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PLATINUM CYCLE AND DEMAND IN THE EU DRIVEN BY FUEL CELL AND ELECTROLYSER TECHNOLOGY DEVELOPMENT

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ABSTRACT

Platinum is of high importance for several emerging energy technologies which could help address our sustainability challenges such as climate change; but their increasing use could also lead to potential supply risk issues due to the over-concentration in mining and production. This paper used a dynamic material flow analysis (MFA) method to quantify current and future European platinum cycle by 2050 considering optimistic, pessimistic, and medium development of fuel cells, electrolysers, and other applications. We found when the primary platinum use shifted from autocatlysts to fuel cells, the European platinum demand will increase significantly and thus result in potential supply risks. Therefore, better end-of-life management systems to address the high losses of open-loop recycling (e.g., autocatalysts) and changing framework conditions (e.g., quantity and quality) of recyclability would be important. In addition, material efficiency and substitution will also become important in an increasingly constraint climate future.

Keywords: Fuel cells, Platinum, Critical materials, Platinum recycling, Emerging energy technology

NONMENCLATURE

Abbreviations

PGMs	Platinum Group Metals
FCVs	Fuel Cell Vehicles
Pt	Platinum
CEVs	Combustion Engine Vehicles

1. INTRODUCTION

The UN Climate Change conference in Katowice, Poland, in December 2018 reaffirms once again the urgency to accelerate achieving a more sustainable and climate safe environment. The International Energy Agency (IEA) reports that 62% of anthropogenic greenhouse gas (GHG) emissions are based on fossil fuels [1]. Fuel cells are widely regarded as one of the promising energy technologies that can help reduce GHG emissions of the transportation sector [2]. They convert hydrogen and oxygen into water and electricity. Similarly, electrolysers generate hydrogen from water in a pollution-free way by being connected to a renewable energy sources like hydropower, wind, or photovoltaic [3]. However, both technologies utilize Pt as catalyst to run the chemical reaction [4], which, as one of the Platinum Group Metals (PGMs), are categorized as critical materials due to their supply risk and economic importance by the EU. The supply of PGMs is relatively concentrated to a few countries such as South Africa and Russia, where a unstable political situation could become an issue for the supply [5].

The anthropogenic cycle of PGMs at both Europe [6] and global levels [7] has been explored previously mostly via a material flow analysis (MFA) approach. The stocks and flows, losses, recoveries, and environmental impact are quantified in these studies. However, these MFA studies of PGMs didn't include future predictions which contain innovative PGMs consuming technologies, especially fuel cells and electrolysers. There is a significant potential in future development of fuel cells [4] , which could have big impact on PGMs demand.

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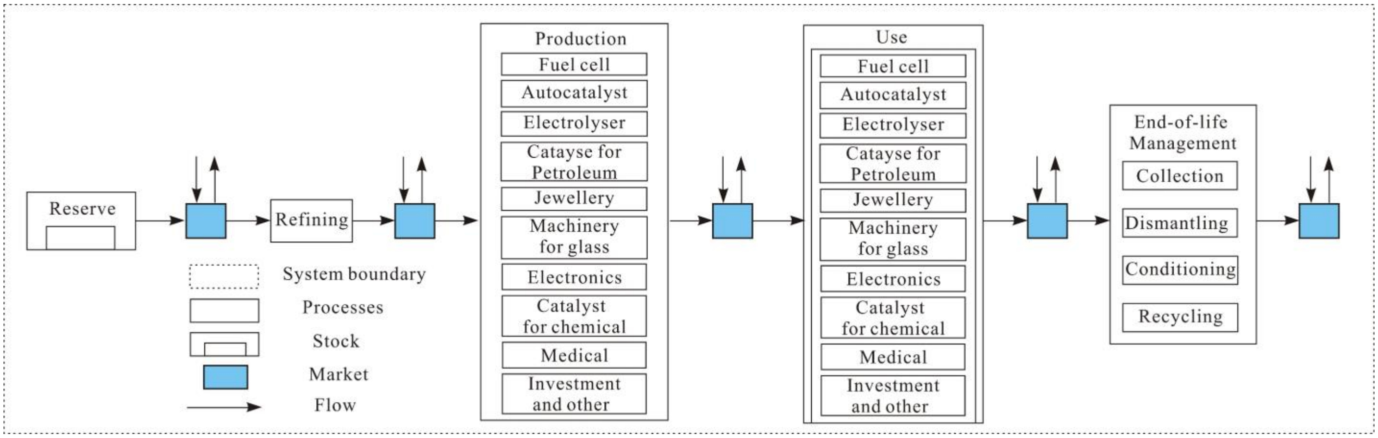

Fig 1 System definition for the EU platinum cycle

This paper aimed at providing a more comprehensive analysis of current and future European Pt cycle including relevant processes, stocks and flows of primary and secondary production, and end-uses, especially with consideration of emerging technologies such as fuel cells and electrolysers in different scenarios.

2. METHOD

2.1 System definition

The European Pt cycle is described, including refining, production, different end-uses, recycling, and international trade in a system as shown in Figure 1.

2.1.1 Production of Pt

Pt is part of PGMs, which includes six chemical elements (ruthenium, rhodium, palladium, osmium, iridium, and platinum). They are found in groups 8, 9, and 10 in the Periodic Table as transition metals. But their abundance and concentration in the Earth's crust is rather low. They are also often found in combination with other metals (e.g., iron, tin, copper, lead, and mercury). In 2017, around 91% of Pt is overconcentrated in South Africa, which provided 73% of the global supply. Therefore, primary production comes from either the PGMs ores or byproduct of those associated ores.

Besides the primary production, secondary production of Pt raises a big interest for both economic and environmental reasons. Pt recycling includes both the open loop recycling and closed loop recycling, which play a big role in making up the gaps between supplies and demands.

2.1.2 Applications of Pt

The applications of Pt include autocatalysts, fuel cells, electrolyser, catalyst for petroleum refining, jewelry, machinery for glass production, electronics, catalysts for chemical production, medical, and investment. By now, the autocatalyst (or catalytic converter) is the largest user of PGMs with 95% of new sold cars equipped with an autocatalyst globally. Fuel cell technologies existed and are applied in the industry. All the same general principles for all fuel cells are to create electricity by reaction of hydrogen and oxygen. And a few types of fuel cells (e.g., AFCs, PEMFCs, DMFCs, and PAFCs) require a Pt catalyst.

2.2 Data Sources

The main data sources of this paper are from Johnson Matthey, United States Geological Survey, the International Pt Group Metals Association, European Commission, IEA, UN Comtrade, and some key literatures [3,6–9].

2.3 Future Scenarios

Future scenarios are modelled by a stock-driven model [10]. Future in-use stock from 2017 to 2050 is calculated with a logistic curve with assumed saturation level and time for stocks.

We set three scenarios considering optimistic, pessimistic, and medium development of fuel cells respectively. For optimistic scenarios, there are no CEVs by 2050, and FCVs (FCVs) would account 25% of total vehicles on the road. For pessimistic scenario, CEVs and FCVs would account 50% and 5% of total vehicles on the road separately by 2050. For medium scenario, CEVs and FCVs would account 25% and 15% of total vehicles on the road separately by 2050.

3. RESULTS

3.1 Historical Pt stock in EU

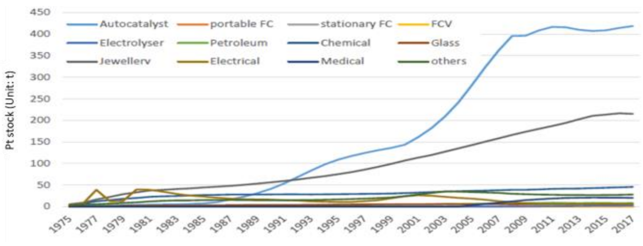

Fig 2 Historical Pt stock in EU

Historical total stocks of all applications increased from 1975 to 2017 (Fig 2). Autocatalyst increased greatly from 1985 to 2007, surpassed jewelry, and ranked first among in-use stocks after 1991. The in-use stocks of autocatalyst stabilized around 200t in recent years. In-use stocks of jewelry increased remarkably, ranking the second among all stocks and ending up above 200t in 2017. In-use stocks of other applications were much smaller than autocatalyst and jewelry.

3.2 Pt cycle in 2017 and 2050

In 2017, 65.86 tonnes equivalent of Pt have to be mined to satisfy the demand in EU (Fig 3 (a)). Total demand for Pt containing applications is 103.52t equivalent. Around 38t of Pt are required to satisfy the demand of closed loop application, with the majority share in chemical. The demand of open loop applications accounts for around 65t, while 22t Pt are recycled with 55 t demand of autocatalysts. Recycling Pt containing products, no matter open-loop recycling or closed loop recycling, help to relieve around half of total demand. But the highest losses, with more than 50% of total losses, happened during end-of-life collection stage. And 80% of losses in recycling is from collection, dismantling, and conditioning of autocatalysts. The second highest loss is during the use stage with 19% of total losses.

The three scenarios showed that the development of FCVs would have big impact on Pt demand. The development of electrolyser would also have impact on Pt demand, but the demand of electrolyser is small compared with other applications. There are no big differences in demands of optimistic and medium scenarios. But primary production varies for these three scenarios. For optimistic scenarios, 149.30t equivalent of Pt ores would be mined to satisfy the demand in EU in 2050 (Fig 3 (b)). For pessimistic scenarios, 177.36t equivalent of Pt ores would be extracted. While for medium scenarios, 236.25t equivalent of Pt ores would need to be extracted. The differences are caused by the recycling of Pt containing products especially open loop recycled products. The losses in transportation sectors (including autocatalysts and FCVs) are bigger compared with other applications.

3.3 Pt demand and recycling potentials for the medium scenario

Annual amount of recycled Pt is constant around 50 t from 2010 to 2030. The amount of Pt recycled will increase to 250t in 2050. The demand for Pt containing applications in EU is around 100t from 2010 to 2020and will increase to 430t in 2040. The primary Pt demand will shift from autocatalysts before 2030 to FCVs after 2030, with the commercialization and penetration of FCVs. Demands for Pt are always larger than Pt recycling. And gaps between demand and recycling potentials will become larger, which may indicates increase challenges

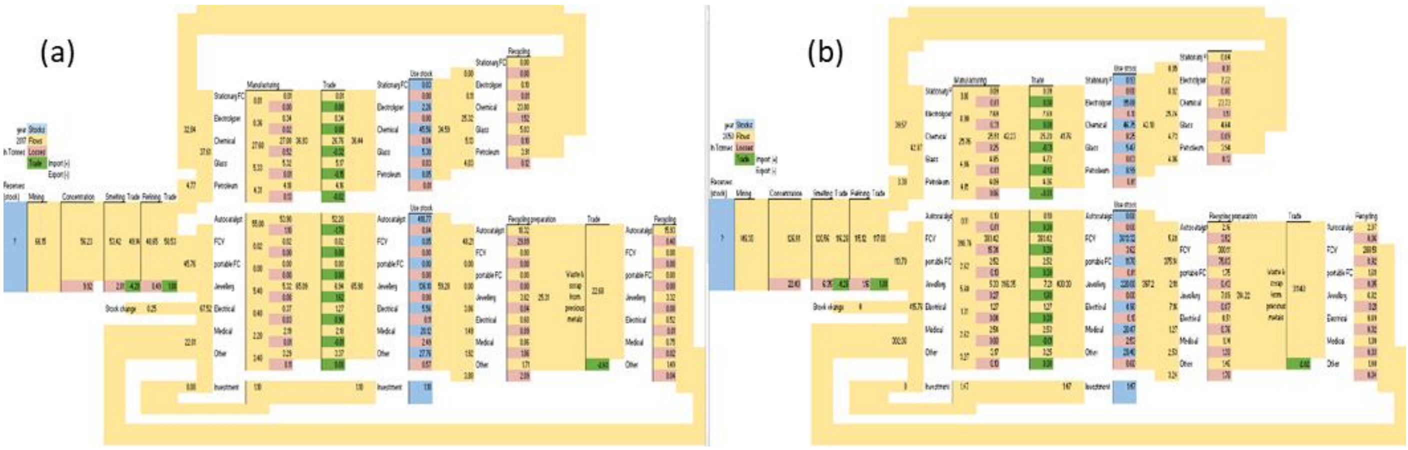

Fig 3 The EU Pt cycle in 2017 (a) and 2050 under optimistic scenario (b)

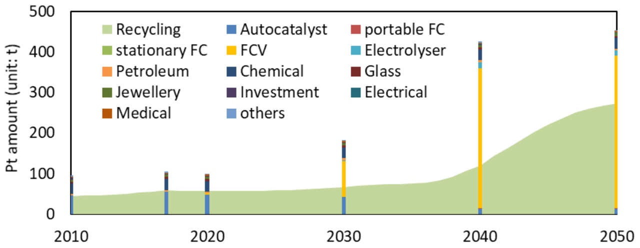

Fig 4 Demand and recycling of Pt from 2010 to 2050

of supply and potential future supply risks for EU's renewable energy technologies.

4. DICUSSION

The amount of Pt needed for EU in 2017 is about 30% of global supply. Viewing all future scenarios, the future Pt demand will increase dramatically because of the introduction of Pt intensive fuel cells in the transportation sector and electrolyser technologies on the market. Recycling can't fully cover such total demand. The primary Pt demand in 2050 for all scenarios is multiple times of the current level in the EU, implying potential supply risks in the future.

Options to relieve the problems include reducing the losses, improving material efficiency, and finding useful substitution. On-going research is conducted to accomplish higher material efficiencies by using Pt nanoparticles in catalytic applications. Currently, the reduction and substitution of Pt in its applications is mostly confined to the substitution by other Pt group metals (PGMs). We found that the highest losses occurred in recycling preparation of open-loop recycled products like autocatalyst and FCVs. Improving the recycling efficiency would reduce resource depletion and lower dependence on primary production. Besides, recycling would significantly lower emission with only 7% of CO2 emissions of mining processes [11]. Therefore, it is vitally important to improve current recycling situation of all applications. Structural and technological improvements in recycling are needed to shift to an industrialized recycling system with changing boundary conditions

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