Sponge Iron/Direct Reduced Iron (DRI)

Patent Landscape Report

This report provides a patent landscape of the advances in Sponge Iron/ Direct Reduced Iron (DRI) production technology. It includes the analysis of 3183 patents of various companies from 2010 to 2024.

STRIM ANALYTICS

Patent LandscapeReport

Sponge Iron/Direct Reduced Iron (DRI)

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Key Findings

Rapid Increase in Patent Activity

The Sponge Iron sector has witnessed a remarkable increase in patent activity over the past 14 years. The number of patents filed in this domain has grown sevenfold, significantly outpacing the general technological patent growth. This surge underscores the sector's vibrant innovation landscape, driven by advancements in direct reduction technologies and heightened industrial demand for more efficient and sustainable iron production methods.

China Leading in Patent Registrations

China emerges as the top jurisdiction for Sponge Iron patent registrations, boasting a substantial lead with 1894 patents. The United States follows, albeit with a much smaller share of 312 patents. The dominance of China in patent filings reflects its robust industrial focus and investment in metallurgical advancements, driven by both governmental support and the needs of its expansive manufacturing sector.

China vs. US: A Contrast in Patent Strategies

China and the United States present a stark contrast in their Sponge Iron patent landscapes. China not only leads in the number of patents but also exhibits a strong domestic focus, with patents primarily registered within the country. This indicates a strategy centered around internal industrial development and self-sufficiency. In contrast, the US shows a broader approach, with companies like MIDREX Technologies Inc. filing patents across multiple jurisdictions, reflecting a global market strategy aimed at wider commercial exploitation.

Dominance of Metallurgy and Reduction Processes

The top technologies in Sponge Iron patents are primarily concentrated in the areas of "Metallurgy of iron" and "Direct reduction processes." These technologies focus on enhancing the efficiency and sustainability of iron production, addressing critical issues such as energy consumption, emission reductions, and the utilization of alternative reducing agents like natural gas and hydrogen. The emphasis on these technologies highlights the industry's drive towards more innovative and environmentally friendly production methods.

Key Technologies Shaping the Future

The five pioneering technologies in the Sponge Iron sector, showing the highest growth in recent years, include:

1. Direct reduction processes (C21B13)

2. Preliminary treatment of ores or scrap (C22B1)

3. General processes of reducing to metals (C22B5)

4. Manufacture of carbon steel (C21C5)

5. Making pig-iron in blast furnaces (C21B5)

These technologies are evolving to meet the demands for higher efficiency and lower environmental impact, reflecting the sector's adaptation to regulatory pressures and market needs for sustainable practices.

Leading Innovators in Sponge Iron

The leading companies in the Sponge Iron patent landscape include MIDREX Technologies Inc., Jiangsu Province Metallurgical Design Institute Co., Ltd., and Danieli Off Mecc. MIDREX Technologies Inc. focuses on shaft furnace technologies and hydrogen utilization in reduction processes. Jiangsu Province Metallurgical Design Institute is noted for its extensive domestic patent filings and innovations in furnace design and ore treatment. Danieli Off Mecc emphasizes efficient material charging and feeding mechanisms, showcasing a commitment to improving operational efficiency in iron production.

Strategic Alliances Driving Innovation

Collaborations play a crucial role in the Sponge Iron industry, with leading companies forming strategic alliances to enhance technological development. For example, MIDREX Technologies collaborates with various partners to advance hydrogen-based reduction processes. These cooperative efforts facilitate the sharing of knowledge and resources, driving innovation and helping companies to address complex challenges more effectively.

Executive Summary

This report is the first of a series of patent landscape reports on Direct Reduced Iron (DRI) by STIMAnalytics. It presents the results of patent analyses in DRI domain, which were performed by STIMAnalytics AI-Powered service in collaboration with experts in patent knowledge and subject-matter. The aim of this report is to provide a summary of the main patent trends in DRI production technology and related areas. Patent information is a valuable source of technical information on patented inventions that reflect the commercial expectations of the applicants. Patent information often contains technical and other information that is not available from any other source.

This report can be useful as an information source in the Sponge Iron area. The report's methodology relies on AI-Powered service developed by STIMAnalytics. This app uses advanced algorithms and models to meet the needs of various stakeholders (Inc. R&D managers, product managers, technologist, researchers and academics) in established or emerging technical fields.

The number of inventions in Sponge Iron area has grown rapidly in recent years. The number of inventions in this field increased seven times over the last 14 years, which is much higher than the general growth in all fields of technology. The figure on the next page shows the number of International Patent Families in Sponge Iron and in all technical fields, as a function of the year when the inventions were first disclosed to the public.

- Patent Landscape Report at a Glance

In this report, 3183 patents have been examined, of which 1286 are active and 796 are pending. This shows the large number of patents requested in the last 3 years. Also, the three companies including Jiangsu Province Metallurgical Design Institute Co., Ltd., Jiangsu Province Metallurgical Design Institute Co., Ltd.and Danieli Off Mecc (Danieli & C. Officine Meccaniche S.p.A.) are the pioneers in patent registration in this field.

China leads the world in patent registrations with 1894 patents, followed by the US with 312 patents. Most of the top applicants across all regions are corporations.

Also, Jiangsu Province Metallurgical Design Institute Co., Ltd. has the largest number of highly-cited patents, which is a sign of the high value of this company's patents. The main themes of the patents represent the thematic focus of patents on areas such as water, iron, gas, furnace, reduction and sponge. In addition, “Metallurgy of iron” and “Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals” are the top technology areas in this field. In addition, three main patent applicant companies were examined separately.

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1. Introduction

Sponge Iron, also known as Direct Reduced Iron (DRI), is a product used in the steel manufacturing industry. It is created through a process called direct reduction, which involves converting iron ore into metallic iron without melting it. This is achieved by using a reducing gas made from natural gas or coal, which removes oxygen from the iron ore at temperatures below iron's melting point. Sponge Iron is crucial for metallurgical progress, offering a dependable iron source for steel-making. It aids in developing new materials and technologies, leading to robust and eco-friendly infrastructure. Its adaptability and reusability address today's engineering demands.

The purpose of this report is to give an overview of the key patent trends in the field of Sponge Iron. For this, the report uses publicly available patent information, which is a very rich source of technical information on inventions that were patented based on the commercial expectations of the applicants. Patent information often has technical information that is not found from any other source.

This report is based on the patent information collected from various patent databases related to different countries' patent offices. The keywords and classifications were selected to cover the relevant patents in this field. The text and metadata of the patents were analyzed using descriptive statistics and artificial intelligence (natural language processing) methods.

This patent landscape report is useful for commercial companies and technology developers in this field. This report consists of four main parts. First, the Patent Outlook section provides an overview of patent application macro trends, major applicants, major owners, market coverage of patents applied for by major players, and high-value patents.

Then, in the Technology Analysis section, the technology areas of interest to the applicants are introduced at four levels, based on the technology tree aligned with IPC. The emphasized technologies in the last five years are also presented. Key patents that have the most citations are also introduced. In addition, using machine learning methods, patents are clustered into different groups and top terms are presented for each cluster. The key themes of all patents are also presented using the topic modeling method.

Next, the Market and Competitor Analysis section examines the cooperation network of the main actors, the continuation of their activities in the last 10 years, and their patenting behavior through clustering of requested patents and investigating pending patents.

Finally, the patenting behavior of three key applicants is examined individually and in detail. The patent family of these three companies, along with emphasized technologies, technology collaborations, key patents, main themes of the requested subjects and patent clustering for each of these players are presented.

Overall, this report provides a 360’ view and a detailed picture of technology trends, market, and behavior of key players in this field. This valuable information can help companies in formulating technology, new product development and market entry strategies.

The Report Scope

This report covers:

- The trend of technology development in this field
- The patenting activities of various applicants
- The focused industries
- The top applicants

This report does not cover:

- A specific patent(s) analysis
- A detailed market analysis based on other sources besides patents
- A decision making suggestion

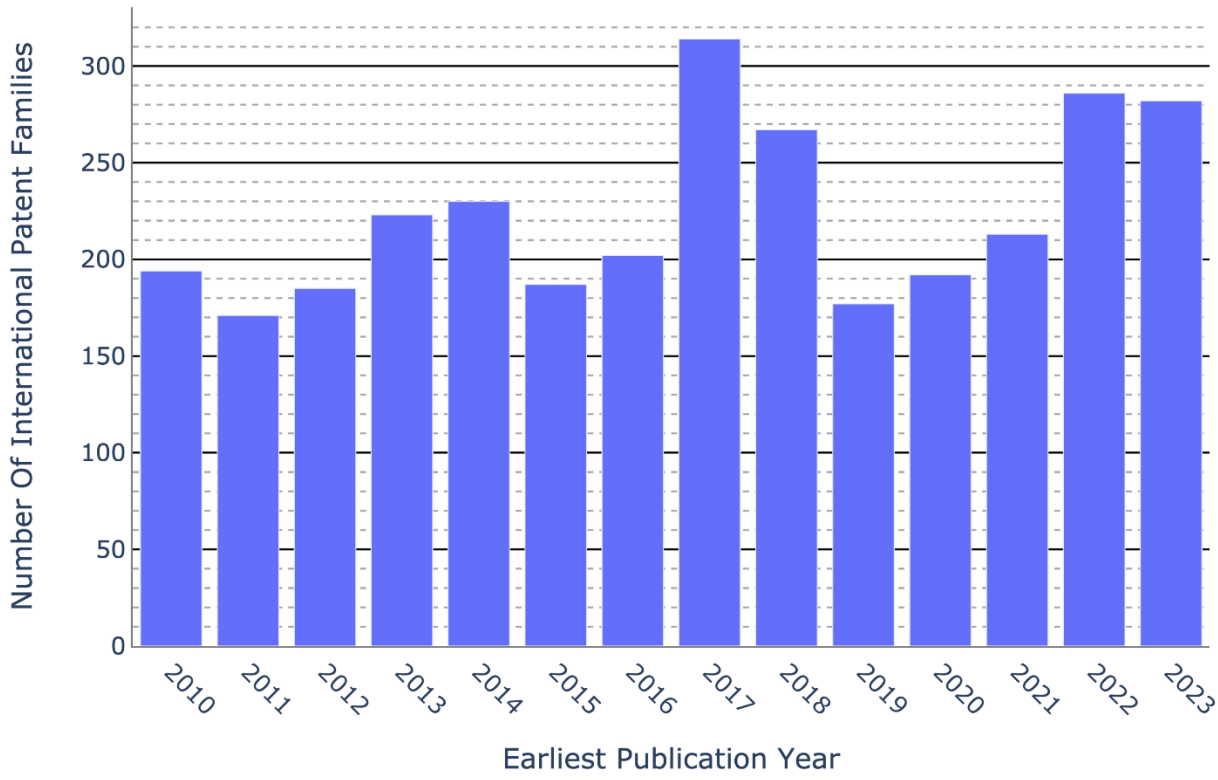
For more information, visit the STIMAnalytics.net website.

2. Patent Landscape Overview

2.1. Patent Family Analysis

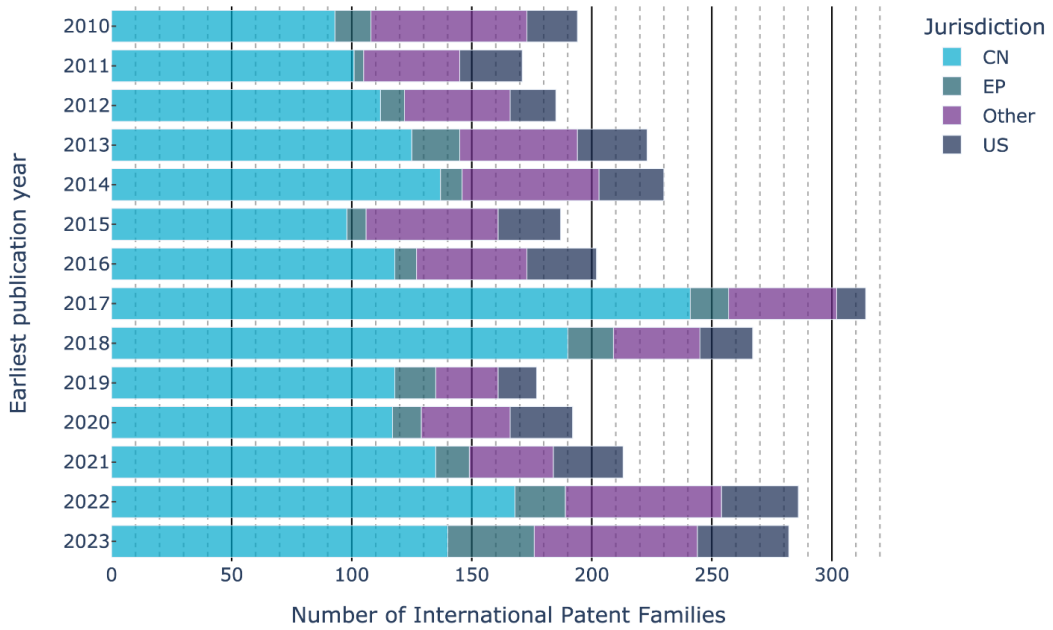
Analysis of patents related to DRI sector reveals a notable increase, with 3183 patents registered between 2010 and 2023. Although patent applications in this field have fluctuated over time, experiencing ups and downs, they have shown a steady overall increase in recent years, indicating strong commercial potential. The peak in registrations occurred in 2017. Currently, there are 796 pending patents, many of which are expected to be approved within the next 24 months, further contributing to recent statistics. Out of the total, 1286 patents are active, while 1101 are inactive, discontinued, or expired. This robust patent activity underscores the growing importance of this technology sector, with expectations of continued growth in patent filings in the coming years.

Another important point is that 67% of these patents have been registered since 2015 and this indicates that, with great probability, various products using these patents will be presented to the market in the coming years.

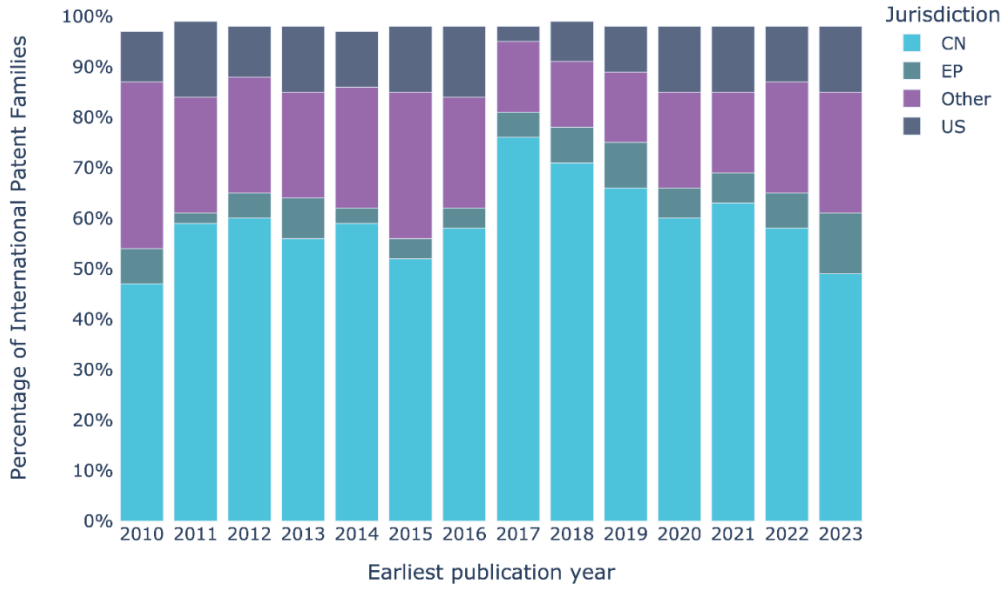


2.2. Patent-Market Coverage

China leads globally in patent registrations, consistently demonstrating a remarkable volume of patents registered each year.



Patent registrations in the United States have maintained a steady and relatively low level annually compared to China. Additionally, patent filings in Europe are trailing behind other regions. There has been a noticeable surge in companies registering patents in China, with a marked increase observed since 2011 reaching its peak in 2017 before declining. However, China still maintains the highest number of patent registrations.



2.3. Geographical jurisdiction

The distribution of registered patents across various countries highlights that the USA and China, collectively accounting for approximately 69% of all registered patents, significantly outpace other nations. This trend underscores the substantial growth potential for the future market of Sponge Iron field, particularly in these leading markets. Additionally, the European market is also following suit, albeit at a slower pace compared to the USA and China. Meanwhile, other countries like Australia, South Korea and Sweden are also important markets in this field.

3. Market and Competitor Analysis

3.1. Market at a Glance

Steady Growth with Significant CAGR

The global Sponge Iron market was valued at approximately USD 89.62 billion in 2022 and is projected to reach USD 117.5 billion by 2032, with a Compound Annual Growth Rate (CAGR) of 2.73% during this period. This growth is driven by increasing demand for high-quality steel in construction, automotive, and other industries, along with technological advancements in production processes that improve efficiency and reduce environmental impact.

Positive Sales Trajectory

The market sales forecast for Sponge Iron indicates a steady increase in global demand. By 2032, the market is expected to reach USD 117.5 billion, reflecting ongoing investments in infrastructure projects and urbanization, particularly in emerging economies. The forecasted growth underscores the importance of Sponge Iron as a critical raw material in steel production, with its usage expanding across various industrial applications.

Diverse Industrial Applications

Sponge Iron is predominantly used in the metallurgical and steel industries. The metallurgical industry utilizes Sponge Iron as a crucial raw material for producing high-quality steel via electric arc furnaces. In the steel industry, it serves as an efficient and cost-effective feedstock alternative to traditional iron ore. Additionally, Sponge Iron finds applications in manufacturing wrought iron and iron powder for various industrial purposes.

Asia-Pacific Leading the Charge

The Asia-Pacific region, particularly India and China, dominates the Sponge Iron market due to their extensive steel production capacities and abundant raw material resources. North America and Europe also hold significant market shares, driven by technological advancements and regulatory support for sustainable practices. Other regions such as Latin America, the Middle East, and Africa are witnessing steady growth, fueled by increasing infrastructural developments and industrial activities.

Key Industry Players and Their Market Share

Leading players in the Sponge Iron market include MIDREX Technologies Inc., Tata Sponge, Mobarakeh Steel Company, Jindal Steel & Power Ltd., and Danieli Off Mecc. These companies dominate the market through extensive patent portfolios, innovative production methods, and strategic market expansions. The competitive landscape is characterized by these players' continuous investments in R&D and their efforts to enhance production capacities to meet the growing demand.

Strategic Consolidations to Strengthen Market Position

The Sponge Iron market has seen numerous mergers and acquisitions as companies strive to expand their market presence and technological capabilities. Notable examples include Tata Steel's investment of USD 2 billion to expand its Sponge Iron production capacity and ArcelorMittal's strategic investments in creating new production units for specialized steel products. These strategic moves are aimed at enhancing competitiveness, driving innovation, and addressing the increasing demand for high-quality steel.

Main Drivers: From Urbanization Development to Cost Efficiency

Urbanization and Infrastructure Development: Growing urbanization and infrastructure projects boost the demand for steel, thereby driving the Sponge Iron market.

Technological Advancements: Innovations in direct reduction technologies and the use of hydrogen as a reducing agent enhance production efficiency and environmental compliance.

Cost Efficiency: Sponge Iron is a cost-effective alternative to traditional iron ore, making it attractive to steel manufacturers aiming to optimize production costs.

Main Challenges: Environmental Issues as a main Concern

Environmental Concerns: The production process of Sponge Iron can raise environmental issues due to carbon emissions, leading to regulatory challenges and the need for cleaner technologies.

Competitive Alternatives: The availability of alternative materials and processes for steel production, such as scrap metal recycling and traditional blast furnaces, can impact the demand for Sponge Iron.

Economic and Trade Factors: Changes in trade policies, tariffs, or geopolitical tensions can affect the global flow of raw materials and finished steel products, influencing market dynamics.

3.2. Market Share of Main Producers

The market share of main players in the Sponge Iron industry is closely tied to their sales and the technologies they employ. MIDREX Technologies Inc. leads with a dominant market share due to its efficient gas-based shaft furnace technology. Indian companies like Tata Sponge and Jindal Steel & Power Ltd. rely heavily on coal-based rotary kiln processes. Danieli Off Mecc and Mobarakeh Steel Company leverage advanced gas-based reduction technologies to maintain their market positions. The integration of innovative and environmentally friendly technologies is a key factor driving the market leadership of these companies.

MIDREX Technologies Inc.

- Market Share: MIDREX Technologies Inc. holds approximately 60% of the global Sponge Iron market share.
- Sales: Estimated sales of around USD 5-6 billion annually.

- Main Technologies: MIDREX Process – a gas-based shaft furnace technology that uses natural gas to reduce iron ore, making it one of the most efficient and widely used DRI technologies globally.

Tata Sponge

- Market Share: Tata Sponge holds about 10-12% of the global market share.
- Sales: Estimated sales of approximately USD 1-1.2 billion annually.
- Main Technologies**: Rotary Kiln Process – primarily coal-based technology for direct reduction, widely used in India due to the availability of coal.

Jindal Steel & Power Ltd.

- Market Share: Jindal Steel & Power Ltd. has an 8-10% market share.
- Sales: Estimated sales of around USD 800 million to 1 billion annually.
- Main Technologies: Rotary Kiln Process – similar to Tata Sponge, using coal-based reduction methods, with a focus on enhancing operational efficiencies and product quality.

Danieli Off Mecc (Danieli & C. Officine Meccaniche S.p.A.)

- Market Share: Danieli Off Mecc holds approximately 5-7% of the market share.
- Sales: Estimated sales of around USD 500-700 million annually.
- Main Technologies: ENERGIRON Process – a joint venture with Tenova, using a gas-based direct reduction technology that allows for flexibility in the use of reducing gases, including natural gas and hydrogen.

Mobarakeh Steel Company

- Market Share: Mobarakeh Steel Company has a market share of about 5-7%.
- Sales: Estimated sales of around USD 500-700 million annually.
- Main Technologies: PERED Technology – a Persian reduction process that uses natural gas as a reducing agent, developed specifically for Iran’s iron ore and natural gas resources.

Welspun Group

- Market Share: Welspun Group holds approximately 4-6% of the market share.
- Sales: Estimated sales of around USD 400-600 million annually.
- Main Technologies: Rotary Kiln Process – similar to other Indian manufacturers, utilizing coal-based reduction techniques.

ArcelorMittal

- Market Share: ArcelorMittal has around 3-5% market share.
- Sales: Estimated sales of around USD 300-500 million annually.
- Main Technologies: Various DRI technologies including MIDREX and ENERGIRON processes, with a strong emphasis on integrating green hydrogen to reduce carbon footprint in iron production.

3.3. Main Processes in Sponge Iron Production

MIDREX Technology

MIDREX Technology is one of the leading processes for the production of Direct Reduced Iron (DRI). It uses natural gas as the reducing agent and operates in a shaft furnace. The main advantages of MIDREX Technology include high efficiency, low energy consumption, and the ability to produce high-quality DRI with minimal impurities.

Rotary Kiln Process

The Rotary Kiln Process is another widely used method, particularly in regions with abundant coal resources. This process involves the reduction of iron ore using coal in a rotary kiln. It is known for its flexibility in raw material usage and the ability to produce various forms of iron.

ENERGIRON Process

The ENERGIRON Process, developed by a joint venture between Tenova and Danieli, is a flexible direct reduction technology that can utilize both natural gas and hydrogen as reducing agents. It emphasizes environmental sustainability by reducing carbon emissions.

3.4. DRI Production Plants by Process

MIDREX® Process

Plant Location	Capacity (Mt/y)	Modules	Product	Start-up	Status	Process
ArcelorMittal Hamburg	0.40	1	CDRI	1971	O	MIDREX®
ArcelorMittal Canada 1	0.40	1	CDRI	1973	O	MIDREX®
Tenaris Siderca	0.40	1	CDRI	1976	O	MIDREX®
ArcelorMittal Canada 2	0.60	1	CDRI	1977	O	MIDREX®
SIDOR I	0.35	1	CDRI	1977	I	MIDREX®
Acindar	0.60	1	CDRI	1978	O	MIDREX®
Qatar Steel 1	0.40	1	CDRI	1978	I	MIDREX®
SIDOR IIA, IIB, IIC	1.29	3	CDRI	1979	O	MIDREX®
ArcelorMittal Point Lisas I & II	0.84	2	CDRI	1980/82	I	MIDREX®
Delta Steel I & II	1.02	2	CDRI	1982	I	MIDREX®
Hadeed A & B	0.80	2	CDRI	1982/83	O	MIDREX®
OEMK I - IV	1.67	4	CDRI	1983/85/87	O	MIDREX®
Antara Steel Mills	0.65	1	HBI	1984	O	MIDREX®
EZDK I	0.72	1	CDRI	1986	O	MIDREX®
Khouzestan Steel Co. I - III	2.05	3	CDRI	1989/90/92	O	MIDREX®
LISCO 1 & 2	1.10	2	CDRI	1989/90	O	MIDREX®
AM/NS India I & II	0.88	2	CDRI/HDRI	1990	O	MIDREX®
FMO	1.00	1	HBI	1990	O	MIDREX®

VENPRECAR	0.82	1	HBI	1990	O	MIDREX®
AM/NS India III	0.44	1	HBI/HDRI	1992	O	MIDREX®
Hadeed C	0.65	1	CDRI	1992	O	MIDREX®
Mobarakeh Steel A - E	4.00	5	CDRI	1992/93/94	O	MIDREX®
JSW Steel Ltd.	1.00	1	CDRI	1994	O	MIDREX®
EZDK II	0.80	1	CDRI	1997	O	MIDREX®
LISCO 3	0.65	1	HBI	1997	O	MIDREX®
ArcelorMittal Lázaro Cárdenas	1.20	1	CDRI	1997	O	MIDREX®
COMSIGUA	1.00	1	HBI	1998	O	MIDREX®
ArcelorMittal Point Lisas III	1.36	1	CDRI	1999	I	MIDREX®
ArcelorMittal South Africa	0.80	1	CDRI	1999	I	MIDREX®
EZDK III	0.80	1	CDRI	2000	O	MIDREX®
Khouzestan Steel IV	0.85	1	CDRI	2001	O	MIDREX®
AM/NS India IV	1.00	1	HBI/HDRI	2004	O	MIDREX®
Nu-Iron	1.60	1	CDRI	2006	O	MIDREX®
AM/NS India V	1.50	1	HBI/HDRI	2006	O	MIDREX®
Mobarakeh Steel F	0.85	1	CDRI	2006	O	MIDREX®
DRIC I & II	1.00	2	CDRI	2007	O	MIDREX®
Hadeed E	1.76	1	HDRI/CDRI	2007	O	MIDREX®
LGOK HBI-2	1.40	1	HBI	2007	O	MIDREX®
Qatar Steel 2	1.50	1	CDRI/HBI	2007	O	MIDREX®
Khouzestan Steel V	0.92	1	CDRI	2008	O	MIDREX®
Lion DRI	1.54	1	HDRI/HBI	2008	I	MIDREX®
Hormozgan A & B	1.66	2	CDRI	2009/10	O	MIDREX®
AM/NS India VI	1.50	1	CDRI	2010	O	MIDREX®
Khorasan Steel I	0.80	1	CDRI	2010	O	MIDREX®
JindalShadeed	1.50	1	HDRI/HBI	2010	O	MIDREX®
Ghadir Iron and Steel Company	0.80	1	CDRI	2011	O	MIDREX®
Khorasan Steel II	0.80	1	CDRI	2011	O	MIDREX®
South Kaveh Steel A & B	1.86	2	CDRI	2012	O	MIDREX®
Mobarakeh Steel (Kharazi A & B)	2.76	2	CDRI	2012/14	O	MIDREX®
Tuwairqi Steel Mills	1.28	1	HDRI/CDRI	2013	I	MIDREX®
SULB	1.50	1	HDRI/CDRI	2013	O	MIDREX®
Arfa Steel Company	0.80	1	CDRI	2013	O	MIDREX®
Mobarakeh Steel (Saba)	1.38	1	CDRI	2013	O	MIDREX®
JSW Steel Ltd.	1.20	1	HDRI/CDRI	2014	O	MIDREX®
Sirjan Iranian Co.	0.80	1	CDRI	2014	O	MIDREX®
Jindal Steel & Power	1.80	1	HDRI/CDRI	2014	O	MIDREX®
ESISCO	1.76	1	HDRI/CDRI	2015	I	MIDREX®
Sirjan Jahan Co. 1	0.96	1	CDRI	2015	O	MIDREX®
Golgohar Iron & Steel Development 1	1.70	1	CDRI	2015	O	MIDREX®
ArcelorMittal Texas HBI	2.00	1	HBI	2016	O	MIDREX®
Sefid Dasht Steel	0.80	1	CDRI	2016	O	MIDREX®
LGOK HBI-3	1.80	1	HBI	2017	O	MIDREX®

Persian Gulf Saba Steel	1.50	1	HBI	2017	O	MIDREX®
Sabzevar Steel Company	0.80	1	CDRI	2018	O	MIDREX®
Golgohar Iron & Steel Development 2	1.70	1	CDRI	2018	O	MIDREX®
Tosyali Algérie 1	2.50	1	HDRI/CDRI	2018	O	MIDREX®
Chadormalu M & I Co.	1.55	1	HDRI/CDRI	2018	O	MIDREX®
Pasargad Steel	1.50	1	HDRI/CDRI	2019	O	MIDREX®
Ardakan Steel	0.96	1	CDRI	2020	O	MIDREX®
Cleveland-Cliffs HBI Plant	1.60	1	HBI	2020	O	MIDREX®
Algerian Qatari Steel (AQS)	2.50	1	HDRI/CDRI	2021	O	MIDREX®
Qaenat	0.80	1	CDRI		C	MIDREX®
Makran	1.60	1	HBI		C	MIDREX®
Sirjan Jahan Co. 2	0.90	1	CDRI		C	MIDREX®
Torbat	1.85	1	CDRI		C	MIDREX®
Saqqez	1.00	1	HBI		C	MIDREX®
Tosyali Algérie 2	2.50	1	HDRI/CDRI		C	MIDREX®
Khouzestan Steel VI	1.76	1	CDRI	2023	C	MIDREX®
H2 Green Steel	2.10	1	HDRI/CDRI	2025	C	MIDREX®

HYL/ENERGIRON Process

Plant Location	Capacity (Mt/y)	Modules	Product	Start-up	Status	Process
Ternium Monterrey	0.70	1	CDRI	1980	O	HYL/ENERGIRON
Suez Steel	1.95	1	HDRI	2012	O	HYL/ENERGIRON
Ezz Rolling Mills	1.90	1	HDRI	2012	O	HYL/ENERGIRON
Emirates Steel Industries I	2.00	1	HDRI	2009	O	HYL/ENERGIRON
Emirates Steel Industries II	2.00	1	HDRI	2011	O	HYL/ENERGIRON
Tosyali Toyo	1.80	1	HDRI	2021	O	HYL/ENERGIRON
Jindal Shadeed	1.80	1	HDRI	2021	O	HYL/ENERGIRON
Algerian Qatari Steel	2.50	1	HDRI/CDRI	2021	O	HYL/ENERGIRON
Baosteel Zhanjiang	1.00	1	CDRI		C	HYL/ENERGIRON
Mobarakeh Steel (Kharazi A & B)	2.76	2	CDRI	2012/14	O	HYL/ENERGIRON
Mobarakeh Steel (Saba)	1.38	1	CDRI	2013	O	HYL/ENERGIRON

Rotary Kiln Process

Plant Location	Capacity (Mt/y)	Modules	Product	Start-up	Status	Process
Tata Sponge Iron Ltd.	0.39	2	CDRI	1983/93	O	Rotary Kiln
SAIL Rourkela	0.15	1	CDRI	1985	O	Rotary Kiln
Jindal Steel & Power	1.80	1	HDRI/CDRI	2014	O	Rotary Kiln
Prakash Industries	0.60	2	CDRI	1994/95	O	Rotary Kiln

Monnet Ispat	0.30	2	CDRI	1994/98	O	Rotary Kiln
BMM Ispat Ltd	0.73	2	CDRI	2003/04	O	Rotary Kiln
Godawari Power and Ispat	0.50	2	CDRI	2001/04	O	Rotary Kiln
Vandana Global	0.05	1	CDRI	2002	O	Rotary Kiln
Electrotherm (India) Ltd.	0.15	1	CDRI	2005	O	Rotary Kiln
Sarda Energy and Minerals Ltd.	0.36	1	CDRI	2006	O	Rotary Kiln
PT Meratus Jaya	0.32	1	CDRI	2013	O	Rotary Kiln

PERED Process

Plant Location	Capacity (Mt/y)	Modules	Product	Start-up	Status	Process
Shadegan Steel	0.80	1	CDRI	2017	O	PERED
Mianeh Steel	0.80	1	CDRI	2017	O	PERED
Neyriz Steel	0.80	1	CDRI	2017	O	PERED
Baft Steel	0.80	1	CDRI	2017	O	PERED

3.5. Main Processes and Market Trends

Global DRI Production Reaches New Heights

The global production of Direct Reduced Iron (DRI) in 2022 reached a record 127.36 million tons (Mt), marking an increase of 6.9% from the previous year. This growth was primarily driven by substantial production increases in India and Iran, which together accounted for more than half of the global output. The surge in production over the past six years has been significant, with a 75% increase driven by the expansion of coal-based DRI production in India and the doubling of natural gas-based production in Iran.

MIDREX Process Dominates 2022 DRI Production

In 2022, the MIDREX process continued to lead DRI production, accounting for 57.8% of the global output, equivalent to 73.55 Mt. The Rotary Kiln process followed with 27.9%, while the HYL/Energiron process contributed 12.1%. The PERED process and other methods made up the remaining 2.3%. The majority of DRI produced using MIDREX technology was gas-based, highlighting its efficiency and environmental benefits compared to coal-based methods.

Shift Towards Low CO2 DRI Production

In 2022, the emphasis on reducing CO2 emissions in DRI production was evident, with 70.1% of the global DRI output being produced using natural gas, a low CO2 emitting source. The remaining 29.9% was produced using coal, which has higher CO2 emissions. The MIDREX process, being primarily natural gas-based, played a crucial role in reducing the carbon footprint of the DRI industry.

Expansion of Hydrogen-Based DRI Plants

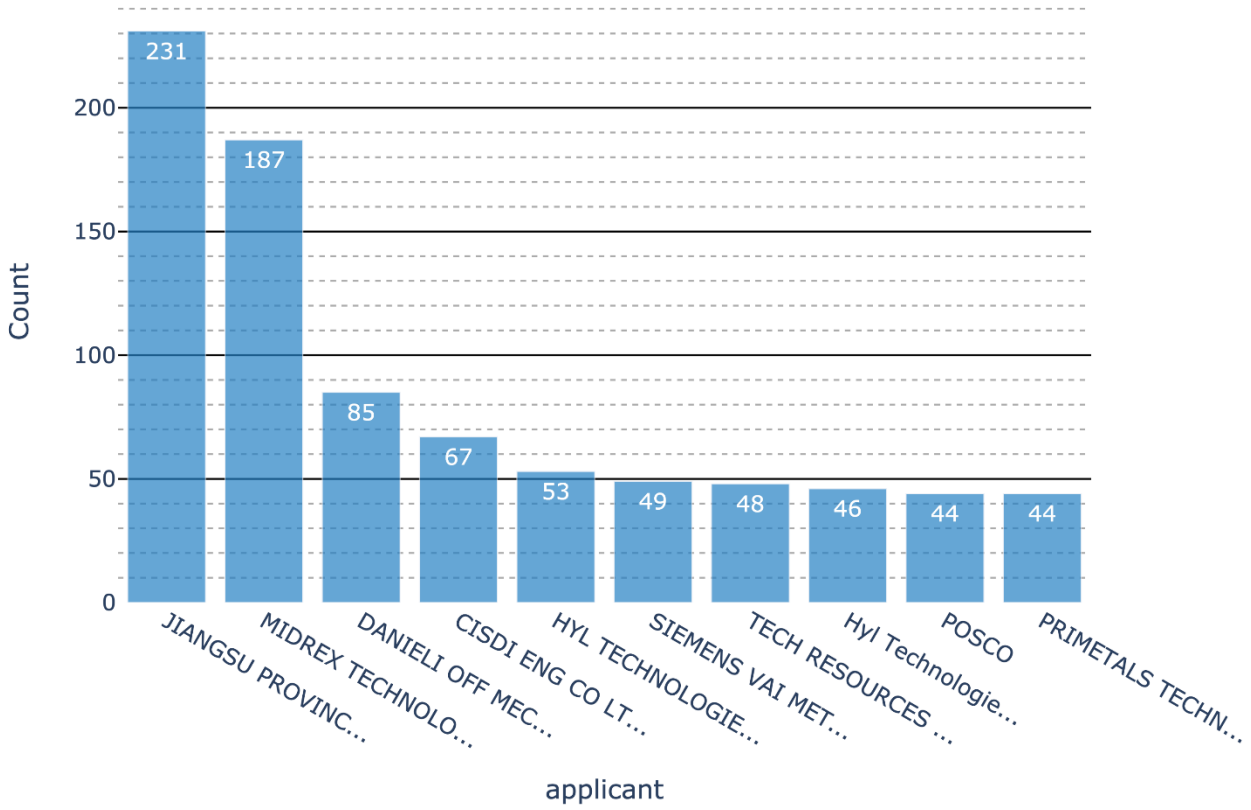
Significant new capacities were announced in 2022, particularly focusing on hydrogen-based DRI production. Notably, H2 Green Steel selected Midrex and Paul Wurth to supply the world's first commercial 100% hydrogen-based DRI plant in Sweden, set to begin production in 2025. ArcelorMittal also chose ENERGIRON technology for its Dofasco steel mill in Canada, with plans to incorporate hydrogen. These developments indicate a strong shift towards green steel production using hydrogen to significantly cut CO2 emissions.

New DRI Projects Underway to Meet Growing Demand

Several DRI production plants were under construction in 2022, including innovative projects that integrate hydrogen into the reduction process. Notable projects include the hydrogen-ready ENERGIRON plant at Baosteel Zhanjiang in China and various MIDREX and ENERGIRON plants across Iran and Algeria. These plants are expected to boost global DRI production capacity and enhance the adoption of environmentally friendly technologies in the iron and steel industry.

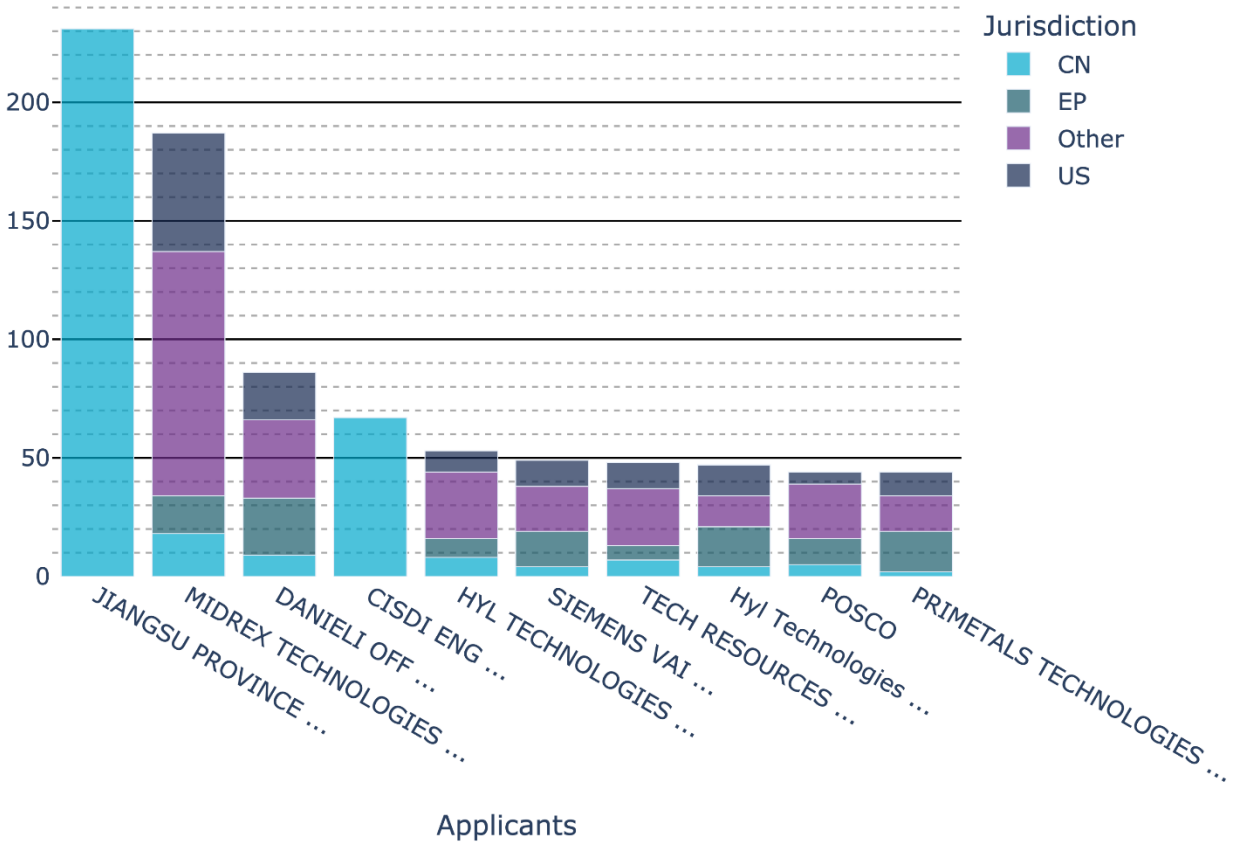
3.6. Top Applicants

The top patent applicant is Jiangsu Province Metallurgical Design Institute Co., Ltd., with over 200 patent applications, significantly ahead of other competitors. Following closely behind are MIDREX Technologies Inc. and Danieli Off Mecc.

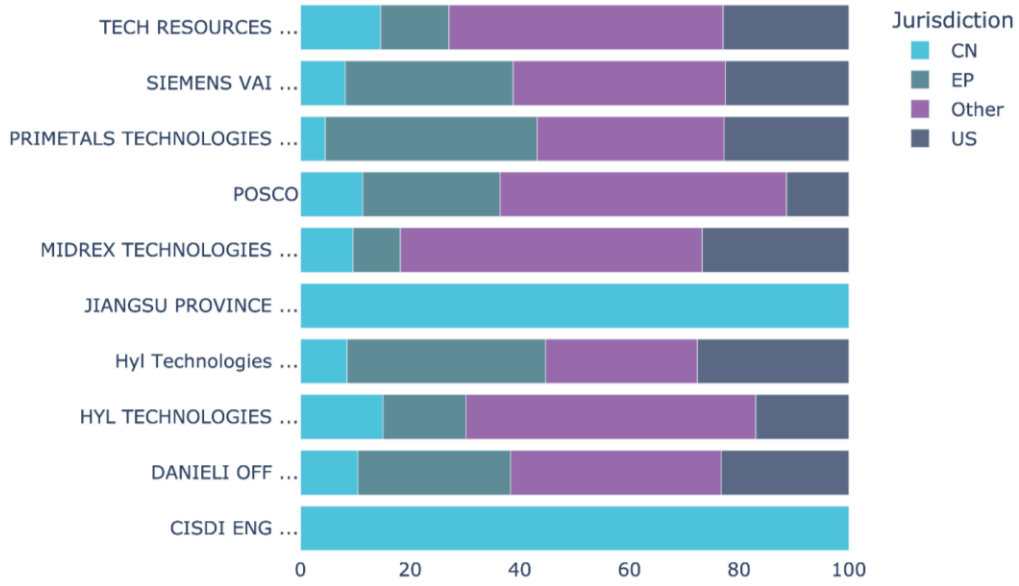


3.7. Market Coverage of Top Applicants

As can be seen in the chart below, MIDREX Technologies Inc. has considered a wide range of markets for its technologies and related products and has filed patent applications in all major jurisdictions.

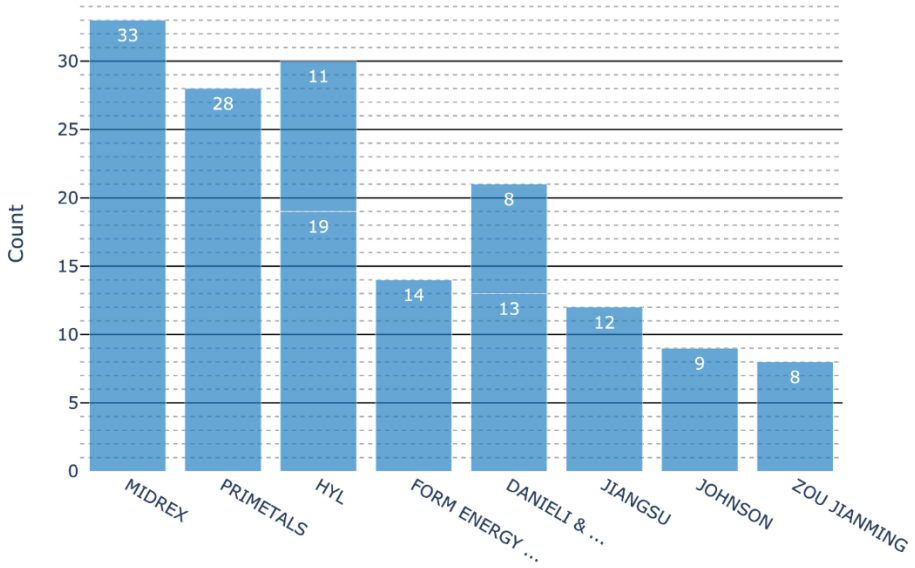


Moreover, major Chinese applicants have predominantly registered patents within China, suggesting a focus on domestic production or potentially licensing patents to other Chinese companies. The figure below shows the distribution of patent applications by the top applicants across different jurisdictions.



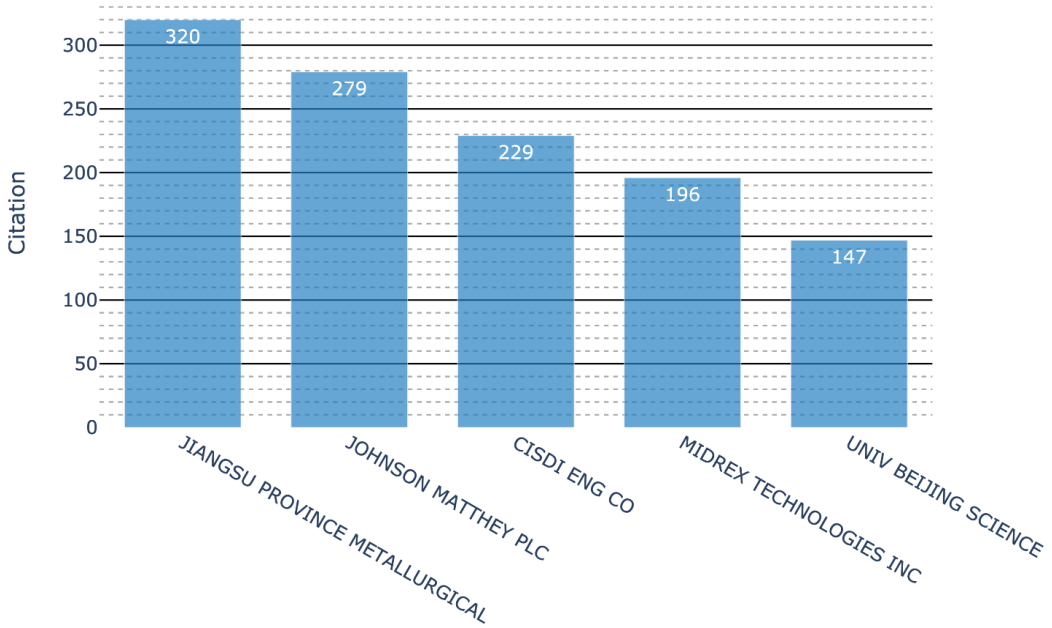
3.8. Top Owners

Patent owners may not always be the same as the applicants. Typically, the owners are the primary beneficiaries of patents. In the realms of Sponge Iron, MIDREX Technologies Inc holds the most extensive patent portfolio, followed by HYL Technologies S.A. de C.V. and PRIMETALS Technologies Austria GmbH.



3.9. Highly-Cited Applicants

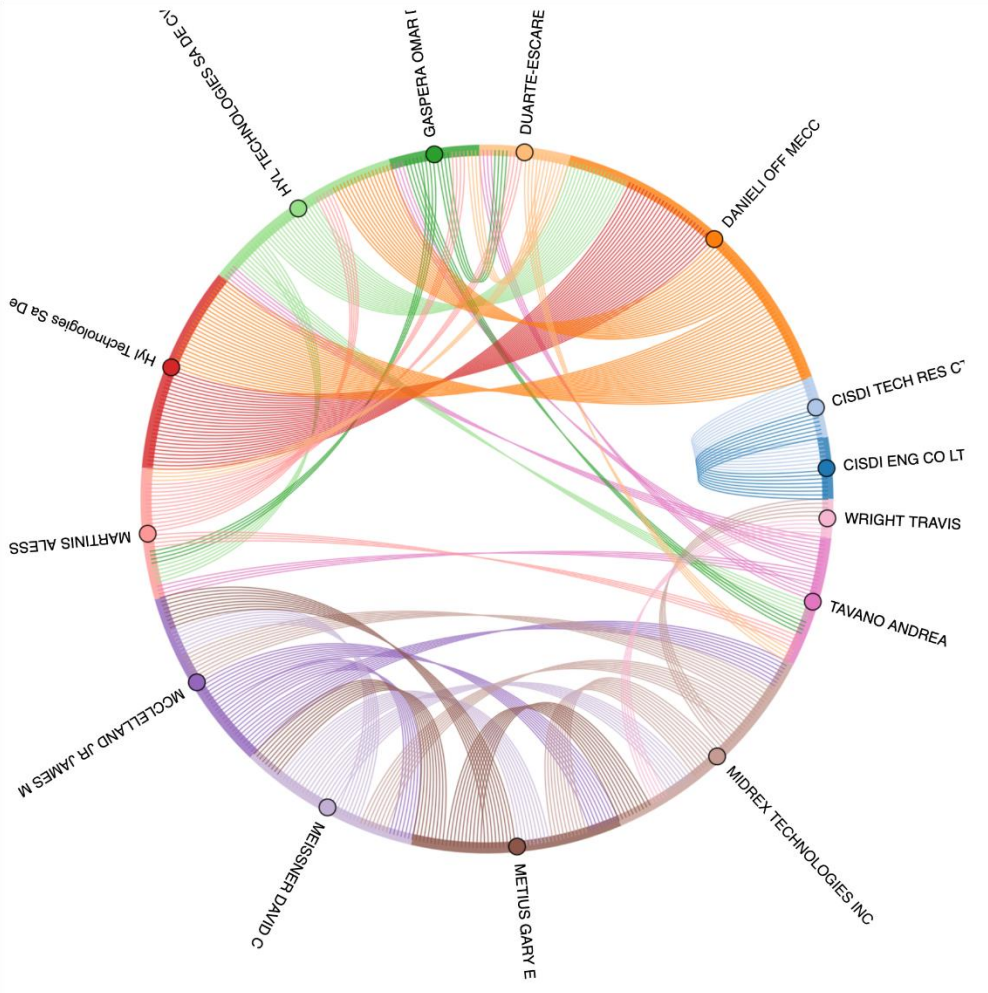
Jiangsu Province Metallurgical Design Institute Co., Ltd. holds the highest number of citations with 320, followed by Johnson Matthey PLC and CISDI ENG CO. The significant number of citations for Jiangsu Province Metallurgical's patents reflects the high value attributed to their registered patents.



3.10. Collaboration

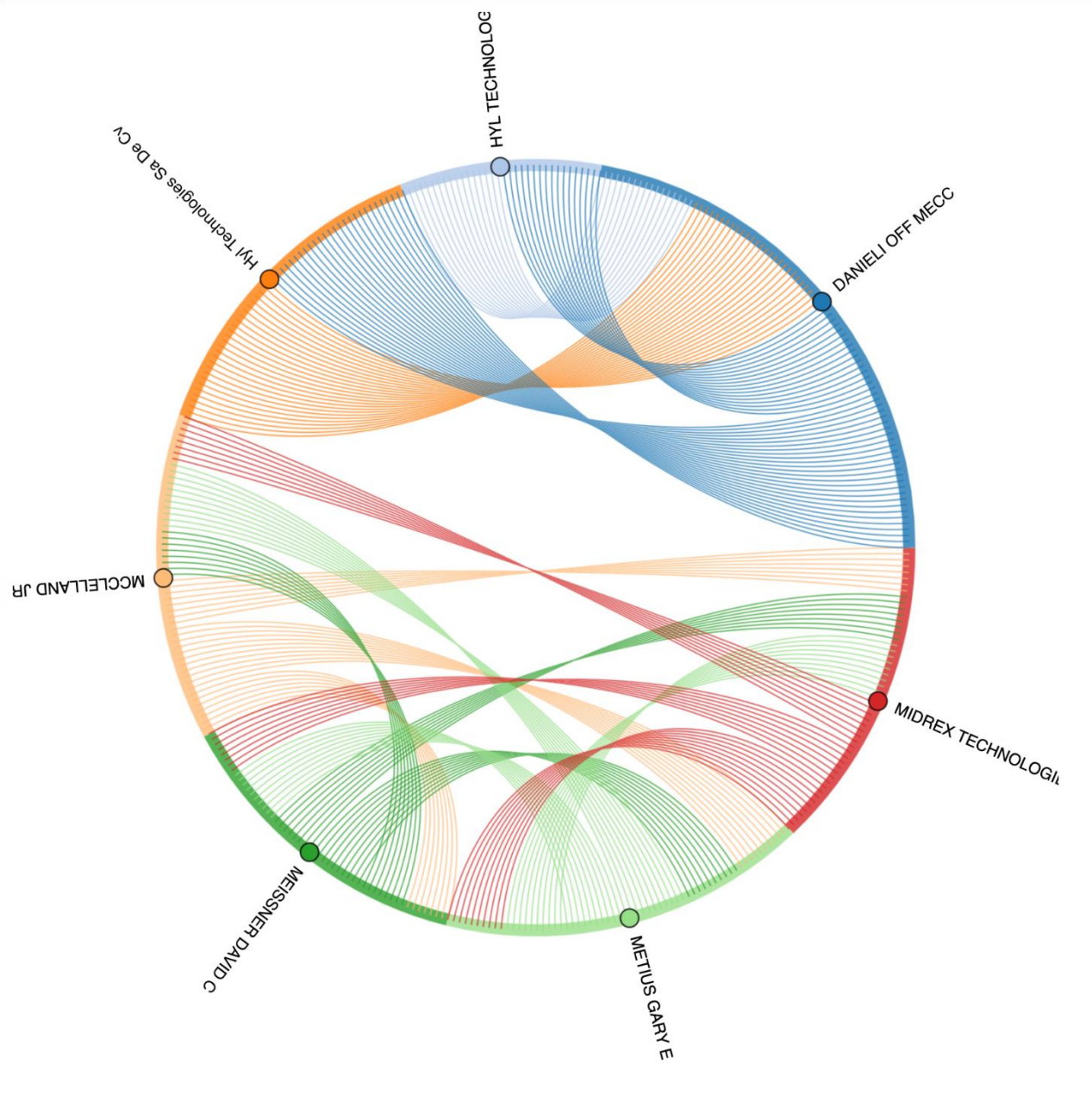
3.10.1. Top Ten Applicants' collaborations

Technological development and innovation occur in a network of cooperation between actors. Understanding the cooperation network of leading companies in the field of patent application can indicate the policies of different companies in the field of technology development and innovation. Also, the precise understanding of these networks can help to find new partners in the path of technology development. In the figure below, the collaborations of the main patent applicant companies are presented.



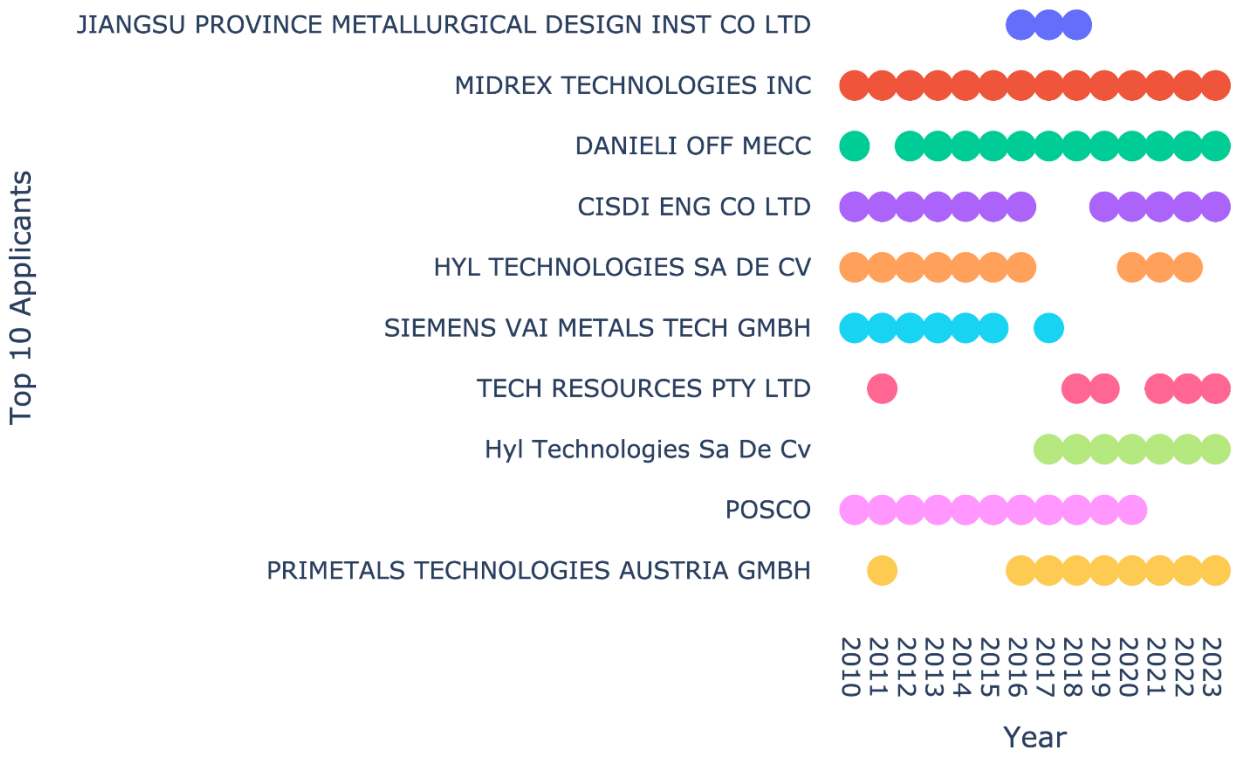
3.10.2. The strongest cooperation networks

In this section, the cooperation between different actors has been investigated, and among them, the cases of cooperation that have led to the highest application for patents have been counted. The identification of these cooperation networks can be used to analyze the future trends of technology development and cooperation between actors.



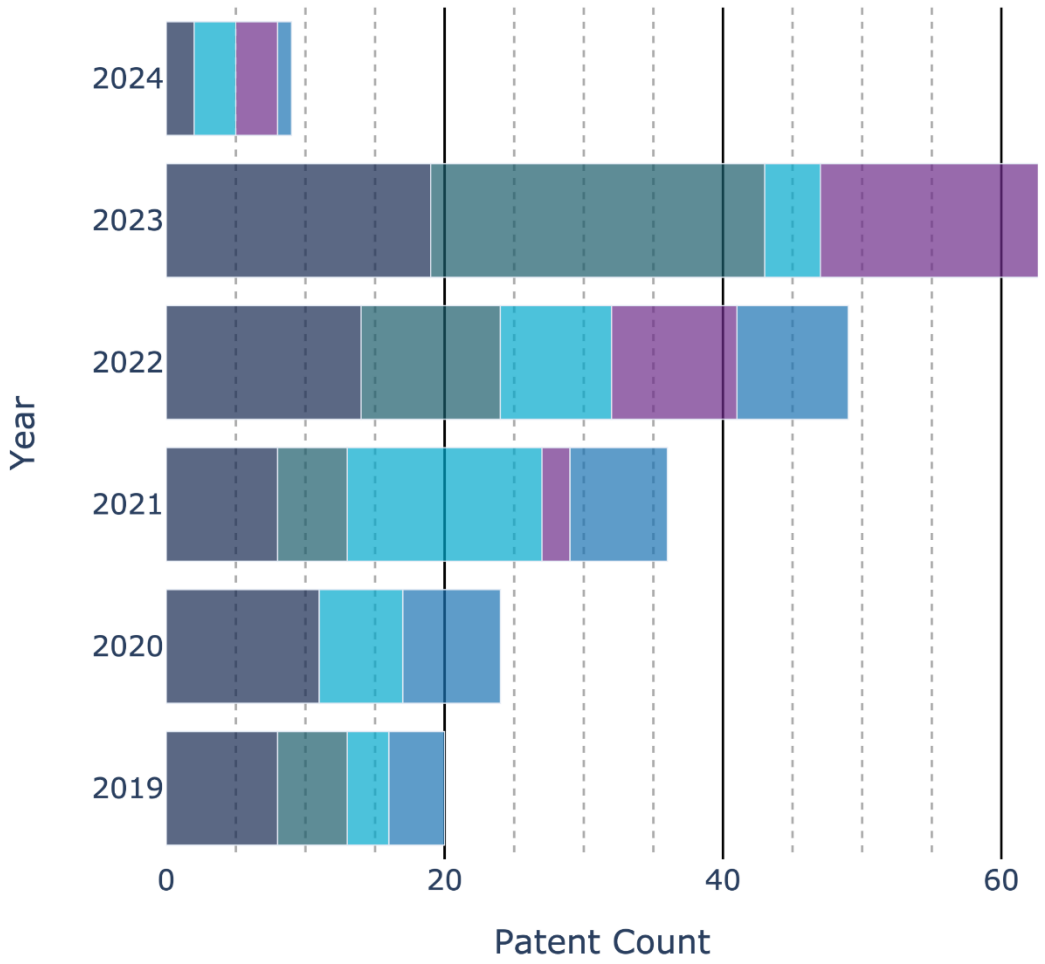
3.11. Top applicant activity

The continuation of technological activities in the main patent applicant companies over time shows the level of attention and concentration of companies in the field of their technological activities. As can be seen in the diagram below, the continuity of patenting activities of ten main patent applicant companies in the field of Direct Reduced Iron (DRI) is presented.



3.12. Pioneer companies in the last 5 years

The amount of patent registration of companies in the last 5 years can indicate the possible business strategies of these companies in the coming years. As you can see in the figure below MIDREX Technologies Inc. is the leader in patent registration in this field. After this company, there are Tech Resources, Danieli Officine Meccaniche S.p.A. and Hybrit Development AB.



1 MIDREX Technologies Inc
Total Patents: 62

2 Tech Resources
Total Patents: 44

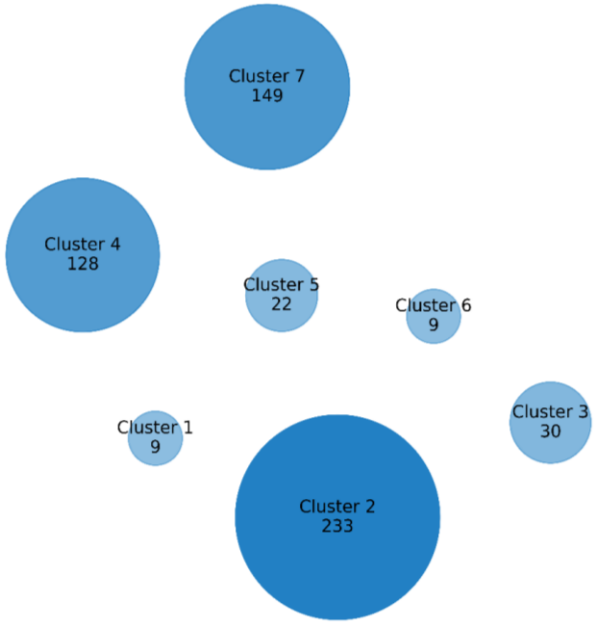
3 Danieli Officine Meccaniche S.p.A.
Total Patents: 38

4 Hybrit Development AB
Total Patents: 36

5 Primetals Technologies Limited
Total Patents: 35

3.13. Top applicant clustering

Besides knowing the focus areas of companies in the DRI technologies field, it is also very important to examine the top 10 patent applicant companies. The patenting activities of these companies, as leaders in this field, can have a direct impact on the market and other players' behavior. As it is clear below, cluster number 2 with top terms “furnace, gas, shaft, iron, reduction” has the largest number of registered patents. Next, there is cluster number 7 with top terms “gas, reducing, carbon, stream, cog”.



01 Top terms: loop, affecting, hydrogen, dedusting, step
The number of Patents: 9

02 Top terms: furnace, gas, shaft, iron, reduction
The number of Patents: 233

03 Top terms: fluidized, bed, particle, oxidic, fine
The number of Patents: 30

04 Top terms: entry, pellet, rotary, hearth, device
The number of Patents: 128

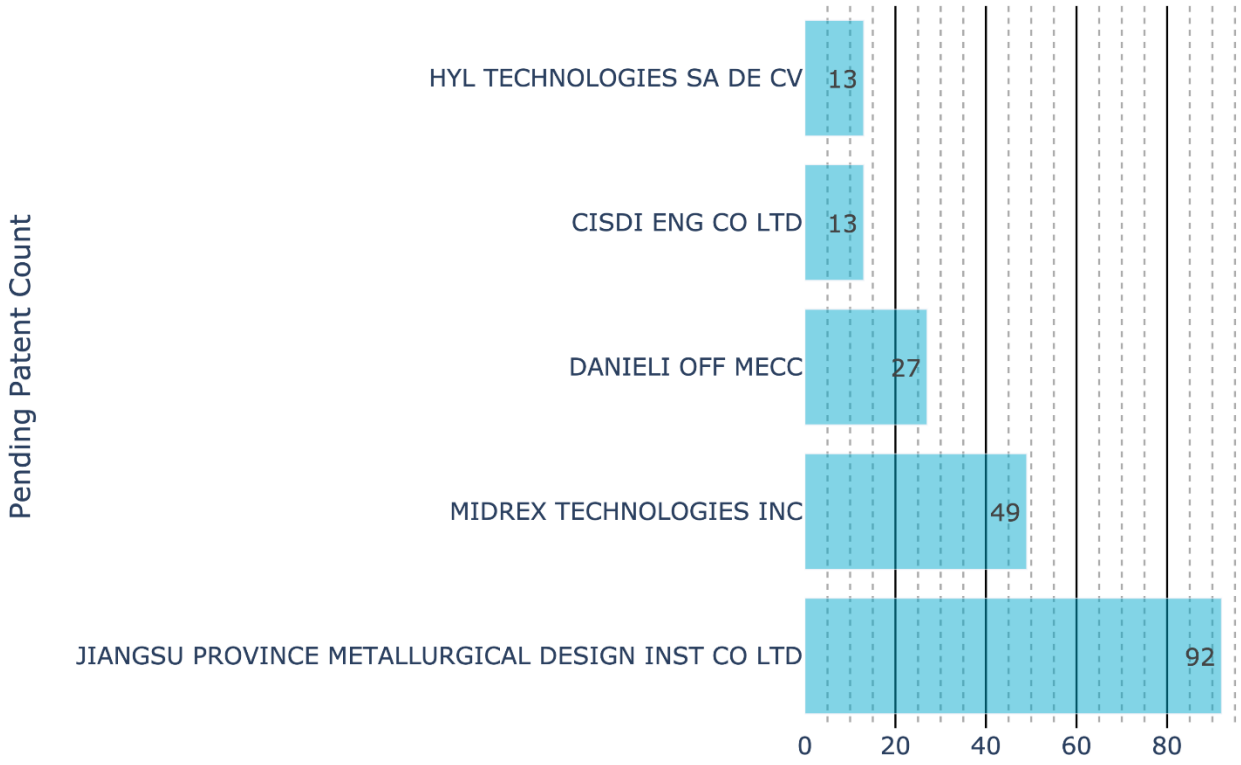
05 Top terms: biomass, electromagnetic, ore, anoxic, source
The number of Patents: 22

06 Top terms: interior, zone, circumferential, outer, disposed
The number of Patents: 9

07 Top terms: gas, reducing, carbon, stream, cog
The number of Patents: 149

3.14. Pending patents

The patent examination process is a time-consuming process and sometimes lasts up to 5 years. However, a significant number of these applications will be granted. Therefore, the analysis of pending patents is very important in predicting the future paths of technology. As can be seen, the Jiangsu Province Metallurgical Design Institute Co., Ltd. is at the top of the companies with 92 pending patents, and this indicates that this company will most likely maintain its technological superiority for the next 5 years.



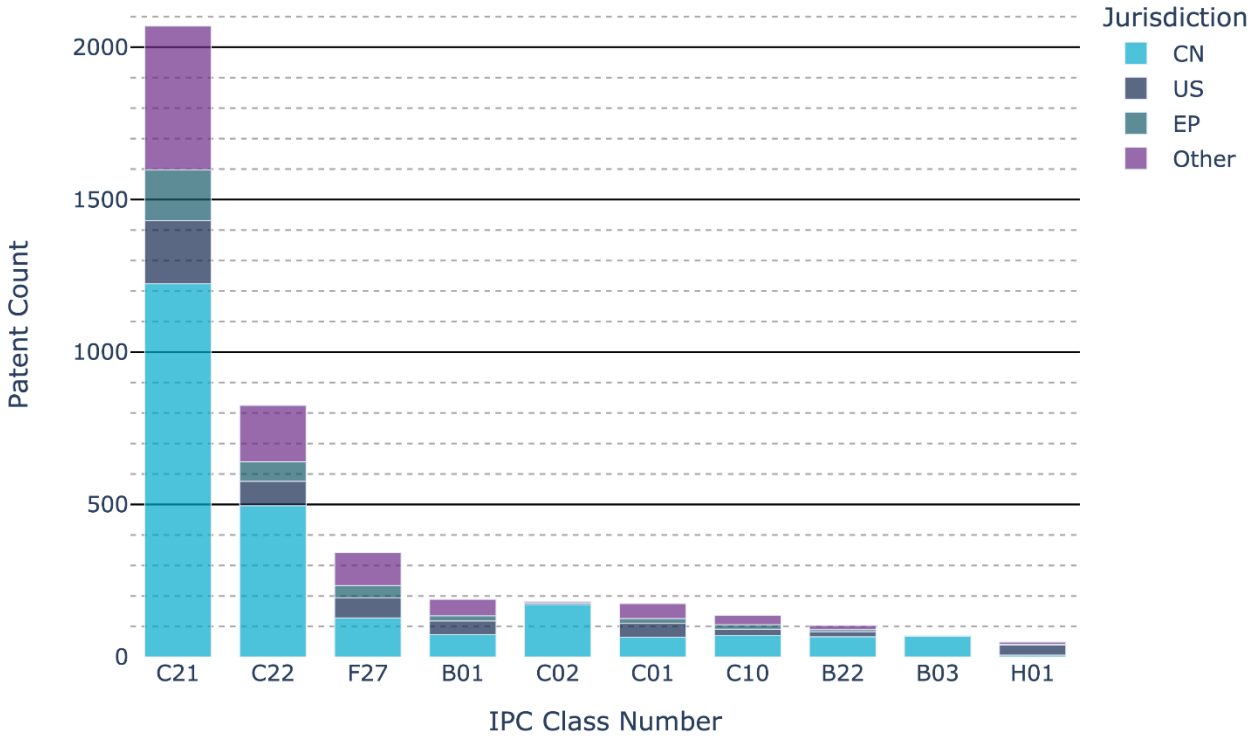
4. Technology Analysis

4.1. Top Technologies

4.1.1. Top Technologies by Class

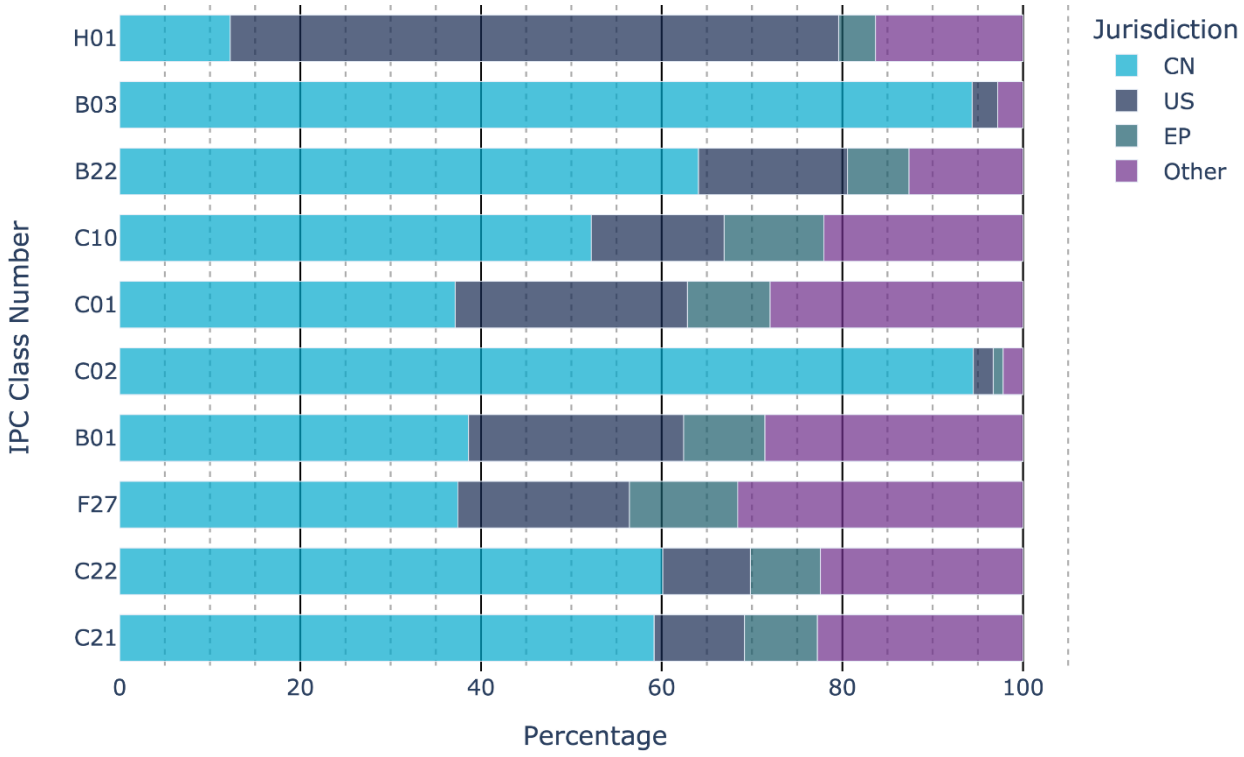
According to the IPC[1] classification, patents can be classified in 4 levels: class, subclass, main group and subgroup, each of the components of this technology tree represents a range of technologies and their applications. The chart below shows the top classes in terms of the number of patent applications in that class.

As it is shown, “Metallurgy of iron” In General is at the top, followed by “Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals”.



The figure below shows the distribution of top technology areas at first level -by class- across different jurisdictions.

[1] - If consider an IPC for a patent like C08L23/12
C08: Class
C08L: Sub-Class
C08L23: Main-Group
C08L23/12: Sub-Group



C21: Metallurgy of iron

C22: Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals

F27: Furnaces; kilns, ovens or retorts

B01: Physical or chemical processes or apparatus in general

C02: Treatment of water, waste water, sewage, or sludge

C01: Inorganic chemistry

C10: Petroleum, gas or coke industries; technical gases containing carbon monoxide; fuels; lubricants; peat

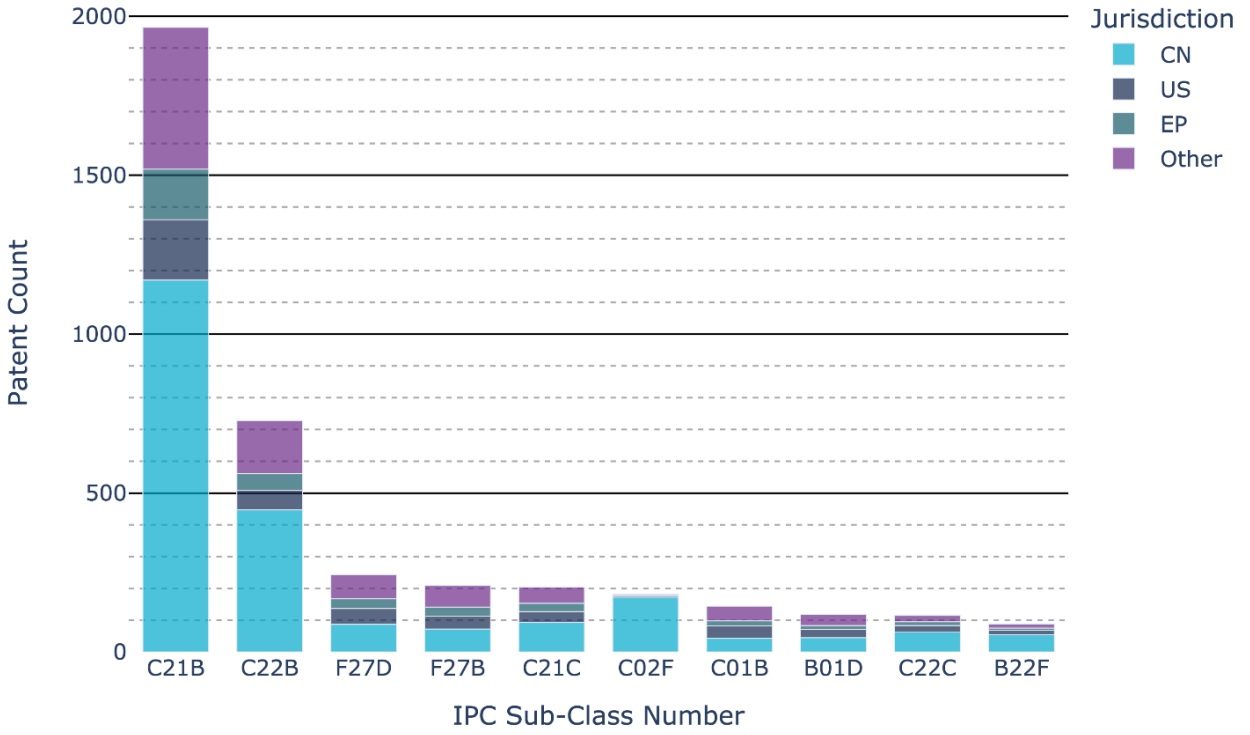
B22: Casting; powder metallurgy

B03: Separation of solid materials using liquids or using pneumatic tables or jigs; magnetic or electrostatic separation of solid materials from solid materials or fluids; separation by high-voltage electric fields

H01: Electric elements

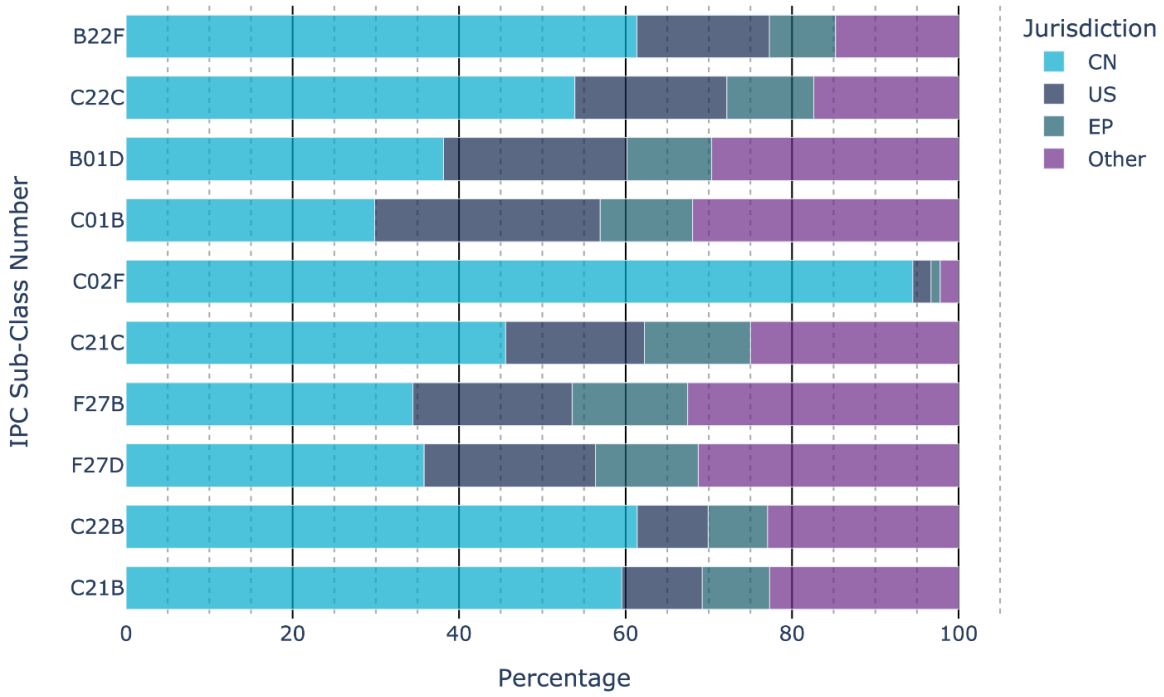
4.1.2. Top Technologies by Sub-Class

The chart below shows the top sub-classes -second level of technology tree- in terms of the number of patent applications in that sub-class. As it is shown, “Manufacture of iron or steel (preliminary treatment of ferrous ores or scrap C22B 1/00)“ with code C21B is at the top, then there is “Production or refining of metals (making metallic powder or suspensions thereof B22F 9/00; production of metals by electrolysis or electrophoresis C25); Pretreatment of raw materials”.



“Details or accessories of furnaces, kilns, ovens, or retorts, in so far as they are of kinds occurring in more than one kind of furnace (combustion apparatus F23; electric heating H05B)”, “Furnaces, kilns, ovens, or retorts in general; open sintering or like apparatus (combustion apparatus F23; electric heating H05B)” and “processing of pig-iron, e.g. Refining, manufacture of wrought-iron or steel; treatment in molten state of ferrous alloys” are among the subclasses with the highest number of registered patents.

The figure below shows the distribution of top technology areas at second level -by sub-class- across different jurisdictions.



C21B: Manufacture of iron or steel (preliminary treatment of ferrous ores or scrap C22B 1/00)

C22B: Production or refining of metals (making metallic powder or suspensions thereof B22F 9/00; production of metals by electrolysis or electrophoresis C25); Pretreatment of raw materials

F27D: Details or accessories of furnaces, kilns, ovens, or retorts, in so far as they are of kinds occurring in more than one kind of furnace (combustion apparatus F23; electric heating H05B)

F27B: Furnaces, kilns, ovens, or retorts in general; open sintering or like apparatus (combustion apparatus F23; electric heating H05B)

C21C: Processing of pig-iron, e.g. Refining, manufacture of wrought-iron or steel; treatment in molten state of ferrous alloys

C02F: Treatment of water, waste water, sewage, or sludge

C01B: Non-metallic elements; compounds thereof

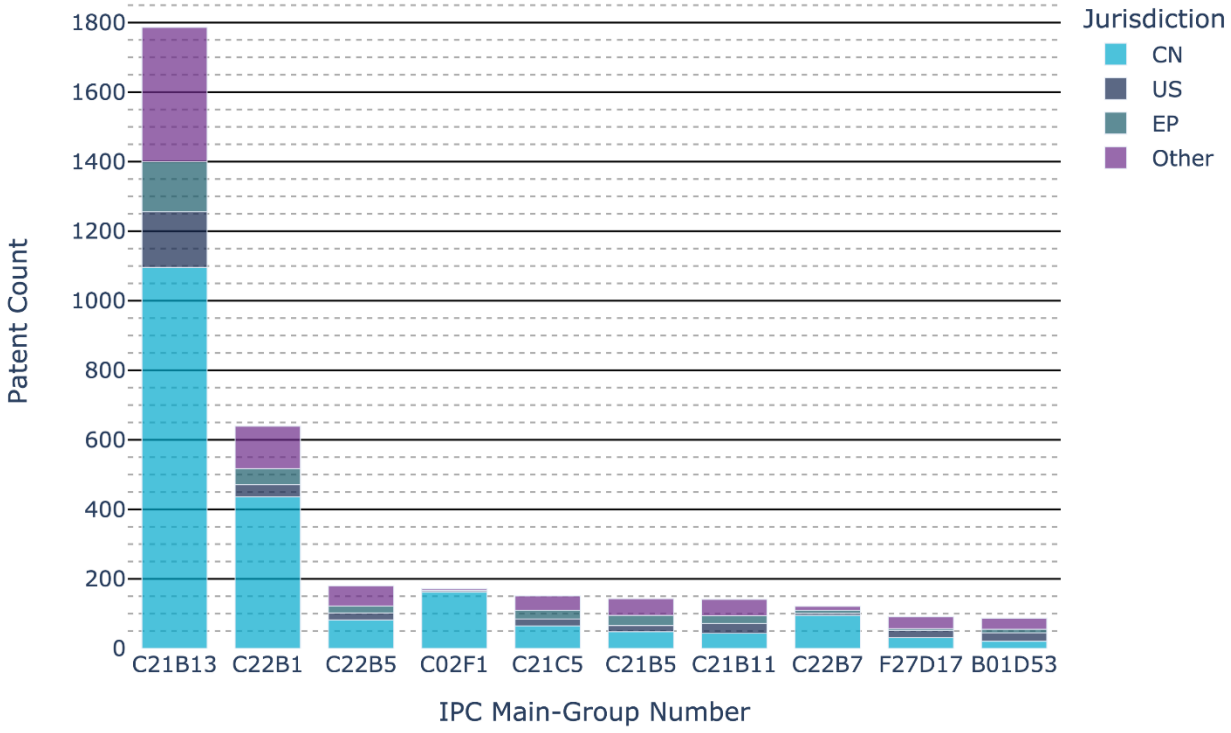
B01D: Separation (separating solids from solids by wet methods B03B, B03D, by pneumatic jigs or tables B03B, by other dry methods B07; magnetic or electrostatic separation of solid materials from solid materials or fluids, separation by high-voltage electric fields B03C; centrifuges B04B; vortex apparatus B04C; presses per se for squeezing-out liquid from liquid-containing material B30B 9/02)

C22C: Alloys (treatment of alloys C21D, C22F)

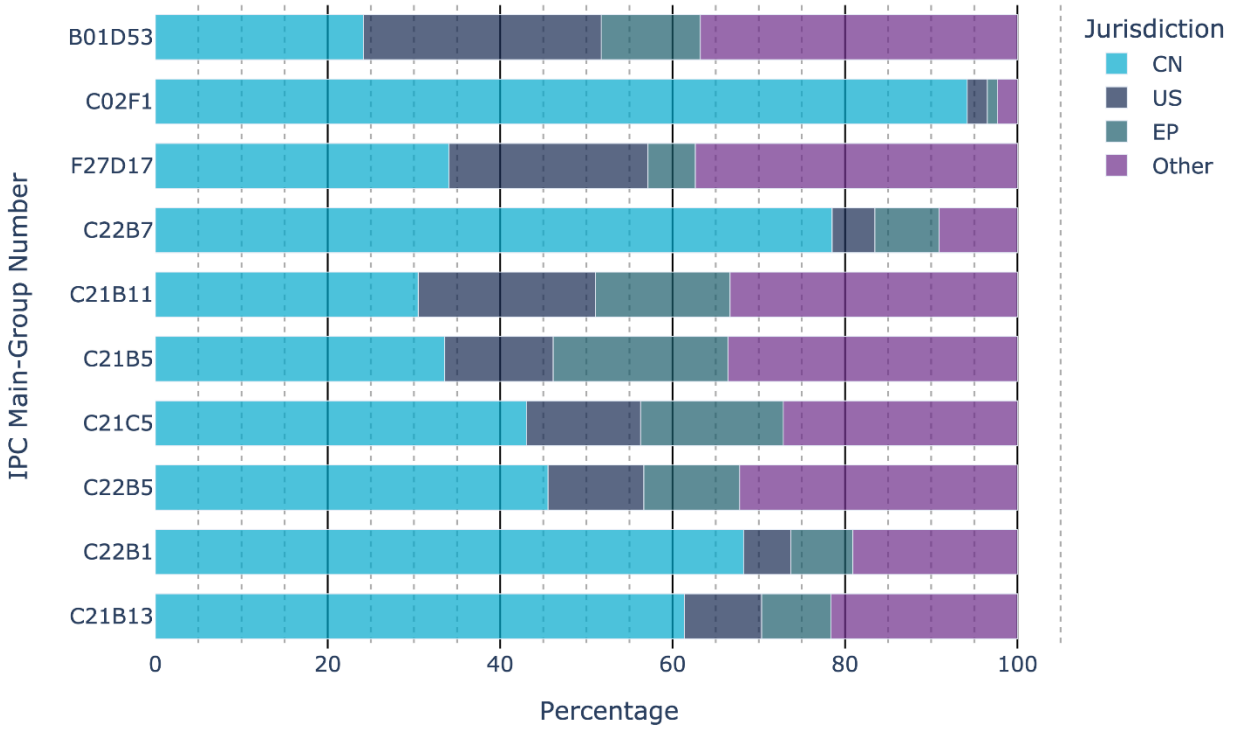
B22F: Working metallic powder; manufacture of articles from metallic powder; making metallic powder (making alloys by powder metallurgy c22c); apparatus or devices specially adapted for metallic powder

4.1.3. Top Technologies by Main-Group

The chart below shows the top main-groups in terms of the number of patent applications in that main-group. As it is known, “Making spongy iron or liquid steel, by direct processes“ with code C21B13 is at the top, then there is “Preliminary treatment of ores or scrap”.



“General processes of reducing to metals”, “Manufacture of carbon steel, e.g. plain mild steel, medium carbon steel, or cast-steel” and “Making pig-iron in the blast furnace” are among the Main-Groups with the highest number of registered patents. The figure below shows the distribution of top technology areas at third level -by main-group- across different jurisdictions.



C21B13: Making spongy iron or liquid steel, by direct processes

C21B11: Making pig-iron other than in blast furnaces

C22B1: Preliminary treatment of ores or scrap

C22B7: Working-up raw materials other than ores, e.g. scrap, to produce non-ferrous metals or compounds thereof

C22B5: General processes of reducing to metals

F27D17: Arrangement for using waste heat (heat-exchangers per se F28); Arrangement for using, or disposing of, waste gases (removing fumes in general B08B 15/00)

C21C5: Manufacture of carbon steel, e.g. plain mild steel, medium carbon steel, or cast-steel

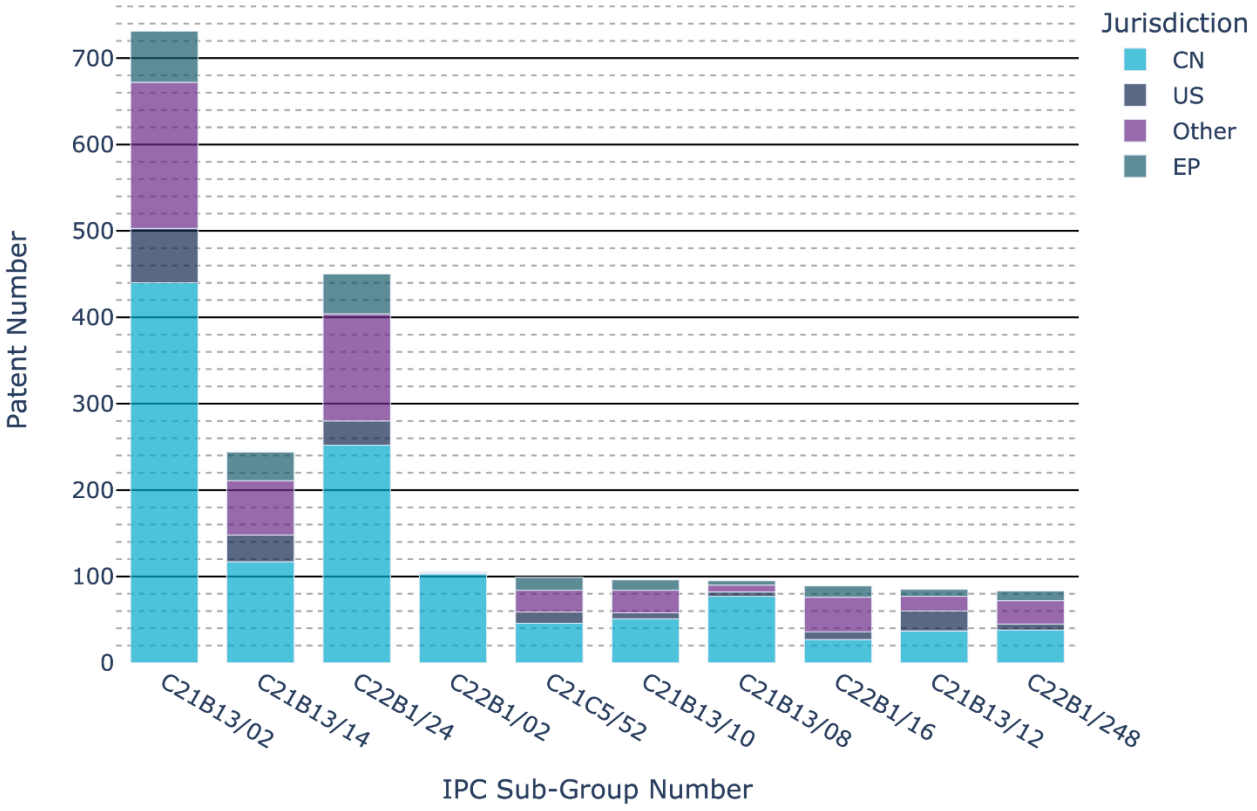
C02F1: Treatment of water, waste water, or sewage (C02F 3/00-C02F 9/00 take precedence)

C21B5: Making pig-iron in the blast furnace

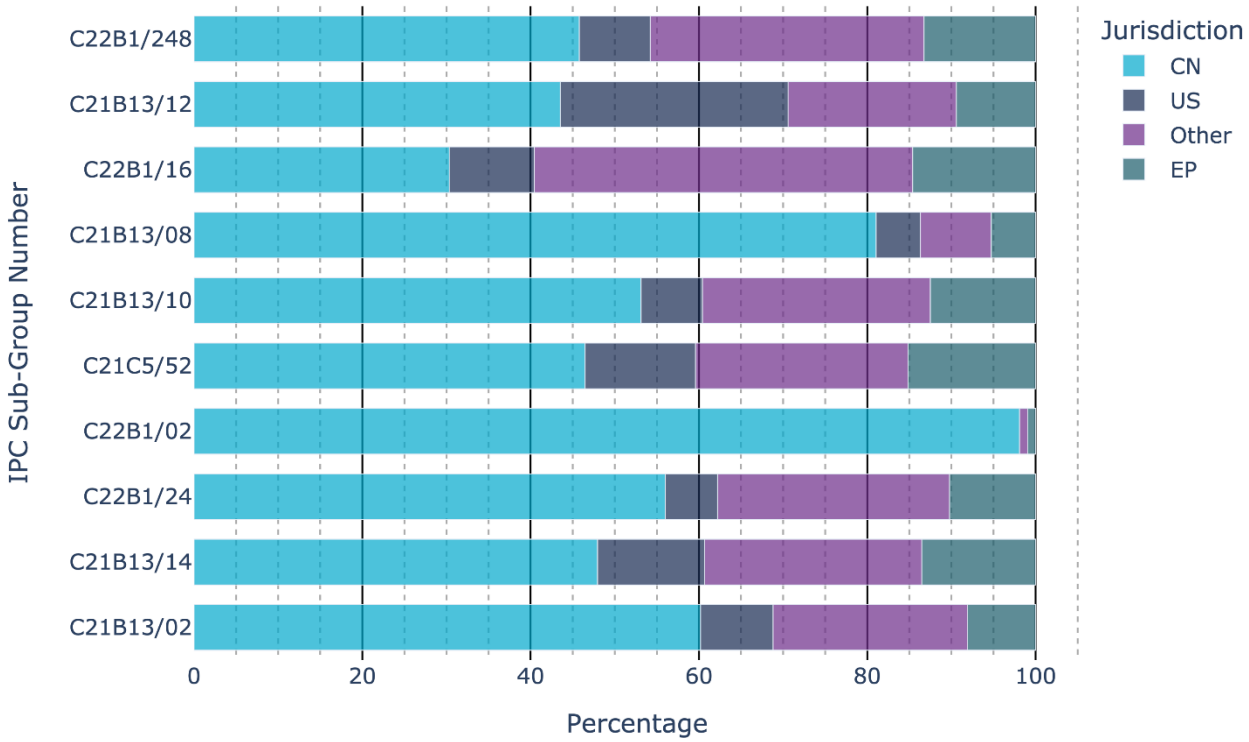
B01D53: Separation of gases or vapours; Recovering vapours of volatile solvents from gases; Chemical or biological purification of waste gases, e.g. engine exhaust gases, smoke, fumes, flue gases or aerosols

4.1.4. Top Technologies by Sub-Group

The chart below shows the top sub-groups in terms of the number of patent applications in that sub-group. As it is shown, “in shaft furnaces” with code C21B13/02 is at the top, then there is “Binding; Briquetting”.



“Multi-stage processes”, “Roasting processes (C22B 1/16 takes precedence)” and “Manufacture of steel in electric furnaces)” are among the sub-groups with the highest number of registered patents. The figure below shows the distribution of top technology areas at fourth level -by sub-group- across different jurisdictions.



C21B13/02: Making spongy iron or liquid steel, by direct processes (in shaft furnaces)

C21B13/14: Making spongy iron or liquid steel, by direct processes (Multi-stage processes)

C22B1/24: Preliminary treatment of ores or scrap (Binding; Briquetting)

C22B1/02: Preliminary treatment of ores or scrap (Roasting processes (C22B 1/16 takes precedence))

C21C5/52: Manufacture of steel in electric furnaces)

C21B13/10: Making spongy iron or liquid steel, by direct processes in hearth-type furnaces

C21B13/08: Making spongy iron or liquid steel, by direct processes (In rotary furnaces)

C22B1/16: Preliminary treatment of ores or scrap (Sintering; Agglomerating)

C21B13/12: Making spongy iron or liquid steel, by direct processes in electric furnaces

C22B1/248: Preliminary treatment of ores or scrap of metal scrap or alloys

4.1.5. Top Technologies and Main Trends

Efficiency Enhancements

Many patents focus on increasing the overall efficiency of Sponge Iron production. This includes optimizing the design of furnaces, improving heat recovery systems, and enhancing the gas-solid interaction within the reduction reactors. For instance, patents related to MIDREX Technology often highlight advancements in shaft furnace designs that improve gas flow distribution and reduce energy consumption.

Emission Reduction

Environmental concerns are a major driver of innovation in Sponge Iron production. Patents often aim to reduce greenhouse gas emissions by incorporating alternative reducing agents like hydrogen or by improving carbon capture and storage techniques. The ENERGIRON Process, for example, includes patents on the use of hydrogen as a cleaner alternative to natural gas, significantly reducing CO2 emissions.

Raw Material Utilization

Improving the utilization of raw materials is another key theme. Patents may address the use of lower-grade iron ores or alternative iron sources such as iron ore fines or dust. Innovations in pre-treatment processes, such as beneficiation and pelletization, are also common to enhance the quality and reactivity of the iron ore used in the reduction process.

Process Control and Automation

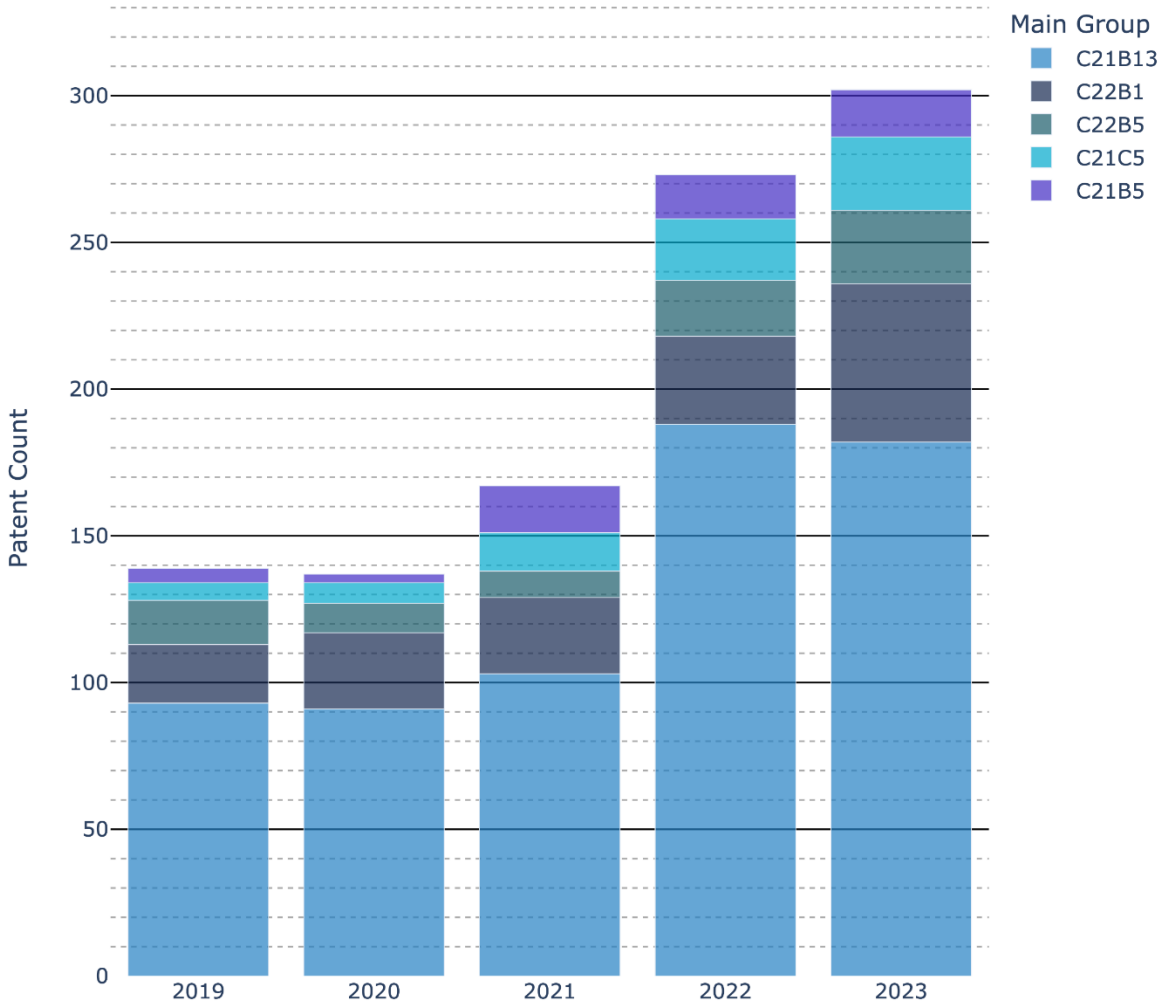
The integration of advanced control systems and automation technologies is crucial for optimizing Sponge Iron production. Patents in this area often involve the development of sophisticated monitoring and control systems that enable real-time adjustments to the production parameters, ensuring consistent product quality and operational efficiency.

Energy Consumption Reduction

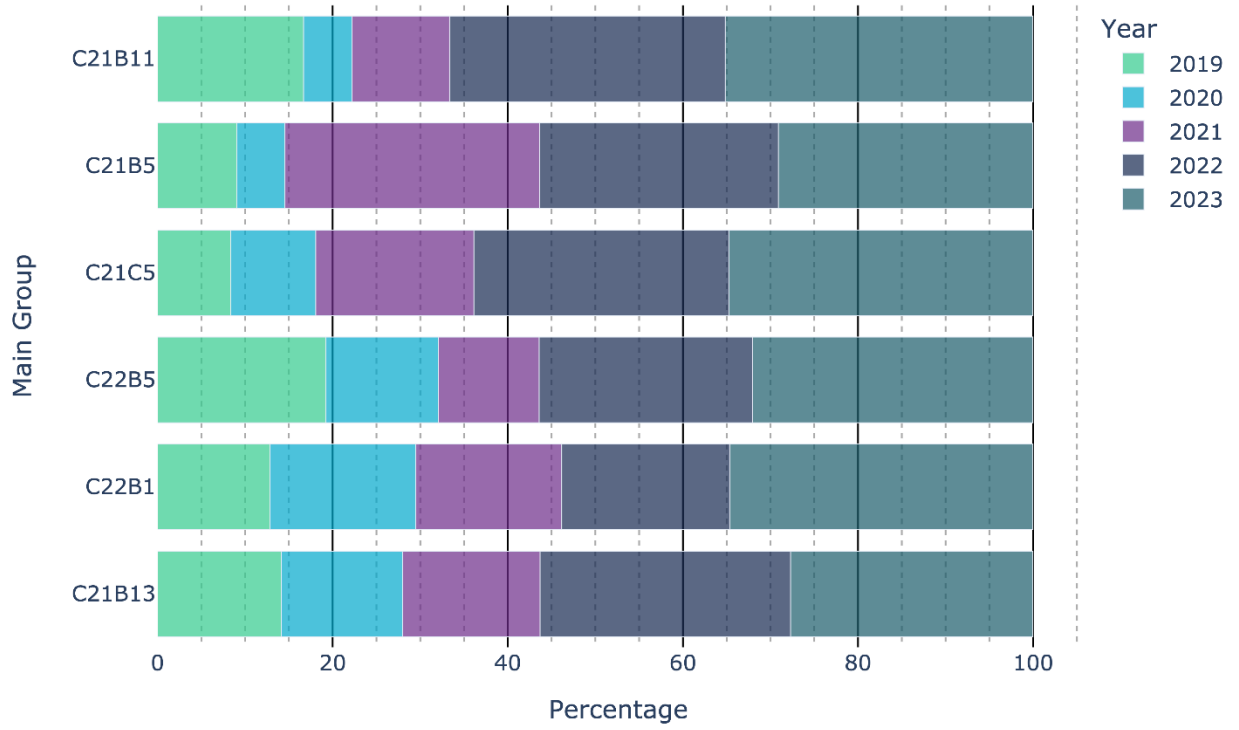
Reducing the energy consumption of Sponge Iron production processes is a persistent theme in patents. Innovations may include more efficient heating methods, improved insulation materials for furnaces, and the development of energy recovery systems that capture and reuse waste heat generated during the reduction process.

4.2. Five Recent dominant technologies

The five key technology areas that have the highest number of patents in the last 5 years are presented in the figure below. “Making spongy iron or liquid steel, by direct processes” is at the top of the technology fields with the highest growth rate in the last 5 years.



Following this technology, there are “Preliminary treatment of ores or scrap”, “General processes of reducing to metals”, “Manufacture of carbon steel, e.g. plain mild steel, medium carbon steel, or cast-steel”, and “Making pig-iron in the blast furnace” technologies.



C21B13
Making spongy iron or liquid steel, by direct processes

C22B1
Preliminary treatment of ores or scrap

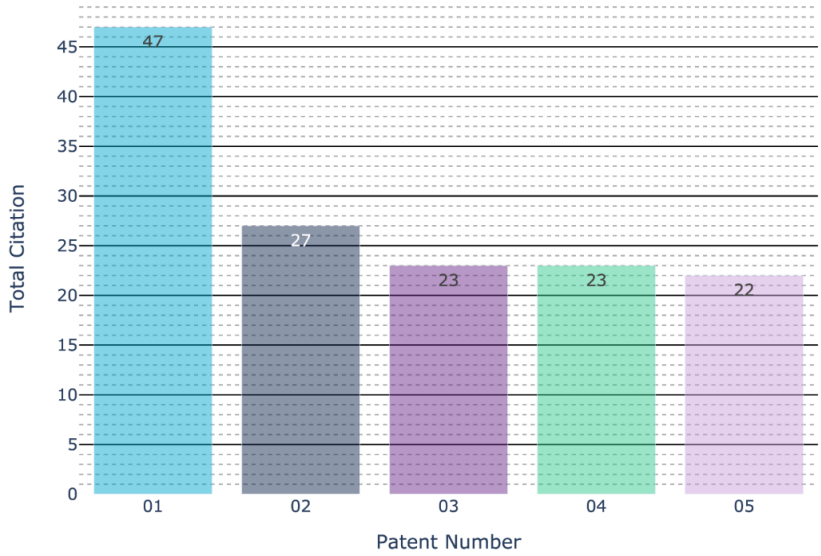
C22B5
General processes of reducing to metals

C21C5
Manufacture of carbon steel, e.g. plain mild steel, medium carbon steel, or cast-steel

C21B5
Making pig-iron in the blast furnace

4.3. Key Patents

Key patents are patents that have received the most citations over time. These patents are expected to be the foundational patents in this field in the future.



1

US 2013/0081516 A1
Direct Production of Iron Slabs and Nuggets From Ore Without Pelletizing or Briquetting
Applicant: SIMMONS JOHN J
Publish year: 2013

2

CN 102994678 A
Method and system for pulverized coal gasification for gas generation and direct reduction metallurgy of gas-based shaft furnace
Applicant: Beijing Shenwu Environment & Energy Technology Co., Ltd.
Publish year: 2013

3

US 8557728 B2
Shaped heterogeneous catalysts
Applicant: Birdsall, David James; et al
Publish year: 2013

4

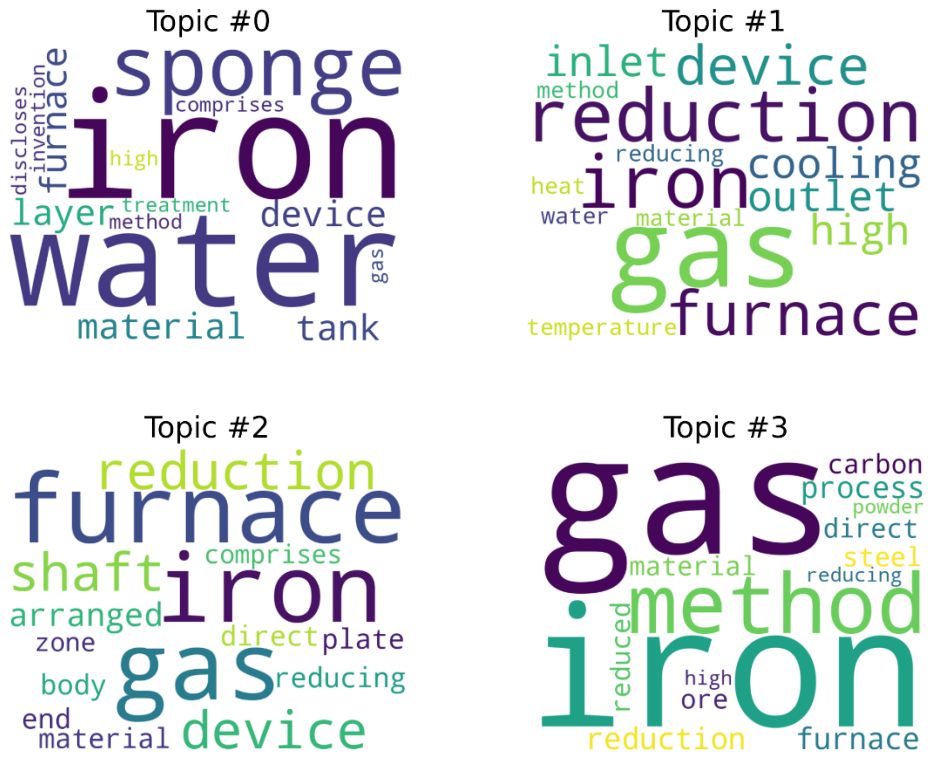
US 2020/0385827 A1
Direct reduction process utilizing hydrogen
Applicant: Midrex Technologies Inc.
Publish year: 2020

5

CN 106367600 A
Method for treating high-zinc iron-containing slime through utilizing rotary kiln
Applicant: Gansu Jiu Steel Group Hongxing Iron & Steel Co., Ltd.
Publish year: 2017

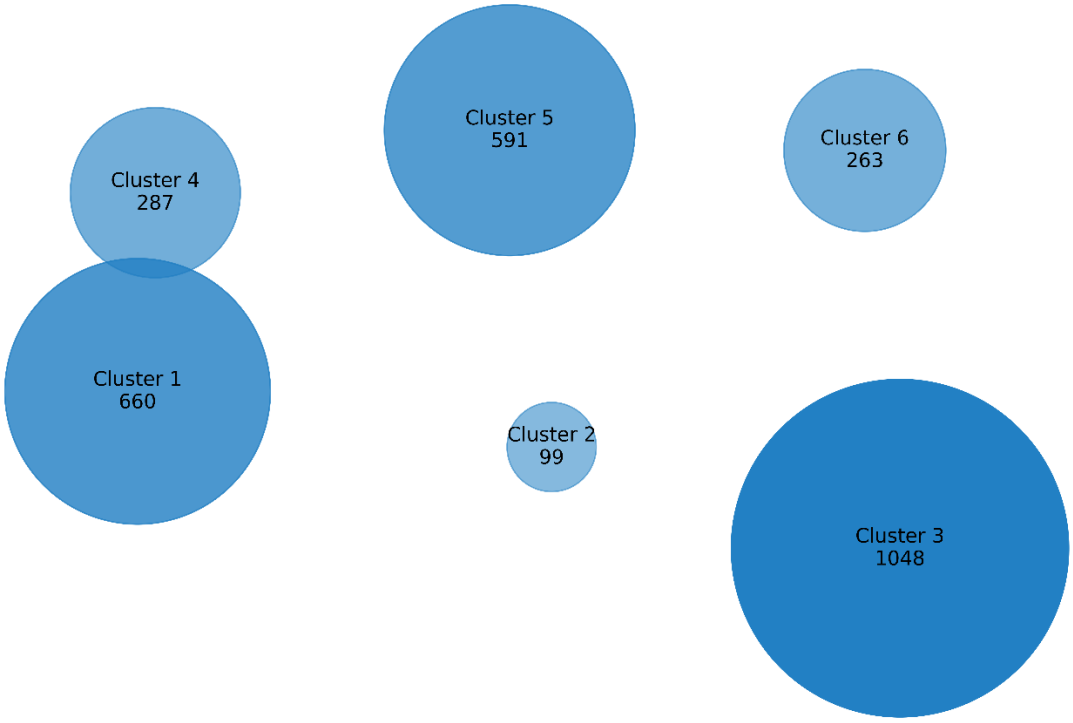
4.4. The main themes of patents

In this section, using the topic modeling method, the most important topics mentioned in the patents of this field are presented in the figure below. Topic modeling is a way of finding the main themes or topics in a collection of the patents. It is a type of unsupervised machine learning, which means it does not need any human input or labels to group the words together. The frequency of topics indicates the research direction of patents on fields such as water, iron, gas, furnace, reduction and sponge.



4.5. Technology clustering

The main goal in this section is to group patents in the form of different semantic groups. In this section, Sponge Iron patents are grouped into 7 main clusters and the top terms are determined in each cluster. In addition to being able to provide a good view of the focus points of patents, clustering also provides the possibility of a targeted study of patents.



As shown above, cluster three with 1048 patents, focusing on “iron, material, method, powder, ore“ is the largest cluster in this field. Then the number of patents in the cluster one with focus points of “gas, reduction, reducing, furnace, shaft” is considerable.

01 Top terms: gas, reduction, reducing, furnace, shaft
The number of Patents: ٦٦٠

02 Top terms: vanadium, titanium, slag, magnetite, chromium
The number of Patents: ٩٩

03 Top terms: iron, material, method, powder, ore
The number of Patents: ١٠٤٨

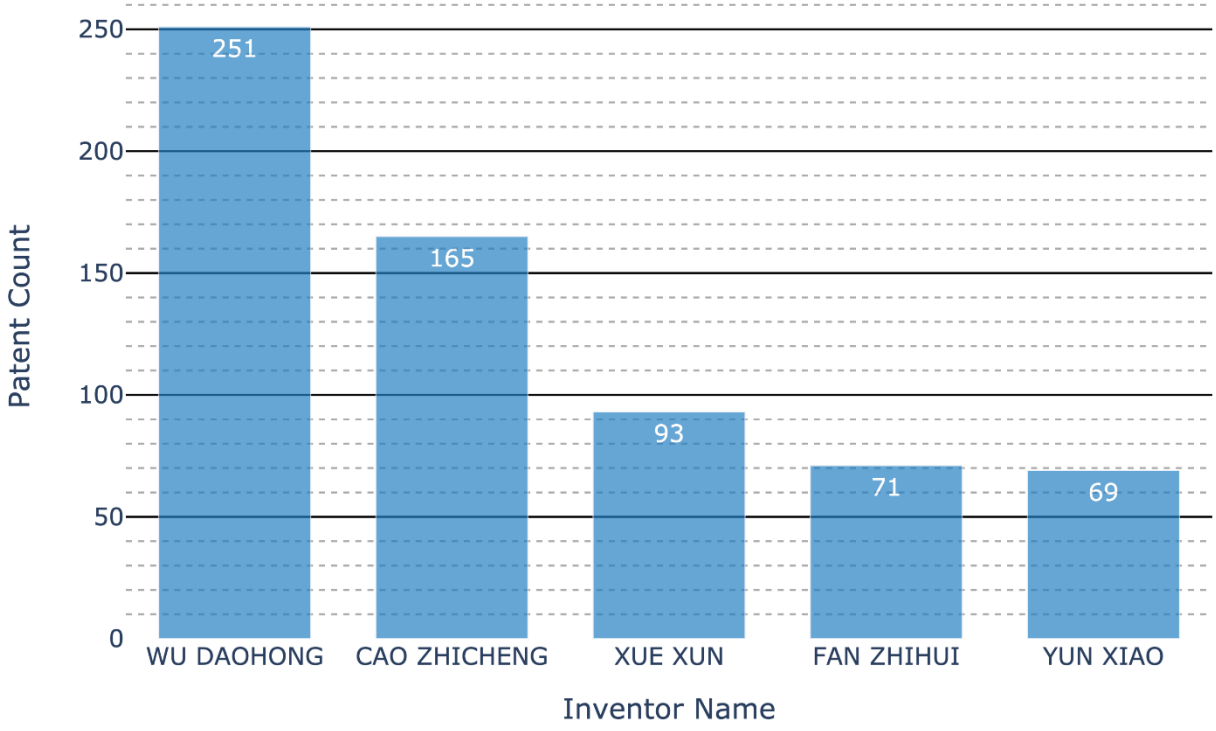
04 Top terms: rotary, pellet, hearth, kiln, furnace
The number of Patents: ٢٨٧

05 Top terms: device, furnace, body, arranged, chamber
The number of Patents: ٥٩١

06 Top terms: furnace, steel, molten, iron, electric
The number of Patents: 2٦٣

4.6. Top inventors

An inventor in patent documents is the person or persons who contribute to the claims of a patent. The claims are the part of the patent document that define the scope and boundaries of the legal protection granted by the patent. The inventor is not necessarily the same as the applicant or the owner of the patent, who may be different entities or individuals. This analysis can be beneficial to know the main scientist and technologist in this field for next technological collaborations.



5. Key Players' Patent Profile

5.1. MIDREX Technologies Inc

5.1.1. Midrex Technologies Company Overview

Midrex Technologies, Inc. is a leading global company specializing in the development, design, and implementation of direct reduction ironmaking technologies. Founded in 1969 and headquartered in Charlotte, North Carolina, USA, Midrex has established itself as the world's leading supplier of direct reduced iron (DRI) technology, holding a dominant market share in the DRI production sector.

Core Technology: MIDREX Process

The MIDREX Process is the company's flagship technology, known for its efficiency, flexibility, and environmental benefits. This process uses natural gas as a reducing agent to convert iron ore into high-purity direct reduced iron (DRI). The MIDREX Process is highly regarded for its ability to produce DRI with a low carbon footprint compared to traditional blast furnace methods that rely on coal.

Innovations and Sustainability

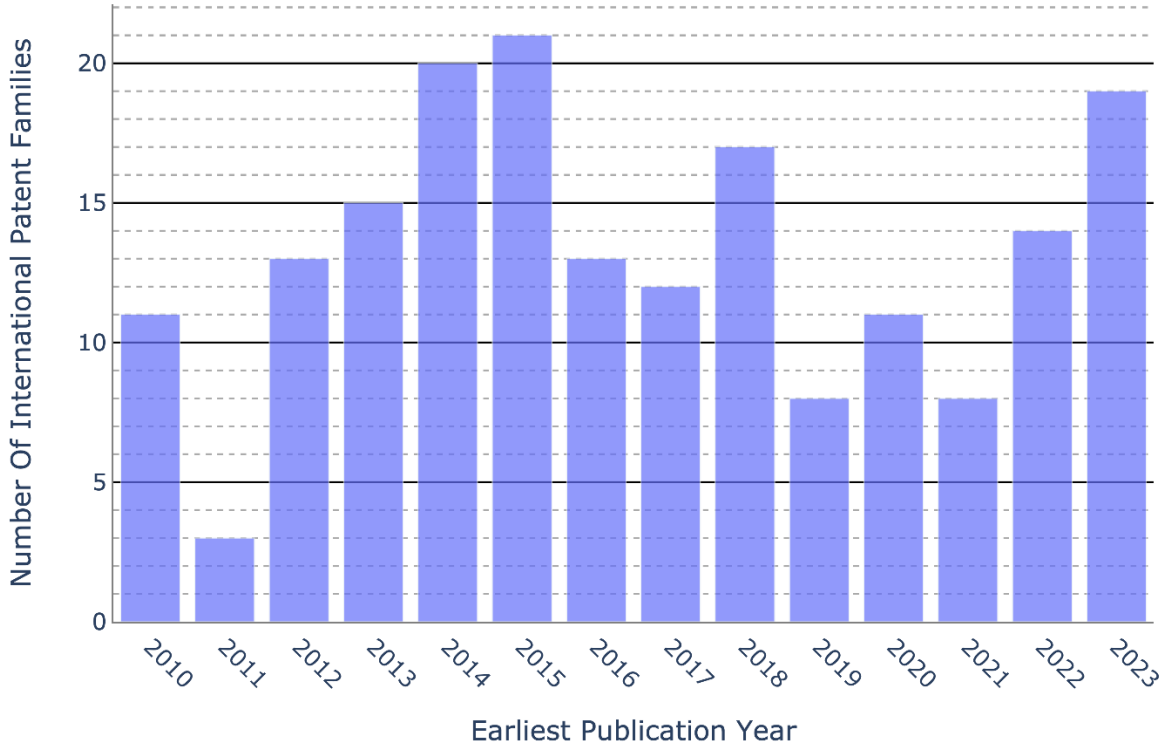
Midrex Technologies is at the forefront of innovation in the iron and steel industry, continuously improving its processes to enhance efficiency and sustainability. The company is actively involved in developing hydrogen-based DRI production, aiming to further reduce CO2 emissions. One notable project is the collaboration with H2 Green Steel to supply the world's first commercial 100% hydrogen-based DRI plant in Sweden, set to begin production in 2025.

Global Reach and Market Leadership

Midrex has a significant global footprint, with numerous MIDREX plants operating worldwide, particularly in regions with abundant natural gas resources. The company's technology is used in major steel-producing countries, including the USA, India, Iran, and Algeria. In 2022, MIDREX plants produced approximately 73.55 million tons of DRI, accounting for 57.8% of the world's total DRI production.

5.1.2. Patent family analysis

An analysis of patent filings by MIDREX Technologies Inc. in the Direct Reduced Iron (DRI) field shows a cumulative total of 187 patents submitted between 2010 and 2023. The number of patent applications varied over the years but started to increase notably from 2022 and reached its peak in 2023. This trend is expected to impact the company's product development strategy. Currently, 49 patents are pending approval, with a significant number expected to be granted within the next 24 months, shaping the recent two-year data.



5.1.3. Top Processes

MIDREX® Process

The MIDREX® Process is the flagship technology of Midrex Technologies, Inc., renowned for its efficiency and environmental benefits. It is a natural gas-based direct reduction ironmaking technology used to convert iron ore into high-purity direct reduced iron (DRI). The MIDREX® Process is the most widely used DRI technology in the world, producing over 60% of the global DRI supply. It is recognized for its ability to produce DRI with lower carbon emissions compared to traditional blast furnace methods.

Key Features of the MIDREX® Process:

- Utilizes natural gas as the primary reducing agent, significantly reducing CO2 emissions.
- Can be adapted to use up to 100% hydrogen (MIDREX H2™), further reducing the carbon footprint.
- Produces various forms of DRI, including hot briquetted iron (HBI), which is easier to transport and store.

MIDREX H2™

As part of its commitment to sustainability, Midrex has developed the MIDREX H2™ technology, which utilizes hydrogen as the reducing gas. This process is designed to achieve nearly zero CO2 emissions, aligning with global efforts to decarbonize the steel industry. The technology can be integrated into existing MIDREX plants or used in new installations.

MIDREX Flex™

MIDREX Flex™ is a versatile technology that allows the use of a combination of reducing gases, including natural gas, hydrogen, and syngas. This flexibility enables steel producers to adapt to varying gas availabilities and prices, optimizing production costs and reducing environmental impact.

MxCol®

The MxCol® technology is designed for coal-based DRI production. It uses synthesis gas derived from coal gasification as the reducing agent. This process expands the application of MIDREX technology to regions where natural gas is not readily available, providing an efficient and environmentally improved alternative to traditional coal-based methods.

Hotlink® Technology

Hotlink® is an innovative solution for transporting and charging hot DRI (HDRI) directly into an electric arc furnace (EAF). This technology minimizes energy loss and maximizes efficiency by

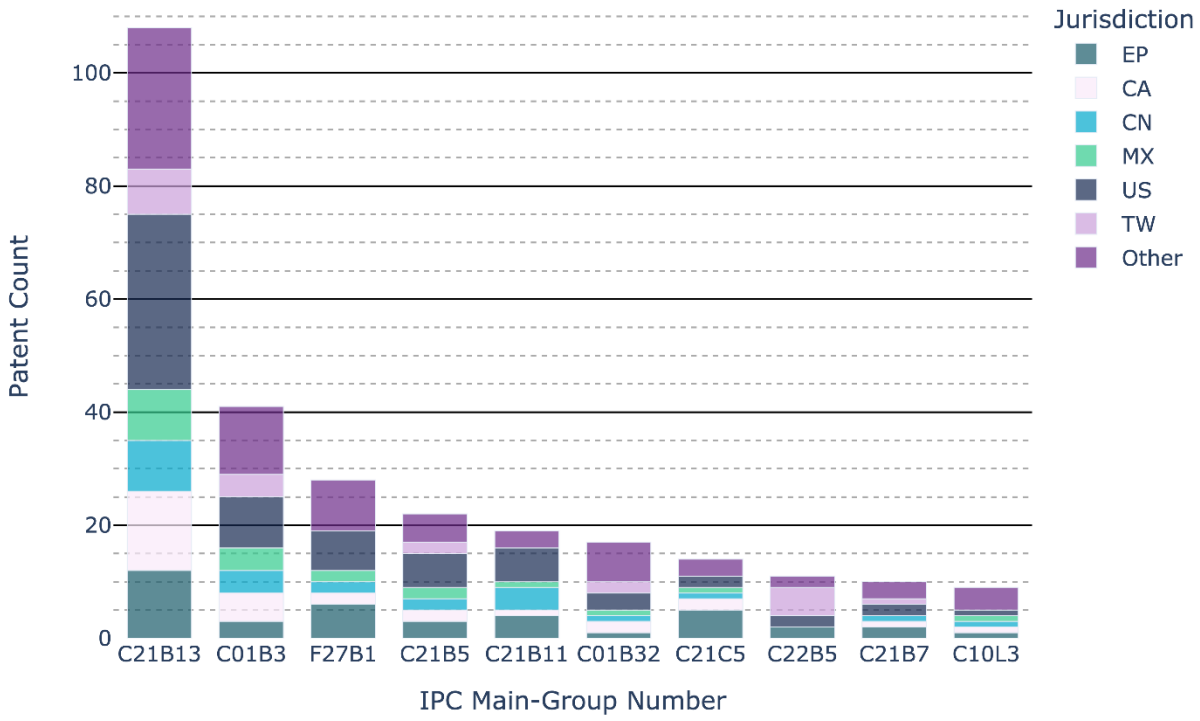
maintaining the high temperature of DRI throughout the process, leading to significant energy savings and improved steel quality.

MIDREX NG™ with H2 Addition

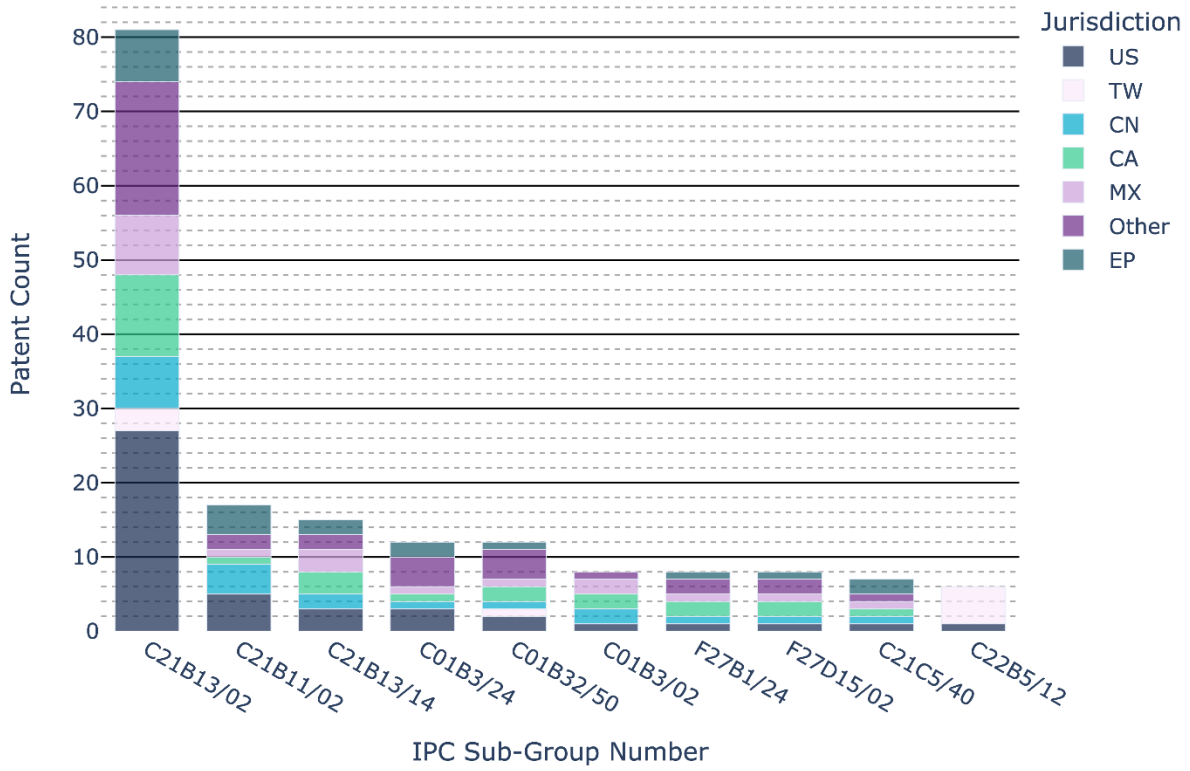
The MIDREX NG™ process with H2 addition allows for the gradual incorporation of hydrogen into the natural gas-based MIDREX process. This technology supports a phased approach to decarbonization, enabling plants to start with a natural gas base and incrementally increase the hydrogen proportion. This flexible approach ensures that steel producers can adapt to changing energy availability and pricing while steadily moving towards a low-carbon future.

5.1.4. Top Technologies

The chart below shows the main technology fields that MIDREX Technologies Inc has been focusing in terms of the number of patent applications in that main-group. As it is showed, “Making spongy iron or liquid steel, by direct processes “ with code C21B13 is at the top, then there are the areas of “Hydrogen; Gaseous mixtures containing hydrogen; Separation of hydrogen from mixtures containing it; Purification of hydrogen (production of water-gas or synthesis gas from solid carbonaceous material C10J)”.



C21B13:	Making spongy iron or liquid steel, by direct processes	**C01B32:**	Carbon; Compounds thereof (C01B 21/00, C01B 23/00 take precedence; percarbonates C01B 15/10; carbon black C09C 1/48)
C01B3:	Hydrogen; Gaseous mixtures containing hydrogen; Separation of hydrogen from mixtures containing it; Purification of hydrogen (production of water-gas or synthesis gas from solid carbonaceous material C10J)	**C21C5:**	Manufacture of carbon steel, e.g. plain mild steel, medium carbon steel, or cast-steel
F27B1:	Shaft or like vertical or substantially vertical furnaces (for preheating, burning, calcining or cooling lime, magnesia or dolomite C04B 2/12)	**C22B5:**	General processes of reducing to metals
C21B5:	Making pig-iron in the blast furnace	**C21B7:**	Blast furnaces
C21B11:	Making pig-iron other than in blast furnaces	**C10L3:**	Gaseous fuels; Natural gas; Synthetic natural gas obtained by processes not covered by subclasses C10G, C10K; Liquefied petroleum gas

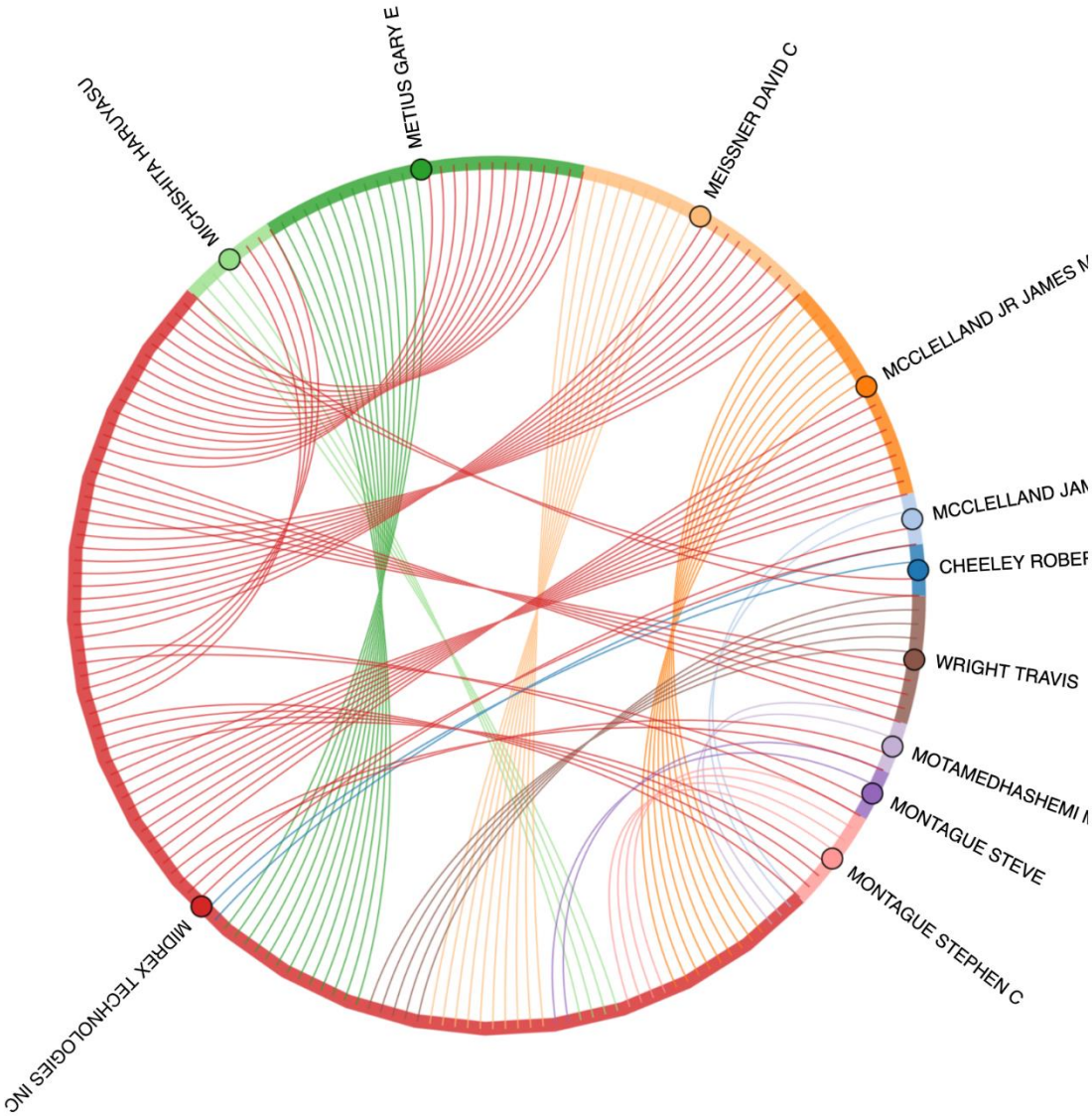


C21B13/02:	Making spongy iron or liquid steel, by direct processes (in shaft furnaces)	**C01B3/02:**	Production of hydrogen or of gaseous mixtures containing hydrogen
C21B11/02:	Making pig-iron other than in blast furnaces (in low shaft furnaces)	**F27B1/24:**	Shaft or like vertical or substantially vertical furnaces (Cooling arrangements)
C21B13/14:	Making spongy iron or liquid steel, by direct processes (Multi-stage processes)	**F27D15/02:**	Handling or treating discharged material (Cooling)
C01B3/24:	Hydrogen; Gaseous mixtures containing hydrogen; … (of hydrocarbons)	**C21C5/40:**	Offtakes or separating apparatus for converter waste gases or dust
C01B32/50:	Carbon; Compounds thereof (Carbon dioxide)	**C22B5/12:**	General processes of reducing to metals (by gases)

The main patenting activities of MIDREX Technologies Inc. in the areas of " Making spongy iron or liquid steel, by direct processes in shaft furnaces" and " Making pig-iron other than in blast furnaces in low shaft furnaces" indicate that this company focuses on technologies related to iron and steel production, particularly methods for direct reduction of iron ore and associated processes for alloy production and refining.

5.1.5. Collaboration

MIDREX Technologies Inc. has established collaborations with partners including Metius Gary E, Meissner David C, McClelland Jr. James M, Wright Travis, and several others.



5.1.6. Merge and Acquisitions

Acquisition by Kobe Steel Ltd.

One of the most significant mergers in the history of Midrex Technologies was its acquisition by Kobe Steel Ltd. in 1983. This acquisition positioned Midrex as a wholly-owned subsidiary of Kobe Steel, enabling it to leverage Kobe Steel's extensive resources and expertise in metallurgy and steel production. This strategic move has allowed Midrex to expand its technological capabilities and global market reach significantly.

Partnership with Paul Wurth and SMS Group

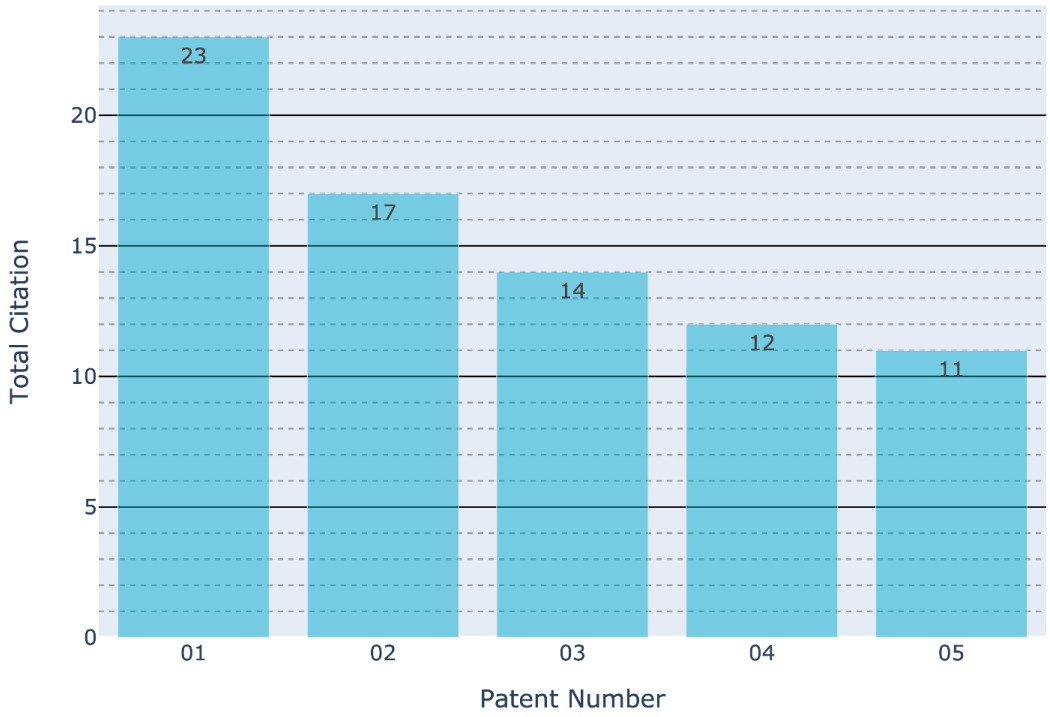
In recent years, Midrex Technologies has entered into strategic partnerships rather than outright acquisitions. A notable collaboration is with Paul Wurth, a subsidiary of SMS Group, to develop hydrogen-based direct reduction plants. This partnership aims to advance the development of green steel production technologies, focusing on reducing carbon emissions in the steelmaking process.

Collaboration with H2 Green Steel

In a groundbreaking collaboration, Midrex Technologies and Paul Wurth are set to supply the world's first commercial-scale, 100% hydrogen-based DRI plant for H2 Green Steel in Sweden. This plant, expected to begin production in 2025, exemplifies Midrex's commitment to pioneering hydrogen-based ironmaking technologies. The project is a testament to Midrex's leadership in developing sustainable steel production methods that significantly reduce CO2 emissions.

5.1.7. Key patents

The key patents of MIDREX Technologies Inc can be seen in the figure below.



1 US 2020/0385827 A1
Direct reduction process utilizing hydrogen
Publish year: 2020

2 US 2013/0312571 A1
System and method for reducing iron oxide to metallic iron using coke oven gas and oxygen steelmaking furnace gas
Publish year: 2013

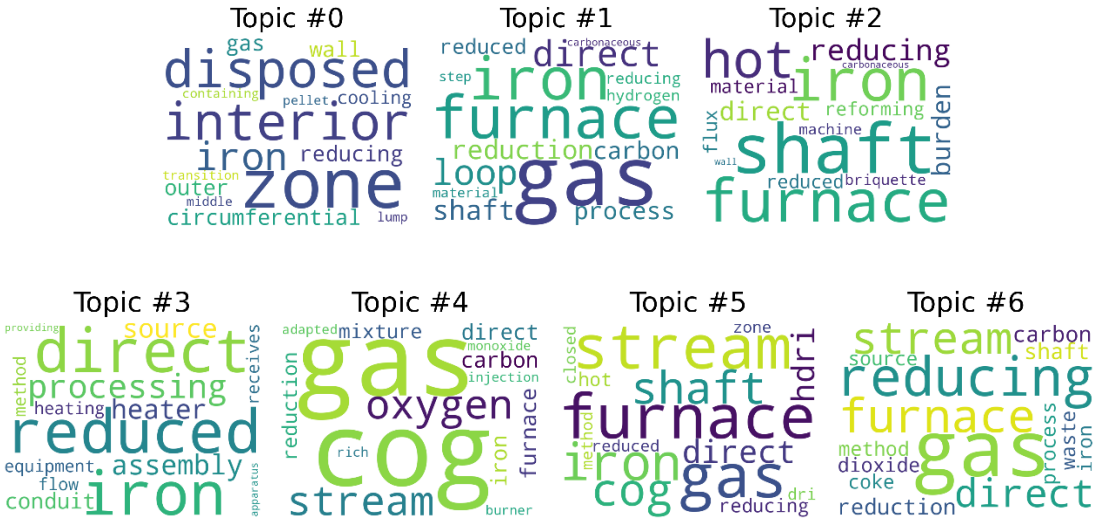
3 US 8496730 B2
System and method for reducing iron oxide to metallic iron using coke oven gas and oxygen steelmaking furnace gas
Publish year: 2013

4 US 2012/0125159 A1
System and method for reducing iron oxide to metallic iron using coke oven gas and oxygen steelmaking furnace gas
Publish year: 2012

5 US 7678176 B2
Method and apparatus for charging hot direct reduced iron from hot transport vessels into a melter or finisher
Publish year: 2010

5.1.8. Topic modeling

Patents registered by MIDREX Technologies Inc can be classified in terms of content in the following seven groups. As can be seen, the main focus of this company's patents is cog, gas, zone, shaft, furnace and interior.



A Moment's Pause

MIDREX H2™: A Revolutionary Step in Hydrogen-Based Ironmaking

Name of Process/Technology: MIDREX H2™

Year of Establishment: Developed in recent years, with significant advancements and commercial projects announced around 2021-2023.

Key Features:

- Utilizes hydrogen as the primary reducing agent in the direct reduction ironmaking process.

- Capable of producing DRI with nearly zero CO2 emissions.

- Flexible operation allows initial use of natural gas, transitioning to hydrogen as it becomes available.

- Designed to be scalable and adaptable to various production needs.

Benefits:

- Environmental Impact: Drastically reduces CO2 emissions compared to traditional coal-based or natural gas-based ironmaking processes.

- Flexibility: Can operate with varying ratios of hydrogen and natural gas, making it adaptable to changing energy landscapes.

- Efficiency: Maintains high energy efficiency and productivity, ensuring economic viability while supporting environmental sustainability.

- Future-Proofing: Aligns with global efforts to decarbonize the steel industry, ensuring long-term regulatory compliance and market competitiveness.

Main Innovation:

The main innovation of MIDREX H2™ lies in its ability to use hydrogen as a reducing agent in place of natural gas or coal, which are traditionally used in the direct reduction process. This shift not only significantly lowers greenhouse gas emissions but also aligns with global sustainability goals and the push towards a hydrogen economy. The technology's flexibility to transition from natural gas to hydrogen is a crucial innovation, enabling steelmakers to adopt the technology progressively as hydrogen infrastructure develops.

Related Patents:

MIDREX Technologies has been actively patenting various aspects of the MIDREX H2™ technology. Some key patents related to this technology include advancements in hydrogen-based reduction methods, systems for flexible use of hydrogen and natural gas, and innovations in reactor design to optimize the hydrogen reduction process.

Table of Some Related Patents for MIDREX H2™ Technology

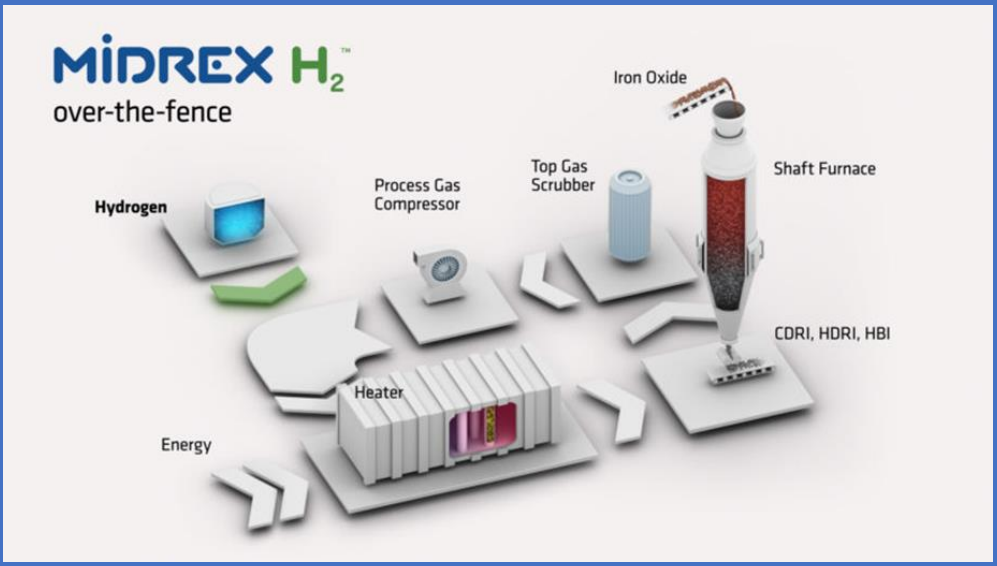
Patent Name	Patent Number	Priority Date
Process for Hydrogen-Based Ironmaking	US10227212B2	2017-03-15
Hydrogen-Based Reduction Reactor	US10247654B2	2017-04-12
Flexible Hydrogen/Natural Gas Reduction	US10329841B2	2017-06-20
System for Hydrogen Utilization in DRI	US10400475B2	2018-01-05
Method for Hydrogen-Enriched Iron Reduction	US10532189B2	2018-07-10

The Way Ahead:

The future of MIDREX H2™ looks promising as the global steel industry increasingly prioritizes sustainability and decarbonization. Midrex is actively involved in several high-profile projects, including:

- H2 Green Steel in Sweden: Set to start production in 2025, this will be the world's first commercial-scale plant using 100% hydrogen-based DRI.

- Partnership with thyssenkrupp Steel: Developing a hydrogen-ready DRI smelter to reduce CO2 emissions significantly.



5.1.9. Patents clustering

The number of 231 patents registered by MIDREX Technologies Inc can be classified in the following 7 clusters. The top terms of each cluster are also presented below. As can be seen, the largest number of patents of this company is in cluster number 2 with 42 patents and top terms of “gas, cog, reducing, shaft, furnace”. After this cluster, there is cluster number 1 with 26 patents and top terms of “material, hdri, hot, reduced, carbonaceous”.

01 Top Terms: material, hdri, hot, reduced, carbonaceous
The number of patents: 26

02 Top Terms: gas, cog, reducing, shaft, furnace
The number of patents: 42

03 Top Terms: zone, interior, circumferential, outer, disposed
The number of patents: 9

04 Top Terms: burden, reforming, shaft, structure, stationary
The number of patents: 11

05 Top Terms: gas, carbon, waste, dioxide, stream
The number of patents: 25

06 Top Terms: oxygen, adapted, mixture, injection, main
The number of patents: 8

07 Top Terms: loop, step, hydrogen, dedusting, affecting
The number of patents: 9

5.2. Jiangsu Province Metallurgical Design Institute Co., Ltd.

5.2.1. JMDI Overview

Jiangsu Province Metallurgical Design Institute Co., Ltd. (JMDI) is a leading engineering and technology company based in China. Established in 1963, JMDI specializes in providing comprehensive engineering design, consulting, and project management services for the metallurgical industry. The institute has played a pivotal role in the development and modernization of China's iron and steel sector.

Engineering Design

JMDI offers detailed engineering design services for metallurgical plants, including steel mills, rolling mills, and iron-making facilities. Their design solutions encompass the entire production process, from raw material handling to finished product processing.

Consulting Services

The institute provides expert consulting services, covering feasibility studies, project evaluation, technical advisory, and optimization of existing operations. Their consulting expertise helps clients improve efficiency, reduce costs, and enhance production quality.

Project Management

JMDI manages large-scale industrial projects, ensuring timely and cost-effective execution. Their project management services include planning, coordination, procurement, construction supervision, and quality control.

Technology Development

The institute is at the forefront of technological innovation in the metallurgical industry. They focus on developing advanced technologies for energy conservation, environmental protection, and process optimization. JMDI's R&D efforts aim to enhance productivity and sustainability in steel production.

Environmental Engineering

Recognizing the importance of environmental sustainability, JMDI offers specialized services in environmental engineering. This includes designing and implementing solutions for pollution control, waste management, and resource recycling in metallurgical operations.

Key Projects and Achievements

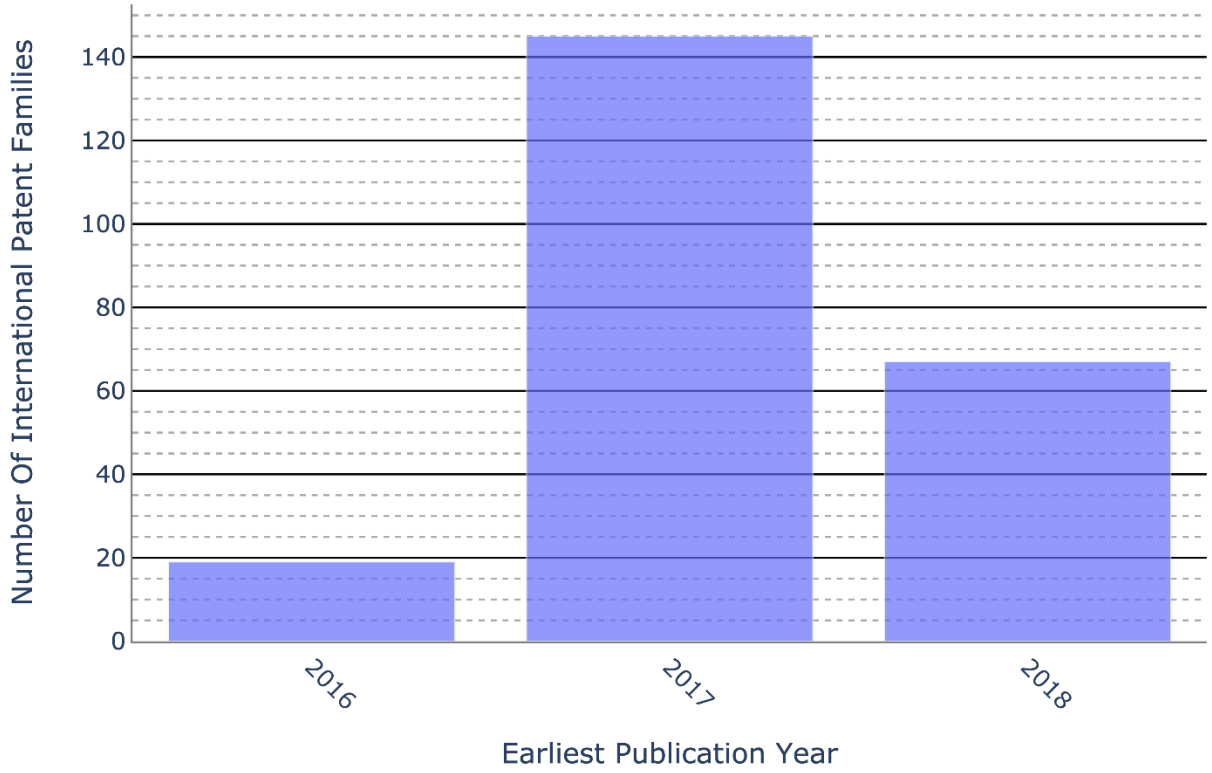
Modernization of Chinese Steel Plants: JMDI has been instrumental in the modernization of numerous steel plants across China, incorporating advanced technologies and automation to boost production efficiency and environmental compliance.

International Projects: The institute has expanded its services globally, undertaking engineering and consulting projects in various countries, contributing to the global metallurgical industry's growth and development.

Innovative Technologies: JMDI has developed and patented several innovative technologies aimed at reducing energy consumption and minimizing the environmental impact of steel production processes.

5.2.2. Patent family analysis

The figure below shows the patenting activities of Jiangsu Province Metallurgical Design Institute Co., Ltd. in the DRI sector from 2016 to 2018. The company has registered 231 patents in this field and applied for 92 more that are still pending. The patent applications peaked in 2017. It is likely that many of the pending patents will be registered in the next two years and increase this number.



5.2.3. Top Processes

Energy-Saving Metallurgical Processes

Description: JMDI has introduced advanced energy-saving technologies for steel production processes. These include innovations in furnace design and thermal management systems that significantly reduce energy consumption.

Benefits: Enhanced efficiency and reduced operational costs.

Advanced Environmental Engineering Solutions

Description: New environmental technologies for pollution control and waste management, aimed at minimizing the ecological footprint of metallurgical operations.

Benefits: Compliance with environmental regulations and sustainable production practices.

High-Efficiency Iron and Steel Production

Description: Development of advanced processes for iron and steel production, such as improvements in direct reduction and electric arc furnace operations.

Benefits: Higher quality steel production with increased efficiency.

Thermal Process Optimization Technologies

Description: Innovations in heat recovery and advanced combustion techniques to optimize thermal processes in metallurgy.

Benefits: Reduced fuel consumption and improved thermal efficiency.

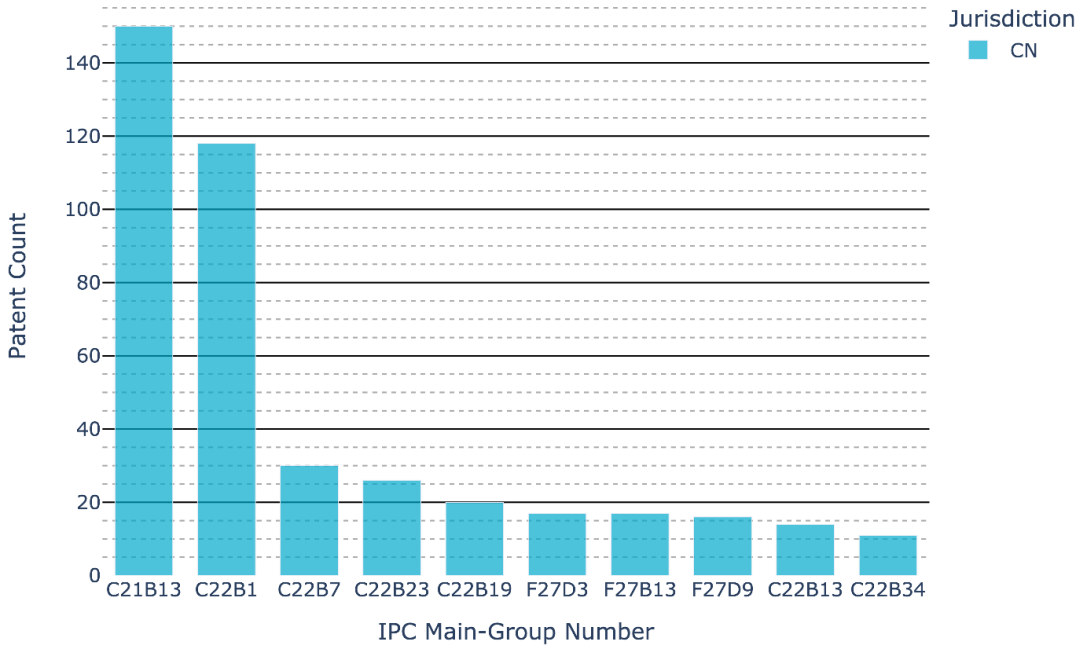
Novel Materials and Metallurgy Innovations

Description: Development of new materials and specialized alloys, as well as innovative casting techniques to enhance metal properties.

Benefits: Improved performance and durability of metallurgical products.

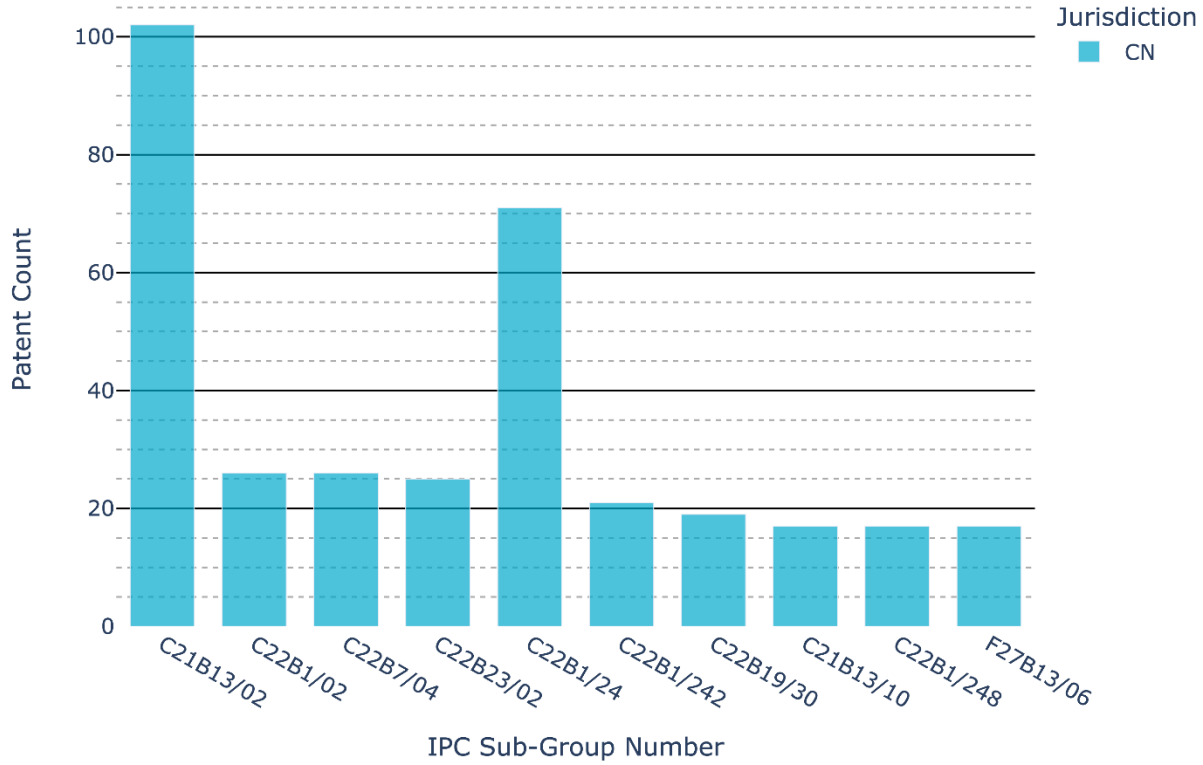
5.2.4. Top Technologies

The chart below shows the main technology fields that Jiangsu Province Metallurgical Design Institute Co., Ltd. has been focusing in terms of the number of patent applications in that main-group. As it is showed, “Making spongy iron or liquid steel, by direct processes “with code C21B13 is at the top, then there are the areas of “Preliminary treatment of ores or scrap” and “Working-up raw materials other than ores, e.g. scrap, to produce non-ferrous metals or compounds thereof”.



C21B13:	Making spongy iron or liquid steel, by direct processes	**F27D3:**	Charging; Discharging; Manipulation of charge
C22B1:	Preliminary treatment of ores or scrap	**F27B13:**	Furnaces with both stationary charge and progression of heating, e.g. of ring type, of type in which segmental kiln moves over stationary charge
C22B7:	Working-up raw materials other than ores, e.g. scrap, to produce non-ferrous metals or compounds thereof	**F27D9:**	Cooling of furnaces or of charges therein
C22B23:	Obtaining nickel or cobalt	**C22B13:**	Obtaining lead
C22B19:	Obtaining zinc or zinc oxide	**C22B34:**	Obtaining refractory metals

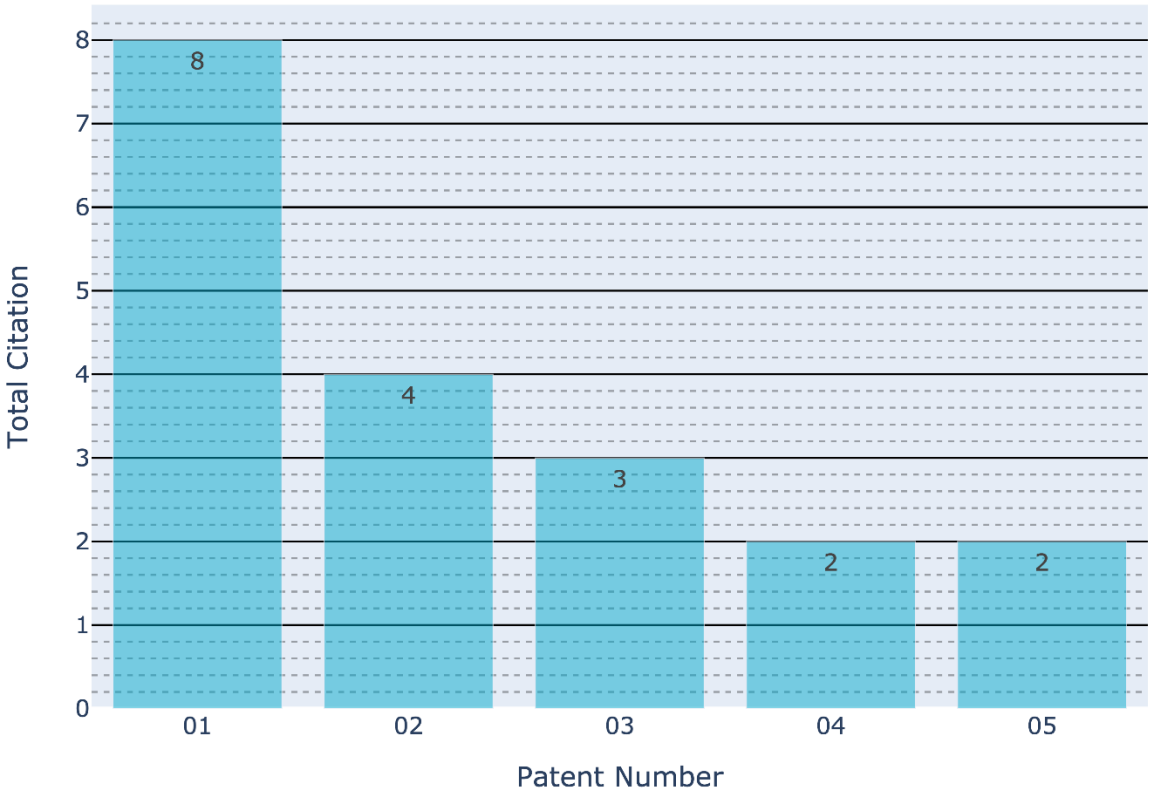
The main patenting activities of Jiangsu Province Metallurgical Design Institute Co., Ltd. in a deeper layer of the technology tree are related to two aspects of "in shaft furnaces" and "binding; briquetting". These priorities indicate that this company focuses on iron and steel production technologies and methods for agglomeration and binding of materials, such as in the production of iron ore pellets or briquettes.



C21B13/02:	in shaft furnaces	**C22B1/242:**	with binders
C22B1/02:	Roasting processes (C22B 1/16 takes precedence)	**C22B19/30:**	from metallic residues or scraps
C22B7/04:	Working-up slag	**C22B13/10:**	Separating metals from lead by crystallising, e.g. by Pattison process
C22B23/02:	by dry processes	**C22B1/248:**	of metal scrap or alloys
C22B1/24:	Binding; Briquetting	**F27B13/06:**	Details, accessories, or equipment peculiar to furnaces of this type

5.2.5. Key patents

The key patents of Jiangsu Province Metallurgical Design Institute Co., Ltd. can be seen in the figure below.



1 CN 106086469 A
Method and system for extracting nickel oxide through laterite nickel ore
Publish year: 2016

2 CN 105838839 A
Granular iron preparation method and system
Publish year: 2016

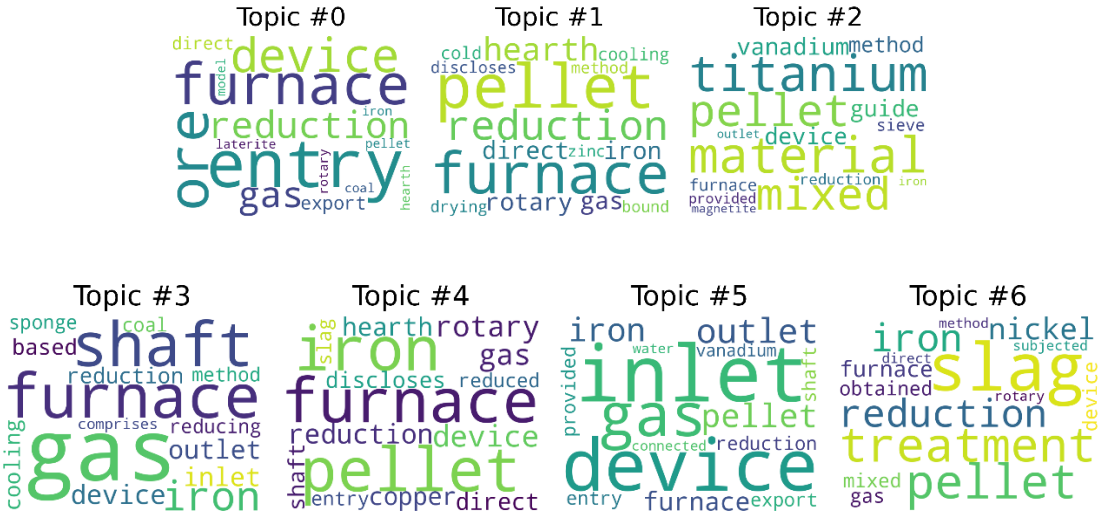
3 CN 105925806 A
Direct reduction and metallurgy method
Publish year: 2016

4 CN 106319209 A
Iron extracting process of lead and zinc residues treated through rotary hearth furnace
Publish year: 2017

5 CN 207567272 U
Rotary hearth furnace reduction system
Publish year: 2018

5.2.6. Topic modeling

Patents registered by Jiangsu Province Metallurgical Design Institute Co, Ltd. can be classified in terms of content in the following 7 groups. As can be seen, the main focus of this company's patents is in the fields of furnace, inlet, device, shaft, gas, slag and pellet.



A Moment's Pause

Name of Process/Technology: Advanced Iron and Steel Production (AISP)

Year of Establishment: 2022

Key Features:

- Energy Efficiency: Uses advanced furnace designs and thermal management systems to significantly reduce energy consumption.

- Process Optimization: Incorporates real-time monitoring and control systems to enhance operational efficiency.

- Environmental Compliance: Integrated pollution control technologies to minimize emissions and waste.

Benefits:

- Cost Reduction: Lower energy and operational costs.

- Enhanced Quality: Improved quality and consistency of the steel produced.

- Sustainability: Meets stringent environmental regulations, reducing the ecological footprint.

Main Innovation:

The integration of state-of-the-art thermal management systems with real-time process optimization to maximize efficiency and minimize environmental impact.

Related Patents:

Patent Name	Patent Number	Priority Date
Advanced Furnace Design	CN112233445	2021-05-15
Real-Time Process Control System	CN112233446	2021-07-20
Integrated Pollution Control Technology	CN112233447	2021-09-10

The Way Ahead:

JMDI plans to expand the adoption of AISP technology globally, focusing on continuous improvements in efficiency and sustainability. Future developments include enhancing the integration of AI and machine learning for smarter process control and further reducing the environmental impact of steel production.

5.2.7. Patents clustering

The number of 231 patents registered by Jiangsu Province Metallurgical Design Institute Co., Ltd. can be classified in the following 7 clusters. The top terms of each cluster are also presented below. As can be seen, the largest number of patents of this company is in cluster number 5 with 58 patents and top terms of “furnace, gas, shaft, cooling, pipe”. After this cluster, there is cluster number ۷ with 57 patents and top terms of “slag, pellet, device, obtained, copper”.

01 Top terms: entry, export, gas, device, link
The number of Patents: 41

02 Top terms: hearth, rotary, cooling, furnace, space
The number of Patents: 16

03 Top terms: gas, outlet, inlet, furnace, based
The number of Patents: 33

04 Top terms: ore, laterite, nickel, pyrolysis, deposit
The number of Patents: 14

05 Top terms: furnace, gas, shaft, cooling, pipe
The number of Patents: 58

06 Top terms: cold, bound, gas, pellet, sponge
The number of Patents: 12

07 Top terms: slag, pellet, device, obtained, copper
The number of Patents: 57

5.3. Danieli Off Mecc

5.3.1. Danielli Overview

Danieli Officine Meccaniche S.p.A., commonly known as Danieli, is a prominent Italian company specializing in the design, manufacture, and installation of equipment and plants for the steel industry. Founded in 1914 and headquartered in Buttrio, Italy, Danieli is a global leader in engineering and technology for the steel and non-ferrous metals sectors.

Plant Engineering

Danieli designs and builds plants for the production of steel and non-ferrous metals. This includes complete turnkey solutions for steelmaking, rolling mills, and processing lines. Their engineering expertise covers all stages of plant design, from initial feasibility studies to final commissioning.

Technological Innovation

The company is known for its continuous innovation in metallurgical processes and equipment. Danieli has developed numerous proprietary technologies aimed at improving efficiency, reducing costs, and minimizing environmental impact in steel production. Innovations include advanced electric arc furnaces (EAF), continuous casting machines, and rolling mills.

Product Range

Danieli offers a wide range of products and services, including:

- Steelmaking and casting equipment
- Rolling mills for long and flat products
- Tube and pipe mills
- Processing lines for steel and non-ferrous metals
- Automation and digitalization solutions

Sustainable Solutions

Danieli is committed to sustainability and environmental protection. The company develops technologies that reduce energy consumption, lower CO2 emissions, and minimize waste. Their "Danieli Green" initiative focuses on creating eco-friendly solutions for the metals industry.

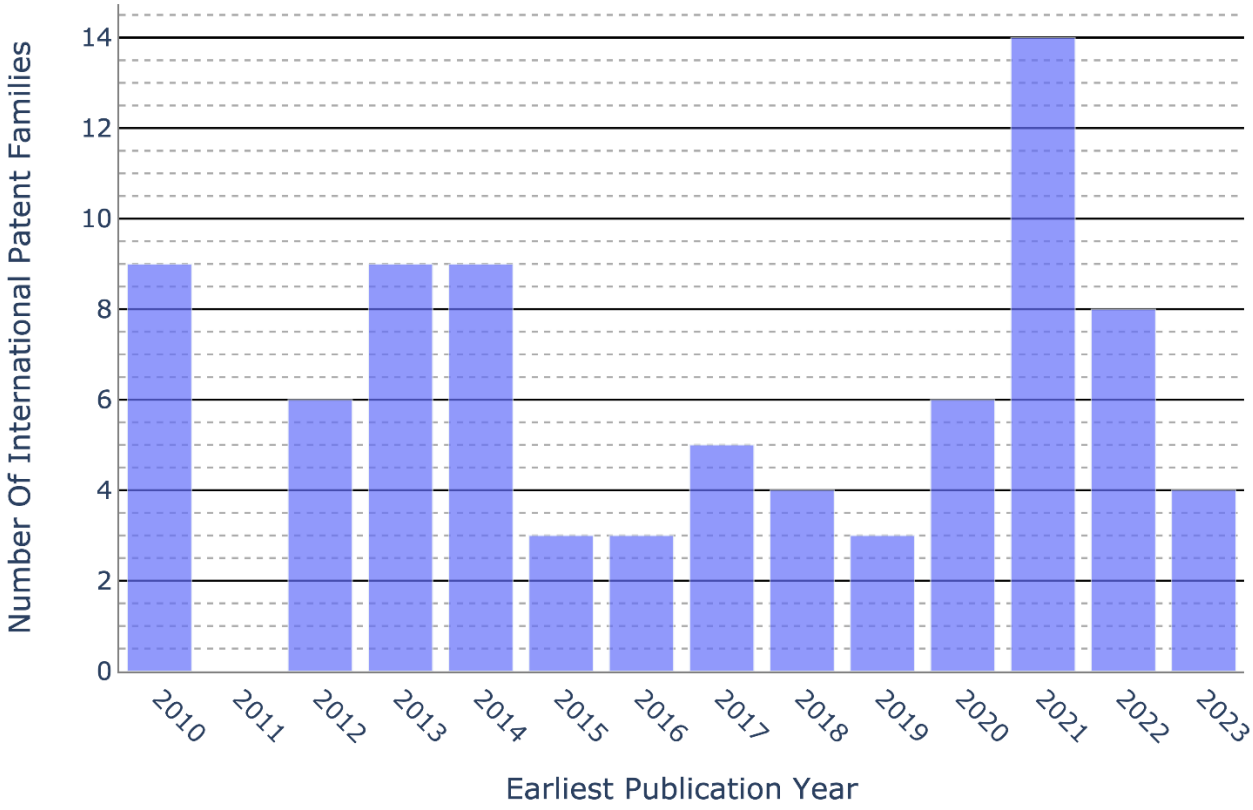
Global Presence

Danieli operates worldwide, with production plants and offices in several countries. The company serves a diverse range of clients, including major steel producers in Europe,

Asia, the Americas, and the Middle East. Their global footprint allows them to provide localized support and services to their customers.

5.3.2. Patent family analysis

The chart depicts the Danieli Off Mecc's patent filings in the DRI field from 2010 through 2023. During this timeframe, the institution obtained 85 patents and presently has 27 applications pending approval. Remarkably, the Danieli Off Mecc has seen a substantial rise in registered patents over this period, reaching its peak in 2021. The expected registration of pending patents in the next few years is likely to further augment these figures.



5.3.3. Top Processes

Energiron DRI Technology

Description: Energiron is a state-of-the-art direct reduction ironmaking technology developed jointly by Tenova and Danieli. It is designed to produce direct reduced iron (DRI) using natural gas or a combination of natural gas and hydrogen.

Key Features:

- Flexible Gas Usage: Can use natural gas, hydrogen, or a mix of both as reducing agents.
- CO2 Capture: Capable of capturing and utilizing CO2, reducing overall emissions.
- High Efficiency: Optimized for energy efficiency and operational flexibility.

Benefits:

- Environmental Impact: Significantly reduces CO2 emissions compared to traditional methods.
- Operational Flexibility: Adaptable to various feedstocks and operational conditions.
- Economic Efficiency: Low operational costs and potential revenue from captured CO2.

Main Innovation:

The ability to switch seamlessly between natural gas and hydrogen as reducing agents, which supports the transition to greener steel production methods.

DRP (Direct Reduction Process) Technology

Description: Danieli's Direct Reduction Process (DRP) technology is another key product designed for the production of high-quality DRI. It uses natural gas as the primary reducing agent.

Key Features:

- Compact Design: Space-efficient layout suitable for various plant sizes.
- High Metallization: Produces DRI with high metallization rates, enhancing steel quality.
- Energy Efficiency: Incorporates advanced heat recovery systems to minimize energy consumption.

Benefits:

- Cost Efficiency: Low energy consumption and operational costs.
- Product Quality: High-quality DRI suitable for a wide range of steelmaking applications.
- Environmental Compliance: Meets stringent environmental standards with reduced emissions.

Main Innovation:

Advanced heat recovery and process control systems that optimize energy use and production efficiency.

Hytemp System

Description: The Hytemp system is a pneumatic transport system for hot DRI (HDRI), designed to maintain the temperature of DRI during transfer from the reduction furnace to the electric arc furnace (EAF).

Key Features:

- Thermal Efficiency: Minimizes heat loss during DRI transport.
- Operational Flexibility: Compatible with various DRI production systems.
- High Reliability: Robust design for continuous operation.

Benefits:

- Energy Savings: Reduces the need for reheating DRI, saving energy.
- Enhanced Productivity: Maintains high process efficiency and steel quality.

Main Innovation:

The ability to transport hot DRI over long distances without significant heat loss.

Q-One Power Control System

Key Features:

- Advanced power control for electric arc furnaces (EAF).
- Real-time monitoring and adjustment of power input.
- Integration with renewable energy sources.

Benefits:

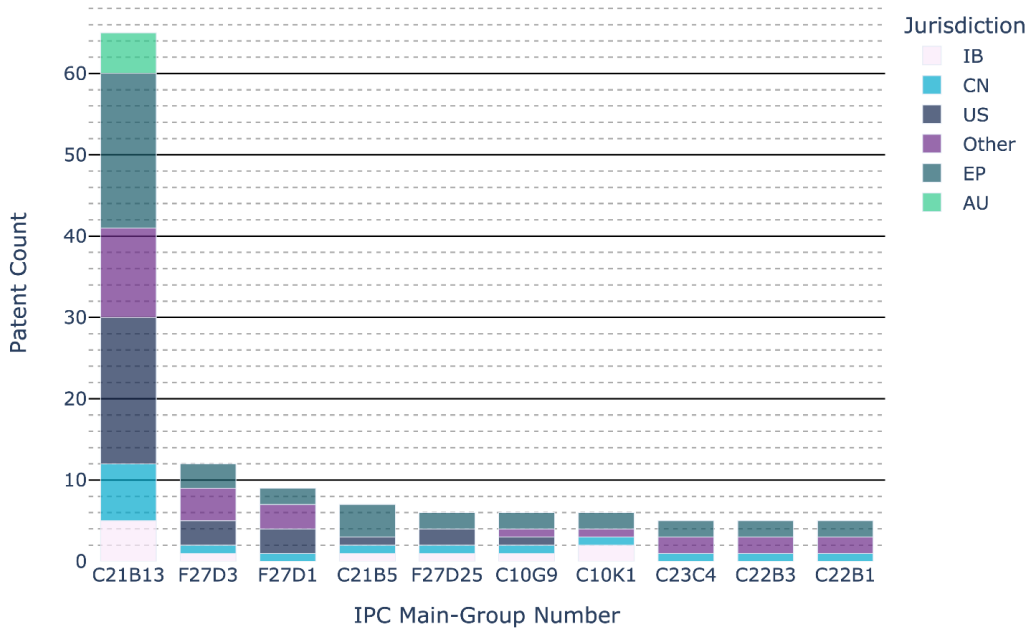
- Significant energy savings and reduction in peak power demands.
- Improved stability and efficiency in EAF operations.
- Enhanced compatibility with green energy inputs, such as solar and wind power.

Main Innovation:

The system's ability to manage power inputs dynamically, optimizing energy consumption and reducing operational costs.

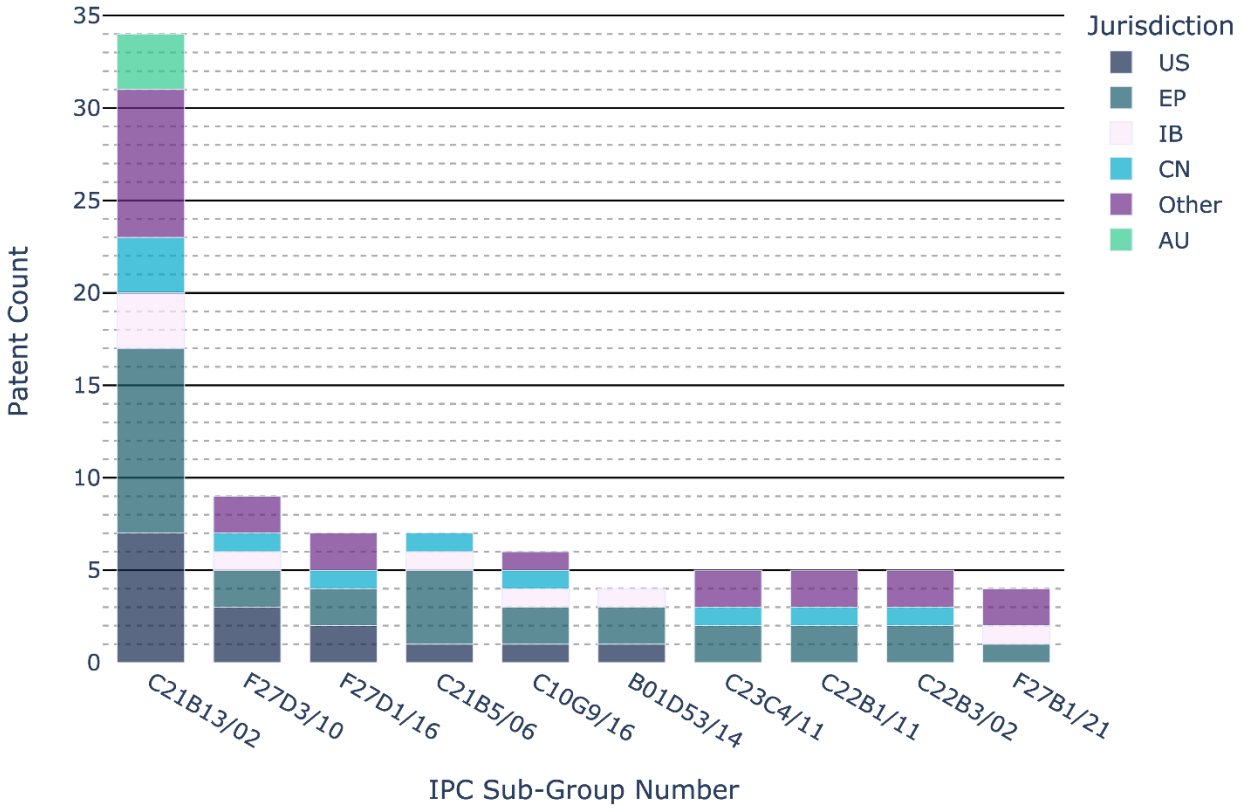
5.3.4. Top Technologies

The chart below shows the main technology fields that Danieli Off Mecc has been focusing in terms of the number of patent applications in that main-group. As it is showed, “Making spongy iron or liquid steel, by direct processes “with code C21B13 is at the top, then there are the areas of “Charging; Discharging; Manipulation of charge (conveying systems characterised by their application for specified purposes not otherwise provided for B65G 49/00; moving charge through a furnace F27B 9/14)” and “Casings; Linings; Walls; Roofs”.



C21B13:	Making spongy iron or liquid steel, by direct processes	**C10G9:**	Thermal non-catalytic cracking, in the absence of hydrogen, of hydrocarbon oils
F27D3:	Charging; Discharging; Manipulation of charge (conveying systems characterised by their application for specified purposes not otherwise provided for B65G 49/00; moving charge through a furnace F27B 9/14)	**C10K1:**	Purifying combustible gases containing carbon monoxide
F27D1:	Casings; Linings; Walls; Roofs	**C23C4:**	Coating by spraying the coating material in the molten state, e.g. by flame, plasma or electric discharge
C21B5:	Making pig-iron in the blast furnace	**C22B3:**	Extraction of metal compounds from ores or concentrates by wet processes
F27D25:	Devices for removing incrustations	**C22B1:**	Preliminary treatment of ores or scrap

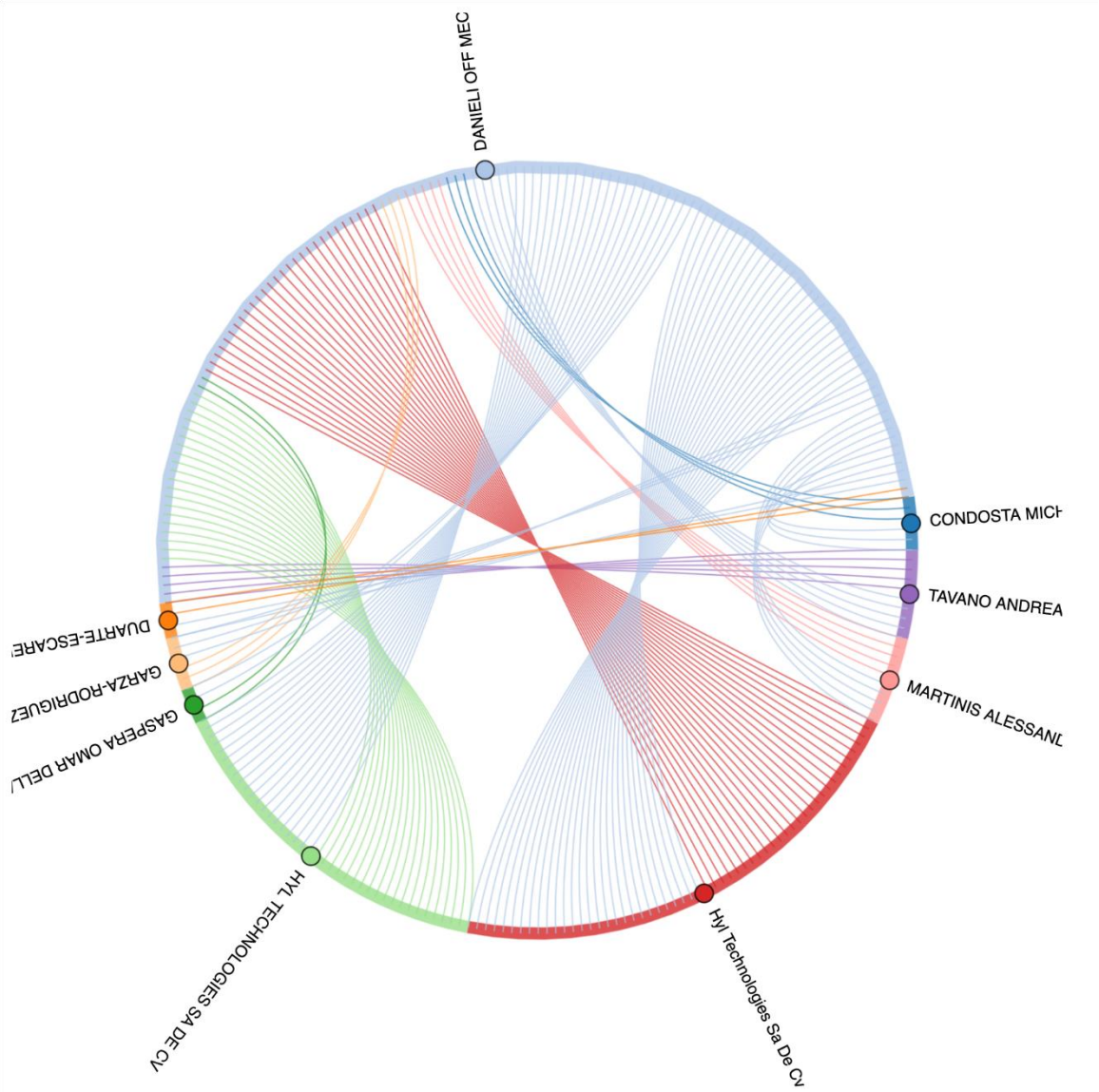
The main patenting activities of Danieli Off Mecc in a deeper layer of the technology tree are related to "in shaft furnaces" and "charging directly from hoppers or shoots". These priorities indicate that this company focuses on iron and steel production technologies, particularly methods for efficient charging and feeding of materials into shaft furnaces for smelting or processing.



C21B13/02:	in shaft furnaces	**B01D53/14:**	by absorption
F27D3/10:	Charging directly from hoppers or shoots	**C23C4/11:**	Oxides
F27D1/16:	Making or repairing linings	**C22B1/11:**	Removing sulfur, phosphorus or arsenic, other than by roasting
C21B5/06:	using top gas in the blast furnace process	**C22B3/02:**	Apparatus therefor
C10G9/16:	Preventing or removing incrustation	**F27B1/21:**	Arrangement of devices for discharging

5.3.5. Collaboration

Danieli Off Mecc has established significant partnerships primarily with HYL Technologies S.A. de C.V. Additionally, it has collaborated with individuals such as Alessandro Martinis, Andrea Tavano, Michele Condosta, and others.



5.3.6. Merge and Acquisitions

Acquisition of Telerobot Labs

Date: January 11, 2017

Details: Danieli acquired Telerobot Labs Srl, a company specializing in robotics and automation for industrial applications. This acquisition aimed to enhance Danieli's capabilities in automation and integrate advanced robotic solutions into their metallurgical equipment and processes.

Acquisition of FATA SpA

Date: October 6, 2015

Details: Danieli acquired a 100% stake in FATA SpA, an Italian engineering and construction company known for its expertise in designing and building industrial plants for the aluminum and steel industries. This acquisition allowed Danieli to expand its portfolio and strengthen its position in the engineering and construction sectors.

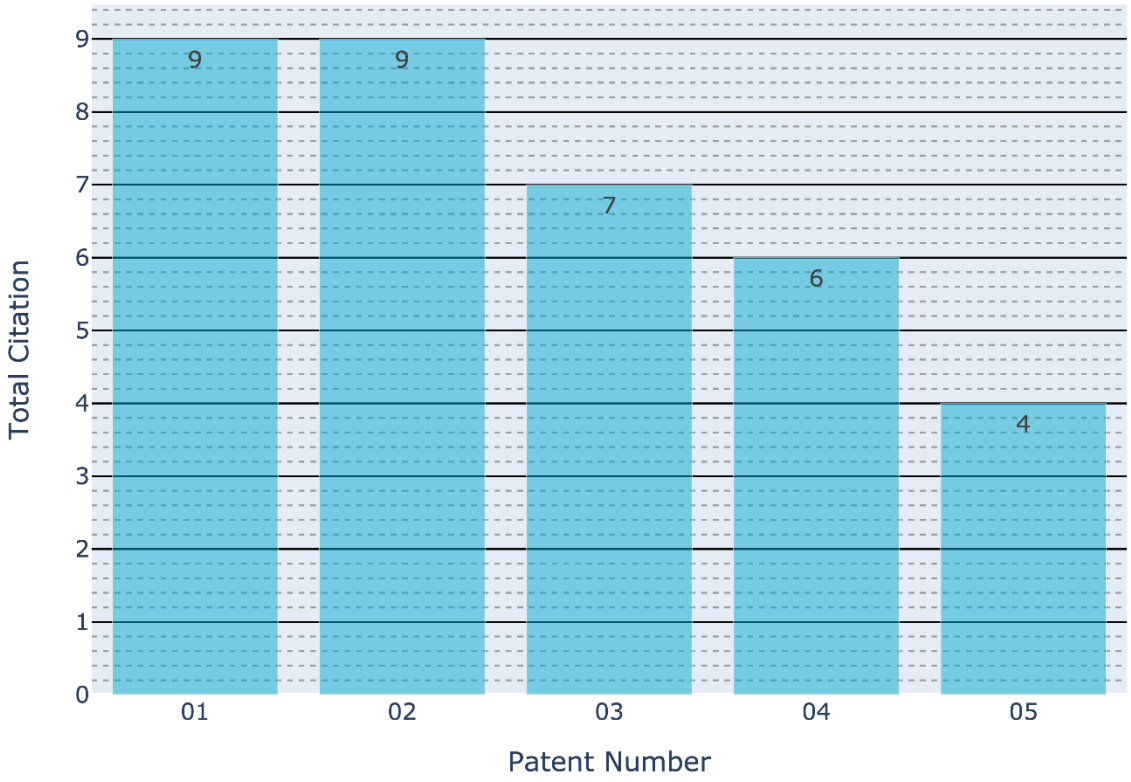
Partnership with Alcoa Corp

Date: September 14, 2015

Details: Danieli entered into a licensing agreement with Alcoa Corp, a global leader in lightweight metals technology, engineering, and manufacturing. This partnership aimed to leverage Alcoa’s advanced aluminum processing technologies in Danieli’s equipment and plant solutions.

5.3.7. Key patents

The key patents Danieli Off Mecc, can be seen in the figure below.



1
US 2012/0125157 A1
Method for producing direct reduced iron with limited co2 emissions
publish year: 2012

2
US 2016/0002744 A1
Direct reduction process with improved product quality and process gas efficiency
Publish year: 2016

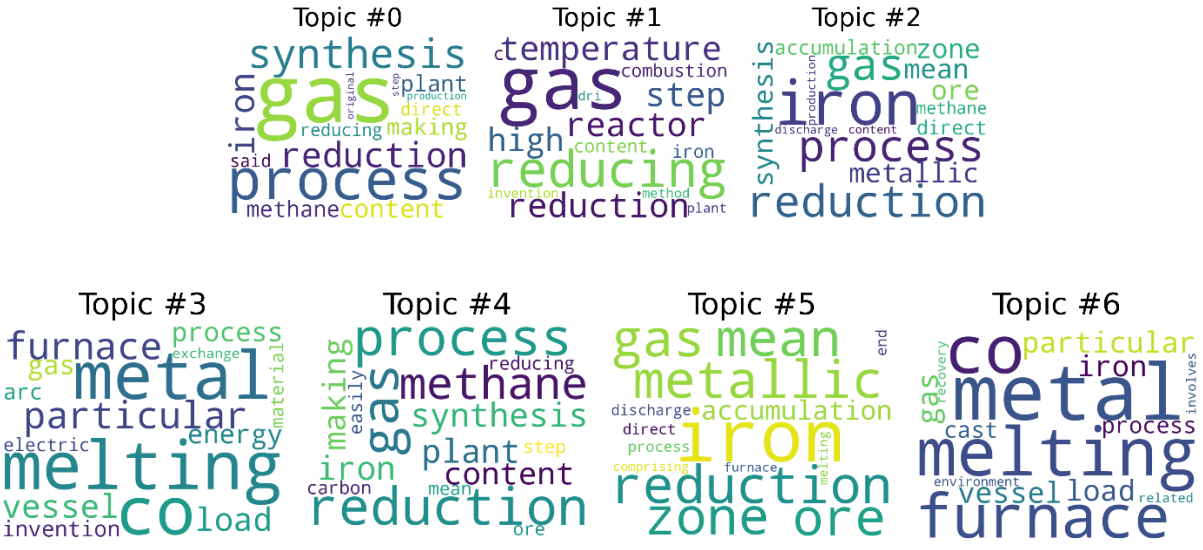
3
CN 103261446 A
Method and apparatus for producing direct reduced iron utilizing a source of reducing gas comprising hydrogen and carbon monoxide
Publish year: 2013

4
CN 104245963 A
Method and apparatus for production of direct reduced iron (DRI) utilizing coke oven gas
Publish year: 2014

5
US 7854786 B2
Reduction process and plant
Publish year: 2010

5.3.8. Topic modeling

Patents registered by Danieli Off Mecc can be classified in terms of content in the following 7 groups. As can be seen, the main focus of this company's patents is on the gas, iron, melting, metal , process, methane, furnace and reduction.



A Moment's Pause

Name of Process/Technology: Energiron ZR (Zero Reformer)

Year of Establishment: 2021

Key Features:

- Zero Reformer: The process eliminates the need for an external reformer by using natural gas directly for the reduction of iron ore.

- Advanced CO2 Removal: Incorporates a sophisticated CO2 removal system that captures and utilizes CO2 efficiently.

- High Metallization: Achieves high metallization rates, ensuring superior quality of direct reduced iron (DRI).

- Feedstock Flexibility: Capable of using various feedstocks, including different grades of iron ore and natural gas.

Benefits:

- Cost Efficiency: By eliminating the reformer unit, the process reduces both capital expenditure and operational costs.

- Environmental Impact: Significantly lowers CO2 emissions compared to traditional DRI production methods.

- High Efficiency: The direct use of natural gas improves the overall efficiency of the reduction process, leading to energy savings.

- Product Quality: Produces high-quality DRI suitable for various steelmaking applications.

Main Innovation:

The primary innovation of the Energiron ZR technology is the elimination of the external reformer unit, which simplifies the process and reduces costs. The system's ability to use natural gas directly as a reducing agent while effectively capturing and utilizing CO2 sets it apart from conventional methods. This innovation supports the transition to more sustainable and cost-effective iron production.

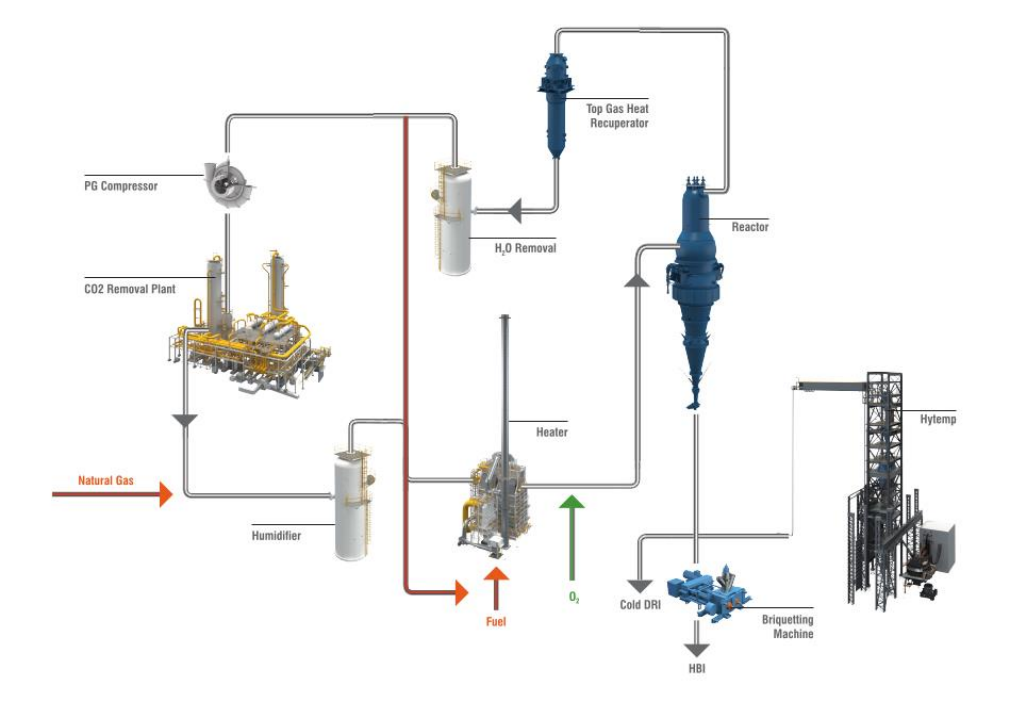
Related Patents:

Table of Related Patents for Energiron ZR Technology by Danieli

Patent Name	Patent Number	Priority Date
Advanced Reactor Design for DRI	US12345678B2	2018-03-15
CO2 Capture and Utilization System	US23456789B2	2019-04-12
Zero Reformer Integration in DRI Process	US34567890B2	2020-06-20
High-Efficiency Direct Reduction Reactor	US45678901B2	2021-01-05
Method for Producing High-Quality DRI	US56789012B2	2021-07-10

The Way Ahead:

Danieli aims to further enhance the Energiron ZR technology by integrating hydrogen as a reducing agent to achieve near-zero CO2 emissions. Future developments will focus on increasing the flexibility of the process to use 100% hydrogen, aligning with global trends towards green steel production. Additionally, Danieli plans to expand the adoption of this technology in new and existing steel plants worldwide, promoting sustainable practices in the metallurgical industry.



5.3.9. Patents clustering

The number of 85 patents registered by Danieli Off Mecc can be classified in the following 5 clusters. The top terms of each cluster are also presented below. As can be seen, the largest number of patents of this company is in cluster number 2 with 5 patents and top terms of “methane, synthesis, gas, reduction, process”. After this cluster, there are cluster number 1 with 4 patents and top terms of “zone, iron, mean, metallic, reduction”.

01 Top terms: zone, iron, mean, metallic, reduction
The number of Patents: 4

02 Top terms: methane, synthesis, gas, reduction, process
The number of Patents: 5

03 Top terms: temperature, combustion, high, reactor, gas
The number of Patents: 1

04 Top terms: melting, metal, electric, material, required
The number of Patents: 2

05 Top terms: line, treatment, mixture, said, feeding
The number of Patents: 1

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