Castrip

A case study

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Innovation:	**Strip casting in steel production**
Intervention:	**Castrip**
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Methodology:	3 interviews, 2 site visits (Limited interview access, especially to actors within Castrip consortium)
Case Study Overview	
Sector(s):	Steel
Value Chain Stage(s):	Production
Type of Intervention:	Technical
Date & Duration:	1985 (ongoing)
Location:	Australia/Japan/USA
Initiating Actors:	BHP (Australia) IHI (Japan)
Actor Constellation:	BHP Steel (now BlueScope Steel; steelmaker initiating R&D) IHI (machine manufacturer partnering with BHP for R&D) Nucor (steelmaker pushing for industrial scale, first to use Castrip technology at their plants) Castrip LLC (joint venture between BHP, IHI and Nucor licensing the technology to steelmakers)
Short Description of Intervention:	When looking at carbon emissions in the steel industry, the focus often lies on the iron- and steelmaking steps in primary steel production, i.e. the CO_2 directly released from the blast furnace and basic oxygen furnace. For secondary steelmaking, it is the indirect emissions caused by an electric arc furnace through the use of electricity generated from the burning of fossil fuels. Often overlooked are the less carbon-intensive but still significant finishing steps that follow, independent of the steelmaking route: casting and rolling. The standard set-up for large integrated steel mills is to have a continuous caster (casting liquid steel into slabs) and a hot-rolling mill (rolling slabs into steel strip). This two-step process not only requires a lot of space, but also a lot of energy. After the casting process, the slabs cool down significantly, and subsequently need to first enter a reheating furnace before being ready for hot rolling. Strip casting is an innovative process that combines the steps of casting and rolling into one. There have been variations of this concept; the Castrip process is a twin-roll strip-casting process, in which liquid steel is directly cast between two rolls, usually requiring only minimal additional finishing, depending on the application. This significantly cuts down on energy usage and, as a result, on carbon emissions, energy costs and the capital costs and physical space required for on-site hot rolling. This opens smaller-capacity steel mills up to new possibilities: these so-called 'mini mills' would normally have to outsource the hot-rolling process due to capital and space restrictions. By operating an on-site strip caster they can have the benefit of producing higher value-added products, while cutting down on both process and transport emissions. As one of the major players in the mini-mill sector, American steel company Nucor was a strong force behind bringing the strip-casting technology developed by BHP and IHI to market. The three companies formed Castrip LLC in 2000, and Nucor has since begun operation of Castrip strip caster at two of their sites.
Research Theme Summaries	
1. Innovation History & Dynamics:	The Castrip consortium was one of many in the long race to commercialise strip-casting technology for steel. The idea of a twin-roll strip-casting process for steel is over 150 years old, originally going back to an 1857 patent by renowned English inventor Sir Henry Bessemer. Due to technical difficulties (especially with regard to controlling the rolling speed and temperature in the rotating mould), the concept was taken up and then abandoned several times over the decades. While it was successfully applied to other metals quite early on, the thermal-physical properties of steel continued to pose a strong technical barrier. A new rush to commercialise the technology in an increasingly competitive market led to the emergence of numerous R&D consortia in the 1970s and 80s, the driving force behind which were the steelmakers themselves wanting to reap the

	economic benefits such a technology could bring. They usually teamed up with either a machine manufacturer or engineering firm to develop different variations of the strip-casting process for steel. Some received initial funding, then ran into financial difficulties when it was time to take their strip casters to an industrial scale. What is more, the emergence of thin-slab casting technology brought about some significant efficiency gains, which meant that further possible efficiency gains were now smaller, reducing incentive to invest in strip casting. Many of these consortia dissolved as a result of this. The R&D partnership that was initiated between BHP and IHI in 1985, however, received a fresh boost when Nucor Nucor became involved in 2000. Strip casting technology is particularly suited to small-scale production of specialty steels, while capacity limits have so far prevented the technology from being scaled up to large-scale carbon steel production. Furthermore, the long lifecycles of existing continuous casters and hot-rolling mills means that the need for replacement, and consequently also the adoption of new technologies like strip casting, is very slow. Some of the initial technical barriers also still remain, preventing the application of the process to certain alloys. A competing strip-casting innovation is the belt casting process developed by SMS, which has been in trial use at Salzgitter since 2012.
2. Governance Arrangements & Agents of Change:	There were numerous R&D consortia working on the development of strip-casting technology. Innovation was strictly driven by steel companies, with support from machine manufacturers, but limited contributions from universities and public research facilities. The R&D consortia monitored each other's activities, and benchmarked themselves against the others' progress. After more and more of them closed down their R&D activities, only three remained: next to what is now Castrip, the other remaining consortia included EUROSTRIP and a collaboration between Nippon Steel and Mitsubishi. There was no public funding for Castrip; initial investment was largely carried by BHP (and some by IHI). Castrip LLC is owned in equal parts by BHP and Nucor, with IHI also holding a small percentage. Nucor carried the investment to get its first Castrip plant up and running. Altogether, estimates suggest that between 1980 and 2000, roughly 1-2% of the global steel industry's annual R&D spending went into strip-casting technology. Some of the competing R&D consortia received some public funding. Interestingly, none of them reached industrial scale, while the ones that did received no (or only minimal) funding. The development of strip casting was mostly driven by the prospect of saving on capital costs (investment for a strip caster is significantly lower than for a continuous caster and hot-rolling mill) and operating costs (especially by cutting down on energy and transport costs). Over strip casting's long innovation cycle, investment in R&D was particularly high when energy costs were high, as well as during the steel crises, which strengthened the need for more flexible and more compact process technologies. The other main driver, particularly for Nucor, was to integrate casting and rolling in mini mills, which would open up new market segments for them (e.g. the U.S. construction market for sheet steel). The prospect of turning a profit on thin strip steel at much lower output rates than are required for large integrated mills was appealing in a market that increasingly demanded flexibility. One important occurrence was Allegheny's 1984 claim to have had success in steel strip casting. This helped establish strip-casting technology as an important (and feasible) next step on many steelmakers' agendas, strengthening firm internal support for its development.
3. Transformative Capacities:	Seeing as the Castrip initiative was the first to put their strip casters to commercial use, it can be said that it was quite capable of generating the skills, knowledge and resources required for implementation. The Castrip process's low-carbon qualities were not distinguished by the consortium or the LLC at all. It was marketed as a way to cut costs, particularly energy costs, and as an option for small sites to become competitive in a new segment. It stands to reason, that this innovation would be marketed differently today, as the need for deep decarbonisation has started to appear on the industry's agenda. In fact, there is some evidence for this: Older press releases, news articles and scientific publications do not reference emissions at all. Only more recently (e.g. in announcing the licencing of Castrip technology to the Chinese Shagang Group) has the reduction of CO_2 emissions been mentioned as one of the technology's benefits.
4. Assessment &	Over the years, some estimates on emissions reductions have been made based on the

Evaluation:	energy savings reported by Castrip. According to these calculations, the Castrip process can reduce CO2 emissions by 80-90% over those from conventional casting and hot rolling. There are currently no estimates on absolute emissions reductions achieved at the plants currently operating a Castrip line; nor are there estimates of potential contributions that could be achieved by upscaling the innovation. So far, some technical limitations prevent such predictions from being feasible, as it is unclear whether the technology will be able to reach larger scales.
5. Uptake & Consequences:	In recent years, Castrip technology has been licensed to steel manufacturers outside of Nucor, in order to help the technology expand. The first of these licensees was Mexican steelmaker TYASA, who built a Castrip line near Orizaba, Veracruz. Chinese steelmaker Shagang has also constructed in Castrip line, and the technology has since sparked interest from British start-up Albion, leading them to consider building a Castrip line. So far, the technology has not achieved upscaling to capacity levels of large integrated steel mills. It will, however, be interesting to see future development as steel stocks saturate in developed countries and more and more steel could be made in smaller, secondary production facilities for which Castrip technology is well suited. The compactness of the technology also opens the industry up to new possibilities in terms of location: production could be set up much closer to customers, and could possibly even be integrated in the factories themselves.
Conclusion & Outlook	
Key Learnings:	*Unique features of this case:* Strip-casting innovation has spanned 150 years, which is a remarkably long time period even for the slow-moving steel sector. This makes it a very compelling case study, as the influence of market factors (steel crises, energy prices, demand for increased flexibility) and step-wise innovation making processes incrementally more efficient (from ingot casting to continuous casting to thin-slab casting to strip casting) can be observed with unusual clarity. *Key insights from this case regarding …* *Overall decarbonisation:* While the finishing steps of casting and rolling are not the main culprit when it comes to GHG emissions from the steel industry, they can still play an important role in decarbonisation. Their significance will become clearer as deep decarbonisation is achieved in primary and secondary steelmaking (e.g. through hydrogen direct reduction, CCS/CCU and the use of low-carbon electricity), making the need for efficient processes further down the value chain more apparent. *Drivers:* The relentlessness of the steelmakers in wanting to commercialise the technology (and the significant R&D investments that were made) show just how powerful a driver the prospect of cost reductions through efficiency gains can be. Looking ahead, an increase in CO_2 costs could prove to be an equally powerful incentive. What is more, the technology's suitability for smaller-scale production is an interesting driver that could play an important role as future steelmaking shifts more toward secondary production. *Barriers:* Up to this point, the main barriers to the further spreading of strip-casting technology have been related to long equipment lifecycles and technological limitations (some in terms of quality, but mostly in terms of scalability). *Instruments to overcome them:* The technology has already overcome a lot of its initial technical limitations, so continued innovation could prove to solve remaining quality issues. It will be interesting to observe whether strip-casting technology adapts to large-scale steel production, or whether there will be less pressure to do so as smaller, more local production gains importance. *Role of policy:* The bulk of the innovation process took place before decarbonisation entered any political agenda. As an energy-efficient option that could be suitable for any production route, it should be interesting to see if the technology will benefit from such policies in the future. As for public funding, the innovation process does not seem to have been negatively impacted by the fact that it did not receive any. The cost-cutting incentives were sufficient to merit full investment from the involved companies.
Open Questions & Further Research Requirements:	Future research could monitor the on-going development and dissemination of the technology, and address the possibilities for scaling it up to be used in big integrated carbon steel plants, and its application for different steel grades. Will the technology remain limited to small-capacity mini mills? How much of global thin-strip steel

	production could technically be covered by strip casting? Are there further efficiency improvements that could potentially be realised in the future (e.g. by further decreasing the need for secondary finishing)? What could be the technology's overall contribution to the decarbonisation of the steel sector?

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

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PARTICIPANTS & FUNDING

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