Nippon Steel and hydrogen: Why Super COURSE50 is the wrong path for climate action

With its "Super COURSE50" technology brand, Nippon Steel claims to use hydrogen injection and carbon capture to reduce climate-harming emissions from its steel plants.

However, for all its green promises and elaborate branding, the company is backing a plan that is fundamentally misaligned with what the climate needs and will result in decades of continued carbon pollution from coal burning. Nippon Steel is choosing to use hydrogen to continue steelmaking with coal.

There is a better pathway Nippon Steel could take for a future without coal. It does include hydrogen, but it would be green hydrogen, used for direct reduced iron production, so that coal-burning blast furnaces are retired.[1]

What needs demystifying?

When Nippon Steel claims to be serious about decarbonising and promotes its use of hydrogen in steel production, many observers assume it is a technology leader, taking serious climate action. But there is a need to understand the difference between deep decarbonisation using green hydrogen in steel and what Nippon Steel is planning.

In this brief we explain:

- A clear distinction between two different uses of hydrogen that Nippon Steel is exploring in its steel production: 1) injecting hydrogen into a blast furnace and 2) hydrogen-based DRI and how they are fundamentally different technologies with very different climate impact;
- Why Nippon Steel's planned Super COURSE50 to mix hydrogen with coal in a blast furnace is not serious climate action;
- Why caution must be used when Nippon Steel or others talk about 'hydrogen' and not 'green or fossil-free hydrogen'.

[1] Nippon Steel operates 11 blast furnaces. Two are already scheduled for closure by the company by 2030. Five others are at risk of relining by 2030 (assuming a 20-year lifetime from the last relining).

"Steel and hydrogen will change our planet and our future" says Nippon Steel.[2]

A misleading statement. Coal-based steelmaking is already burning our planet, and the type of hydrogen use planned by Nippon Steel is not going to stop that.

The best use of hydrogen in steelmaking is *direct reduction of iron*

Steel production emits around 4 gigatonnes of GHG each year and the largest share of these emissions is due to the fact that iron ore is turned into iron in coal-fired blast furnaces (coal is used for "reduction" of iron oxides contained in iron ores to produce metallic iron.)

Amongst an array of decarbonisation technologies in development, there is only one that can eradicate coal, get iron-making close to zero emissions and is near commercial viability. This process, known as hydrogen-based direct iron reduction (H2-DRI) turns iron ore into iron in a DRI furnace, using green hydrogen to react with the iron oxides.[3]

Steel produced via the coal-based blast furnace emits around 2 tonnes of CO2 per tonne of steel, while steel produced via H2-DRI, with renewable energy for the hydrogen, iron-making and steel-making, emits as little as 0.05 tonne of CO2 per tonne of steel.[4]

Shifting from coal-based blast furnace production to green H2-DRI can save 25kg of CO2 for every kg of hydrogen used.[5]

[2] Nippon Steel, 【NIPPON STEEL】Carbon Neutral Movie (60sec), (Video) Youtube, 1 July 2022.
[3] HYBRIT, *Fossil-free steel production ready for industrialisation. Summary of the HYBRIT pilot phase report*, August 2024.
[4] ibid.
[5] SteelWatch, *Green hydrogen and steel decarbonisation: what matters from a climate lens*, Explainer Series, October 2024. (Japanese version)

Figure 1:

Green hydrogen produces green iron and saves CO2

Renewable electricity		Hydrogen		Direct reduced iron		CO_2 abatement With H_2-DRI displacing the same amount of blast furnace iron
50 kWh	→	1 kg	→	18.5 kg	→	25 kg
1 TWh	→	20,000 t	→	370,000 t	→	500,000 t

The transition from blast furnaces to H2-DRI cannot happen overnight. But steelmaking needs to be part of a zero emissions economy by 2050. With only 25 years left to go, companies should already be planning this transition.

Injecting externally produced hydrogen into blast furnaces **is wasteful**

Nippon Steel and some other steel makers including ArcelorMittal, Cleveland-Cliffs, Tata Steel and ThyssenKrupp are talking about a very different use of hydrogen in steel production, although the way they talk about it often does not make the difference clear. **Their focus is on hydrogen injection into blast furnaces *alongside continued use of coal.***

This hydrogen injection is at the heart of Nippon Steel's Super COURSE50. In this technology, hydrogen provides partial substitution for coal-based products (coke and pulverised coal), and some reduction in CO2 emissions.

But hydrogen cannot fully substitute coal-based products in blast furnaces because:

- some coke remains necessary to bear iron ore in the blast furnace and facilitates the reduction process;
- unlike iron reduction with coal-based products, iron reduction with hydrogen is endothermic (it absorbs heat around), meaning that past a certain proportion of hydrogen in the process, the blast furnace needs additional energy (possibly *more*

coal-based products) to compensate for the energy consumed by hydrogen-driven iron reduction.

The advantage is that this approach does not require much change in technology - it's simply an added input to blast furnaces. If it used green hydrogen there can be some CO2 saving. So far, many of these applications do not actually use green hydrogen, but use either hydrogen recovered from process gases, or hydrogen produced through processes that do not qualify as green or fossil-free.

The core problem is that this technology perpetuates coal mining, coal use, and blocks the necessary transformation to truly clean, fossil-free steel production that is necessary to halt climate change at 1.5C.

Nippon Steel and other steelmakers tend to provide very little technical detail about hydrogen injection in blast furnaces.

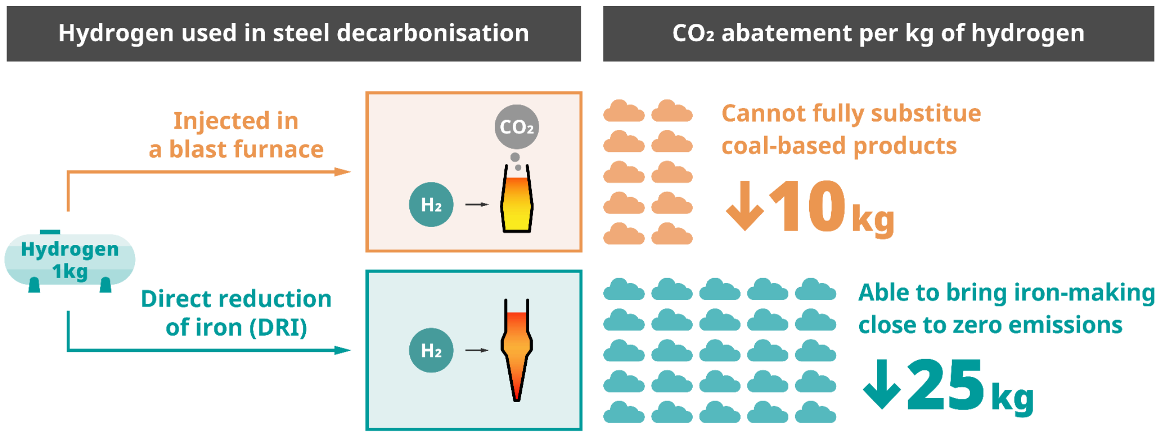
In particular, they tend to omit key information such as the source of hydrogen[6], the actual quantities consumed and the associated CO2 emission savings achieved. Instead, companies provide percentage figures for CO2 emission reductions with no baseline, and sometimes the reduction in coal based products used, in an amount or percentage. Nippon Steel tends to give a single percentage relating to CO2 (like 30% reduction) without quantities or definitions.

But from a review of the academic literature, Yilmaz et al. (2017)[7] and Shatokha (2022)[8] converge in their estimates of **approximately 10 kg of CO2 emissions reduction for one kilogramme of hydrogen injected in a blast furnace**.

This compares to 25kg of CO2 saved per kg of hydrogen, if it is used to shift to H2-DRI.

[6] Bellona, *Hydrogen in steel production: what is happening in Europe – part one*, March 2021.
[7] Yilmaz, C., J. Wendelstorf and T. Turek, Modeling and simulation of hydrogen injection into a blast furnace to reduce carbon dioxide emissions, *Journal of Cleaner Production*, 15 June 2017.
[8] Shatokha, V, Modeling of the effect of hydrogen injection on blast furnace operation and carbon dioxide emissions, *International Journal of Minerals, Metallurgy and Materials*, 22 August 2022.

Figure 2:
Comparing green hydrogen use for blast furnace injection or DRI



Which hydrogen? For a safe climate, hydrogen has to be *green*

When steel companies talk about using ‘hydrogen’ they often do not specify which type of hydrogen and do not mean green hydrogen unless they specify green. Nippon Steel promotes that they use ‘hydrogen’, without specifying which type. This can lead others to assume it is green hydrogen, or that the company has gone green, when that is not actually the case.

Almost all the hydrogen currently produced in the world is derived from fossil fuels.[9] So while the hydrogen molecule itself (H2) is physically carbon-free, its production can cause significant greenhouse gas (GHG) emissions. Therefore, for hydrogen to be a genuine decarbonisation tool, it must be produced in a process that is itself near-zero-emission all along the way: today that means hydrogen produced from water in electrolysers powered by renewable sources of electricity, and is known as *green hydrogen* or *fossil-free hydrogen*.

[9] IEA, *Global Hydrogen Review 2023*, 2023, p. 64.

Nippon Steel plans for Super COURSE50 will waste hydrogen in coal-fired blast furnaces

Sixteen years of effort have already been spent on developing blast furnace technology known as COURSE50. It began as a research project back in 2008[10] with the participation of the three largest Japanese steelmakers - Nippon Steel, JFE, and KOBELCO / Kobe Steel, and the support of the New Energy and Industrial Technology Development Organization (NEDO), Japan's main public research and development agency.[11]

COURSE50 aims to reduce CO2 emissions coming from blast furnaces through the partial substitution of coal-based products, with hydrogen that is already present today in off-gases generated in BF-BOF steel plants. Nippon Steel states that COURSE50 targets a 30% CO2 emissions reduction from blast furnaces, of which only 10% is from the use of recycled hydrogen, and 20% from CCUS by 2030.[12]

Given the insufficiency of COURSE50 relative to the goals of the 2015 Paris Agreement, in 2018 the Japan Iron and Steel Federation outlined an approach towards achieving 'Zero Carbon Steel' and included a new **'Super COURSE50'** in their roadmap.[13] Research and development on Super COURSE50 received government backing from NEDO in 2020,[14] and continues to attract support including funding from 'Green Innovation Fund'.[15]

The difference between COURSE50 and Super COURSE50 is that in Super COURSE50 hydrogen is produced specifically for injection into blast furnaces, in addition to the hydrogen recovered from capturing off-gases. With this additional supply of hydrogen, Super COURSE50 aims for 50% or more total CO2 emissions reduction from blast furnaces, compared to 30% for COURSE50 (Figure 2).

Nippon Steel, announced in February 2024[16] that it *"had achieved the world's highest level of 33% reduction in CO2 emissions from the blast furnace."* However, no emissions data was provided to explain how this 33% is calculated. These tests were made only in a miniature furnace of 12m3, that is 400 times smaller than commercial-scale blast furnaces.

[10] The Japan Iron and Steel Federation, *COURSE50 - Research*. https://www.greins.jp/course50/en/research/
[11] New Energy and Industrial Technology Development Organization, *About NEDO*, retrieved 13th September 2024.
[12] Hydrogen Steelmaking Consortium, *Technology to reduce CO2 emissions from blast furnaces,* retrieved 13th September 2024.
[13] Japan Iron and Steel Federation, *JISF Long-term vision for climate change mitigation- A challenge towards zero-carbon steel*, September 2019.
[14] New Energy and Industrial Technology Development Organization, Developing Technologies to Achieve 'Zero Carbon Steel.' (Japanese), May 2021.
[15] Ministry of Economy, Trade and Industry, Green Innovation Fund, retrieved 13th September 2024.
[16] Nippon Steel, Verified the World's Highest Level of CO2 Emissions Reduction at 33% by Heated Hydrogen Injection in the Super COURSE50 Test Furnace, 6th February 2024.

The company is working on scaling up the process to large-scale blast furnaces, with an indicative date for deployment in the 2040s, but the company explicitly recognises the challenge represented by this difference in scale.

Nippon Steel has never made it publicly clear whether the externally sourced hydrogen for its future Super COURSE50-equipped blast furnaces would be *green*.[17] If it is *not* green, any claim to reduce CO2 emissions relating to steel production should be discounted by the *additional* CO2 emissions stemming from the production of the hydrogen consumed in these blast furnaces.

If it *will be* using green hydrogen, it still has to be a wise use of renewable electricity compared to other options, to count as a sound climate action. This may be in doubt, given Japan currently has limited capacity for green hydrogen due to a lack of renewable energy,[18] while importing green hydrogen in the form of ammonia wastes energy in conversion. And it is certainly a wasteful use of green hydrogen compared to using the precious resource for H2-DRI.

Super COURSE50: waste of effort and loss of decades

SteelWatch is criticising[19] Nippon Steel's plans for the use of hydrogen in Super COURSE50 for 4 main reasons:

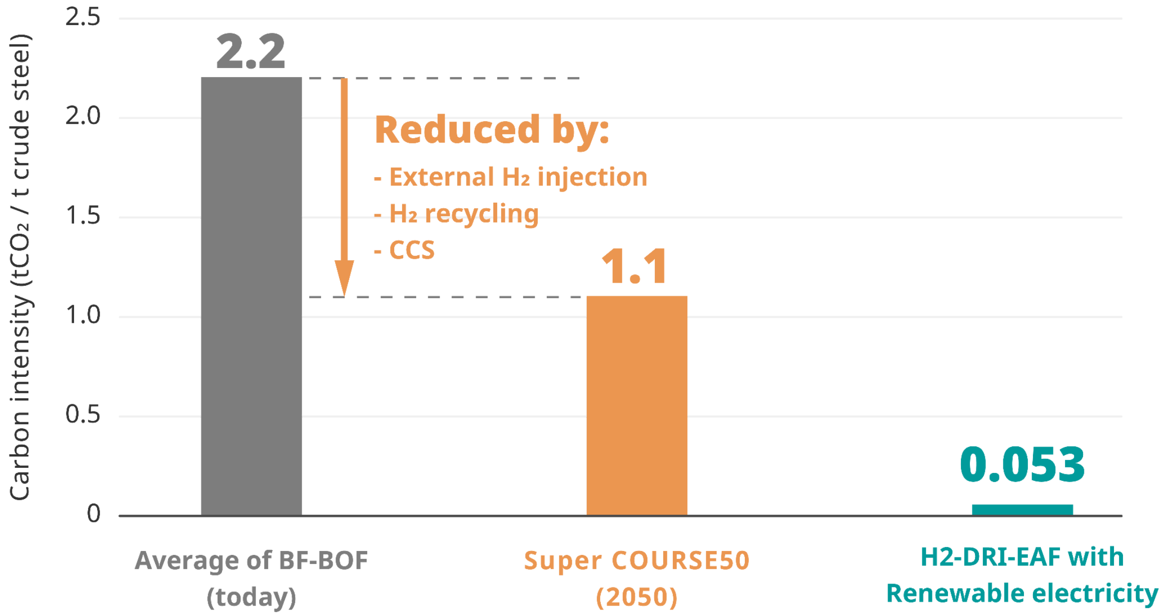
1. It's too little too late for emissions reductions : 50% reduction by 2050 from heavy polluting coal-based assets is way off track with what is needed to address climate change.
2. It perpetuates coal use: trimming some emissions from coal-burning blast furnaces does not shift steel production out of coal into a clean future. It perpetuates coal mining, coal use, coal pollution, indefinitely.
3. It's fundamentally inefficient: If fossil-based hydrogen is used, it's simply adding more emissions to a dirty system. If green hydrogen is used, it's a waste of that precious resource. The same green hydrogen could save 25 kg of CO2 if used for H2-DRI in substitution of BF-BOF - 2.5 times more than what it can save if used in a blast furnace.
4. Misguided use of technological potential: It's taken 16 years to get this far, and it seems at least another 16 years is needed for commercial deployment, with full

[17] The Japanese Government has a target of using 3 million tonnes of hydrogen a year by 2030 but does not say whether this is green or not, nor where this is produced.
[18] REI, The Path to Green Steel; Pursuing Zero-Carbon Steelmaking in Japan, 18 November 2022
[19] SteelWatch, *Too Little, Too Late – Corporate Climate Assessment of Nippon Steel*, 2024.

implementation apparently set for 2050. Spending the next quarter century delivering a technology that is fundamentally not a climate solution is a terrible waste of the innovation and investment by the leading Japanese steelmaker. Had Nippon Steel invested the past decade and half in true decarbonisation technology, the industry would have been on a different path.

Figure 3:

Carbon intensity of Nippon Steel's existing and planned production technologies compared to H2-DRI



What is needed?

Don't be fooled: Media, government officials, investors and other stakeholders need to know that when Nippon Steel talks about using hydrogen for steel decarbonisation it is not specifying green hydrogen, not moving away from coal-burning and the hydrogen is only trimming a fraction of emissions even 30 years from now.

Injecting hydrogen into blast furnaces is a way to perpetuate Nippon Steel's addiction to coal-based steelmaking.

Nippon Steel needs to invest in true decarbonisation technology. If Nippon Steel opts for H2-DRI, the climate impact per kg of green hydrogen is far higher. The green iron can be produced overseas in countries with abundant renewable energy and iron ore, such as Australia, then transported to Japan as green Hot Briquetted Iron (HBI).[20] Steelmaking would still be done in Japan, with the difference being iron, rather than iron ore, is imported.

For 1.5C aligned climate action, Nippon Steel needs to be actively planning to close its blast furnaces, not relining them, so as to end coal-based steelmaking within the decade ahead.

Key terms

Blast Furnace / BF-BOF	A blast furnace (BF) is where iron oxides are mixed with coal to produce molten iron. The iron is then processed into steel in a basic oxygen furnace (BOF). This overall iron and steelmaking process is referred to as BF-BOF.
COURSE50 / Super COURSE50	A Japanese government-supported research project initiated in 2008 to reduce CO2 emissions coming from blast furnaces through the combination of two technologies: hydrogen injection and carbon capture. Super COURSE50, launched in 2018, is an enhanced version of COURSE50, with a higher overall emissions reduction objective (50% in total instead of 30%). Technologically, the difference between COURSE50 and Super COURSE50 is that while COURSE50 would use hydrogen recovered from off-gases generated within steel plants, Super COURSE50 would use hydrogen produced specifically for injection into blast furnaces.
Hydrogen / Green Hydrogen	Hydrogen (technically dihydrogen or H2) is a molecule that is both energy-rich and carbon-free. As hydrogen for the time being cannot be simply extracted, it must be produced from primary sources of energy such as fossil energy and renewables. The ultimate climate impact of hydrogen depends on how it is produced. For hydrogen to be a genuine decarbonisation tool, it must be produced in a near-zero-emission process: today that means hydrogen produced from water in electrolysers powered by renewable sources of electricity,

[20] According to Transition Asia, given Japan's current structure of power generation, producing hydrogen in the country to produce DRI and using it in electric arc furnaces (H2-DRI-EAF) would result in a higher carbon intensity per tonne of crude steel than the BF-BOF route. Transition Asia, *Prioritising Renewable Electricity for Steel in Japan's 7th Strategic Energy Plan*, 21 August 2024.

	and is known as *green hydrogen* or *fossil-free hydrogen*.
DRI / H2-DRI	Direct reduction of iron oxides (DRI) is an ironmaking technology that is an alternative to the blast furnace. Unlike the blast furnace which cannot function without coal-based products, DRI can operate with a broad range of materials to reduce iron oxides: coal, gas, hydrogen. DRI is today commonly used with gas. It can get close to zero CO2 emissions if it uses *green hydrogen*. This process is hydrogen-based direct reduction of iron, known as H2-DRI.
CCS / CCUS	Carbon capture, utilisation and storage (CCUS) is a broad family of technologies found in many different industries, not only the iron and steel sector. CCUS technologies aim at capturing CO2, and then storing it for a long period of time or using it to produce goods.