DECARBONISING STEEL MAKING IN CHINA THROUGH CIRCULAR ECONOMY APPROACHES

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Summary
In this issue of One Earth, Li and Hanaoka explore technological and policy options for decarbonising China's iron and steel sector, which produces more than half of the world's crude steel. We expand on the discussion to consider opportunities and challenges associated with circular economy approaches of steelmaking.

Steel is a core material for infrastructures such as buildings and construction, transport, machinery and equipment and, incidentally, low-carbon technologies including wind turbines and electric vehicles. Thus, steel manufacturing is a core foundational industry and precursor of economic and social development. In 2021, the global production of steel was 1951 million tonnes, half of this demand was generated by China, where domestic demand increased substantially from 773.8 to 952.0 million tonnes between 2017-2021[1].

Although a vital material, steel is also among the most energy intensive products: around 75% of energy inputs for steelmaking comes from coal, making the steel sector the largest industrial consumer of coal – the most carbon-intensive energy source. As a result, every tonne of steel in 2019 was, on average, associated with 1.851 tonnes of CO2 emissions. The total CO2 emissions generated by the steel sector reached 2.6 billion tonnes in 2019, accounting for 7%-9% of global Greenhouse Gas (GHG) emissions[2].
In a recent One Earth article, Li and Hanaoka[3] use the AIM/ENDUSE model to examine different technological and policy options at regional scales that can accelerate the decarbonisation of the steel sector in China. They consider 12 scenarios with different low-carbon technology adoption rates and environmental taxation systems. The comprehensive modelling helps to map the effect of different technologies, including Electric Arc Furnaces (EAFs), Direct Reduced Iron-EAF, hydrogen, power grid decarbonisation, carbon capture and storage (CCS); as well as policy instruments such as carbon and energy taxes. The analysis estimates emissions of GHG and other pollutants under the different scenarios and concludes that successful decarbonisation will require a profound restructuring of the current steel sector in China, including the reduction of the share of the Basic Oxygen Furnaces (BOF) and addressing the overcapacity issue that can result in installing excessive production capacity. Importantly, the study emphasises the role of policy as an enabler of the low-carbon transition. The combination of different measures including a shift to EAF production, decarbonisation of the power grid, energy saving technologies and carbon/energy taxes and other regulatory instruments are all necessary to move the sector towards carbon-neutrality. The most ambitious scenario, which combines all technological and policy measures, estimates an 83% saving in CO2 emissions relative to 2015 levels, whereas additional ambitious decarbonisation efforts, such as energy efficiency, waste energy recovery and CCS, would all be needed to ensure China meets its 2060 carbon-neutrality commitment.

Low carbon steel making via a circular economy approach

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The steel sector globally has made substantial efforts to reduce its environmental footprint. This has been the result of a combination of technological innovation and policies. One pivotal technology, as highlighted in Li and Hanoka[3], has been the use of EAF, which on average can save between 80-90% of primary energy[4] and uses metal scrap instead of iron ore as the main input material. Interestingly, the EAF route not only contributes to the decarbonisation of steelmaking via electrification, but also aligns with circular economy principles by substituting the extraction of raw material (iron ore) with recycled steel scrap.

In 2020, around 30% of global steel production followed the EAF route, but mainly took place in the Global North. The other parts of the world such as Asia, South America, and Africa, are still largely dominated by the Blast Furnace-BOF production route, which is, as mentioned earlier, coal-dependent and emission-intensive. China currently adopts the EAF route for only about 10% of its steel production.

If the decarbonisation of China's iron & steel industry heavily relies on the progressive adoption of EAFs, as discussed in Li and Hanaoka[3], a well-functioning scrap market will be essential, since the production technology of EAFs requires metal scrap as main input material. However, given China's rapid growth in steel production and the relatively long technical life span of steel, especially the steel used in construction and infrastructures, the steel scrap market in China remains underdeveloped[5]. Exports of steel from China to the rest of the world also means that a significant part of all steel produced is not available for reprocessing in China.

Therefore, the establishment of a well-functioning scrap market would not only call for increasing capture rate of scrap, monitoring quality, improving logistics and maintaining competitive prices, but may also require advances in the standardisation of scrap qualities and segregation methods. All these requirements suggest that it would be useful to deploy a Circular Economy approach for steelmaking to create market opportunities of scrap throughout the steel value chain. Furthermore, it is also helpful to consider the circular economy approach from a more holistic industrial view, which can include the application of industrial symbiosis and the creation of multi-sector industrial ecosystems to recover raw material, avoid waste generation and recover excess heat. Almost all by-products and waste streams from iron and steel production can be used by other sectors as substitutes of primary raw materials, with similar or even improved performance compared to those original primary raw materials[6]. For example, steel slag, electric arc furnace dust, mill scale, and other by-products such as BTX (benzene, toluene, and xylene) have applications across cement production, ceramics, plastics, road construction or metal processing (e.g., zinc smelting, galvanisation, etc).

There are also opportunities to recover and reuse excess heat generated during steelmaking in other industrial processes, leading to accelerated decarbonisation across industries. For example, the production of green hydrogen through electrolysis requires electricity but also heat, the latter can help to accelerate the efficiency of the green hydrogen production process. The waste heat of steelmaking can therefore become a valuable input in producing green hydrogen. Green hydrogen can then be further used to produce low carbon steel, by replacing fossil energy used either in the BF-BOF route or in the production of Direct Reduced Iron. Many countries, including China, have pilot plants which have substituted coal by hydrogen. The aggregation of iron & steel plants located within large industrial areas (e.g., industrial parks) in China creates a significant geographical advantage to establish such industrial symbiosis systems, reducing overall system emissions.

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We therefore adjust the texts a little, mainly by relocating the ending texts of the previous paragraph now to lines 77-80. This will help to set the stage for the introduction of the Circular Economy notion. Then, we provide a little more context (line 82-83) to highlight your insights regarding how the CE approach could be expanded more broadly across different industrial sectors. We feel that, with such edits, the narrative could be a little more closely connected and also enable the broader reader to better appreicate the merit of your important points. ... [1]

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Such a circular approach must, however, overcome sectoral silos and promote cross-sectoral collaborations. China has already made significant progress in the application of industrial symbiosis approaches in the spatial organisation of industry through the concept of Eco-Industrial Parks (EIPs) and the regeneration of traditional Industrial Parks. Eco-industrial systems can contribute to energy savings and raw material and waste reductions, and thus advance the low carbon transition at lower abatement costs. For example, Lizhou and Jinan industrial areas in China host iron-steel industrial clusters, where the application of industrial symbiosis principles has led to multiple projects with significant resource savings and carbon emissions reduction, leading to the creation of additional value added[7]. Similar approaches could be replicated throughout China. While Li and Hanaoka[3] explore some of these industrial symbiosis approaches, such as the potential of heat recovery and reuse in some scenarios, a broader application of the concept is likely to accelerate the transition towards carbon-neutrality. Indeed, a well-orchestrated circular approach across sectors, rather than a hasty single sector approach, is more likely to lead to the long-term actions necessary to achieve carbon-neutrality. Yet, the extent to which such circular and systems thinking has become a part of China's carbon-neutrality roadmap remains unclear.

Implications for global decarbonisation pathways

One in every two tonnes of steel is produced in China. Therefore, steel sector decarbonisation efforts in China will have implications for the sector around the world. The World Steel Association (WSA) has developed a sustainability charter which reflects the increasing focus of the sector on sustainability, including addressing climate change and maximising efficient use of resources. However, relatively high costs of electricity and lower prices of primary raw materials in China make the change towards a circular approach less likely unless rapid action is taken towards: 1) decreasing government incentives and subsidies to primary extracting activities and inefficient steel production 2) ramping up the supply of renewable energies in line with carbon pricing and emission trading schemes in China in parallel with decreasing the carbon intensity in the energy mix[8]. Advances in the iron & steel sector will require a country-wide modernisation of energy systems in China. If China fails to move fast enough and steadily, decarbonisation of steel globally will be compromised, and the embodied carbon emissions via steel exports can affect scope 3 emissions accounting (i.e. emissions accounted throughout the value chain) and therefore compromise decarbonisation strategies in importing countries.

How will China's national governments, institutions and industries react to changes domestically and abroad are important issues deserve further research and discussions across disciplines and stakeholders.

Removing socio-political barriers

Although the sophisticated modelling exercise presented by Li and Hanaoka[3] provides insights on decarbonising China's iron and steel sector at the regional-level, a practical unanswered question is whether the institutional and political frameworks in those regions would be able to set priorities and advance at the speed and scale required for a profound carbon-neutrality transformation of steel production.

Recent analysis[9] confirms huge implementation gaps between early eco-pioneers and mass markets and coordination challenges arising through regional differences in China. So, whereas some steelmaking plants have implemented highly efficient technologies or adopted the EAF

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route, a large share of China's steel production facilities remains technologically outdated (e.g., the vast majority of steel plants still adopts the BF-BOF route). Future analysis needs to undertake critical assessments to help uncover other non-technical issues (e.g., institutional level problems) in China that are related to the implementation gaps and coordination challenges across provinces and sectors. Furthermore, a data base on the lifetime of steel stocks and estimated future scrap supply, ideally based on common indicators and a comprehensive data protocol, could help establishing low carbon steel foresight with an extended understanding of cost-benefit analysis and modelling tools.

One critical aspect that should be investigated further, yet is beyond the scope of the Li and Hanaoka article[3], is related to the deployment of active policies for demand-side management. This may include incentives to promote the reuse of structural steel, initiatives to extend its use life and the expansion of the remanufacturing market for steel products (e.g., cars). Demand-side management policies could make a very substantial contribution towards circularity and decarbonization but call for a different set of policy instruments such as building passports (which provide a detailed list of materials and specific information on building materials to enable construction material recovery), development of facilities and infrastructure for reused steel testing, certification standards and improved steel/scrap traceability. A combination of the above can create the conditions for the developing world to benefit from a surplus of green steel that would help accomplish the Sustainable Development Goals[10].

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