Materials Processing Institute

GOING SMART AND GOING GREEN: DIGITISATION AND DECARBONISATION TO MEET THE CHALLENGES OF INDUSTRIAL STRATEGY

A Keynote Speech Given at the National Student Conference of the EPSRC and SFI Centre for Doctoral Training in Advanced Metallic Systems

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Introduction

Thank you for the invitation to deliver the keynote address at this National Student Conference of the EPSRC and SFI Centre for Doctoral Training in Advanced Metallic Systems. This centre is an important collaboration between some of the UK and Ireland's leading universities in the field of metallurgical research. At the time that this centre was first established in 2009, there was insufficient recognition of the important role of metals in meeting the challenges of future society, but now we can readily see that the challenge of decarbonisation and the Green Industrial Revolution that it has sparked, rely on new metallurgical and engineering solutions. Those of us in industry look to centres, like this, for those solutions and also for the highly trained, expert individuals that, alongside technology and knowledge, are the valuable products of this research.

My background is in the steel industry, where I have worked in a variety of roles, in manufacturing, strategy and technology. However, I have spent most of my career in technology and innovation and for the last 6 years I have been the Chief Executive Officer of the Materials Processing Institute and it is that capacity in which I speak here, though I am also the Chair of the UK Metals Council, representing 23 trade associations and 30,000 employees in the UK metals sector.

The Institute is the UK's national centre for innovation for metals, having been established more than 75 years ago, to support the development of the UK steel industry. Over that time, researchers at the institute have worked in collaboration with industry and academia, to develop many technologies that are in standard practice in the steel industry globally, but in recent years our focus has broadened beyond steel to encompass the full metals supply chain. We are currently delivering the first year of a five year programme of research and innovation support for the UK Steel and Metals sector, known as PRISM, on behalf of the UK government.

We have achieved this success in innovation by the application of the in depth academic and industry knowledge of our talented research team, supported by a unique range of specialist research equipment, the centre piece of which is our pilot scale steelmaking and casting facilities, including an electric arc furnace, continuous casting machine and both induction and vacuum induction melting.

At the Institute our aim is to apply our expertise and facilities, to support industry and the economy in addressing the major societal challenges of our age. To achieve this we have four areas of research focus:

> **Advanced Materials:** This area of research primarily involves the development of new steel alloys, of improvements in the efficiency of metals processes, to improve quality and productivity. Key facilities include our Advanced Materials Characterisation Centre, which has world leading, state of the art characterisation facilities, including for high temperature metallography. Future developments include an Advanced Materials Development Facility, building on our unique pilot plant facility, expanding capability into metals beyond steel and downstream processes.

> **Industrial Decarbonisation:** Sustainable metals manufacture that does not involve damaging climate emissions is the greatest challenge facing our industrial economy. We need to find ways to decarbonise our steel production, both to make this industry sustainable and to ensure that we can provide the essential steel to underpin the new technologies we need for the rest of the green economy, such as offshore wind, nuclear energy and electric vehicles. We have developed significant expertise in this area and I will speak about this in more detail later in this speech.

> **The Circular Economy:** Another aspect of sustainability is resource efficiency and whilst this can be about minimising the amount of material that we use in a particular application, it is also about ensuring that at end of life, materials are extracted and recycled back into the supply chain. This is particularly important for many rare, or critical metals, such as lithium, cobalt, platinum and palladium, that are essential for modern technologies, such as smart 'phones, or electric vehicle batteries. Our role in this area is in developing extraction and recycling processes, drawing on our vast metals processing expertise in both pyro- and hydro-metallurgy, alongside mechanical separation technology.

> ➢ Our 4th area of innovation underpins the others and it is **Digital Technologies**. Across metals manufacturing we are identifying opportunities for major leaps in productivity, of as much as five times, that are enabled by new digital technologies. Our role here is not in the invention of these new technologies, but in demonstrating their application within a steel and metals environment. Sometimes this can be about ensuring that the technologies can survive in a hostile environment, or developing new instruments and sensors that can provide the essential data input to a digital architecture. Often this also involves application of our detailed processing knowledge to enable transfer of a digital technology from one environment to another. We are currently working on advanced data analytical techniques, AI enabled process control, wearable technology, robotics and blockchain for supply chain management, amongst others. We are also in the process of investing in a new robotics laboratory.

Policy Context

The Materials Processing Institute, was established at a time of crisis in the steel industry. Towards the close of the second world war, just a few days before D-Day, Winston Churchill's government began the process of planning for recovery and established the Institute as a vehicle to support the transformation of the steel industry and the rebuilding of our country.

There are strong parallels here with today, where emerging from a pandemic and needing to rebuild a green and sustainable economy, requires a strong, resilient and zero carbon steel sector. Indeed, the commitments made by G7 leaders this weekend, on COVID recovery, on decarbonisation and on infrastructure, cannot be achieved without the steel industry. More than this the commitments made by the Prime Minister in his ten-point plan for a Green Industrial Revolution, in areas such as offshore wind, electric vehicles, the hydrogen economy and advanced nuclear technology, are all reliant on advanced steel capabilities in the UK.

Achieving these aims requires investment in innovation in the steel and wider metals sector and government is committed to this through the PRISM programme of innovation and research being delivered by the Materials Processing Institute, covering decarbonisation, alongside digitisation and the circular economy. PRISM is the name for an innovation fund awarded to the Materials Processing Institute by the Chancellor in the March 2020 budget. It is funded by InnovateUK and is the £22m referenced in the response of BEIS, to the select committee steel inquiry, as core to decarbonising steel in the UK.

The strategic importance of domestic steel production has long been understood in terms of defence, but during the pandemic we also saw how we depend on the steel industry for our basic needs, with tinplate from South Wales for canned goods and steel tubes from Corby for beds in Nightingale hospitals. Looking to the future, particularly as global trade becomes less reliable, we need our steel industry to support advanced manufacturing and infrastructure, as government seeks to both decarbonise and invest to level-up, across the country.

It was heartening for me to hear the critical importance of the steel sector confirmed by the Secretary of State, when he and I both gave evidence recently at a BEIS Select Committee hearing. The minister affirmed the strategic importance of steel and said that: *'Once you are strategically committed to the industry, you have to provide some measure of support. It does not make sense to say that we are strategically committed to this industry and then not support it….'* There is cross party agreement here, with Sir Keir Starmer remarking that *'Steel is not just an industry of our past. It must have a place in our future, too. A robust steel sector enables economic prosperity and growth and it's vital for national security.'*

We need to acknowledge that all governments around the world rightly intervene to support their steel sector and so if we want a sustainable steel industry, then we must use policy to create a level playing field. This morning, I will talk through how we can decarbonise, but also what this means for jobs in steel communities.

Decarbonisation Technology Choices

Perhaps the greatest of these four challenges is decarbonisation of the steelmaking process and so I would like to focus on this area in more detail.

We know that the steel industry is the largest industrial emitter of carbon dioxide and so measures to reduce those emissions will require a wholesale change in the technology of steel production. Fortunately we already know what the technologies to decarbonise will be a combination of electric arc furnaces, hydrogen, and carbon capture and storage. I estimate the cost of adopting these technologies at around £6bn for the UK industry, in addition to the associated infrastructure. This is not a huge sum in the context of steel. For instance, recently Metinvest, a Ukranian producer, announced an investment of $1.2bn in a new rolling facility.

Electric arc furnaces are a proven technology for melting and refining steel. In the mind of many people, these furnaces are intrinsically linked with the recycling of scrap steel and indeed the UK has a big opportunity, as one of the world's largest exporters of scrap steel, to recycle more at home, for our own manufacturing and infrastructure.

It is true that the electric arc furnace still lacks some quality capability, but this is an innovation challenge for Institutes like my own to resolve, rather than a barrier to the technology being introduced. However, for reasons of both steel quality and quantity, the UK cannot survive on recycled steel alone and so we need to be able to use raw materials derived from iron ore.

The electric arc furnace is not capable of dealing with iron ore in its raw form. Currently the task of smelting ore into iron is carried out by the blast furnace, which relies on coking coal and is the major emitter of carbon dioxide. This is where hydrogen has a role to play. By replacing the blast furnace with a Direct Reduction furnace, we can replace coking coal with a gas, such as hydrogen, and produce a raw material that can be fed, alongside scrap, directly into the electric arc furnace. Making this switch will require innovation and we can see this progressing now in other nations around the world, including in China, where the world's first hydrogen reduction furnace will be commissioned this year.

While electric arc furnaces and hydrogen can be quite readily understood, the use of carbon capture presents some choices. Carbon capture could be applied to the electric arc furnace, the direct reduction furnace, hydrogen production and the blast furnace. Emissions from the electric arc furnace are around 15% that of the blast furnace, but nonetheless they will need to be dealt with. There is currently no available technology to do this, but it is something we are considering at the Materials Processing Institute, where we have a pilot scale electric arc furnace.

Capturing emissions from the blast furnace is dangerously beguiling. What seems at first the most straightforward solution, risks locking in older technology, that will struggle to compete against more productive plants, operating with the latest advanced automation.

The reason for this is that the most modern steel plants in the world, such as those in North America, operate not only with electric arc furnaces, but advanced downstream processes, that result in up to five times the efficiency of a conventional blast furnace plant. The consequences of this can be seen in a recent report in the Wall Street Journal[1], where traditional producers, including Cleveland Cliffs and US Steel, are choosing to keep their plants idle emerging from the pandemic, because they cannot compete with newer rivals, despite record steel prices.

Countries around the world are now competing in a race to zero.

In this race to net zero, we can see countries around the world competing hard to be the global leader and that race is now accelerating. Until recently, Sweden was seen to be the leading nation, with their flagship HYBRIT project, a collaboration of three industrial groups all either wholly, or partly state owned, aiming to introduce hydrogen produced Green Steel to the market in 2026. This project was joined in February this year, by a new start up steelmaker, H2GreenSteel[2], which aims to build a brand new, 'fully integrated, digitalised and automated greenfield steel plant', in Northern Sweden, to be start up production in 2024 and be fully operational by 2030.

Until recently the HYBRIT project was the front runner, but on 25th June HBIS, the world's third largest steelmaker, based in China, announced that as well as starting the World's first hydrogen direct reduced iron (DRI) plant in 2021, they will have a full scale hydrogen plant up and running by 2025[3]. In the same week, Austrian steel producer voestalpine, announced the commissioning of their pilot hydrogen DRI plant[4].

Each of these projects has required significant government investment.

Resource Efficiency

In addition to decarbonisation, the Materials Processing Institute is also focussed on improving resource efficiency through a circular economy approach, particularly for metals and how this provides benefits that go beyond net zero, to include ethics and sovereign security.

Metals have an almost limitless capability for recycling. Steel in particular has many inherent properties that mean that recycling is usually synonymous with upcycling, as scrap steel is transformed into increasingly high performance and advanced products. Recycling is also intrinsically more environmentally friendly. Mining accounts for 10% of world energy consumption and the more we recycle, the less we need to mine. Even leaving mining aside, for steel switching from primary production to recycling leads to an 85% reduction in carbon dioxide emissions.

[1] 'Steelmakers Keep Old Plants Idle Despite Surging Prices', Wall Street Journal, 10 June 2021, https://www.wsj.com/articles/steelmakers-keep-old-plants-idle-despite-surging-prices-11623322802?redirect=amp#click=https://t.co/RnXJncpUZY

[2] https://www.h2greensteel.com/

[3] https://www.steelguru.com/steel/hbis-unveils-plan-for-low-carbon-steel-development-in-china

[4] https://www.steelguru.com/steel/primetals-hyfor-pilot-for-hdri-starts-at-voestalpine-in-donawitz

A second benefit is that some metals are sourced from locations around the world where the proceeds of the mining industry prop up undemocratic and exploitative regimes, where workers are poorly treated, child labour blights the lives of millions and modern slavery persists. For too long Western consumers have been able to turn a blind eye to the consumption of materials produced overseas in ways that would not be acceptable at home. A circular economy approach gives the opportunity for consumer and producer choice and competition, to drive up ethical standards and working conditions in the supply chain.

This reduction in our reliance on international supply chains is an important consideration for our sovereign security. With increasing geopolitical tensions and the security of materials seen as vital to national interests, it is worrying to see how many metals vital for our future are now listed as having a supply risk. If anyone doubts our vulnerability think how the blockage in the Suez Canal quickly emptied international supply chains. The circular economy provides resilience to UK manufacturing and infrastructure projects.

Increasing the circularity of metals is also vital for delivering the Green Industrial Revolution. New technologies for electrification, energy generation and associated infrastructure, all need metals. There is a strong environmental case for metals to be favoured above other materials where this is possible. As a consequence, the drive to eliminate carbon will result in a in materials demand and a greater shift towards metals.

Digital Technologies

At the same time that we are decarbonising our industries, we are also working through an explosion in digital technologies, that have the capability to transform how we process and use metals. This is a mutually symbiotic relationship, as harnessing the potential of industry 4.0 to deliver a zero carbon economy, requires zero carbon materials. Delivering the infrastructure of a zero carbon economy will require new renewable energy, electric vehicles and greater connectivity. It needs concrete, steel, copper and cobalt. All materials that are currently produced at a great carbon cost to the planet and, in the case of cobalt, at a great human cost.

Industry 4.0 technologies can be of great use to us here. My own Institute is delivering a £10m industrial digitalisation innovation project, for energy intensive materials production, supported by InnovateUK through the Made Smarter Industrial Strategy Challenge Funds.

Digital technologies are not only important in the design and development of alternative, zero carbon manufacturing techniques, but also in improving resource efficiency and delivering the circular economy, which has been bolstered recently by two new UKRI circular economy centres for metals, at Brunel, Exeter universities.

The reason why this is so important is that there can be no zero carbon economy without zero carbon materials and yet materials are the most difficult parts of industry to decarbonise, being both energy intensive and chemically reliant on carbon. Industry 4.0 technologies, particularly through the application of 5G and AI for instance, gives us the opportunity to improve reuse and recycling, but also increase resource efficiency.

As we know, the nature of fourth industrial technologies makes process-oriented jobs more susceptible. Future Advocacy, a think tank focused on new technologies such as AI, broke down the impact by region, showing that there is a high degree of regional variation with the Midlands and north of England hit hardest. They suggest that over two-thirds of the top 50 parliamentary constituencies with the highest proportions of high risk jobs are in these regions

Just Transition

Greening our materials industries and improving resource efficiency, whilst at the same time investing in the latest automation and production technology will lead to a requirement for fewer jobs per tonne of steel produced and this is why I believe a Just Transition is an essential part of the Green Industrial Revolution.

Getting this right makes sound economic sense and it is a matter of social justice, but for me it is also personal. I grew up in the Durham coalfield, where entire communities faced worklessness as we lost the main employer on which my family and our wider community depended. I still live in this community and the long shadow of that devastating economic shock can still be seen today. I do not want to see families in places such as Port Talbot and Scunthorpe suffer these same experiences. Nor do they have to.

Steelworkers understand the impact and the importance of productivity improvements. Since the 1970s, productivity improvements have reduced employment in the UK steel sector by 90%, or 9 out of every ten jobs. New technologies have the potential to reduce this by a further 80%, or four in five jobs. To be clear these figures are about improvements in efficiency, rather than industrial contraction. If we act now, we have the time to phase this transition over a decade, giving workers and the wider community the time to adjust.

Alongside timing we also need to stimulate co-investment in the new, high growth and exporting industries of the green industrial revolution. These industries require a highly skilled workforce and steelworkers have valuable, transferable skills. From electric vehicles, to offshore wind and nuclear, with investment and retraining, our steelworkers can provide the steel on which these industries will rely and the workforce to make them a success.

The improved competitiveness of the UK steel industry can become the foundation of a new era of growth, particularly in downstream activities where thousands of jobs could be created. By taking the needs of individual companies into account alongside the UK's wider industrial strategy, the steel industry can be decarbonised, allowing a smooth and just transition for the workforce.

Policy Choices

Globalised modern economies, like the UK, face an unprecedented challenge as we emerge from the COVID-19 pandemic, in responding to shifting geopolitical power, racing to decarbonise and protecting our sovereign security. Digitisation is a major part of the solution to these challenges, but brings with it disruption to jobs and communities, as hard won skills are made redundant, and step changes in productivity that risk mass unemployment. The Green Industrial Revolution is also heavily reliant on critical materials, often sourced from unstable, undemocratic and unethical regimes.

The response that is required is an optimistic, interventionist industrial strategy, that places a just transition at its heart. By targeting the required green investment in the places where skills are being released from digitisation, will ensure these new industries can be successful, as well as securing a just transition for communities. Nations that are successful in this transition will invest heavily in innovation and commercialisation of intellectual property and act to secure critical materials in their economy, protecting sovereign capability in defence, infrastructure and critical manufacturing.

Thank you once again for the invitation to speak today and I would like to offer my best wishes to the researchers in the Advanced Metallic Systems CDT, for their important work in equipping our society for a greener, smarter future.

Materials Processing Institute

Chris McDonald is the Chief Executive Officer of the Materials Processing Institute. The Institute carries out industrial research and innovation in advanced materials, industrial decarbonisation, digital technologies and the circular economy supporting the materials, processing and energy sectors for over 75 years. Chris led the divestment and return to independent, not-for-profit ownership of the Institute in 2014.

Chris's background is in industrial research and manufacturing, where he has worked internationally. A graduate of Cambridge University, Chris is a Fellow the Institute of Chemical Engineers and of the Institute of Materials, Minerals and Mining. He sits on industrial advisory boards at a number of universities, including Oxford and Sheffield.

Chris has an interest in innovation management and industry dynamics and in addition to leading the Institute, he provides expert opinion and consultancy support to companies, institutes, Governments and public bodies in innovation and technology strategy and management. He also advises on the technical due diligence aspects of mergers and acquisitions.

Chris is prominent in the development of public policy, around innovation, steel, SMEs, where he works to support growth and inward investment. Chris is the policy chair for Innovation and Enterprise for the Federation of Small Businesses, a member of the CBI Regional Council and Shadow Monetary Policy Committee for the North East, the Chair of the UK Metals Council and a member of the Steel Advisory Board for UK Steel (EEF).

Chris is often called to commentate in the media on innovation leadership and the steel industry.

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Chris McDonald
Chief Executive Officer
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The Materials Processing Institute is an independent, open access and not-for-profit technology and innovation centre working with industry, government and academia worldwide. Support ranges from small scale, site based investigations, through to long term collaborative research programmes.

The Materials Processing Institute is expert in advanced materials, industrial decarbonisation, digital technologies and the circular economy, specialising in challenging processes, particularly those involving high specification materials, high temperatures and difficult operating conditions.

The Institute has over 75 years' experience as a leading UK technology provider. Extensive materials processing knowledge is supported by state-of-the-art facilities with a broad range of equipment, from laboratories through to demonstration, scale-up and production plant.

Scientists and engineers work with industry and apply their expertise to develop and implement robust solutions to research and development and improvements for products and processes.

Expertise is spread across a wide range of disciplines, including:

- Materials Characterisation, Research and Development
- Simulation and Design
- Monitoring, Measurement and Control in Hostile Environments
- Process Development and Upscaling
- Specialist Melting and Steel / Alloy Production
- Engineering / Asset Management
- Materials Handling
- Minerals and Ores

Research and project management teams deliver support across a wide range of industrial and manufacturing sectors including:

- Metals and Metals Manufacture
- Chemicals and Process
- Nuclear
- Oil & Gas
- Energy
- Aerospace and Defence
- Mining and Quarrying

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