often shared and have similar criticality rankings. For the two most mature electrolysis technologies (PEM and AWE), three (two of which are for PEM) have a criticality factor above three (Figure 2): Iridium, Ruthenium and Lanthanum.⁶

For advanced materials, the technology most at risk due to its supply chain dependencies is PEM, followed by AEM and SOEC. Advanced materials with the highest supply risks (and their main suppliers) are: raney Nickel (India), titanium fiber mesh (China), iridium and its derivatives (different origin), carbon supported Platinium (Pt/C) (US), yttria stabilised zirconia (China), silver brazing alloys (India), benzyltrimethylammonium hydroxide (China), nickel-chromium alloys (China), and nickel foam (China).⁷

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⁶ The Electrolyser Partnership reserves the right to consider the list as incomplete and possibly not fully representative of its members’ current usage of critical raw materials, as listed by the JRC.

⁷ JRC, Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study, Publications Office of the European Union, Luxembourg, (2023)

⁸ The Electrolyser Partnership reserves the right to consider the list as incomplete and possibly not fully representative of its members’ current usage of advanced materials, as listed by the JRC.
Figure 3. Supply risk of advanced materials in the electrolyser supply chain

Source: JRC, Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study (2023)
Annex I – Electrolyser technologies and barriers

**Fig. 4 - Glossary of Acronyms**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
</tr>
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<tbody>
<tr>
<td>AEMEL</td>
<td>Anion Exchange Membrane Electrolyser</td>
</tr>
<tr>
<td>AWEL</td>
<td>Alkaline Water Electrolyser</td>
</tr>
<tr>
<td>Co</td>
<td>Cobalt</td>
</tr>
<tr>
<td>CRM</td>
<td>Critical Raw Material</td>
</tr>
<tr>
<td>F</td>
<td>Fluorine, chemical element</td>
</tr>
<tr>
<td>H₂</td>
<td>Hydrogen, molecular form</td>
</tr>
<tr>
<td>Ir</td>
<td>Iridium, chemical element</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>MRL</td>
<td>Manufacturing Readiness Level</td>
</tr>
<tr>
<td>Ni</td>
<td>Nickel, chemical element</td>
</tr>
<tr>
<td>PEMEL</td>
<td>Proton Exchange Membrane Electrolyser</td>
</tr>
<tr>
<td>PGM</td>
<td>Platinum Group Metal</td>
</tr>
<tr>
<td>Pt</td>
<td>Platinum</td>
</tr>
<tr>
<td>RDI</td>
<td>Research, Development &amp; Innovation</td>
</tr>
<tr>
<td>REE</td>
<td>Rare Earth Elements</td>
</tr>
<tr>
<td>Sc</td>
<td>Scandium</td>
</tr>
<tr>
<td>SOEL</td>
<td>Solid Oxide Electrolyser</td>
</tr>
<tr>
<td>SRM</td>
<td>Strategic Raw Material</td>
</tr>
<tr>
<td>Ti</td>
<td>Titanium, chemical element</td>
</tr>
<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>Y</td>
<td>Yttrium</td>
</tr>
</tbody>
</table>

**Fig. 5 - Summary of main challenge(s) relating to CRMs, SRMs and advanced materials in electrolyser technologies**

Electrolyser technologies below are listed from highest technological readiness to lowest.

**A) Doing More with Less - Improving use/efficiency of CRMs/SRMs utilisation**

<table>
<thead>
<tr>
<th>Electrolyser Technology</th>
<th>Brief Summary of Challenge(s)</th>
</tr>
</thead>
</table>
| AWEL                    | 1. Ni now classed as a SRM – A Ni reduction in its use would be beneficial in medium to long term.  
2. Co and/or Pt use should be reduced to a minimum consistent with optimal efficiency and durability.  
3. To be achieved whilst delivering on KPIs (e.g., improved current densities, increased pressure operation at low loads, etc.). |
| PEMEL                   | 1. PGMs use as catalysts or coatings - Ongoing challenge (e.g., to large scale commercialisation) is to minimise Ir use (e.g., as electrolyser catalyst) without compromising efficiency and durability.  
2. Reduction in Pt use may also be required without compromising efficiency and durability.  
3. Reduction must deliver on KPIs (e.g., longer device lifetime improves material utilisation)  
4. Reduction in CRM use in tandem with other component development (e.g., reducing Ir use through design of porous transport layers and membrane properties), if high performance systems are to be delivered. |
5. Optimise electrode structure to increase catalyst utilisation.

SOEL

1. Y, Sc, Co and REE (e.g., Lanthanum) of concern at large scale device deployment.
2. Reduction in use must lead to enhanced mechanical strength, oxygen ion conductivity, high current densities, and chemical stability of components.
3. Ni use of potential concern with respect to long term market development (e.g., resource competition).

AEMEL

1. Ni as the main catalyst at current loading of concern if the market adopts technology at large scale (alongside competition in a future market).
2. Ni loading to be reduced and performed in tandem with e.g., membrane performance improvements.
3. In case AEMEL uses Co and/or Pt, the use should be reduced to a minimum consistent with optimal efficiency and durability.

B) Doing More with Alternative(s) – Substitution of CRMs/SRMs.

<table>
<thead>
<tr>
<th>Electrolyser Technology</th>
<th>Brief Summary of Challenge(s)</th>
</tr>
</thead>
</table>
| AWEL                    | 1. CRM substitution requires new highly active and efficient catalytic electrodes to increase current density. Possible replacements should be undergoing thorough assessment of overall reduction of risks.  
2. Requires design, evaluation and adoption of higher performance catalyst morphologies and/or a deeper integration of device elements (e.g., catalyst and electrode surface). |
| PEMEL                   | 1. PGM substitution requires identification of new “lower in CRM content” catalyst compositions, morphologies, etc. that enable higher catalytic activity per atom and the necessary durability to maximise performance in tandem with high material utilisation.  
2. High performance delivered through appropriate support material design (e.g., conductivity, morphology, etc.) and interface engineering.  
3. Advanced CRM free coatings of device elements (e.g., transport layers, bipolar plates) required (e.g., through high entropy alloys) in combination with deeper device integration (e.g., hybrid transport layer/bipolar plate). |
| SOEL                    | 1. New CRM-free ceramics compositions/composites (e.g., featuring optimised functionality, structure, etc.) that enable improved durability (e.g., towards high steam contents) and performance (e.g., low overpotentials, poison tolerant, etc.) |
| AEMEL                   | 1. As per AWE, future status of Ni will likely dictate direction.  
2. Substitution requires design of highly active and efficient catalytic electrodes to deliver KPIs (in tandem with membrane development, interface engineering etc.).  
3. More abundant transition metal-based systems are in focus, particularly those that maximise material utilisation (e.g., single atom catalysts). |
Annex II – Iridium factsheet

Iridium is a scarce material, being a by-product of platinum mining. Hence, assessment of priority and respective measures should be related to availability versus the application of the material. This would directly affect the possible use-cases for Iridium in other applications, like spark plugs, where Iridium most probably can be easier substituted than in PEM electrolyzers, and for which the recycling rate is low due to limited collection at end-of-life. Despite new Iridium applications or changes in Iridium use for established applications, existing Iridium-containing applications must be challenged and re-assessed for higher circularity.

At this moment, yearly Iridium use is based on only 20% recycled content), with much Iridium recycled in “closed loop” processes where ownership of the metal remains within the industry it is being used in. It is therefore vital to increase the recovery rate for existing recycling streams and have the possibility for Europe to access untapped recycling streams. Higher share of recycled material also leads to less carbon-intensive Iridium (CO2 footprint almost 90% lower) as well as lower dependency on primary sources.

Although Iridium will always be supplied from primary and secondary streams, the inclusion of streams from electrolyzers membrane production scraps and end-of-life electrolyser materials must be considered from the beginning. Furthermore, capacities at every step of the material return process should be expanded and be optimised with respect to lower Iridium concentration in already existing applications showing low recycling rates, as well as further develop Iridium-containing hydrogen applications. For the latter, regulatory frameworks for return rates (incentives or penalties) could accelerate technological development and industry/user awareness.

As mentioned, primary materials will still be very important and since Iridium mainly comes from South Africa, Europe should wisely seek to enter partnerships and contracts to strengthen the regional industrial development and thus enabling social benefits. Sourcing strategies must be assessed with a holistic view since high volumes and potential stockpiling would negatively impact the Iridium market. Stockpiling could easily undermine established trading tools and measures that help keep a certain balance and control on the Iridium price level.

Ultimately, thrifting by means of technology advancement is necessary to reduce the use of Iridium and mitigate any supply bottlenecks for PEM electrolyzers. Such a process is well established but must be accelerated by earlier implementation of projects with high TRL. This topic could and should be implemented quickly since materials are already available by various catalyst producers (at TRL > 7) that could mitigate short-term bottlenecks during in the ramp-up phase (Figure 6).
Fig. 6 – Iridium projections until 2050

With further thrifting and recycling there is more than sufficient potential until 2050.

With already today available low loading catalysts more than the announced 70 GW until 2030 can be built. From 2033 on, Recycling will contribute.

Without thrifting, targets cannot be reached.

Source: Hereaus Precious Metals GmbH
This position paper has been drafted by the Electrolyser Partnership, a roundtable of the European Clean Hydrogen Alliance

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