# Red Hydrogen for Green Steel

Release 1.1 - Proposal for a road map

30 October 2023

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The intent of this document is to initiate a program to use Red Hydrogen to revive low cost virgin steel making and thus metalworking production in the UK. The key word is Revival. This is not about a sticking plaster to slow down the inevitable end. It is about overturning existing industry economics to build a growing prosperous future. In the first instance, it is a request to produce a road map to make Green Steel with Red Hydrogen.

This Call for Support has been written for the non specialist without an engineering background. Part of the proposal is to write a more technical and quantitative route map.

Contents



# Management Summary

This is a proposal for a project to reinstate a low cost virgin steel industry that can revive UK metalworking production. It is currently framed for the Port Talbot site where 900 years of iron and steel making may be ending.

The hydrogen route for making low carbon virgin steel is already receiving a lot of attention.

Technology is available under licence. Existing sources of hydrogen include Black hydrogens which are low cost, readily available but generate a large amount of CO2 or Blue hydrogens which are readily available and low carbon but energetically inefficient and high cost as the electricity required has other markets.

The document introduces red hydrogen, potentially very low cost and zero carbon but development is required. Red hydrogen uses experience in Advanced Gas Cooled Nuclear Reactors in which the UK has a unique record of decades of operating experience.

Actions are proposed at the end.





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# Green Steel

Making steel in blast furnaces cannot continue. Steel making in blast furnaces is a major contributor to the rise in atmospheric carbon dioxide thought to contribute to Global Warming.

However, abandoning the industry in the UK will not lead to reductions in carbon dioxide emissions if there is mere substitution by steel produced in less environmentally concerned countries. The UK needs to make low cost green steel for its own use and to displace blast furnace steel from the world market.

There is also a case for access to 'virgin' steel in the UK for technical reasons. Newly produced steel has higher tensile strengths and better surface finish for the production of gun barrels, tin cans and razor blades amongst other things. Recycling scrap steel through Electric Arc Furnaces does not achieve the same level of quality. There are nuances but they are not material for this discussion.

So new steel must be made for the most quality sensitive applications. Traditional virgin steel making is done most cheaply where iron ore, coal and limestone can be mined or transported at low cost to feed blast furnaces. The process 'reduces' the ore to metal.

Port Talbot's lingering competitive advantage is a dock for unloading very large ship loads of coal and limestone used to produce coke for this purpose.

Virgin steel can also be made by the Hybrit process (see below) and in Electric Arc Furnaces using higher quality ore and hydrogen for reduction.

Hydrogen eliminates the need for coal and limestone and their vast handling and environmental costs.

## The EU leads with hydrogen in steel making

In a conventional blast furnace, carbon in the form of coke, in the presence of limestone, strips the oxygen away from iron ore (directly reduces it) to leave behind the metal. This process produces huge amounts of carbon dioxide.

Hydrogen can also be used for Direct Reduction to produce sponge iron without the use of coke and limestone. This is then further refined in an electric arc furnace to make iron.

The Finno-Swedish research project Hybrit is already using this process to deliver steel to Volvo. A Swedish firm H2 Green Steel is building a large scale plant to use the process. The European Union is backing this move to hydrogen.

The following companies have announced plans to convert at least a part of their production to





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hydrogen steel. European companies dominate.

## Hydrogen steel in the EU

- HyBrit (Sweden)
- H2 Green Steel (Sweden)
- SSAB (Sweden)
- ArcelorMittal (Luxembourg)
- ThyssenKrupp (Germany)
- Tata Steel (Netherlands)
- Van Merksteijn (Netherlands)
- Blastr (Norway and Finland)
- GravitHy (France)
- Liberty Steel (France)

## Hydrogen steel in the Rest of the World

- Vulcan Green Steel (Oman)
- POSCO (South Korea)
- Baowu (China)

The US announced a Hydrogen Demand Action plan in February 2023. This included an intention to study hydrogen production in steel but there have been no material results so far. Russia has very substantial plans to make hydrogen and planned to capture a large share of the world market.

The UK steel industry is small but its high quality production is the base for much else. With genuine innovation, in part building on the UK experience in Advanced Gas Cooled Reactors it can be not just revived but grow again and stimulate surviving assets and skills in currently declining industrial areas.

Hydrogen may also be used as a substitute for carbon based fuels in electric arc furnaces. The government proposes to add additional electric arc furnaces (EAF) at Port Talbot to melt scrap to compensate for the closure of the blast furnaces. Scrap steel does not have the high tensile capability of original production nor is it easy to roll into thin high surface quality items like cans and razor blades.

EAFs can as identified above be adapted to make virgin steel.

Tata and Liberty Steel are already using EU money to develop hydrogen based production. This may remove their interest in hydrogen steel production in the UK.

Steel is of course not the only application for cheap hydrogen. Cheap hydrogen solves a lot of





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problems with low carbon transport too.

How is hydrogen produced? Can it be cost-effective?

# Coloured Hydrogens

The EU may be prepared to pay a premium for low carbon steel production. This is less likely in the rest of the world. Red hydrogen can give the UK a chance to meet EU environmental levels and be a cost leader in green steel production by producing cheap hydrogen.

There are a variety of ways of making hydrogen. They are described by colours but the terminology is very inconsistent between industry bodies. To reduce confusion their use in this document is explained below.

## Black (Turquoise/Grey/Gold) Hydrogen

These colours of hydrogen use gas or brown coal as a feedstock. Steam is added and hydrogen and carbon dioxide or carbon black are produced. This is environmentally unsound and couples strongly with the high energy prices that already penalise steel production in the UK. However, it is long established and reliable technology. Scalable process plant is available almost on demand and Wales imports huge amounts of gas at Milford Haven.

Air Products supplies Black hydrogen to Tata Steel from Llanwern. BOC does the same for Port Talbot and some other industrial sites. A number of other firms have on site capabilities for small volumes of hydrogen, all black.

Russia is aiming to become a major producer of Black hydrogen and may determine prices of hydrogen in the tradeable market. Low cost hydrogen production solutions are therefore required for sustainable hydrogen based businesses in the UK.

Gold hydrogen is made by bacterial decomposition of waste organic matter.

## Blue (Green/Pink/Yellow) Hydrogen

The different colours relate to the source of electrical power.

Blue hydrogen uses electricity from the grid from all sources to turn water into hydrogen and oxygen, a process known as electrolysis. The electricity may be from any source.

Green hydrogen uses wind power as the source for electricity. In practice green hydrogen doesn't exist in a practical way due to intermittent supply. The UK grid has 27 GW of wind turbine capacity installed. On a typical summer's day it struggles to reach 5 GW of output.





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In summer, all of this can be sold. There is no spare output for low cost applications. For the whole summer long, wind power is as expensive as any other source of electricity. Thus output is almost always sold to the electricity grid at market price. So intermittent energy rarely provides the nearly free energy advocates claim can be used to generate almost free hydrogen. 20 year old ideas about creating a hydrogen economy along the M4 and the greater UK have failed due to these realities.

For the actual figures see [http://www.gridwatch.templar.co.uk/](http://www.gridwatch.templar.co.uk/). This is not a model but actual results.

At best a mix of blue and green can be achieved.

Pink hydrogen uses electricity produced by nuclear power for electrolysis. In principle this could be accomplished in Port Talbot by a DC cable from Hinkley Point nuclear power station to supply the electrolysers but prices of electricity would be tied to the UK grid and therefore still expensive relative to Black and Red Hydrogen. Russia has surplus hydropower and will add pink hydrogen to its black hydrogen output. Russia may shift some of the Black and Pink investment to its BRICS+ partners in particular Saudi Arabia and the UAE to avoid sanctions.

Yellow hydrogen is produced by electrolysis from solar power. This is inconsequential in the UK. 15 GW of installed solar panels produce trivial output in the UK in winter and over 5 GW peak at noon is a very good day even in summer.

The green steelworks proposed in Oman could reliably use Yellow hydrogen. Other countries with dependable sunshine could enter the steel industry based on the resource of sunlight and very low cost hydrogen especially if sited next to an ore body.

Fortunately for the prospects for steel making in cloudy countries, near perpetual sunshine is usually accompanied by an absence of water, essential for producing Red Hydrogen and steel.

Nevertheless, Yellow hydrogen may be a serious contender for making steel if linked to desalination. Once the plant in Oman demonstrates a Yellow hydrogen process the Islamic world has the investment funds to make it happen at scale, for example in Iran, an existing steel producer.

## Red Hydrogen

Red hydrogen is a plausible UK advantage.

Hydrogen and oxygen can be produced from water by high temperature chemical reactions in the presence of catalysts. This is far more thermodynamically efficient than electrolysis (The Blue hydrogens) and inherently lower cost requiring only heat.

Iodine and sulphur are used for intermediate compounds but are available for reuse at the end of the cycle thus costing nothing. The process has been





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demonstrated at industrial semi tech scale in Japan with a High Temperature Gas Cooled Reactor.

The inputs are high temperature provided at very low fuel cost by nuclear reactors and water. This is an inherently low cost process.

The outputs are hydrogen, oxygen, surplus heat (that can still generate electricity) and at the cost of some sulphur, sulphuric acid.

The UK has unique experience in operating a fleet of Advanced Gas Cooled Reactors (AGRs). The UK has operated them for decades. No other country has. the operational experience and engineering know-how. This can enhance any development programme for high-temperature gas cooling.

The Japanese High Temperature Test Reactor first produced Red Hydrogen in 2004. In 2010 the HTTR achieved 50 days of continuous operation at semi-tech scale (30 MW) useful enough for industrial production. The Fukushima incident resulted in the closure of the project. It was reopened in 2021 and the HTTR has been producing hydrogen continuously ever since. A much larger unit is being planned with Mitsubishi Heavy Industry in cooperation with Air Liquide. The Japanese government aims to be producing 3 million tonnes of hydrogen a year by 2030. French industry has also declared interest in developing this source of hydrogen.

The National Nuclear Laboratory in the UK and the Japan Atomic Energy Agency have a long history of cooperation. Their working agreement was renewed this year, 2023. Cooperation on red hydrogen would make this agreement economically meaningful.

It is a case where the UK making its own deal with Japan might move faster than the EU which is weighed down with conflicting interests, Including Germany's reluctance to engage with nuclear technology, although of course France is already in place.





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# Welsh Hydrogen Economy

In the Welsh context very low cost hydrogen is not just about transforming the prospects of the steel industry.

Wales has plans dating back 20 years to establish a wider hydrogen economy including transport, heating and industrial processes. There is even a car manufacturer, RiverSimple. Various local authorities and transport for Wales are looking at hydrogen power for heavy vehicles. Marubeni Energy has invested to address this market. The high cost of Blue hydrogen has been a barrier to this.. This is well covered in other publications.

While an on site location in Port Talbot or Llanwern might make the whole process integrated for steel makers, there are other options. Wales and the West Utilities has a proposal to build a hydrogen pipeline across South Wales (and there is another proposal in North Wales near Shotton), The Red Hydrogen plant could be located along this pipeline remotely from the steel works.

Wales also has industrial, academic and operational nuclear expertise. This is less well described but can be part of a future report. This is in part due to a legacy of process plant engineering thanks to the former presence of not just the steel industry but the petrochemical industry as well. University of South Wales has background in gold hydrogen amongst a diverse portfolio of other interests in hydrogen.

The Siemens and Bessemer processes for making steel were both invented in Wales (The Bessemer process was adopted at an early date by Tata Steel, an historical step forward for India). Fundamental innovation can be done again in Wales with guidance from both governments. The result can be licensed to countries capable of operating high temperature reactors overturning the economics of steel making and industrial location

# Proposed Goals for a Red Hydrogen project

- Make UK steel making a world leader for cost and quality.
- Capture added value by creating the processes with Japanese partners.
- Provide hydrogen and heat for other industries.
- Reducing carbon dioxide worldwide by undercutting prices of blast furnace steel production in countries that do not convert to green processes.





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# Conclusions

Green virgin steel can be made with hydrogen.

Black hydrogen is cheap but dirty. Blue hydrogen is low carbon but selling electricity is always a better option than hydrogen production for volume uses. Red hydrogen is potentially as cheap as water with useful by products and enables many alternative uses reducing market risk.

There is unexplored potential for creating low cost green steel using hydrogen in high temperature nuclear reactors. Success would transform world steel making locations and restore metalworking production to the UK economy as well as provide a base for a more general low carbon hydrogen economy. The main effort should be located in and around Port Talbot as part of a levelling up efforts.

## Initial Actions

1. Port Talbot Transition Board to contact Customer Refocus to discuss options to develop the Red Hydrogen idea.
2. Port Talbot Transition Board to fund a preliminary road map to Red Hydrogen-Green Steel with an emphasis on identifying potential contributors.
3. Identify fit with existing government support schemes.
4. Open discussions with potential stakeholders in UK, Japan, EU, India.
5. GO/NO GO
6. Set up a project team to develop a detailed road map and costing models.
7. Obtain commitments from steel industry members, their customers, other potential users of hydrogen (transport) and nuclear suppliers.
8. GO/NO GO
9. Build a hydrogen based green steel demonstrator (technology to be determined) at Port Talbot.
10. Build a research scale reactor to supply material amounts of hydrogen to Port Talbot for steel making. As there are other markets for hydrogen this could be item 9.
11. Further actions depend on the results.





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## Web links for further reference

This is not a set of academic references. These are media releases accessible to the general reader.

- *Philip Owen the Author* https://www.linkedin.com/in/volgatrader
- *Customer Refocus* http://www.customerrefocus.co.uk
- Hybrit makes carbon free steel This company has delivered the world's first fossil-free steel
- EU support for Hydrogen steel ESTEP - Involvement
- Green steel from Tata in the Netherlands Carbon neutral steelmaking | Tata Steel in Europe
- Colours of hydrogen The hydrogen colour spectrum| National Grid Group
- Colours of hydrogen Hydrogen | Colors
- Red Hydrogen What is Red Hydrogen? Interview With Our DirectIndustry Expert
- Japan scales up JAEA, MHI team up for HTTR hydrogen project
- Hydrogen Baseline Wales Hydrogen development in Wales
- University of Bangor Nuclear Nuclear Futures Institute
- Wales Nuclear Forum Wales Nuclear Forum





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