MX3D

A case study

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Innovation:	**Wire Arc Additive Manufacturing (WAAM) for Steel**
Intervention:	**MX3D**
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Methodology:	4 interviews, extensive desk research
Case Study Overview	
Sector(s):	Steel
Value Chain Stage(s):	Steel processing (but requirement to consider the whole value chain owing to spill-overs)
Type of Intervention:	Technical
Date & Duration:	Started development of robotic printer for resin in 2012; innovation ongoing
Location:	Amsterdam, Netherlands
Initiating Actors:	MX3D ArcelorMittal City of Amsterdam
Actor Constellation:	MX3D ArcelorMittal City of Amsterdam Autodesk Heijmans Air Liquide Oerlikon Lenovo ABB Plymovent OCAS Delft Technical University
Short Description of Intervention:	Additive Manufacturing (AM) with metals has primarily evolved as Powder Bed Fusion, where objects can be formed out of metal powders using laser or electron beams. However, these processing technologies have their limitations in terms of minor deposition rate and limited size of object resulting from the size of the building chambers required. Nevertheless it has greatly evolved using aluminium and titanium for maximum weight reductions with components for aviation and space missions. Wire Arc Additive Manufacturing (WAAM) combines industrial welding robots, wires for welding and software that translates CAD designs of objects into the movement of welding robots to overcome these limitations. At the same time, wires for welding are cheaper than metal powders. With the bridge project, MX3D and its partners have undertaken an effort to showcase the technical and design potentials offered by WAAM steel processing in the construction sector. This required additional funding to cover the extra cost over a conventional bridge and finding sponsors for this. At the same time, substantial legal requirements had to be fulfilled to provide a bridge for use by the general public. As the end result a fully-welded pedestrian bridge for the City of Amsterdam has been entirely produced by WAAM using stainless steel wire.
Research Theme Summaries	
1. Innovation History & Dynamics:	Primarily developed for rapid prototyping, Additive Manufacturing (AM) has become an industrial processing technology and Wire Arc AM has evolved. Steel is somewhat heavy for certain applications (aviation and space) but there are plenty of potential ground-based use cases with vehicles, machinery and construction. The bridge project by MX3D has focused on depicting design options in construction but less on potential impacts on carbon emissions.
2. Governance Arrangements & Agents of Change:	3D printing with metals is high on research agendas and funding is generally available. WAAM with steel has been developed outside the domain of the conventional steel industry by more design-oriented start-ups. However, the bridge project involves specialised industries contributing to the diverse technical set-up of WAAM that would

	otherwise overstretch the capabilities of a start-up. Thus besides MX3D, various companies have been actively involved. Moreover, the City of Amsterdam has taken an active role in defining the bridge project and provided basic funding equivalent to a conventional pedestrian bridge, while other partners have contributed additional financial resources as sponsors.
3. Transformative Capacities:	Transformative capacities of AM and WAAM with steel rest with likely contributions to decarbonising steel value chains and business cases of the various potential use cases, most of which have not yet been sufficiently explored to date. However, transformative capacities of WAAM are not limited to the steel processing stage. Rather, spillovers to upstream processes and the use phase of steel value chains can be expected. Further on, MX3D will focus more on exploring other use cases of WAAM than on the diffusion of knowledge generated during the bridge project or on upscaling of related products and processing technologies.
4. Assessment & Evaluation:	An assessment of the potential carbon impacts of AM and WAAM involves particular methodological difficulties with steel structures which were impossible to be produced using conventional processing technologies. Moreover, the mentioned spillovers to carbon emissions during other phases of steel value chains increase the complexity of lifecycle-wide analyses and deserve additional projects that are sufficiently focused on such assessments. This mainly refers to the material efficiency of processing as such in terms of energy intensity and logistics related to material efficiency and geographical properties of value chains. Moreover reducing the weight of steel structures may have substantial impacts during the use phase. Thus at its current state of development, the carbon impacts of WAAM cannot sufficiently be assessed.
5. Uptake & Consequences:	As mentioned, WAAM may change the way steel is processed for certain applications. Based on the MX3D bridge project, one area of application is construction. However, ground-based vehicles and machinery may also benefit from lighter loads using relatively cheap steel instead of more costly metals. Beyond production of entirely new products, spare parts and on-site repair may be future core areas of application. So far, no unintended consequences of WAAM have been noticed, which may partly result from its very limited application. Given the early development stage of WAAM, it is highly speculative to assess its social consequences. WAAM mainly requires highly skilled workers for designing the products and translating CAD designs into movement of welding robots. The extent to which lower-skilled workforce might be deployed - amongst other factors - might be affected by the need to apply handcrafted post processing.
Conclusion & Outlook	
Key Learnings:	*Unique features of this case:* WAAM with steel is a niche of AM with metals. It remains to be seen to which extent AM with metals and specifically WAAM will grow based on crowding out of conventional processing technologies as well as creating new products that previously were impossible to be produced. This Case Study is unique with regard to creating new processing technologies outside the main steel producing companies. However, it basically uses technologies developed for the automotive industry creating new options in steel processing. At the same time it differentiates itself from conventional production by its artistic features, which are not common for the steel industry. The overall decarbonisation of steel processing will not play the most important role for the steel sector as long as primary and secondary steel production is based on fossil reduction agents or electricity produced from fossil primary energy. However this will change during the decarbonisation of primary and secondary steel production that will increase the relevance of remaining potentials for reducing energy intensity. *Key insights from this case regarding ...* *Overall decarbonisation:* The decarbonisation of steel processing on its own will not allow delivering decarbonisation of the steel sector as long as primary and secondary steel production are based on fossil reduction agents or electricity produced from fossil primary energy. However, this will change and the relative weight of steel processing for carbon emissions and other SDGs will grow. Notwithstanding this, while carbon-neutral primary and secondary steel production will require some time to be put in place, more efficient processing and use of steel along the value chain can make substantial contributions to reducing the overall carbon emissions of steel value chains. Once all primary and secondary steel production is carbon-neutral, the focus will switch to the attainment of other SDGs.

	Drivers and barriers: Customers, particularly from aerospace companies, are very risk averse. However, AM has mainly developed for these customers resulting from the enormous economic incentives offered by reducing the weight of vehicle components. Steel components are scarce in aerospace vehicles. Steel AM is more focused on components for ground vehicles, machinery and construction, where reducing the weight may not always yield cost reductions that can legitimate the use of relatively costly materials like aluminium or titanium. *Instruments to overcome them:* In the construction sector, WAAM with steel will require clients and architects to change their mind-sets and workflows. Governmental bodies at all levels may use WAAM for specific construction projects that simultaneously deliver an artistic visual appearance and allow for enhancing the range of experience with WAAM in the construction sector. As long as construction projects using WAAM result in cost increases over conventional designs, specific financing schemes will be required. *Role of policy:* Policy needs to assist financing of innovative construction projects that use WAAM. Financing activities in the construction sector should be accompanied by research projects that enable the assessment of the total carbon impact along the value chain and service life of structures processed by WAAM. Beyond the construction sector, financing may be readily available where benefits from the use phase can reduce TCO but there may be a lack of willingness to assess the total carbon impacts along the value chain. *Lessons for future innovations:* Niche projects are crucial for dealing with stakeholders' initial risk aversion. Moreover, such projects are required in order to test public acceptance as well as to generate sufficient experience necessary for creating a business case.
Open Questions & Further Research Requirements:	While steel is a relatively cheap material for early applications of WAAM, it might involve more fundamental issues for achieving WAAM business cases over more costly materials like aluminium and titanium that offer additional weight advantages.

For Europe to achieve its long-term climate objectives, carbon-intensive industries have to reduce their emissions.

REINVENT focuses on plastics, steel, paper and meat & dairy – industrial sectors that are key to our daily lives, but where low-carbon transitions are still relatively unexplored.

To gain a broader understanding of the possibilities of transition, entire value chains of the industries are studied. This includes non-technical factors such as supply chains, financing, trade, and social and economic impacts. Together with forward-looking industry leaders and policy-makers, we explore potentials and capabilities for making transitions in these resource-intensive industries.

PARTICIPANTS & FUNDING

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