MaxH2DR: Enabling Deep Decarbonisation of EU Steelmaking through High-Purity Hydrogen Direct Reduction

Policy Brief

MaxH2DR - Maximise H2 Enrichment in Direct Reduction Shaft Furnaces
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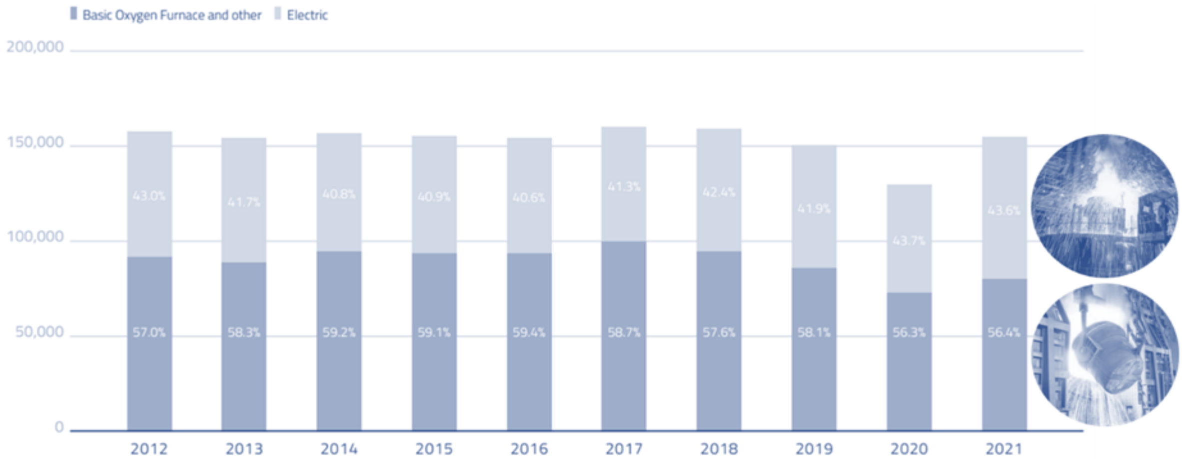
Hydrogen as a Game Changer in Steel Decarbonisation

The **steelmaking industry** is one of the most carbon intensive industrial processes in the world, generating **over 8% of global greenhouse** gas emissions (152 MtCO2e every year). Despite this, most of Europe still uses carbon intensive blast furnace methods (BF/BOF). With steel demand projected to grow 30% by 2050, **decarbonising this sector is a make-or-break priority**.



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	% shares 2021
Basic Oxygen Furnace and other	90,570	89,934	92,981	91,616	91,678	94,354	92,202	87,270	74,498	86,087	56.4%
Electric	68,433	64,384	64,084	63,513	62,620	66,515	67,864	62,974	57,719	66,548	43.6%
Total Crude Steel	**159,003**	**154,318**	**157,065**	**155,129**	**154,298**	**160,869**	**160,066**	**150,244**	**132,217**	**152,634**	**100%**

Figure 1: EU crude steel output by process adopted per year (2012-2021) in thousands metric tons.

Hydrogen direct reduction (H_2-DR) replaces coal with hydrogen to reduce iron ore, producing water instead of CO_2. This makes it a cornerstone of the EU's climate strategy, but the technology is still in its early stages, especially at high hydrogen concentrations. This is precisely the challenge that **MaxH2DR** aims to solve, by developing, demonstrating, and derisking hydrogen-based steelmaking at industrial scale

MaxH2DR at a Glance

MaxH2DR is a Horizon Europe Innovation Action project pioneering the next generation of hydrogen steelmaking. This project aims to accelerate the decarbonisation of steelmaking using high-purity hydrogen direct reduction (H_2-DR). MaxH2DR fills a critical industrial gap by developing mature, scalable hydrogen-integrated processes.

The project combines a physical demonstrator, validated digital twin models for gas-solid flow in shaft furnaces, and a mapped innovation ecosystem of 189 key players with €17 billion in tracked private investment.

This combination of physical demonstration, digital optimisation, and ecosystem intelligence outlines MaxH2DR alignment with EU decarbonisation goals and industrial policy priorities, and contribute to reinforcing European leadership in green steel. MaxH2DR represents a pivotal step in securing Europe's strategic autonomy in green steel technology.

Policy Context: Supporting the EU Green Deal and Industrial Policy

MaxH2DR aligns directly **supports EU Green Deal** contributing to 2030 (55%) and 2050 (net zero) climate goal. In addition, this project aligns with the **EU Hydrogen Strategy** (targeting 40 GW of electrolyser capacity by 2030), the **Fit-for-55 Package** (including reforms to ETS, CBAM, EED, and RED), the **Industrial Emissions Directive** and its BREF updates, and the **Circular Economy Action Plan**. These frameworks create a policy environment highly supportive of industrial decarbonisation.

Yet steelmaking remains a laggard. Entrenched infrastructure, process complexity, and the lack of proven H_2-DR alternatives have slowed the transition. While natural gas-based DR technologies are commercially available globally (e.g., Midrex), they are largely absent in Europe. BF-BOF processes still dominate over half of EU production, even as steel demand is projected to rise by 30% by 2050. Meanwhile, CBAM will impose increasing pressure to localise low-emissions production or face penalisation. At the same time, global frontrunners, especially Japan and the US, are progressing rapidly. Companies like Kobe Steel and Midrex lead in patent filings and demonstration-scale deployment. Without an EU-led scale-up pathway, Europe risks becoming a downstream adopter rather than a global standards-setter.

From Barriers to Breakthroughs: MaxH2DR's Technological Contribution

The MaxH2DR project responds directly to persistent technical barriers in hydrogen steelmaking. These range from process instability at high H_2 concentrations to knowledge gaps in DRI pellet behaviour and furnace design. The table below summarises how MaxH2DR tackles these bottlenecks.

Challenge	MaxH2DR Response
H_2-DR technology immature at >80% H_2 volume	Development of a **hybrid pilot demonstrator** and **digital optimisation toolkit**
Lack of gas–solid flow control in shaft furnaces	Deployment of coupled **DEM–CFD models for DRI conditions**
Uncertainty in pellet behaviour under enriched hydrogen	Establishment of a dedicated **test rig and generation of DRI property data**
Fragmented innovation landscape	**Mapping of 189 stakeholders** and **€17B** in private investment

MaxH2DR is the first EU project combining physical prototyping with market-mapped ecosystem strategy.

The Innovation Landscape: Mapping Europe's Green Steel Ecosystem

Insights from Ecosystem Intelligence

The innovation landscape is active but fragmented. Since 2014, **37 relevant R&D&I projects** have been funded across the **EU and UK, led by Germany, the UK, Austria, and Finland**. **Commercial activity includes 59 commercial initiatives**, most at **TRL 4-6**, with high traction in **Germany, Sweden, and the Netherlands**. **Patent leadership is dominated by a non-EU company**, notably Kobe Steel which acquired Midrex Inc., the world technology leader for DR technologies, while **the most relevant ones are from EU actors**, notably Voestalpine, Tenova and Thyssenkrupp. Major investors shaping the field include ArcelorMittal, H2 Green Steel, Tata Steel, HYBRIT, and Fortescue.

Category	**Volume**
Public R&D&I funding in relevant domains (EU + MS)	€145 billion
Private investment tracked in steel decarbonisation	€17 billion
Number of identified EU/national R&D&I projects	37
Number of commercial projects (mostly TRL 4–6)	59
Share of top relevant patents held by EU actors	Majority

Positioning the Players: Market & Innovation Positioning Map (MIPM)

The analysis reveals a clear imbalance: while Europe hosts a dense research landscape, IP ownership and advanced TRL projects are often concentrated in non-EU actors. Patent clustering shows Japan and multinational corporations outpacing EU-based filings, particularly in shaft furnace optimisation and H_2 injection technologies. This highlights both the strategic necessity and opportunity of accelerating European-led demonstration and IP capture.

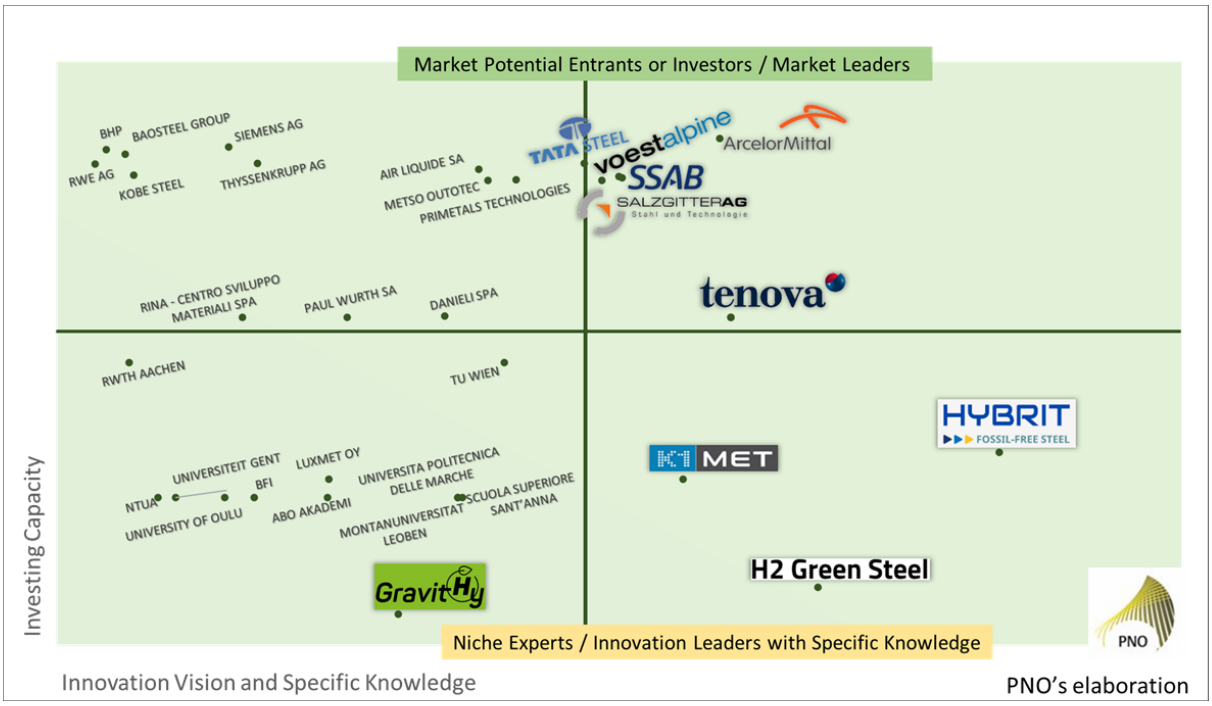


Figure 2 The Market & Innovation Positioning Map (MIPM) produced by PNO Innovation Italy, reporting a graphical distribution of the most relevant organisations emerged from the MaxH2DR intelligence analysis

- **Incumbents**: ArcelorMittal, SSAB, Voestalpine, Salzgitter, Tata Steel, Tenova – scaling fast, high purchasing power.
- **Technology Providers**: HYBRIT, H2 Green Steel, K1-MET – domain specialists with strong IP and technical depth, backed by private capital.
- **Followers**: Specialised SMEs and digital modellers.
- **Potential Entrants**: Industrial majors pivoting under CBAM and ETS pressure.

Policy Levers for Accelerated Impact

MaxH2DR provides a ready blueprint for decarbonising EU steelmaking. To scale hydrogen steel and move from innovation to implementation, policymakers should act across five coordinated fronts:

1. **Integrate hydrogen-enriched DR into industrial regulation**
   Position MaxH2DR outcomes within IED BREF updates as candidate Best Available Techniques and ensure CBAM benchmarks reflect the carbon performance of hydrogen-based processes.

2. **Mobilise funding for demonstration at scale**
   Use EU instruments, – including the Innovation Fund, EIB, and InvestEU to finance retrofitting, hybrid digital-physical pilots, and validation of processes operating above 80 vol-% hydrogen.

3. **Establish cross-sector standards for green steel**
   The development of EU-wide certification schemes for low-carbon steel can ensure traceability and facilitate adoption across sectors such as construction, automotive, and defence. Harmonised standards will be key to unlocking market confidence and procurement alignment.

4 **Leverage ecosystem intelligence in mission-driven R&I**
Align Horizon Europe, RFCS, and national calls with ecosystem gaps and tech maturity. So, apply MaxH2DR's network of 189 innovation actors and €17B of private investment to steer clustering, call design, and value chain development under Horizon Europe, RFCS, and the Green Deal Investment Plan.

5 **Advance gender equity in industrial innovation**
Address structural imbalance in the sector (>70% male-dominated) by embedding Gender Equality Plans and tracking leadership indicators in EU funding eligibility and reporting frameworks.

Urgency is clear: **without coordinated alignment of funding, regulation, and certification, the EU risks falling behind global competitors already scaling hydrogen-based steelmaking.** Europe's green steel future h**inges not just on technology, but on timing. MaxH2DR provides a tested foundation,** but it is now up to EU and national actors to operationalise this advantage. The next two years will be decisive: either Europe leads the hydrogen steel transition, or it adapts to standards set elsewhere.

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