JM

Two key focus areas will ensure iridium availability does not stall electrolyser growth

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Johnson Matthey is confident that iridium supply can be made to support PEM electrolyser growth ambitions to 2030 and beyond if the supply chain works together to innovate, recycle and reuse this critical element.

Leading forecasters, such as the International Energy Agency, see hydrogen growing to become as big as electric power is today by 2050, as it is increasingly taken up across industry, transportation and the power sector. Proton exchange membrane (PEM) electrolysis is one of the technologies used to produce electrolytic hydrogen, using iridium and platinum, of which the iridium will need to be actively managed as demand for PEM electrolysers grows.

Introduction

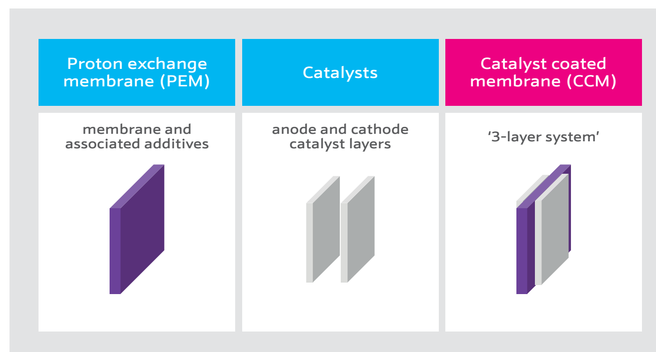
Electrolytic hydrogen is forecast to play a major role in the transition to a net zero economy by 2050. From <1 GW today, the forecast installed capacity required ranges from ~150 GW to >800 GW, using a combination of electrolyser technologies. To power this electrolysis capacity, renewable power is needed, which is variable and intermittent. PEM electrolysers can operate with high efficiency levels, even when connected to intermittent renewable power, due to their more favourable response to varied loads (faster transient response times and low gas impurity at low power ranges) and rapid 'start-up' mechanisms. In addition, PEM systems offer other benefits, including:

- A small footprint (cells are compact and easy to handle without heavy lifting equipment)
- Simple balance of plant requiring low levels of maintenance
- Producing hydrogen from only water without the use of corrosive chemicals

These advantages make PEM electrolysers well-suited to play a key role in the growth of electrolysis capacity.

PEM technology

PEM electrolysers use catalyst coated membranes (CCMs) at their core to split water into oxygen and hydrogen under an electric current. For this reaction to occur, iridium-based (at the anode) and platinum-based (at the cathode) catalysts are used. These platinum group metals (PGMs) are ideal catalysts due to their high activity levels and inherent stability in the electrolyser system – there are no known suitable substitutes that work as effectively in the high-voltage, acidic conditions of a PEM cell. Platinum is used at a low loading already in CCMs but current iridium usage for every kilo of hydrogen produced presents a significant opportunity for optimisation.



PGM overview

What is the platinum group? It is a set of six precious metals – platinum, palladium, rhodium, ruthenium, iridium and osmium – that are close together on the periodic table and have a unique combination of useful properties that make them indispensable in their applications. They also occur in association with each other in mineral deposits.

While platinum is mined globally and considered an 'abundant' PGM, iridium is only extracted as a minor by-product of platinum mining, making it much scarcer. To illustrate, each year approximately 190 tonnes of platinum is mined as opposed to about 7.5 tonnes of iridium.

Iridium is one of the densest elements that exists (22.65 g/cm^3). It is so dense that the iridium mined each year (7500 kg) would fit comfortably into seven carry-on sized suitcases (55 cm x 35 cm x 25 cm or 0.05 m^3).

Iridium has four main applications:

1. Electrodes in various electrochemical processes e.g., for chlorine production, water treatment and copper foil production
2. Electronics e.g., as crucibles for growing crystals used in mobile phones, and in organic light-emitting diodes (OLEDs)
3. Process catalysts for production of certain chemicals e.g., acetic acid
4. Ignition tips in premium spark plugs e.g., long-life plugs for cars and those used in aerospace

In most of these applications, iridium is the only material which can be viably used, and because it is so scarce and valuable, it is actively recycled and re-used as much as possible when it can be. However, with iridium prices having increased substantially in the past few years, applications where iridium can be substituted are starting to switch – for example, premium spark plugs are moving to alternative PGMs. As technology changes take time, the true amount of iridium made available for electrolysis through substitution in other applications will not be clear for some years to come.

Iridium challenge

It has been argued that the scarcity of iridium and its uniqueness in its applications creates an impossible challenge for scaling up PEM electrolysis to the capacities needed. This is simply not true.

The Hydrogen Council estimates that to reach net-zero emissions by 2030, PEM capacity will need to increase from today's level of <1 GW to potentially 80-100 GW by 2030[1] (assuming a 40% PEM market share). As recently as 2021 the amount of iridium required for 1 GW of electrolyser capacity was 400 kg, leading some to argue that the 2030 target would require 32-40 tonnes of iridium. Considering electrolyser production will ramp up over time, with more electrolysers being built each year, at these loadings the capacity build would admittedly be very challenging in the remaining eight-year timeframe.

There is, however, no reason to expect that 'all things will remain equal' over the coming years. Indeed, things must not remain the same. JM advocates that two things need to happen to meet long-term electrolyser capacity targets:

Firstly, iridium must be used much more efficiently. If CCM performance can be improved such that only 100 kg per GW is required, the 80-100 GW target then needs only 8-10 tonnes of iridium over eight years, making it a lot more conceivable to hit, with further thrifting needed to meet 2050 requirements.

It is critical to note that taking this first step is not just about using less iridium in CCMs but also formulating more effective catalysts, more efficient membranes, and tuning the way they are assembled into CCMs in order to maximise performance. Simply put, by making CCMs more efficient, as much hydrogen as possible can be produced from every valuable gram of PGM used – and as these developments progress, the amount of iridium required for every GW of capacity will fall. Hydrogen fuel cells provide an example of innovation driving the increasingly efficient use of PGMs over time. PGM usage has been reduced from ~3 g/kW in 1991 to 1.1 g/kW in 2005 and 0.14-0.2 g/kW today, i.e. an order of magnitude decrease over a 30 year period, and only a few grams will be needed for the fuel cell vehicles of the future.[2–7]

Secondly, recycling iridium will become essential. To illustrate, imagine if 1 GW today is built with 400kg of iridium, but in several years, due to innovation this 400kg of iridium could build a further 4 GW or more. In the long term, the total amount of iridium in the PEM sector will accumulate as more iridium is recycled and enable more and more capacity to be built in coming decades. For this to be realised, we must put in place a recycling system which returns recycled (known as 'secondary') iridium back into new electrolysers in a 'closed loop' – where end-of-life products are processed to recover the metal and return it to the original owner for reuse in the same application, thereby considerably reducing the ongoing requirement for primary (mined) metal. Substantial quantities of iridium are currently circulating constantly in closed loops in existing industrial applications, which is generally unseen by the market (Johnson Matthey does not report closed loop recycling in its supply and demand figures).

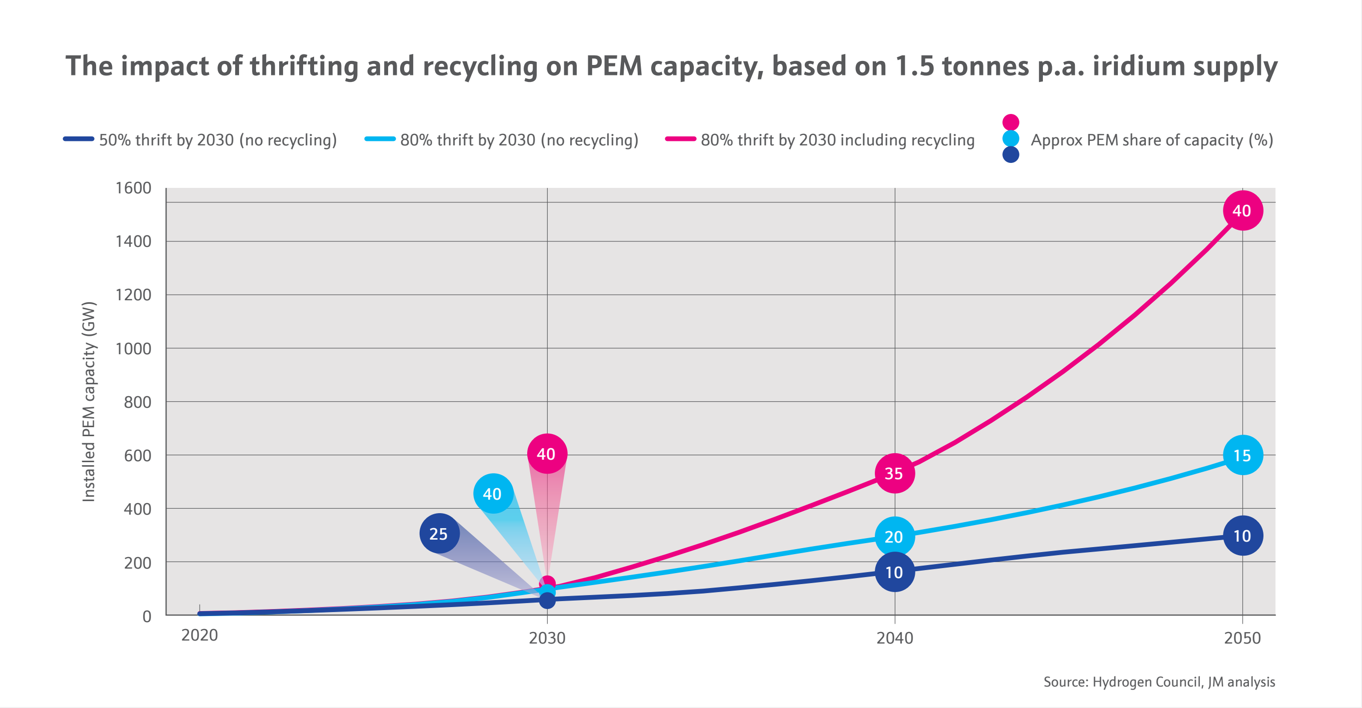


Figure 1. [8]

Demonstrating the potential for PEM growth

The key question then is will there be enough iridium available for PEM electrolysis capacity to grow as hoped? The answer is yes – if we maximise the efficiency with which we use the metal, and if we recycle. Hopefully it has become clear that both of these should be expected for a new technology using a PGM.

To illustrate the power of this, let's look at a theoretical case where 1.5 tonnes per year of iridium is available to be used in PEM electrolysis (this is around 20% of annual mined production and therefore is a realistic assumption). How much PEM capacity could be built up within that constraint?

Today's technology uses around 400 kg per gigawatt of PEM capacity, so 1.5 tonnes doesn't buy you a lot of gigawatts. The blue lines on the chart show the impact of progressive thrifting: reduce the metal per gigawatt by 80% by 2030 and you can build 60% more capacity than if you only halve your metal requirement by 2030[3]. Add recycling to that, with an assumption that it happens in a closed loop, so the iridium is retained within this industry, and we see a growth curve that gives over 2.5 times more capacity by 2050 than with thrifting alone.

In this exercise, even within a constraint of 1.5 tonnes per year of iridium, PEM can make up over 40% of market share based on installed capacity, which would be over 1,000 GW by 2050 (based on the Hydrogen Council 1.5°C scenario and JM analysis).

JM supporting electrolyser growth

As specialists in electrochemistry and PGM catalysis, and with years of experience working with the complexities of iridium, JM knows how to maximise the efficiency of these metals. We've done it before, for example developing leading catalysts for automotive catalytic converters and for fuel cells. JM is applying that knowledge to support the industry in achieving a lower levelised cost of hydrogen (LCOH), so electrolytic hydrogen can compete with alternatives.

To achieve this step change, CCMs must be developed which use less iridium whilst still delivering high performance. This will allow electrolyser manufacturers to produce more hydrogen per GW and per kilo of iridium used, or to use less power and less iridium to produce the required amount of hydrogen.

Once the CCMs and stack reach the end of their service life and need to be changed, as the largest secondary PGM recycler in the world by volume, JM is well placed to efficiently and securely recover the PGMs globally, using an established recycling network and manufacturing operations in Europe, North America and Asia. JM today operates an advanced process for extracting, separating, and refining iridium to a high purity level (particularly important because iridium is one of the hardest PGMs to refine) and continues to invest in research and technology in this area.

JM does not stop there. Our global team of PGM experts support customers in sourcing and managing their PGM supply whilst providing world-leading market updates and insights to inform decision-making.

Summary

We believe that the challenge of growing PEM electrolyser capacity will not be stalled by the availability of iridium – taking the right steps as we have seen previously by the autocatalyst industry, iridium should not be a significant bottleneck for the growth of PEM electrolysis capacity. Yes, there will be potential constraints to navigate, but these can be managed, provided that the sector commits to:

1. Continued innovation to improve electrolyser efficiency, doing more with less and ensuring we use every atom effectively, supporting a reduction in the levelised cost of hydrogen.
2. Recycling and building end-of-life plans for electrolysers, stacks and CCMs when planning the initial installation, formalising the eventual recovery process.

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8. JM projection assumes continued thrifting to 2050, based on the progression seen in other PGM applications. The US Department of Energy's Hydrogen from Next-generation Electrolyzers of Water (H2NEW) consortium's ultimate target for iridium loading is assumed to be reached in 2040, with further thrifting to around half that level by 2050.

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Billingham, UK
Tel +44 (0) 1642 553601
www.matthey.com

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