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CUMBRIA COUNTY COUNCIL

WOODHOUSE COLLIERY PROJECT

REVIEW OF THE USE OF COKING COAL IN THE UK

SEPTEMBER 2020

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AUGUST 2020

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CONTENTS

1 Introduction 1
2 Scope of Work 1
3 Background 2
4 WA Comments 4
5 Suitability of the WCM Coal for the steel making industry 9
6 The Coking Coal Market 11
7 Alternate production methods 15
8 Coal Replacement 17
9 WA Conclusions 23

TABLES

Table 3.1: Type of Hydrogen 16

FIGURES

Figure 4.1: Extract from figure in WM report showing PCI replacement with grey hydrogen source - thyssenKrupp 18

Figure 4.2: Blast Furnace compared with HYBRIT system Source WM Report /Hybrit thyssenKrupp 19

Figure 4.3: DRF Process 21

1 INTRODUCTION

1.1.1 Cumbria County Council (the Council) has received an Application for Process Change April 2020 as a revision to the West Cumbria Mining (WCM) Planning Application, 4/17/9007, which proposes a change to the coal processing methodology. Wardell Armstrong (WA) has been requested to provide advice in relation to the validity of the reasoning behind the revision and the potential impact of the revised process.

1.1.2 In addition comment has been made by objectors as to whether WCM will increase the use of coking coal in the UK and Europe or indeed whether there are methods of steel production that could reduce or eliminate the use of coking coal for making steel. WA has been asked to advise on these issues.

2 SCOPE OF WORK

2.1.1 The original scheme indicated that the mine would produce a Run of Mine (ROM) coal, (the coal as it comes out of the ground), that would require preparation (washing). During the preparation, a clean, low ash, ‘metallurgical’ grade coal would be produced but some 15% of the total recovered coal would be a higher ash, higher sulphur coal classified as ‘middlings’ coal. It was stated that the production of ‘middlings’ coal ensured that the metallurgical coal was maintained as a high grade product.

2.1.2 The revised proposal changes the process to achieve a metallurgical coal product with no ‘middlings’ coal, whilst maintaining the overall product volume.

2.1.3 WA have been requested by the Council to provide the following:

- A technical explanation for the change of classification of all the coal product as metallurgical coal.
- Explanation of how the change from two products, coking coal and middlings coal impacts on the wider considerations, eg. product quality or suitability, and the amount of reject material.
- Comment on the variations in sulphur (and other) content of the revised process impact on the suitability of the coal for steel manufacture.

- Comment on whether the new product can be produced consistently at a suitable quality to be sold exclusively for steel manufacture and comment on whether there may be periods where the overall quality of the coal is too low for that.
- Comment on the evidence to support the arguments put forward for the shift in approach.
- Comment on the wider arguments about markets for steel and demand for coking coal.

2.1.4 Two other issues have arisen related to the WCM project on which WA has been asked to advise.

- Substitution

  Whether the proposed WCM coking coal product will substitute for, or be in addition to, coking coal currently being imported, predominantly from the USA to the UK (or Europe), and

- Elimination

  There have been submissions made which questions the future need for coking coal when there is ongoing research and development into the elimination of coking coal from the main blast furnace/basic oxygen furnace (BF/BOF) steel producing route.

2.1.5 The Council has also provided WA with copies of other submissions by WCM, AECOM, Dr N J Bristow, Wood Mackensie and WCM with Hugh Babbage, as well as feedback on the draft report. WA have read and where these show any inconsistencies with the content of this report then clarifications have been included, however the views and comments within this report have been made independently by WA.

3 BACKGROUND

3.1.1 WCM's original planning application sought permission to produce 2,430,000tpa of metallurgical coal (coking coal) and a by-product of 350,000tpa of 'middlings' coal at full production. The products were determined by the quality of the coal being mined and the coal preparation process that the ROM coal was put through, to remove unwanted elements and produce a saleable product. The coal preparation process design maximised the volume of high value, low ash, high sulphur, coking coal that would be produced but, as part of the cleaning process, would also produce another lower value, higher ash, higher sulphur coal or 'middlings'.

3.1.2 The 'middlings' were part of the discard from the separation of the high value coal from the ROM coal during coal preparation, but generally still had value as a thermal or industrial fuel.

3.1.3 The original intention was for WCM to sell the 'middlings' rather than waste it and put it back underground, which is the intention with the remaining rock waste from the coal preparation. However, two issues have arisen, since the original planning application was sought in 2017, which have resulted in the application for a change of process.

3.1.4 Firstly, the market for thermal or industrial coals has changed as a result of Government Regulation and environmental concerns, indicating that the market anticipated by WCM for the 'middlings' has reduced or disappeared altogether in the UK.

3.1.5 Secondly, that recent results obtained from offshore exploration have indicated that a higher proportion of the coal could meet a new marketable specification for coking coal with a slightly higher sulphur content. This new specification could be achieved by a change to the coal preparation process design.

3.1.6 WCM states that they have undertaken a review of the coal preparation plant process with the objective of minimising or eliminating the 'middlings' material. 'The feasibility work has resulted in a refined process with a minor adjustment to the original design of the processing plant. This process adjustment will enable 100% of the coal recovered from the ROM material to meet the classification requirements for our target product, premium metallurgical coal.'

3.1.7 WCM states that there will be no reduction in the total saleable amount of coal but that the previous total of 2,780,000tpa (2,430,000t premium metallurgical coal plus 350,000t middlings) will now all be sold as metallurgical coal, if the proposed changes are permitted.

3.1.8 WA notes the term 'premium' and would comment that in this context it is used to infer that the coal is a hard coking coal that can command a higher price than other coals when sold. There is no specific classification of 'premium' coking coal except that hard coking is acknowledged as being the best quality for producing coke.

4 WA COMMENTS

4.1 A technical explanation for the change of classification of all the coal product as metallurgical coal.

4.1.1 Coal can be classified as 'metallurgical' and used as coking coal, i.e. to make coke, if it has certain properties that other coals do not, which relate to its fluidity and dilation. Volatile content is also important in determining its classification as a High, Medium or Low Volatile coking coal. These are the key properties of coking coal essential for making the coke used in the production of most of the new steel produced today. Generally, coke is made from a blend of High, Medium and Low Volatile coals. The coking coal is put through a coke oven to form coke and it is this which is used in steel making via the Blast Furnace/Basic Oxygen Furnace route.

4.1.2 Other non-metallurgical coals do not have the same properties as coking coal and cannot be used in steel making.

4.1.3 WA understand that *all* the coal to be mined by WMC has coking properties and therefore it can *all* be classed as metallurgical coal. The WCM metallurgical coal is High Volatile (HV) and can be compared with similar HV coals imported from USA.

4.1.4 However, even though all the WCM coal can be classified as metallurgical coking coal it has to meet marketable specifications to be sold as such. Others have commented on the requirement for different coking coals, High, Medium and Low volatile coking coals to be blended to make a specific coke. All those coals must meet the market specification not only of its coking properties but also other properties i.e. those elements which could affect steel production. Therefore, the specifications include acceptable levels of other properties within the coking coal, such as levels of ash and sulphur, and other less important factors, which will affect its use in the steel making process.

4.1.5 Higher sulphur coals, typically over 1%, can be sold into the market if some of the main parameters related to its classification as coking coal, it's fluidity and dilation, are at levels which are particularly attractive. These coals are blended with other lower sulphur coals to make a suitable coke 'recipe'.

4.1.6 Coal preparation cannot affect a coking coals coking properties but where ROM coal has ash or sulphur levels that are higher than the market will accept, the coal can be put through a coal preparation process which can reduce those levels to ensure the final product, after preparation, meets a saleable specification.

4.1.7 Any coals with higher ash and higher sulphur coals than the saleable specification will be rejected by the preparation process, however they will still retain their coking properties and therefore it does not change the coals classification as metallurgical coal, just its potential to be sold.

4.2 Explanation of how the change from two products, coking coal and middlings coal impacts on the wider considerations, eg. product quality or suitability, and the amount of reject material.

4.2.1 The change from the two products, coking coal and 'middlings', to one of just coking coal could negatively impact on the saleability of the 'new' coking coal product but only if the new specification of the coal, that can be produced after coal preparation, is unacceptable to the market. There is no indication that this is the case.

4.2.2 Coking coals with higher sulphur levels can be sold for blending purposes, however it is normal to try to reduce the sulphur level to as low as possible by coal preparation. The coal preparation process will be designed around the ROM quality of the coal and the customer's specification for the finished product such that it can be sold at the highest price for that quality.

4.2.3 In this case the change to the coal preparation process will raise the 'cut off' i.e. the level of sulphur in the coal at which the process separates acceptable coal from unacceptable coal, from the 1.4% sulphur in the original coal preparation process design to 1.8% sulphur in the new proposal.

4.2.4 The original plant had a 'cut off' of 1.4% sulphur which allowed for a product of 1.3% to 1.4% sulphur to be produced, since not all the ROM coal would be at 1.4% or above. WCM have stated that the latest process design is based on recent offshore coal exploration which has enabled the 'cut off' to be raised to 1.8% sulphur producing a coking coal of between 1.5% and 1.8% sulphur.

4.2.5 It is stated that analysis of the samples appears to show that the tonnes of coking coal which have below 1.8% sulphur was the same as the original total tonnage of coking coal plus middlings, some 2,780,000tpa.

4.2.6 However, if areas of coal are worked where the majority of the coals are at, or exceed the 1.8% sulphur, then the ROM tonnage figure will stay the same, but the proportion of coal produced from the coal preparation plant, at a saleable quality, will reduce and there will be an increase in the tonnage discarded during the coal preparation process. All discarded tonnage is planned to be sent back underground and used for backfill of the workings and there should be no impact on the quality of coal leaving the pit gates, just the volume.

4.3 Comment on the variations in sulphur (and other) content of the revised process impact on the suitability of the coal for steel manufacture.

4.3.1 Specific comment on the variability of the sulphur and ash in the coal, to be mined by WCM, cannot be made by WA without access to the results of the exploration programme that has been undertaken. Typically, exploration involves drilling boreholes which are cored and analysed for the physical properties and chemical content of the coal. A geological model will be produced which allows the coal seams, their thicknesses and depth, and any faults and folds to be identified.

4.3.2 In addition, analysis of the cores from the boreholes will identify the coal quality, including its coking properties but also other elements such as ash, sulphur and phosphorous content. The analysis will include 'washability' tests which will identify what quantities, at what quality, of the coal can be produced after washing (coal preparation).

4.3.3 Analysis and modelling allows quality contour maps of the deposit to be produced for each parameter, enabling the mining company to see the variations in the quality and plan a suitable mining layout accordingly. Coal quality, including ash and sulphur, can vary greatly across a coal field, but the negative impact of this can be reduced by an effective mining plan and the use of a coal preparation plant designed around the washability tests. WCM have stated they have used the exploration results to justify the changes to the coal preparation plant design. Other pertinent answers are covered in points 1 and 2.

4.4 Comment on whether the new product can be produced consistently at a suitable quality to be sold exclusively for steel manufacture and comment on whether there may be periods where the overall quality of the coal is too low for that.

4.4.1 WA has not has access to the results and modelling of the coal deposit but typically, as has been said, the sulphur and ash levels do vary across a coalfield meaning that the quality of the ROM coal may indeed change depending on where the coal is being worked at the time. However, the quality of the saleable output produced from the coal preparation plant designed around the washability testing will be consistent in that coals having ash or sulphur level higher than the 'cut off' will be rejected.

4.4.2 Its use within the steel manufacturing industry will be dependent on its acceptability to the customer. It is stated that the new plant will produce coals ranged between 1.5% to 1.8% sulphur meaning that even when working in areas where the coal may exceed 1.8% in parts, the coal leaving the pit gates will not have a sulphur level which exceeds 1.8%.

4.4.3 The impact will therefore not be on the quality of what is produced and sold but potentially the volume of coal at the specified quality and the volume of waste produced, assuming no middling will ever be produced. Where sulphur levels in the coal being mined is higher than 1.8% then any coal with that level of sulphur will now be discarded and report as waste.

4.4.4 The impact on sales of the product will depend on the contract signed. If specific volumes are stated and WCM does not produce the quantities specified then contracts could be affected, however this is normally taken into account with penalties within the contract.

4.4.5 Therefore, it is likely that if areas are worked where the sulphur is higher and the amount of marketable coal is reduced then the impact will be more 'waste' to be disposed of underground, and not dirtier coal going through the gates.

4.5 Comment on the evidence to support the arguments put forward for the shift in approach.

4.5.1 Coal washing equipment is quite simple and is based on the fact that coal has a lower specific gravity (S.G.) than dirt, ie the coal is lighter than the dirt, and therefore floats whilst the dirt sinks in an aqueous medium. Dirtier coal with higher ash and sulphur has a higher S.G than low ash low sulphur coals, and by altering the SG of the aqueous medium, the 'cut off' can be altered. The design of the plant takes advantage of this to separate the coal from the dirt. The plant can be designed around the S.G. of the required product. A washability curve, based on tests, will show that different quantities of coal will be produced when different S.G's are used in the design. The marketing specification is matched against the washability curve and the plant is designed to produce that specification.

4.5.2 The sulphur in coal is often related to pyrites which has a higher S.G. than coal and is more in line with the dirt. The previous design was related to an S.G. cut off which equated to a sulphur level of 1.4%, which is a marketable specification. The latest design is based around an S.G. cut off which equates to a sulphur level of 1.8%. The change in the process specification allows the coal, that would have reported as 'middlings' previously, to report as a part of the primary product. However, it has to be questioned whether a coking coal product with a sulphur level of 1.8% is saleable. The Council has had feedback from coal vendors and steel producers which are reported on later in this report.

5 SUITABILITY OF THE WCM COAL FOR THE STEEL MAKING INDUSTRY

5.1.1 No single seam, mine or coal basin produces a 'perfect coking coal', so to optimise output, coke makers produce their own 'perfect coal' by blending different coking coal types together. Low, Middle and High volatile coals are mixed to produce a blend from which coke is produced. Each steel producer will have its own 'perfect' coke blend.

5.1.2 Low, middle and high volatile coals are not transferrable between each other so when a replacement is contemplated a like-for-like substitution must occur. In comparison with a typical coal imported from the US, the characteristics of WCM coking coal can be shown to have similar properties and therefore have the potential to replace the high volatile component of the 'perfect' blend.

5.1.3 Comment has been sought from the potential traders and buyers for WCM coals which WA has considered and evaluated. WA have formed an independent opinion of the saleability of the WCM coals.

5.1.4 The WCM coal is of a metallurgical quality, therefore it is the additional impurities which will determine it's saleability. WCM has low moisture & ash but has a relatively high sulphur content in comparison to the US coals which it might substitute.

5.1.5 However, a shorter supply chain, and hence transport costs, means the coal should be considered by both UK and other mainland European Steel Mills an alternative to US supply. In addition, emissions of CO2 and other pollutants such as sulphur dioxide associated with the transportation of coal from other parts of the globe can be avoided. The transport emissions for each tonne of UK coal delivered to Port Talbot (Tata) are typically 5 times lower than the average transport emissions per tonne of coal imported from abroad.

5.1.6 Sulphur is the constraining factor which could limit the use of the coal. At least one steel producer has a total sulphur limit for its operations which has to be applied to the coking coal blend it uses, and that makes WCM Coal for that producer currently unviable.

5.1.7 In 2018, UK production of crude steel was 7.3Mt, of which 5.7Mt was produced using the BF/BOS route. Typically, this would require some 2.6Mt of coking coal (Tata Steel consumes approximately 1.9Mt of metallurgical coal and coke each year in its UK operations).

5.1.8 Responses from traders and steel producers related to the use of WCM Coal indicates they have been advised by WCM that WCM Coal would have a typical sulphur content of 1.4% which is at odds with the stated new cut off for the preparation plant of 1.8% sulphur. Whilst coal is not homogenous in its characteristics, and there will be inherent variation in the coal itself, WMC has indicated in its proposal that variation in the new process control mechanics of the wash plant will produce coals of 1.5% to 1.8% sulphur, which WA have accepted. It is not known the exact proportion of each, but a simple average indicates that an average product would be 1.65%, not the 1.4% indicated.

5.1.9 However, one contributor states 'it should be noted that the classification of WCM coal as an HVA Coal is sensitive to sulphur. If the typical specification of the final product goes beyond 1.70% sulphur (db) then the coal will no longer fall within the HVA Coal category and its market value will fall significantly'.

5.1.10 WA therefore would indicate that there is a risk that at the proposed cut off of 1.8% sulphur, the saleable coal produced may not comply with the HVA Coal category. However, if the coal preparation process were reorganised to give a cut off of 1.7% sulphur it should always be classed as an HVA Coal and, with the other advantages of proximity to market, the coal should be saleable.

6 THE COKING COAL MARKET

6.1.1 In 2018, crude steel production globally was ~1.82 bn tonnes, of which 71% was made in the BF/BOS route and 29% in the Electric Arc Furnace (EAF) route. The amount of steel that is made via the EAF route is constrained by the global availability of scrap, even though reuse and recycling rates for steel products at the end of their life are extremely high (e.g. >99% for structural sections in the UK). The global demand for new steel cannot be satisfied through secondary production.

6.1.2 If the UK were to cease to make new steel from iron ore, then there would have to be a corresponding increase in new steel production elsewhere in the world to make up the shortfall. In other words, there would be no reduction in overall global emissions from steel production. Globally the volume of steel demand, and hence production, is rising mainly due to the influence of China which is increasing production whilst the rest of the world is falling. The market for WCM coal is probably less than 1Mtpa in the UK but the rest would be supplied to mainland Europe.

6.1.3 Europe produced ~160Mt of steel in 2019 and production appears to be dropping by 1 to 5Mt per year. In recent years because of cost and environmental pressures the recycling of steel has impacted the industry and it is estimated that some 39% of the steel produced in Europe is recycled material, the majority using Electric Arc Furnaces.

However, in Europe, of the ~160Mt, some 98Mt (61%) is still produced by Blast Furnaces which requires coal and coke to produce steel from raw iron ore.

6.1.4 The European industry imports 65% of the coking coal used, the remaining 35% is mainly from Poland. The majority of coking coal imported comes from Australia, USA, and Russia, the countries listed in order of imported coal. Coking coal is on the EU's list of Critical Raw Materials. However, the High Volatile coals used in the coke blend, and the competitor for WCM Coal, are predominantly from the USA.

6.1.5 WA has considered a Coking Coal Demand Outlook report produced by Wood Mackenzie (WM) which relate to future demand for coking coal.

6.1.6 It should be noted that this report has been prepared specifically for WCM.

6.1.7 The WM report identifies the demand for coking coal to 2050 which appears to be well considered but without quantifying the size of the steel market to 2050 which creates the demand for coking coal in the first place. The two are inextricably linked and some reference would have been useful to show what the steel demand is and why there will be the demand for coking coal as stated.

6.1.8 Additionally, some indication of the predicted steel production split from the different production technologies would have been useful. The report does state that the most common steelmaking process is the integrated steel-making process via the Blast Furnace – Basic Oxygen Furnace (BF/BOF) and does go on to say the only low carbon alternative for mass steel production commercially available, scrap into EAF, is constrained by scrap availability but does not quantify it.

6.1.9 Traditionally steel has been produced using two different production technologies, one is to use Blast Furnaces (BF) from raw iron ore concentrate using coking coal and PCI coal, which produces pig iron, then to put the hot pig iron into a Basic Oxygen Furnace (BOF) to produce crude steel.

6.1.10 The other is to use Electric Arc Furnaces (EAF) which derives most of their feedstock from scrap and is recycling steel.

6.1.11 Simplifying, BF's use coking coal, EAF's don't. The attention in relation to replacement of coking coal is therefore on the BF route because it takes the raw materials, iron ore concentrate and coking coal, to make pig iron from which steel is produced.

6.1.12 It is noted that many people advocate the replacement of BF's with EAF's but this is currently not possible. Globally some 75% of steel (Tata quotes 71%) is produced using BF's (World Steel Association) but this is skewed by the dominance of China in the industry. Without China's input the Rest of the World (RoW) produces steel at a 60/40 ratio (BF to EAF). Steel made from scrap steel and recycled material (EAF) is increasing but cannot replace totally the requirement for BF produced steel because of a global shortage of scrap, as confirmed by Tata's response, and iron ore processing will always be required to produce volumes of steel from the raw material to supply a growing world population and to replace the steel that cannot be produced from recycling.

6.1.13 The EAF steel route effectively uses no coking coal and therefore the volume of production from that source is important in determining the how much coking coal will be required for the BF/BOF route.

6.1.14 In order to be able to comment on the report some research into the missing facts i.e. the predicted steel production from the various production methods has been required. Finding definitive reports on projected global and EU production and predicted future volumes is difficult, as the situation in the steel industry has changed over the years and some of the earlier predictions do not match later ones.

6.1.15 However, the WA comments below are taken from overviews of papers by Worldsteel, OECD and others, as well as the responses from the steel producers themselves to questions posed by Cumbria CC.

6.1.16 Common predictions appear to be that in the EU the proportion of BF to EAF is only likely to change to a maximum of 50/50 by 2050. The reason for this not being higher is the projected availability of scrap globally, which supplies the EAFs. Reuse and recycling rates for steel products at the end of their life are extremely high (e.g. >99% for structural sections in the UK). The global demand for new steel cannot be satisfied through secondary production.

6.1.17 It is therefore predicted that up to 2050 within the EU, 50% of steel will be produced by BF's and will require coking coal unless this could be offset at some point if some alternate steel production methods, which replaces coking coal, can be commercially developed. The WM paper concludes not, with which WA would concur. See later comments.

6.1.18 In 2017 an OECD paper predicted an overall global increase in steel production of 1.1% per annum peaking in 2050 as demand levels.

6.1.19 If we use similar figures for EU then the requirement for coking coal for use in the BF/BOF process both increases in line with the steel production and also reduces as more steel is produced in EAF's (but only by an increase of 10%). WA concurs with the conclusion reached by Wood Mackenzie that the demand for coking coal will remain pretty much static unless another technology is introduced to reduce the volume of steel produced by BF/BOF's.

6.1.20 The report does not indicate the demand for High Vol A coking coal specifically but does indicate that if nothing else changes the demand for coking coal in all its variations in 2050 will be the same or similar to 2025.

6.1.21 The discussion on whether a reduction in the use of coking coal is possible therefore relates to the development of an alternate production method to the BF/BOF route and the likelihood of such an alternate method being both viable and commercial and the timescale over which such a development could take place.

7 ALTERNATE PRODUCTION METHODS

7.1.1 The report 'Green hydrogen: metallurgical coals kryptonite? Wood Mackenzie April 2020' looks at the impact of green hydrogen on the production of steel from BF's. Such steel is referred to as 'Green Steel' as it has much reduced carbon emissions compared with the normal steel making practices. The term 'Green Steel' has been coined for steel produced using 'Green Hydrogen' which is produced by electrolysers using renewable electricity sources.

7.1.2 Green steel is also produced from EAFs so long as the electricity being used for the furnace is produced from renewable sources.

7.1.3 The current push toward less carbon emissions to combat the 'climate emergency', has created an obvious target for improvement and the report examines the issues for and against the use of green hydrogen in steel making. The impact of any success in using hydrogen on the current method of production would be to reduce the use of PCI and coking coal currently being used for steel making

7.1.4 Two issues relate to the West Cumbria Mining project.

7.1.5 The issues relate to 1) whether the new technology can indeed replace coking coal in the process and 2) the timing of when any new technology is likely to be commercially viable and adopted by steel producers.

7.1.6 The report covers both aspects in certain respects and examines the current state of development of pilot facilities and projects towards commercial application.

7.2 What is Green hydrogen

7.2.1 Green hydrogen is produced by electrolysis of demineralised water using renewable electricity. It is not just 'normal' hydrogen, which is produced using fossil fuels.

7.2.2 Table 7.1 explains the difference between the 'hydrogens' making up a total of 70Mtpa (Global Production).

Table 7.1: Type of Hydrogen		
Hydrogen Type	**Source**	**Current Global Production**
Grey	Fossil Fuels - Gas	71%
Brown	Fossil Fuels - Coal Oil	28%
Blue	Fossil Fuels - Gas	0%
Green	Demineralised Water	1%

7.2.3 The report states that currently only 1% of hydrogen production is 'Green'.

7.2.4 The report explains the production process of Green hydrogen. It takes over 50kWh of renewable electricity to produce 1kg of hydrogen.

7.2.5 Currently the use of Green Hydrogen is uncompetitive for use in steel making due to the cost of its production, but Grey Hydrogen, produced from gas does appear to be feasible and economic and its use is being developed by thyssenKrupp.

8 COAL REPLACEMENT

8.1 Pulverised Coal Injection (PCI) Replacement

8.1.1 PCI coal is a soft, non-coking coal that is finely ground and injected directly into a blast furnace and has the effect of reducing the coke rate. However, it cannot replace coke as a structural support material required as part of the BF process.

8.1.2 The report explains the work going on by thyssenKrupp in Duisburg Germany which is testing the use of grey hydrogen as a reductant in its Blast Furnaces (BF) with the potential to reduce CO_2 emissions by at least 20%.

8.1.3 Started in 2019, on one Blast Furnace (No 9), the testing started by replacing PCI with grey hydrogen injected through one injection nozzle. The BF has 28 injection nozzles, and the test was planned to replace the PCI injection with grey hydrogen through all injection nozzles, over a period of 14 months. If successful, the intention is to expand the change to all four BF's on site.

8.1.4 However, the substitution planned is for the reduction of PCI in favour of hydrogen rather than a reduction in the coking coal used as the coke still has to be used as part of the supporting burden i.e. its structural qualities within the BF, and therefore there would be no reduction in the use of coking coal.

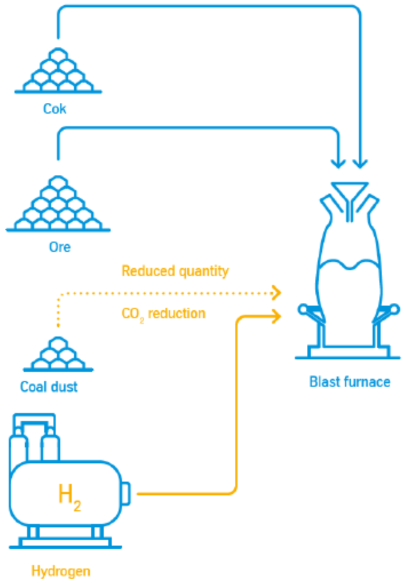

Figure 8.1: Extract from figure in WM report showing PCI replacement with grey hydrogen source - thyssenKrupp

8.1.5 Not within the report but on the thyssenKrupp website there is mention of the next phase in CO_2 reduction which is the site construction of Direct Reduction Iron plants (DRI plants) which produce a different type of steel, solid sponge iron or Direct Reduction Iron (DRI) rather than molten pig iron which would reduce the need for coking coal. This would involve the use of hydrogen to replace the coking coal. The WM report does not indicate this development; however, it appears to be the same process as the HYBRIT system which is commented on.

8.2 Coking coal replacement

8.2.1 The slightly longer term path being targeted by thyyssenKrupp, the production of sponge iron using a Direct Reduction Furnace (DRF) by mid 2020's is also being planned for development over a similar period by SSAB, LKAB and Vattenfall in a system called HYBRIT. The report covers the principles of the HYBRIT system.

8.2.2 The report states that the HYBRIT system intends to produce a completely carbon - free iron reduction process as part of its pilot plant trials with the intention of launching a demonstration plant in 2025 which will supply 'green' products from 2026.

A further demonstration phase is planned to last 10 yrs from 2025 to 2035. This is the same as the thyssenKrupp timescale.

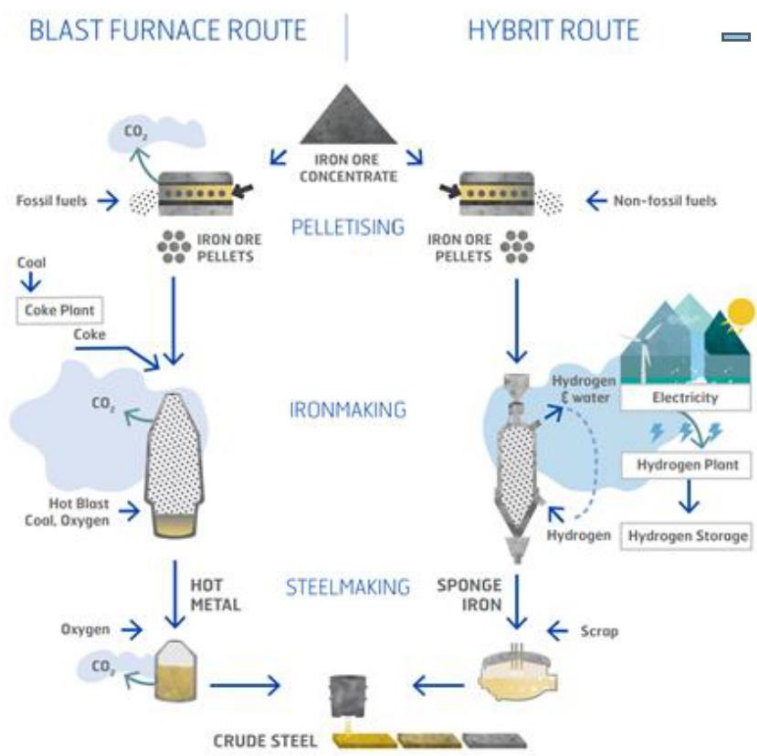

Figure 8.2: Blast Furnace compared with HYBRIT system Source WM Report /Hybrit thyssenKrupp

8.2.3 The figure from the report shows a more traditional blast furnace route versus the HYBRIT route, but note the use of iron ore pellets rather than raw concentrate which is specific to the Swedish situation where WM state a high grade feedstock is available.

8.2.4 However, the headline in the report under Threat to Met Coal says ‘Potential direct risk to coal if Blast Furnace process replaced with Electric Arc furnace’. This is misleading as the plan is not to replace the BF’s with EAF’s but to replace the BF’s with Direct Reduction Furnaces (DRF’s) which are not the same thing.

8.2.5 The report goes on to demonstrate the pros’ and cons of the use of hydrogen in blast furnaces, but this is about the use for hydrogen as a reductant and is a replacement for PCI, not a reduction of coking coal.

8.2.6 The report then goes on to show the reduction in CO_2 by substituting hydrogen. 12kg of H_2 would replace 120kg of PCI reducing CO_2 emissions from the BF by 20% at full injections rates. There is also a note that the project uses grey hydrogen i.e. produced from fossil fuels. If it were to use green hydrogen, some 600kWh of renewable electricity would be required to produce the 12kg of hydrogen. The report identifies a case study on the thyssenKrupp programme related to the supply of green hydrogen as opposed to grey hydrogen. However, the key point is that this section is looking at the replacement of PCI coal which is not as relevant here as the replacement of coking coal.

8.2.7 The report looks at the HYBRIT system as a case study

8.2.8 The case study indicates a pilot plant should be ready by mid 2020, with net zero products by 2026 products. Similar to thyssenKrupp the demonstration plant based on Direct Reduction is to be developed between 2025 and 2035.

8.2.9 Importantly the process requires that iron ore pellets will be used in the plant as well as a large volume of hydrogen. To this end a fossil fuel free iron ore pellet plant and a large scale hydrogen storage plant will be built on site.

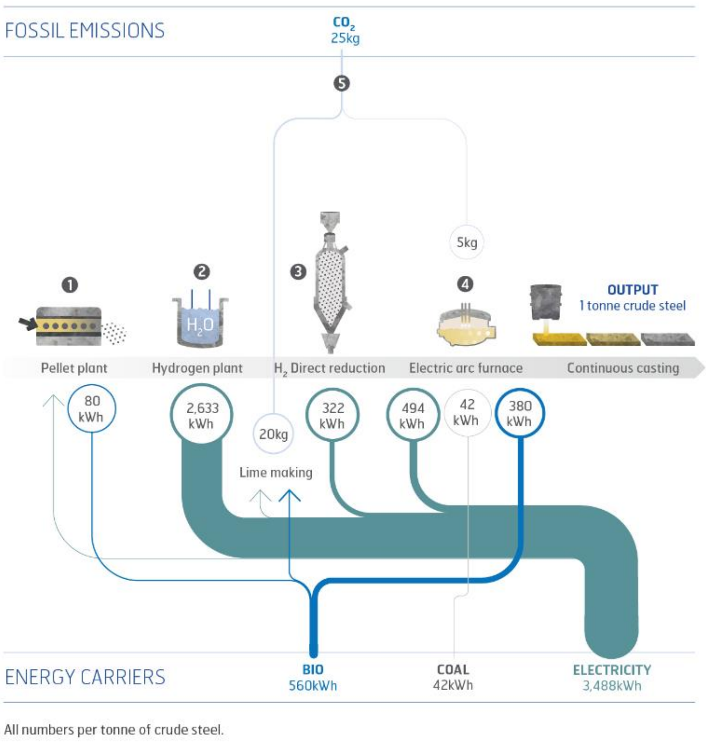

Figure 8.3: DRF Process

8.2.10 Figure 8.3 above is taken from the HYBRIT website and illustrates that the process uses a DRF not a BF.

8.2.11 The report does indicate that the process of direct reduction does have emissions but they are H_2O rather than CO_2.

8.2.12 The report identifies that if the technology can be shown to work there are a number of hurdles to be overcome in relation to the infrastructure and raw materials needed to make the system work.

8.3 Supply of raw materials

1) Green Hydrogen to be used in both PCI and Coking Coal substitution is produced from electrolysers. To put it in perspective it is calculated that a dedicated green hydrogen supply would require an electrolyser rated at 120 MW for BF No. 9 alone (the thyssenkrupp project), the largest built to date is 10MW. Globally, there are currently 17 x 100MW sized projects under various stages of development. The WM report

states that green hydrogen projects are growing exponentially with 8.2GW of projects planned up to 2025.

2) The cost of green hydrogen in the long term is not predictable, there is no attempt to determine the volume of green hydrogen required for the Direct Reduction process. However currently it is too high to be considered. HYBRIT is located in Sweden because of the high volumes of hydropower to produce 'clean' electricity.
3) Renewable power is growing but the infrastructure to supply the dedicated power supply for the electrolysers is not sufficiently developed in Europe to supply their needs. However, the development of such networks is ongoing.
4) The process uses large volumes of hydrogen and the systems for large scale transportation and storage are untested.
5) The quality of the iron ore used needs to be high quality for directly reduced 'sponge iron'. Access to such high iron ore sources are dependent on ocean transport costs.

8.3.1 Arcelor Mittal has indicated that apart from the hydrogen route to reduce the use of coking coal they are researching the use of Smart Carbon, a group of technologies which includes replacing coking coal with alternative carbon-rich energy sources (such as biomass from agricultural waste), and carbon capture and storage or re-use technologies. There is no evidence that any of these projects have been developed to a point beyond concept and whilst technically they may appear feasible, the current development does not indicate that a commercial proposition has been identified or that their development will change the current production process more quickly than that of the hydrogen alternative.

8.4 Summary

8.4.1 The WM report summaries its content as Green H2 costs are currently too high and gives a comparison with PCI coal.

WA Comment - The comparison is correct, but the summary only looks at the cost of green hydrogen versus PCI, some environmental improvement may be gained from the use of grey hydrogen produced form gas vs coking coal. This is not considered.

8.4.2 Scalability challenge – there is a need for substantial investment in electrolysers , H2 transport, H2 Storage and zero emission power generation.

WA comment - This is correct, but the summary appears to apply to the replacement of PCI in existing BF/BOF circuits. For the replacement of coking coal, in addition to the facilities stated there would need to be investment in DRI plant to replace BF/BOF's.

8.4.3 Market penetration will take a long time - the process must be commercial before it can be rolled out and the physical changes to the way in which steel is produced will take years.

WA Comment - The comment made above about investment in new DRI's applies here and WA would agree that any roll out will only be undertaken if the process is commercially viable.

8.4.4 PCI replacement in Germany – limited near to mid term impact on PCI use.

WA Comment - The PCI replacement is for existing BF/BOF's and does not affect the coking coal market as such.

8.4.5 BF replacement - HYBRIT likely to succeed but will remain a unique project to 2040.

WA Comment - WA agree that HYBRIT is likely to succeed but do not agree that it will remain a unique project to 2040. thyssenKrupp have already stated their intention to build a DRI plant between 2025 and 2035. This may be slightly different from the HYBRIT system, since Sweden has access to cheap hydro energy and high grade iron ore pellets but it is possible that a system outside Sweden is developed at the same time.

9 WA CONCLUSIONS

9.1.1 WA has examined the proposal by WCM to change the process to reduce the production of 'middlings' by increasing the cut off within the coal preparation plant from 1.4% Sulphur to 1.8% Sulphur. WA has no doubt this can be achieved. The coal produced is High Volatile A coking coal.

9.1.2 The changes should result in an increase in 'saleable' metallurgical coal equivalent to the tonnage originally planned for both metallurgical coal and 'middlings added together, and having a top Sulphur cut off of 1.8% and an anticipated range of 1.5% to 1.8% Sulphur.

9.1.3 WA is concerned that information provided by WCM to the coal traders and steel producers is incorrect. Average sulphur levels of 1.4% appear to have been considered and whilst that was the original concept the new preparation plant is more likely to produce a product having an average sulphur level of 1.65%. Some feedback on the saleability of this quality would have been useful.

9.1.4 In addition, the coal is being marketed as a High Vol A, the classification of which can only be applied to coals below 1.7% Sulphur. As it stands the coal preparation plant, as proposed, may produce coal above 1.7% on occasions, which would be difficult to sell. Some consideration should be given to restrict the cut off to a max of 1.7% Sulphur.

9.1.5 Assuming the quality is acceptable WA considers that coal could be sold and would be a direct substitute for imported high vol coals from the USA. This is because the volume of coking coal sold is directly related to the tonnes of steel being produced via the BF/BOF process which it is predicted will remain approximately the same as today. That is unless another process to replace BF/BOF is developed to be a commercial alternative.

9.1.6 In respect of likelihood of substitution, the price of the coal delivered from WCM into the UK and EU markets should have a significant advantage due to the distance over which it is being delivered compared with shipping from the USA.

9.1.7 Current research indicates that the substitution of coking coal could be technically possible and would be better for the environment. The WM report concentrates on the costs of producing green hydrogen, but the report does not indicate whether grey hydrogen from gas, which is currently more available could be a cheaper and cleaner option.

9.1.8 The availability and therefore the cost of green hydrogen is currently prohibitive. There are too few facilities producing limited volumes of green hydrogen, currently less than 1% of the global hydrogen production. The current case studies indicate that there needs to be investment in electrolysers, H2 transport and storage plus other major capital facilities.

9.1.9 The HYBRIT and similar systems using DRI's instead of BF's are being developed in Sweden and Germany and there is a head of steam to develop a more environmentally friendly process. WA therefore conclude that it is likely that at some point in the future an alternative to coking coal will be developed and the market is likely to reduce.

9.1.10 WA consider that the timescales for project development in both Germany and Sweden is feasible. These projects indicate having a commercially viable demonstration plant by 2035 but that does not mean that all BF's will be able to be scrapped within the EU and immediately replaced. The demonstration plants will be specifically designed around local infrastructure and supply and will only produce a fraction of what is required. Once the plants have been proven, decisions will need to be made on whether the whole of the hydrogen supply and storage system, whether green or grey, can be upgraded globally to match the demand that will be needed and at the right price, and also whether the cost of replacing BF's with DRI's can be supported. The decision to replace BF's with DRI is unlikely to be taken until the BF's need replacing. Typically these are in operation for 20yrs or more.

9.1.11 Therefore, WA believe that it could be 2050 at least before any significant inroads are made to the volumes of coking coal being used and even then, some plants will still be using coking coal.

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