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Form 59
Rule 29.02(1)

Affidavit

No. of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

Affidavit of: **Dr Anand Indravadan Bhatt**
Address: [redacted] Bullsbrook WA 6084, Australia
Occupation: Manager of Minerals, Research & Development
Date: 1 May 2024

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I, ANAND INDRAVADAN BHATT, [redacted] Bullsbrook WA 6084, Australia, Manager, Electrochemist and Materials Scientist, affirm:

1. I am employed by the Third Applicant, FMG Personnel Services Pty Ltd, in the position of Manager of Minerals, Research & Development. I am an experienced Electrochemist and Materials Scientist. I set out my qualifications and experience in this regard at **Part A**, below.

2. In this affidavit I refer to the Applicants collectively as **Fortescue**.

3. I am authorised to make this affidavit on Fortescue's behalf.

4. The evidence I give in this affidavit is based on my personal knowledge, unless stated otherwise, or the business records of Fortescue to which I have had access in the course of my employment, in which case I have annexed them to this affidavit. Where my evidence is provided on information and belief, I identify the source of that information and I believe it to be true and correct. My expert opinions set out in this affidavit are wholly or substantially based on my specialised knowledge and experience gained from the training, study and experience set out in **Part A**, below.

5. In this affidavit, I refer to documents in each case by a reference based on my initials, for example **Annexure** "**AIB-1**", "**AIB-2**", and so on. In each case, the particular document or item is produced and shown to me and marked as I have described at the time of affirming my affidavit.

6. This affidavit adopts the following structure:

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A. My Background and Expertise

7. My curriculum vitae is annexed and marked **Annexure AIB-1**.

8. In summary, I am an Electrochemist and Materials Scientist. During the course of my career, I have worked both in academia and the private sector, and primarily in the field of electrochemistry. My work at Fortescue in the field of electrochemistry has primarily been concerned with **Green Iron**, which is a term applied to iron produced using a process that generates lower carbon dioxide emissions than traditional iron ore smelting processes. I explain the relevant **Green Iron Technology** in **Part C**, below.

9. In my position of Manager of Minerals, Research & Development, I lead the Fortescue team developing electrolysis-based Green Iron Technology. As I explain further below, I have held this role since January 2022.

A.1 Academic background

10. In 1999, I obtained a Bachelor of Science (with Honours), majoring in Chemistry, from the University of Leicester, UK.

11. In 2004, I was awarded a Doctor of Philosophy (PhD) from the University of Manchester, UK. My thesis reported on chemical research directed towards the utilisation of low temperature ionic liquids in electrochemical applications.

12. In 2010, I obtained a Diploma of Management (People Management) from the Australian Institute of Management, Australia.

A.2 PhD and Fellow research positions – 2003 to 2007

13. From 2003 to 2005, I was a Post Doctoral Research Associate at the University of Manchester, UK. From 2005 to 2007, I was a Research Fellow at Monash University, Australia. In my research role at Monash University, the focus of my research was on electrochemistry and metal electrodeposition from ionic liquid electrolytes.

A.3 CSIRO – 2008 to 2021

14. From 2008 to 2021, I was employed at the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**), Australia, in the following roles:

    (a) 2008 to 2012: Research Scientist in the Division of Energy Technology; and

    (b) 2012 to 2021: Research Team Leader for the Electrochemical Energy Storage Team.

A.4 VSPC – 2021 to 2022

15. From September 2021 to January 2022, I was the Lead Scientist at VSPC Ltd. In that role I led the company's efforts to commercialise lithium iron phosphate cathode manufacturing and transition their process from pilot scale to commercial scale.

A.5 Fortescue – 2022 to present

16. In January 2022, I commenced employment with FMG Personnel Pty Ltd in my current role. In or around July 2023, Future Industries Pty Ltd (**FFI**) and Fortescue Metals Group Ltd (**FMG**) started operating under the 'Fortescue' brand to represent being a unified global metals and green energy company. The current company name of FMG is Fortescue Ltd.

A.6 Publications and presentations

17. I am the author or co-author of over 65 articles published in peer-reviewed journals. Approximately 85% of these articles were on the topics of electrochemistry or Green Iron. My peer-reviewed journal articles have been cited over 2,800 times. I have presented at numerous conferences on the topics of electrochemistry and Green Iron Technology.

B. Composition of iron ore and the process of obtaining iron

18. Iron ores vary in their composition. Relevantly, iron ore in Australia mostly consists of:

    (a) iron oxides such as hematite (Fe_2O_3) (72.4% iron) and magnetite (Fe_3O_4) (69.9% iron); as well as

    (b) other constituents, which are collectively known as **"gangue"**. This may include, for example, silica (SiO_2) and phosphorus bearing compounds. These constituents are undesirable because they cause issues with the later iron-making process.

19. To create metallic iron:

    (a) the gangue impurities must be removed to an acceptable level from the iron ore; and

    (b) oxygen needs to be removed from the iron oxide.

20. When oxygen is removed from a chemical compound, that compound is described as having been "**reduced**" or having undergone "**reduction**". The reduction of iron oxides may be described as follows:

$$Fe_2O_3 \text{ (hematite)} \rightarrow Fe_3O_4 \text{ (magnetite)} \rightarrow FeO \text{ (wustite)} \rightarrow Fe \text{ (iron)}$$

21. The most commonly used process for the removal of gangue and reduction of the iron oxides to iron is called **smelting**. In this process, powdered iron ore is mixed with a coal-derived fuel and heated. Carbon dioxide is a by-product of this process.

22. Alternatively, there are processes by which iron may be extracted from iron ore without burning fossil fuels. These processes may be referred to as "**Green Iron Technology**" and include, amongst other processes, electrochemical reduction of iron ore into iron. Iron made by these processes may be referred to as Green Iron.

23. I describe the process of electrochemical reduction in **Part C**, below.

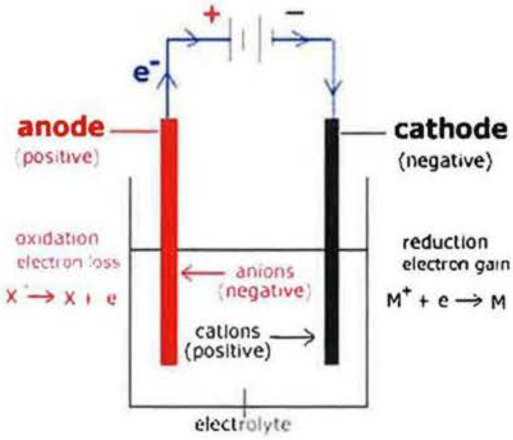
C. Electrochemical Reduction

24. Iron oxides can be directly reduced to metallic iron by electrochemical means (**Electrochemical Reduction**). The chemical concepts behind Electrochemical Reduction are well known. Broadly speaking, it involves an electrolytic cell comprising two electrodes (a positively-charged anode and a negatively-charged cathode) which are immersed in an electrolyte. The electrolyte allows the conduction of electricity and ions (charged particles) and could be an aqueous ionic solution (which may be neutral, acidic or basic), a non-aqueous ionic solution, an ionic liquid or molten salt. When an external voltage is applied between the two electrodes, reduction or oxidation reactions occur at each of the electrodes. Reduction is associated with the loss of oxygen atoms from a compound, whilst oxidation is associated with an increase in oxygen atoms.

25. In Electrochemical Reduction processes, iron oxide is reduced at the cathode to produce iron. The process can be generally represented by the equation ($Fe_xO_y \rightarrow xFe + \frac{1}{2}yO_2$). The by-product of this process is oxygen gas (O_2), which will be generated at the cathode and requires venting from the cell. Iron can be collected from the cathodic side of the cell.

26. Below is a diagram extracted from the University of Wisconsin-Madison's online resource entitled "M18Q8: Electrolysis – CHEM 103/104 Resource Book", found at the URL https://wisc.pb.unizin.org/chem103and104/chapter/electrolysis-m18q8/, which, in my opinion, accurately shows the layout of a generic electrolytic cell which conceptually underpins the reduction of iron oxide.

Generic Electrolytic cell



27. A variety of factors must be considered when designing and implementing an Electrochemical Reduction process. Research into and consideration of these factors

represent a large part of the work required to apply the technology at industrial scale. Some key factors include:

(a) Particle purity preparation (i.e. leaching – explained below at **Part C.1**): improving particle purity ensures that any gangue materials detrimental to the electrolyte are removed and does not go through to final iron product.

(b) Electrolyte formulation: the aim here, amongst other things, is to develop an electrolyte that optimally conducts electricity and ions for the relevant design, and does not undergo unwanted side reactions with other components of the electrolyte and electrolytic cell. Furthermore, the electrolyte formulation must be optimised to capture gangue materials (i.e. dissolve impurities) to prevent them from going through to the final iron product.

(c) Operating temperature: the operating temperature ranges must be optimised because temperature affects multiple factors including the type of chemical reactions that occur (including unwanted reactions), the rate of those reactions, and energy consumption.

(d) Whether a membrane is used, and if so, the type used: ion-conducting membranes may or may not be implemented depending on the design of the relevant electrochemical reactor and the chemicals involved in the reaction. The principal role of the membrane (if used) is to maintain separation between the anodic and cathodic sides of the electrolytic cell in which different reduction-oxidation reactions occur, whilst permitting ions to migrate between the two sides. Membranes are typically made of ion-conducting plastics and a range of membranes of different specifications are available from commercial sources (though they can also be developed in-house). The choice of membrane will influence a range of outcomes, including the rate of movement of ions in the cell and therefore the rate of iron production.

(e) Electrode materials and design: the electrode needs to be optimised to increase the desired reaction and decrease side reactions. This can be achieved by adjusting the material composition of the electrodes or by changing other aspects of their design, such as surface morphology.

C.1 Leaching (pre-processing of iron ore prior to electrolysis step)

28. I refer to particle purity preparation in paragraph 27(a) above. One approach to such preparation is "leaching". I describe leaching in more detail in this section.

29. Iron ore describes a range of rocks and minerals from which metallic iron can be economically extracted. Iron ore usually contains iron oxides such as Fe_2O_3 (hematite) or Fe_3O_4 (magnetite).

30. The pre-processing of iron ore for Electrochemical Reduction may include a process called "leaching". Leaching is a process by which impurities are removed from iron ore to prepare it for further processing, including by electrolysis.

31. Iron ore contains a variety of other minerals in addition to iron oxides, including silicates and aluminates. Leaching of iron ore may involve, for example, treatment of the iron ore in a highly alkaline environment to dissolve the alumina and silica and thereby remove it from the ore. By way of further example, a high-temperature, high-pressure caustic acid leaching process may also be used to remove the impurities.

32. If iron ore containing high levels of impurities (such as silicates and aluminates) is used in an Electrochemical Reduction process, such impurities may accumulate in the electrolyte, thereby damaging the efficiency of the electrolysis process. Depending on the impurities present, electrolysis processes may simply not work properly. Accordingly, leaching may be essential to preparing iron or for later processing, including via electrolysis.

C.2 Electrowinning / electroplating

33. Two approaches to Electrochemical Reduction currently being developed in the ironmaking industry are:

    (a) Electrowinning / electroplating; and

    (b) Electrochemical reduction of solid iron ore particles.

34. I provide further information about each of these approaches below.

35. Electrowinning (also known as "electroplating") involves the dissolution of iron ore into an electrolyte solution, which is electrolysed by applying a voltage between an immersed anode and cathode. As with other Electrochemical Reduction methods, iron ions are reduced into metallic iron; however, in this case the metallic iron is deposited on the surface of the cathode. The metallic iron can be recovered by scraping or peeling it off the cathode in a batch process, whilst the oxygen gas by-product is vented from the reactor.

36. The type of solution used to dissolve iron ore to form the electrolyte can vary. For example, iron ore particles may be dissolved in concentrated acid, aqueous alkaline solutions, or non-aqueous alkaline solutions such as a molten salt/ionic liquid. The Electrochemical Reduction of iron ore by dissolving the ore in an ionic liquid is referred to hereinafter as the **Ionic Process**.

37. The term "ionic liquid", defined most broadly, refers to a liquid comprised entirely of ions (an "ion" being an atom or molecule with a net electrical charge).

38. The authors in Douglas R. MacFarlane, Mega Kar and Jennifer M. Pringle, *Fundamentals of Ionic Liquids: From Chemistry to Applications* (Wiley-VCH, 2017) at page 2 argue that this is the "most useful practical definition" of an ionic liquid. This definition does not impose particular temperature requirements or require that an ionic liquid be in a liquid phase at room temperature. There is, however, no specific, authoritative definition of "ionic liquid" used in the field of chemistry, and various definitions may be used in different contexts.

39. The term "molten salt" refers to the liquid (i.e. "molten") phase of a crystalline ionic compound ("salt" being another term for an ionic compound). This usually refers to a crystalline ionic compound, or a mixture of ionic compounds, that would be solid at room temperature (20–25 °C) and that has melted to a liquid phase at a temperature above room temperature. Different ionic compounds, and mixtures of ionic compounds, may melt to liquid phase across the entire range of temperatures from just above room temperature through to over 800 °C.

40. In common usage in the field of chemistry, "molten salt" refers to the liquid phase of both an individual ionic compound and mixtures of more than one ionic compound, even though the term "molten salt" is not plural. See again Douglas R. MacFarlane, Mega Kar and Jennifer M. Pringle, Fundamentals of Ionic Liquids: From Chemistry to Applications (Wiley-VCH, 2017) at page 2.

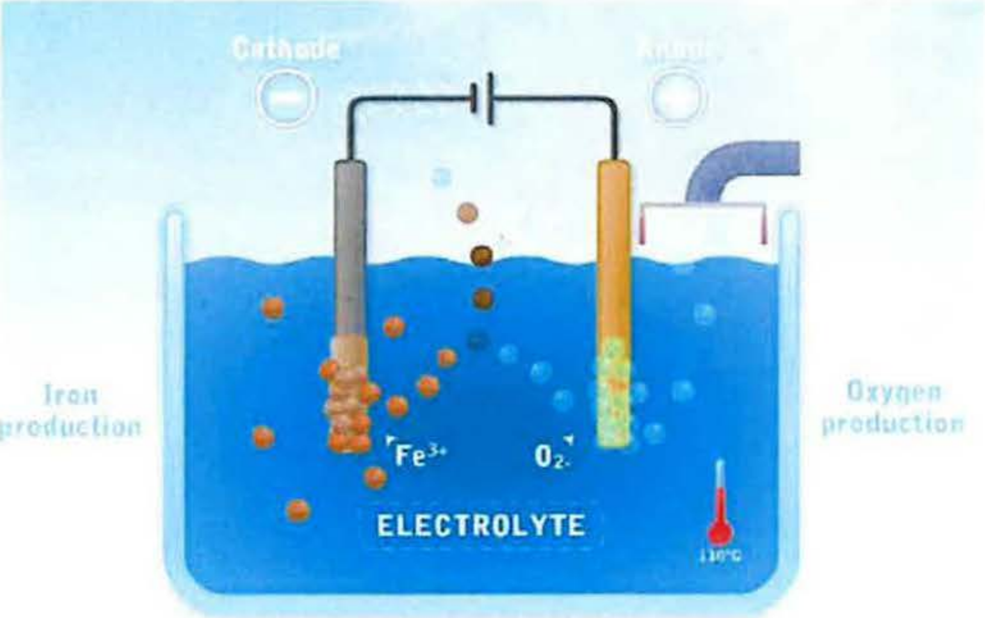
41. The term "eutectic", 'eutectics" or "eutectic melt" refers to a mixture of two or more solids that are heated above room temperature to melt the two solids to produce a liquid (see Douglas R. MacFarlane, Mega Kar and Jennifer M. Pringle, *Fundamentals of Ionic Liquids: From Chemistry to Applications* (Wiley-VCH, 2017) at page 132).

42. Sometimes, ionic liquids and molten salts are differentiated on the basis of a particular temperature at which the ionic compound melts, where ionic compounds with lower temperature melting points are considered "ionic liquids" and ionic compounds with higher temperature melting points are considered "molten salts". For example, sometimes, ionic compounds that are liquid below 100 °C are considered an ionic liquid, whereas ionic compounds that are liquefied above 100 °C are considered molten salts. However, such definitions are not definitive and there is a variety of arbitrary temperatures at which a distinction (if any) between ionic liquids and molten salts can be drawn. Indeed, there can be significant overlap between the terms depending on differing contexts in which they are used and the phrases "ionic liquids", "molten salts" and "eutectic" can be synonymous and used interchangeably.

43. In summary, at its broadest, an ionic liquid is a liquid comprised of ions in a temperature range that may include room temperature, whereas a molten salt or eutectic is a liquid comprised of ions at a temperature above room temperature. Ionic liquids, molten salts and eutectics can conduct electricity and can serve as an electrolyte for an electroreduction reaction.

44. An example of a "molten salt" is a "molten carbonate". This refers to a liquid (i.e. "molten") phase of a crystalline ionic compound that includes a carbonate ion ("carbonate" refers to the negatively-charged ion with the chemical formula CO_3^{2-}).

45. Below is a diagram extracted from the research article M. Abdul Quader et al., 'A comprehensive review on energy efficient CO_2 breakthrough technologies for sustainable green iron and steel manufacturing' (2015) 50 *Renewable and Sustainable Energy Reviews* 594 at page 606, which, in my opinion, accurately demonstrates the main features of electrowinning of iron ore:



C.3 Electrochemical Reduction of solid iron ore particles

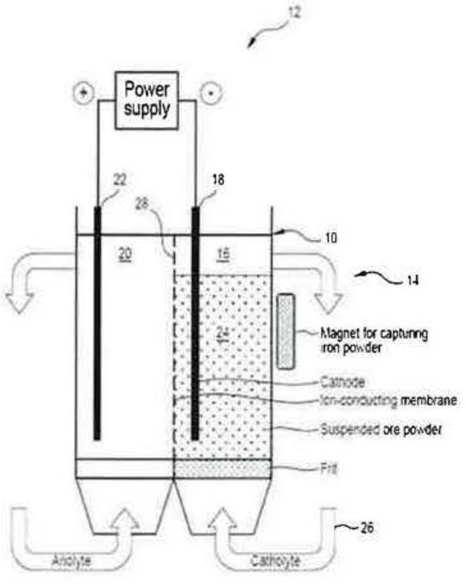
46. A different way of implementing Electrochemical Reduction is to reduce solid iron ore particles suspended in an electrolyte slurry.

47. In the below example of Electrochemical Reduction of solid iron ore particles, we refer to the process used by Fortescue. For clarity, the process used by Fortescue is an example of Electrochemical Reduction of solid iron ore particles, but is not the only way of performing it.

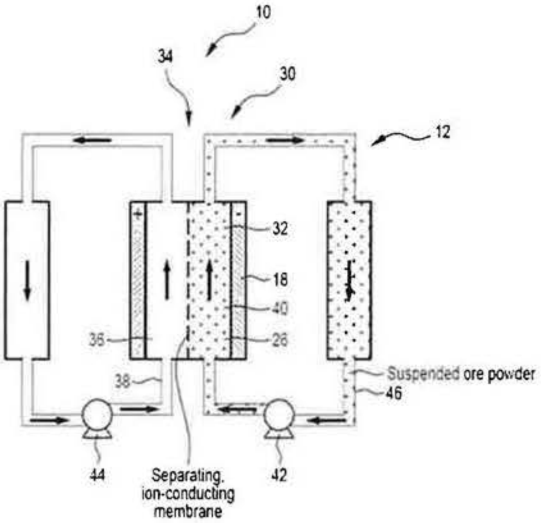
48. According to this process, a voltage is applied across the electrodes in the electrochemical reactor and iron oxide is reduced to metallic iron near the cathode.

49. The key difference from electrowinning is that iron ore powder is suspended in a catholyte (the electrolyte in the vicinity of the cathode), which may be an aqueous alkaline solution (such as up to 50% NaOH or other hydroxide solution). The catholyte slurry is circulated over the cathode by means of a pumping system. After the reduction, the iron particles remain in the slurry for collection in a separate location, unlike electrowinning, where they are stuck to the electrode.

50. This can be achieved in a fluid bed reactor or a flow reactor (demonstrative examples of each are shown in the diagrams below, being extracts of Figures 2 and 3 from the specifications of AU Patent Application No. 2021215184 A1 in the name of Fortescue, which, in my opinion, accurately depict a fluid bed reactor and a flow reactor that can be used in electrochemical reduction). As the slurry moves past the cathode, the suspended iron oxide particles undergo reduction into metallic iron particles, which can then be separated out of the slurry by a physical process, such as the use of a magnetic separator. Particles of iron oxide which have not been reduced can continue to cycle for further reduction cycles. This process allows electrochemical reduction of iron ore at relatively low temperatures (100–200°C).



Fluidized bed layout for ore reduction



Flow reactor for ore reduction, first iteration

51. The numbered components of the apparatus shown in Figures 2 and 3 (above) in the specifications of AU Patent Application No. 2021215184 A1 are identified in the 'Listing of Reference Numerals' (page 14) as follows:

10	Electrochemical reactor	24	Iron ore powder	38	Anolyte
12	Apparatus for producing iron	26	Catholyte	40	Powder slurry
14	Fluid-bed reactor	28	Ion-conducting membrane	42	Pump
16	Primary catholyte chamber	30	Electrochemical flow reactor	44	Second pump
18	Cathode	32	Primary catholyte chamber	46	Pumping system
20	Primary anolyte chamber	34	Electrochemical cell		
22	Anode	36	Primary anolyte chamber		

52. The Electrochemical Reduction processes produce iron from iron ore with lower carbon emissions than the traditional smelting process and are considered forms of Green Iron Technology. Where electricity can be derived from renewable sources and because no carbon-based compounds are generated by the relevant chemical reactions, these processes can be theoretically zero-carbon.

53. In this affidavit, when I refer to the **Fortescue Process**, I am referring to the Electrochemical Reduction of solid iron ore particles suspended in an electrolyte slurry, as developed by Fortescue and as described above in this **Part C.3**.

D. Dr Bart Kolodziejczyk's development of the Ionic Process while at Fortescue

54. In order to understand the work undertaken by Dr Kolodziejczyk during his employment at Fortescue, in January 2024 I caused a review to be undertaken of all emails sent or received by Dr Kolodziejczyk on his Fortescue email address, bkolodziejcz@fmgl.com.au, during his employment at Fortescue between 25 March 2019 and 5 November 2021. I am informed by and believe that Ms Susanne Monica Hantos, a registered patent attorney employed by Fortescue, undertook this review in the manner described in her affidavit filed in this proceeding.

55. Following that review, I was provided with the emails listed in this **Part D** of my affidavit and asked to provide my understanding of those emails with respect to Dr Kolodziejczyk's development of a low temperature Ionic Process.

D.1 August – October 2020 correspondence with [redacted]

56. In the period of August to October 2020, Dr Kolodziejczyk engaged in email correspondence with [redacted] who I understand from his email signature was then an [redacted]

57. Shown to me and marked **Confidential Annexure AIB-2** is a copy of an email dated 5 August 2020 from Dr Kolodziejczyk to [redacted] requesting an introductory call to discuss [redacted] project titled [redacted] Dr Kolodziejczyk appears to frame this request in the email as being relevant to Fortescue's exploration of "*various low-emission technologies*" as part of its "*commitment to decarbonise our operations*".

58. Shown to me and marked **Confidential Annexure AIB-3** is a copy of an email dated 13 August 2020 from Dr Kolodziejczyk to [redacted] In this email, Dr Kolodziejczyk arranges a first call with [redacted].

59. Shown to me and marked **Confidential Annexure AIB-4** is a copy of an email dated 21 September 2020 from [redacted] according to his email signature) to Dr Kolodziejczyk. To this email, [redacted] attached [redacted] "*standard NDA*" in order to "*begin discussions between* [redacted] *and Fortescue*".

60. Shown to me and marked **Confidential Annexure AIB-5** is a copy of an email dated 22 September 2020 from Dr Kolodziejczyk to Tamahra Dempsey, who I have been informed by Mr Adrian Huber (Senior Legal Counsel at Fortescue), was Legal Counsel at Fortescue. The email states (emphasis added):

> "*Under Chairman's request, I have approached a team at* [redacted] *to explore opportunities for* [redacted] *and low-temperature oxide (predominantly iron ore) reduction technology*".

61. Further, the email states that according to the Chairman (Andrew Forrest) a non-disclosure agreement (**NDA**) should be prepared, which has the approved purpose of (emphasis added):

[redacted]

62. Shown to me and marked **Confidential Annexure AIB-6** is a copy of an email dated 13 October 2020 from Dr Kolodziejczyk to [redacted] and [redacted] attaching an confidentiality agreement executed by both Fortescue and [redacted] The [redacted]

[redacted]

63. In October 2020, Dr Kolodziejczyk discussed low temperature iron ore reduction using ionic liquids with [redacted] Shown to me and marked **Confidential Annexure AIB-7** is a copy of an email dated 21 October 2020 from Dr Kolodziejczyk to [redacted] in which he promised to draft and send *"a quick overview of preliminary work that we have done in ionic liquids and low temperature iron ore reduction*" (emphasis added). I am informed by Ms Hantos and believe that she was unable to find a later email from Dr Kolodziejczyk to [redacted] that included such an overview.

64. Shown to me and marked **Confidential Annexure AIB-8** is a copy of an email dated 28 October 2020 from [redacted] to Dr Kolodziejczyk, in which he sent a proposal concerning [redacted]

D.2 December 2020 emails to senior Fortescue management

65. In early-mid December 2020, Dr Kolodziejczyk sent emails to senior Fortescue management in which he stated that he had developed, and would continue to develop low temperature processing of iron ore using an ionic liquid electrolyte.

    (a) Shown to me and marked **Confidential Annexure AIB-9** is a copy of an email from Dr Kolodziejczyk to Andrew Forrest (copied to Mr Masterman and others) dated 6 December 2020, in which he stated that he will work on setting up a testing facility for "*low-temperature processing from ionic liquids*" (emphasis added).

    (b) Shown to me and marked **Confidential Annexure AIB-10** is a copy of an email from Dr Kolodziejczyk to Michael Masterman (copied to Mr Forrest and others) dated 15 December 2020 at 1:46 pm, where he stated, in the context of Fortescue's Green Steel project, that (emphasis added):

    > "*[w]e'll do it at low temperature using ionic liquids as iron ore solvents. Low temperature electrochemical reduction will allow us to switch on and off our "iron ore electrolyser" within seconds or minutes and as such we will be able to operate with highly intermittent power supply like wind and solar*".

66. I note from the above emails that Dr Kolodziejczyk suggested that he could develop a low temperature Ionic Process that mimics the [redacted] process that occurs at [redacted]

[redacted]

[redacted]

D.3 December 2020 patent assessment form

67. By late December 2020, Dr Kolodziejczyk states he was working on a patent application for "*<u>low-temperature electrochemical iron ores reduction in ionic liquid electrolytes</u>*" (<u>emphasis</u> added). Shown to me and marked **Confidential Annexure AIB-12** is an email from Dr Kolodziejczyk to Andrew Forrest and Michael Masterman dated 22 December 2020 at 10:06 am in which he stated he was "*currently working*" on such a patent application and that the patent application was based on his "*initial work done a couple of years ago, where [he] has managed to produce iron from iron oxides, copper for copper complexes and nickel from nickel oxides*".

68. As I explain below at **Part K.2**, I have reviewed Dr Kolodziejczyk's curriculum vitae sent on 25 November 2019 and the list of publications contained therein. I did not find any indication that Dr Kolodziejczyk had experience in, or conducted prior research into, iron oxides, copper complexes or nickel oxides, nor the use of ionic liquids in iron ore processing.

69. Shown to me and marked **Confidential Annexure AIB-13** is an email dated 4:08 pm on 22 December 2020 from Dr Kolodziejczyk to Robert Grant, attaching a completed "patent assessment form". I understand from the attachment that Mr Grant was Dr Kolodziejczyk's manager at the time.

70. In that email, Dr Kolodziejczyk states (<u>emphasis</u> added):

> *"I have attached a patent assessment form for the intended patent application covering <u>low-temperature electrochemical ores reduction in ionic liquids</u>. Applying Fortescue stretch targets we are aiming to test it in Pilbara by June 30, 2021."*

71. In the patent assessment form, Dr Kolodziejczyk describes, amongst other things, an invention entitled "Low-temperature Electrochemical Ore Reduction" involving "*the use of ionic solvents and electrochemical devices for the low-temperature reduction of ores and oxides, including but not limited to iron ores and nickel ores*" (p 1). He also states that the "*[c]areful selection of ionic liquid or mixture of ionic liquids allows to dissolve ores at low-temperatures*" (p 1). As to the status, "*[t]he concept has been tested in a laboratory setting and is intended to be scaled up to a commercial system in 2021*" (p 1). As to whether the invention had been disclosed, "*No, invention has not been publicly disclosed. <u>All information related to this invention is kept internally within</u>* [Fortescue]" (p 3).

72. In the covering email at **Confidential Annexure AIB-13**, Dr Kolodziejczyk states (emphasis added):

> *"[t]he technology is proven. I have developed this method and tested in a small scale laboratory setting before."*

D.4 December 2020 – January 2021: Dr Kolodziejczyk continues his development of low-temperature Ionic Process

73. The email correspondence shows that in late December 2020 to January 2021, Dr Kolodziejczyk was progressing two technologies for processing iron ore into iron, being:

    (a) the low-temperature Ionic Process (refer **Parts D.1** to **D.3**, above); and

    (b) a 'molten carbide' route.

74. Shown to me and marked **Confidential Annexure AIB-14** is an email dated 23 December 2020 at 8:20 am from Dr Kolodziejczyk to Julie Shuttleworth, the former CEO of FFI, which states (emphasis added):

> *"We are proposing the development of two green steel technologies. One will be low-temperature electrochemical ore reduction in ionic liquids. The second one will be electrolysis of iron ore in molten carbides. I am drafting R&D roadmaps for both of those technologies. Those roadmaps and write-ups will subsequently be used for patent applications."*

75. Also shown to me and marked **Confidential Annexure AIB-15** is an email dated 6 January 2021 at 2:15 pm from Dr Kolodziejczyk to Michael Masterman and other Fortescue employees in which he stated (emphasis added):

> *"In our development, we are looking at using solvents capable of dissolving iron ore at low temperatures < 300 deg C and/or using molten carbonate electrolyte, which would allow the dissolution of iron ore at temperatures ranging between 700 and 800 deg C. ..."*

76. Shown to me and marked **Confidential Annexure AIB-16** is an email dated 6 January 2021 at 2:39 pm from Dr Kolodziejczyk to Shanta Barley of Minderoo Foundation. Minderoo Foundation is a philanthropic organisation founded and chaired by Andrew Forrest (the chairman of Fortescue) and Nicola Forrest. Dr Kolodziejczyk wrote (emphasis added):

> *"We are working internally at Fortescue on alternative processes that would utilise lower temperatures and direct electrochemical reduction of iron ore into iron and further steel.*

> *The electrochemical reduction is done in a liquid phase. Hence iron ore has to be dissolved in the electrolyte prior to being electrolysed. ..."*

77. Dr Kolodziejczyk again addresses the ongoing development of the Ionic Process later in January 2021. Shown to me and marked **Confidential Annexure AIB-17** is an email dated 22 January 2021 at 11:41 am from Dr Kolodziejczyk to Fortescue's Media and Corporate Affairs employees regarding an enquiry by the *Australian Financial Review* for more information about Fortescue's Green Steel processes, following a speech given by Mr Forrest. In his email, Dr Kolodziejczyk stated (emphasis added):

> *We are exploring various existing technologies, but we are also developing internally enabling technologies for iron ore processing to produce green commodities. It is going to be a small scale pilot plant...*
>
> *...Internally, we are developing a process that will allow us to take green electricity produced from wind, solar, hydropower, etc., and apply this green electricity to electrochemically reduce Fortescue's iron ore dissolved in a unique electrolyte. In other words, green electricity will be used to separate oxygen from iron. The selection of electrolyte, electrode material, and other materials used in the process is proprietary, and at this point, Fortescue's trade secret. In the future, we are aiming to file a series of patents covering this development".*

78. Fortescue has filed patents in the Electrochemical Reduction field; however, these only concern *solid* (i.e. not dissolved) iron ore particles suspended in an electrolyte slurry. An example of that is referred to in **Part C.3** above. No patent application has been prepared or filed in Fortescue's name that involves the Electrochemical Reduction of iron ore utilising ionic liquids or molten carbonate at low temperatures.

D.5 January-February 2021: Dr Winther-Jensen's suggested change in approach

79. From 24 January 2021, Dr Kolodziejczyk began conversing by email with Dr Winther-Jensen. I am informed by Adrian Huber, Senior Legal Counsel at Fortescue, that Dr Winther-Jensen had accepted the position of "Technology Development Lead" on 18 January 2021, with an official start date of 15 February 2021. I note that Dr Winther-Jensen corresponded with Dr Kolodziejczyk at this time through his personal email address, <bjornwj@gmail.com>.

80. For example, shown to me and marked **Confidential Annexure AIB-18** is an email from Dr Winther-Jensen to Dr Kolodziejczyk dated 5:33 pm on 24 January 2021 in which Dr Winther-Jensen raised the "*need for doing/achieving something fast (pilot project)*". I understand this to mean that there was a need to meet Fortescue's 30 June 2021 stretch target for the Green Iron project (as mentioned in the email at **Confidential Annexure AIB-13**). Dr Winther-Jensen suggested to Dr Kolodziejczyk that slurry electrolysis of

higher purity, solid-state magnetite from the Iron Bridge site (suspended in sodium hydroxide) should be pursued to "*do something (meaningful) fast*" (i.e. in order to meet the 30 June 2021 stretch target). Also included in this annexure is Dr Kolodziejczyk's reply email dated 5:29 pm on 27 January 2021. In this email, Dr Kolodziejczyk acknowledged Dr Winther-Jensen's suggested solid-state approach and stated that ionic liquid or molten carbonate routes could potentially be used in the future.

81. Shown to me and marked **Confidential Annexure AIB-19** is an email from Dr Kolodziejczyk to Dr Winther-Jensen dated 5:42 pm on 27 January 2021, in which Dr Kolodziejczyk confirmed that he had, to date, "*looked at water, ionic liquids and molten carbonate*" (emphasis added) for processing iron ore into ore. I understand these options to be referring to possible electrolytes.

82. Also shown to me and marked **Confidential Annexure AIB-20** is an email from Dr Winther-Jensen to Dr Kolodziejczyk dated 23 February 2021 and the "*draft research plan*" attached to that email. Dr Winther-Jensen's draft research plan suggested that the preferred "priority" scenario from a research and development standpoint be the pursuit of solid-state reduction of magnetite concentrate to steel (page 5). The draft research plan suggested that the Ionic Process ("*Dissolved Iron Route(s)*") be considered as "parallel research with [a] longer lead-time" (page 5). Dr Winther-Jensen stated that he has not found any "*convincing reports*" that ionic liquids can dissolve iron ore (hematite) (pages 7-8, (d)). Dr Winther-Jensen also suggested considering Professor Geir Haarberg's work on molten salt and molten carbonate systems for various metals (page 7, (c)).

83. Finally, shown to me and marked **Confidential Annexure AIB-21** is an email from Dr Winther-Jensen to Dr Kolodziejczyk dated 24 February 2021, in which Dr Winther-Jensen advised Dr Kolodziejczyk that in light of the demanding stretch target and lack of facilities, amongst other factors, he "*cannot commit to produce any meaningful "something" (understood as solid iron samples made by electrochemical reduction of FMG iron ore) by the end of June 2021*".

84. Apart from the above emails, I am informed by Ms Hantos and believe that she and the Fortescue IT team have not been able to locate any other emails or any documents that mention an Ionic Process. Accordingly, there is no mention of this process on the Fortescue IT system after 23 February 2021.

E. Fortescue is unable to locate documentation regarding the Ionic Process

85. Based upon the above emails, I consider that a likely timeline of Dr Kolodziejczyk's work on the Ionic Process is as follows:

Year	**Month**	**Event**	**Source of belief**
2020	June	Dr Kolodziejczyk must have commenced preliminary work in ionic liquids and low temperature iron ore reduction. Based on my expertise it is reasonable to assume that such work would have taken several weeks to several months. I would also expect to see literature searching, and preliminary proof of concept experiments form laboratory, data analysis of experiments using different analytical techniques such as optical imaging, microscopy, materials and samples characterisation etc.	Inferred from emails in October and December 2020 (paras 63 to 72 above)
2020	October	By this date Dr Kolodziejczyk has undertaken preliminary work in ionic liquids and low temperature iron ore reduction.	Email dated 2020-10-21 (para 63 above)
2020	December	Dr Kolodziejczyk has progressed his work on ionic liquids and low temperature iron ore reduction to the point where he is working on a patent application. Dr Kolodziejczyk lodges a patent assessment form with Fortescue in which he states that the "*technology is proven*" and that he "*developed this method and tested in a small scale laboratory setting before*".	Emails dated 2020-12-06 2020-12-15 2020-12-22 2020-12-23 (paras 65 to 72 above)

Year	**Month**	**Event**	**Source of belief**
2021	January	Work on the ionic liquids and low temperature iron ore reduction process has progressed to the point where Dr Kolodziejczyk states that Fortescue's iron ore will be "*dissolved in a unique electrolyte*" and that the "*selection of electrolyte, electrode material, and other materials used in the process is proprietary, and at this point, Fortescue's trade secret*". At this time, based on the above statements, I would expect that experiments must have taken place to test the above parameters. I would expect such experiments to be ongoing because the statement suggests a choice or narrowed choices of electrolyte, and a choice or narrowed choices of electrode materials, have been selected. This implies to me that experimental data has been gathered to enable informed selections based on that data.	Emails dated 2021-01-06 2021-01-22 (paras 75 to 77 above)
2021	February	The decision is made by Dr Winther-Jensen and Dr Kolodziejczyk to pivot away from ionic liquids or molten carbonate as the primary Fortescue process. The Ionic Process is to be the subject of "parallel research with a longer lead-time".	Emails dated 2021-01-27 2021-02-23 (paras 80 to 83 above)
2021	March – October	No further mention of the ionic liquids or molten carbonate processes in any Fortescue documents.	IT searching of the Fortescue System (para 84 above)
2021	November	Both Dr Kolodziejczyk and Dr Winther-Jensen cease their employment with Fortescue.	Information from Adrian Huber, Senior Legal Counsel, based on Fortescue's employment records

86. Assuming the above timeline is correct, based on my experience and expertise described above, I would expect to be able to locate the following documents and information on the Fortescue IT system:

(a) experimental data from electrochemical measurements on ore reduction;

(b) physical sample characterisation data from electrochemical experiments;

(c) experimental data regarding physical properties of iron ores and ionic liquids;

(d) materials characterisation data showing iron ores dissolving into ionic liquids;

(e) experimental data on electrode material selection and interactions with ionic liquid/ore mixes;

(f) reports and analysis of data;

(g) refinement experiments after data analysis;

(h) drafts of provisional patent applications; and/or

(i) data analysis to insert into specifications for patent applications.

87. I am informed by Ms Hantos and believe that, following the extensive further searching described in her affidavit, no other documents have been located in relation to the work undertaken by Dr Kolodziejczyk during the period of:

(a) at least October 2020 to January 2021 (four months) as is apparent from the emails identified above; and

(b) the period of around June 2020 to October 2021, which is the time during which Fortescue is concerned that Dr Kolodziejczyk and Dr Winther-Jensen were in fact working on the Ionic Process or molten carbonate processes.

88. I am therefore concerned that Dr Kolodziejczyk and Dr Winther-Jensen have intentionally not uploaded onto the Fortescue IT system and/or taken and/or deleted the above work product during or prior to ceasing their employment with Fortescue.

F. Element Zero's Electrowinning process

89. In this **Part F** of my affidavit I provide my opinion in relation to the process that is currently being used by Element Zero to purify iron ore (**Element Zero Process**).

90. There is no publicly available information of which I am aware that completely describes the Element Zero Process. Because of this, in order to form my opinion, I have reviewed all sources of information available in the public domain that I have been able to locate as at the date affirming this affidavit. I list those sources and explain my approach below.

F.1 My opinion as to the Element Zero Process

91. The Element Zero website on the Element Zero, *Our Technology* (Web Page) <https://elementzero.green/technology/> (**Element Zero technology page**) is annexed hereto and marked **Annexure AIB-22**.

92. The Element Zero technology page contains the following statements and image which describe the Element Zero Process:

   (a) "*Our patents cover the overall process and its unique chemistry as well as the complete circuit design for mineral processing incorporating a unique electrolyte*";

   (b) "*Element Zero has developed a novel approach to cost-effectively and efficiently convert metal ores such as iron ore, nickel ore and other future facing metals, to pure metal form with zero carbon emissions*";

   (c) "*Iron ore and other minerals dissolve in 15–30 minutes with full dissolution within 60 minutes*";

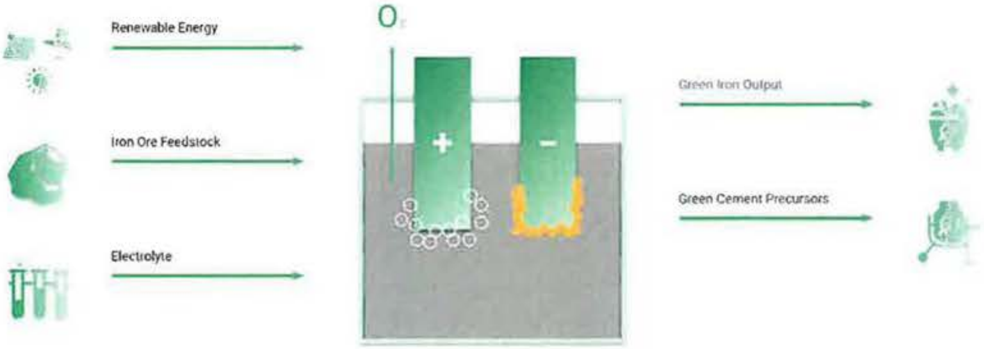
   (d) "*Electroreduction converts iron ore to high purity iron ~98%*";

   (e) "*The technology can process low grade (30% Fe) to high grade (72% Fe) iron ore*";

   (f) "*Low operating temperature in the range of 250 – 300°C enables rapid ramp up and ramp down of the processing capacity*";

   (g) "*No membrane is needed*"; and

   (h) The following schematic showing the electrochemical cell:



93. Shown to me and marked (**Annexure AIB-23**) is an news article by Peter Ker, titled 'Former Fortescue duo in breakaway green iron dream', *Australian Financial Review* (online, 17 January 2024) <URL: https://www.afr.com/companies/mining/former-fortescue-duo-in-breakaway-green-iron-dream-20240115-p5exic> (**AFR article**);

94. The AFR article contains the following statements which are relevant to understanding the Element Zero Process:

   (a) "*Under Element Zero's process, iron ore is dissolved into a clear, alkaline solution that does not include water*"; and

   (b) "*When renewable electricity is passed through the solution, the pure iron plates onto a cathode, from where it can be collected for sale*".

95. Shown to me and marked (**Annexure AIB-24**) is a news article titled 'Element Zero Raises US$10M Seed Funding Led by Playground Global to Scale up Green Materials Platform, Decarbonize Iron and Other Critical Metals Production', *BusinessWire* (online, 17 January 2024) <https://www.businesswire.com/news/home/20240117257036/en/Element-Zero-Raises-US10M-Seed-Funding-Led-by-Playground-Global-to-Scale-up-Green-Materials-Platform-Decarbonize-Iron-and-Other-Critical-Metals-Production> (**BusinessWire article**).

96. Shown to me and marked **Annexure AIB-25** is a news article by Mariaan Webb, titled 'Startup aims to transform WA from world's mine into world's foundry', *Mining Weekly* (online, 19 January 2024) <https://www.miningweekly.com/article/start-up-aims-to-transform-wa-from-worlds-mine-into-worlds-foundry-2024-01-19> (**Mining Weekly article**).

97. The information contained in these articles is consistent with the information contained in the Element Zero Technology page as described in paragraph 92 above and also in the AFR article in paragraph 94 above.

98. In my opinion, based upon the information referred to in paragraphs 92, 94 and 97 above, I consider that the Element Zero Process:

    (a) is an electrochemical reduction process;

    (b) operates at low temperatures (250–300°C) and therefore is capable of being operated using renewable electricity sources (as these sources provide intermittent power);

    (c) utilises an ionic liquid electrolyte, as the Element Zero Process dissolves the iron ore into an electrolyte which does not contain water. Further, the electrolyte is alkaline and therefore contains hydroxide ions;

    (d) is membrane free; and

    (e) utilises electrowinning as the pure iron is deposited onto the cathode.

99. Additionally, in my opinion, I consider that the Element Zero Process utilises a leaching step prior to electrochemical reduction step. This is because the Element Zero home page at https://elementzero.green/ (annexed hereto and marked **Annexure AIB-26**) refers to extracting and capturing impurities from iron ore and the Element Zero technology page states that Element Zero's "*patents cover the overall process*" for mineral processing (which overall process I consider refers to any pre-processing or leaching of the ore) and that its patents cover "*the complete circuit design for mineral processing incorporating a unique electrolyte*" (which complete circuit design would necessarily include a unit for leaching).

F.2 Detailed Analysis of the Chemistry underlying the Element Zero Process

100. As stated above, in my opinion, the Element Zero process is an electrowinning process in an alkaline solution operating at 250–300 °C.

101. In order to achieve the water-free conditions (as mentioned above at paragraph 94(a)), a mixture of hydroxide salts will be required (for example, sodium hydroxide-potassium hydroxide (NaOH-KOH) mixtures, or lithium hydroxide-potassium hydroxide (LiOH-KOH) mixtures, or mixtures of more than two hydroxide salts, commonly referred to as "ionic liquids" or "molten salts" within the field. Both of these NaOH-KOH or LiOH-KOH mixtures, at suitable compositions, can achieve the operating temperature stated by Element Zero (i.e. the system is in an electrically-conducting liquid phase at approximately 250–300°C).

102. This is evidenced by the binary phase diagrams for NaOH-KOH and LiOH-KOH mixtures reported in the literature by researchers. Binary phase diagrams represent the physical states of a chemical mixture at various compositions (horizontal axis) and temperatures (vertical axis). Below is a binary phase diagram for a NaOH-KOH mixture taken from Sergei Devyatkin, 'Interaction of Oxides and Molten Alkalis, Products of Reaction and Application' in F Kongoli et al (eds), *Sustainable Industrial Processing Summit SIPS 2015 Volume 7: Ionic Liquids & Energy Production* (FLOGEN Star Outreach, 2015) 237–40, which in my opinion, accurately depicts a binary phase for a NaOH-KOH mixture. A copy of this journal article is shown to me and annexed as **Annexure AIB-27**:

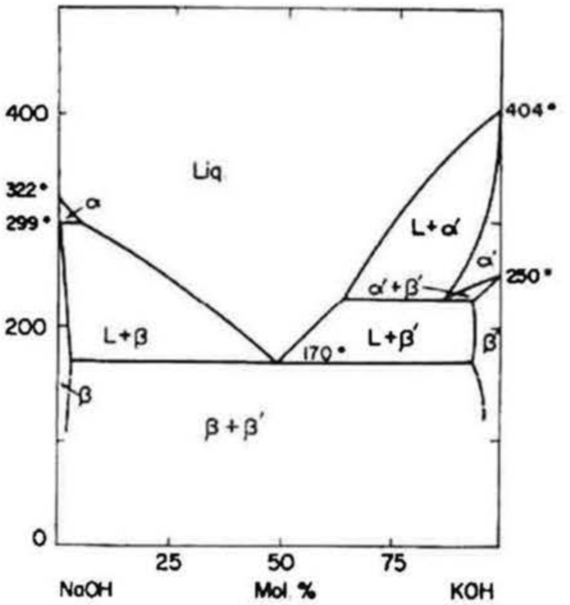


Fig.1. Phase diagram NaOH-KOH[2]

103. As can be seen, at a NaOH-KOH composition around 50:50 (mol/mol) and a temperature between 250–300°C (y-axis, left-hand side), the mixture is in a single ionic liquid phase (indicated by the region labelled "Liq." in the diagram).

104. Below is a binary phase diagram for a LiOH-KOH mixture, taken from Fouzia Achchaq et al, 'Characterization of Li2K(OH)3 as material for thermal energy storage at high temperature' (Conference Paper, 13th International Conference on Energy Storage, 2015), which, in my opinion, accurately depicts a binary phase for a LiOH-KOH mixture. A copy of this journal article is shown to me and annexed as **Annexure AIB-28**. This shows that a LiOH-KOH mixture at a composition of approximately 15:85 (g/g) is in a single ionic liquid phase between 250–300°C (indicated by the region labelled "LIQUID" in the diagram):

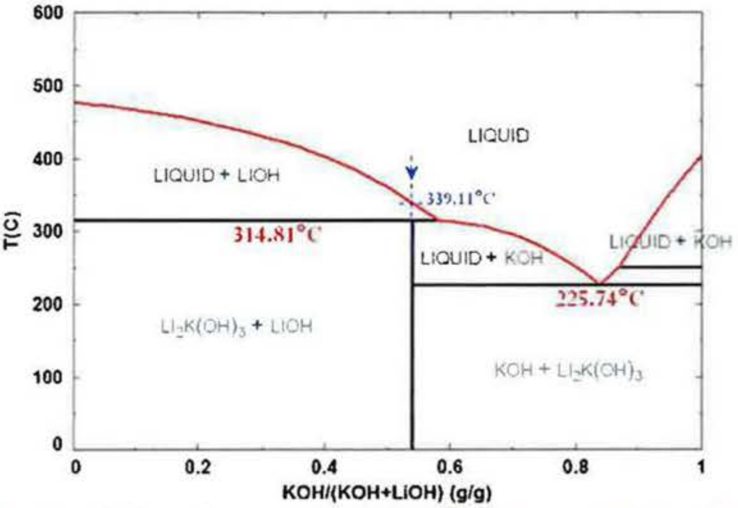


Figure 1. Theoretical phase diagram of KOH/LiOH binary system (liquidus line in red)

F.3 Consideration of the Element Zero PCT Application

105. I have considered the Element Zero PCT Application entitled "WO2024082020 - METHOD OF ORE PROCESSING" filed by Element Zero, which became open to public inspection on 25 April 2024 (**Element Zero PCT Application**). I have also considered the affidavit of Ms Hantos at Part F, where Ms Hantos provides her analysis of the electrowinning process disclosed by Element Zero in the Element Zero PCT Application.

106. I agree with Ms Hantos' analysis of the process disclosed by Element Zero PCT Application. Further, I consider that the matters disclosed by the Element Zero PCT application are consistent with (i) what Element Zero has disclosed on its website and to the media (Part F.1 above), and (ii) my view as to the chemistry that would be required to achieve the water-free conditions in an electrowinning process operating at 250–300 °C (Part F.2 above).

G. Comparison of Dr Kolodziejczyk's work at Fortescue and the Element Zero Process

107. Based on my analysis of the email correspondence set out at **Part D** above, my understanding of the progress of Dr Kolodziejczyk's work in relation to the electrowinning

concept is that it involved removal of water from electrolyte and an increase in temperature to achieve an ionic liquid electrolyte.

108. Based on my analysis of Dr Kolodziejczyk's work on the Ionic Process at Fortescue in **Part D** above and my understanding of the Element Zero Process in **Part F** above, I consider that the Element Zero Process is substantially the same process as that which Dr Kolodziejczyk took steps to develop whilst employed at Fortescue. That is because both processes are based on a hydroxide electrolyte where the water has been removed to make an ionic liquid.

109. The Element Zero Process includes leaching, which is also research that Dr Kolodziejczyk oversaw during his tenure at Fortescue.

110. Based on my expertise and experience as set out in **Part A** of this affidavit, and based upon the information described at **Parts D and F**, above, I consider that while he was employed by Fortescue, Dr Kolodziejczyk had developed, tested and was continuing to work on a process of electrochemical reduction that has the features described in the below table.

	Feature	**Reference to Dr Kolodziejczyk's work at Fortescue**	**Reference to Element Zero Process**
(a)	electrochemical reduction process	paras [56]-[65], [67], [69]-[72], [74]-[77], [82] above	paras [92], [97], [105]-[106] above
(b)	utilises electrowinning	paras [65]-[66] above	paras [92], [94], [105]-[106] above
(c)	membrane free	paras [65]-[66] above	para [92] above
(d)	operates at low temperature	paras [60]-[67], [69]-[72], [74]-[76] above	paras [92], [97], [105]-[106] above
(e)	utilises an ionic liquid electrolyte	paras [63]-[65], [67], [69]-[72], [74]-[77], [81]-[82] above	paras [94], [100]-[104], [105]-[106] above
(f)	capable of operating using renewable electricity sources.	paras [57], [65], [77] above	paras [92], [94], [97] above

H. Review of the Green Iron Project Share Point Folder

111. On 17 January 2024, I was informed by Adrian Huber, Senior Legal Counsel at Fortescue, that Fortescue was investigating the conduct of Dr Winther-Jensen, Dr Kolodziejczyk, and Mr Masterman while employed at Fortescue.

112. I was informed by Mr Huber that Dr Winther-Jensen and Dr Kolodziejczyk were both members of the Green Iron Project team and that, during their employment at Fortescue, they were expected to store their work output in a **SharePoint Folder**. Based on my own experience using SharePoint at Fortescue, I understand that SharePoint is a Microsoft software application that allows organisations to store and organise content, including documents.

113. On 8 April 2024 I was asked by Adrian Huber, Fortescue Legal Counsel to undertake a review of the SharePoint folder for the Green Iron Project (SharePoint Folder) to identify the documents that, if taken by Dr Winther-Jensen and Dr Kolodziejczyk, would be of particular value in progressing a competing research and development project in relation to the purification of iron ore utilising electrochemical reduction.

114. I have been informed by a Fortescue IT staff member named Paul Waldin that the SharePoint Folder is an 'archived' version of the SharePoint site as it existed during Dr Winther-Jensen's and Dr Kolodziejczyk's employment. Since then, the SharePoint Folder has been migrated to a newer version with later software updates. The searched SharePoint Folder is a snapshot of the original version as a backup.

115. The methodology for my review of the SharePoint Folder is as follows.

116. First, on 8 April 2024, I conferred with Ms Hantos to compile key words relevant to the development of a pilot plant and direct electrochemical reduction. A document setting out the key words that Ms Hantos and I is included at **Annexure AIB-29**.

117. Second, from 9 to 12 April 2024, I used the selected key words to search the documents saved in the SharePoint Folder. I limited the search results to documents which showed 'last modifications' from January to November 2021. I then visually scanned the documents in the search results list for documents that appeared likely to relate to pilot plant development. Where a suitable document was identified I opened the document, read the entirety of the contents, and considered whether its contents fell into one of the following categories of information:

    (a) Defining concept of pilot plant and defining the limits of what the plant will achieve. This is also known as basis of design in engineering parlance.

    (b) Detailed design of the pilot plant where process flow diagram (PFD), piping and instrument diagrams (P&ID) or flowsheets are designed and developed. These documents are used as the basis of further engineering which will lead to eventual construction.

    (c) Equipment suppliers for components or parts of a pilot plant (for example, tanks, pumps, grinders, etc.). This information helps speed up pilot plant development by providing a list of known suppliers and thereby cuts down time invested in identifying suppliers.

(d) Research and development where the research is targeted specific to questions that arise from pilot plant development and aimed to fill knowledge gaps for the basis of design.

(e) Contained information regarding Fortescue ore specifications and green iron business plans which allows for a market positioning exercise to build a green iron business.

(f) Documents which could be used for estimation of pilot plant costs or economics which may help to identify the overall project costs and size.

118. Based on my knowledge and experience, I then identified if the document identified was one that if taken by Dr Winther-Jensen and Dr Kolodziejczyk, would be of particular value in progressing a competing research and development project in relation to the purification of iron ore utilising electrochemical reduction. I then listed each document identified against the aforementioned criteria. I refer to **Annexure AIB-29** above which contains the list of identified documents.

I. Fortescue's confidential information taken by Dr Winther-Jensen

119. As part of Fortescue's investigation, on 19 January 2024, Mr Huber asked me to review Dr Winther-Jensen's Fortescue 'Outlook' inbox and outbox connected with his work email address <bjorn.wintherjensen@fmgl.com.au>.

120. On or around 19 January 2024, I instructed a Fortescue IT staff member named Mr Waldin to provide me with access to Dr Winther-Jensen's Fortescue Outlook. As a result of this request, Mr Waldin sent me approximately 1000 emails (including Outlook calendar invites) to review.

121. I then read each of these emails individually. Following that review, I identified five documents of concern that Dr Winther-Jensen emailed from his Fortescue professional email address, <bjorn.wintherjensen@fmgl.com.au>, to his personal email address, <bjornwj@gmail.com>, between his resignation from Fortescue on 3 November 2021 and his final day at Fortescue, 12 November 2021 (**November 2021 Period**).

122. Each of the five documents is confidential and directly relevant to the Fortescue Project. Following my review in **Part H** above I consider that the Leaching Technical Report, Iron Ore Leaching Update, TEA Sheet and TEA Covering Email contain information that would be of particular value in progressing a competing research and development project in relation to the purification of iron ore utilising electrochemical reduction.

123. I cannot conceive of any legitimate reason for Dr Winther-Jensen to have sent an email attaching any of these documents in the November 2021 Period.

124. I am concerned that the confidential information in each document could have been misused, could continue to be misused and/or may in the future be misused by Dr Winther-Jensen and Element Zero.

125. In this Part L, I consider four of those documents below.

126. As the fifth document, being a PDF copy of a Microsoft PowerPoint document with the internal title, 'Green Iron Forum', internally dated 1 November 2021, was authored by John Paul William Testaferrata Olivier (the Director, Innovation & Technology Development at Fortescue), I have provided that document to him for review. I understand he provides his opinion of that document in his affidavit.

I.1 Leaching Technical Report

127. Shown to me and marked **Confidential Annexure AIB-30** is a copy of a Microsoft Word document titled '211029_Iron ore leaching_Report_ASH.R1.docx' (**Leaching Technical Report**) and a covering email dated 8 November 2021 attaching the Leaching Technical Report.

128. As can be seen from **Confidential Annexure AIB-30**, Dr Winther-Jensen forwarded the covering email, attaching the Leaching Technical Report, to his personal email address on 8 November 2021. I note that the covering email forwards an email from Aabhash Shrestha, an electrochemist at Fortescue dated 8 November 2021 at 9:39 am, but otherwise contains no text.

129. The Leaching Technical Report contains the results of Fortescue's first iteration of iron ore leaching experiments, including critical analysis of the results. This is an internal, confidential document which was only shared to certain members of Fortescue.

[redacted]

[redacted]

[redacted]

132. The Leaching Technical Report was prepared on 8 November 2021 by Dr Aabhash Shrestha, an electrochemist at Fortescue. Dr Shrestha no longer works for Fortescue. I consider it would have taken Dr Shrestha two weeks to prepare the Leaching Technical Report. However, the process of conducting the various experiments which are the subject of the Leaching Technical Report would have taken much longer. I estimate that the total time required to prepare the Leaching Technical Report, including experiments, is four months.

133. Including based on the matters in paragraphs 129 to 132 above, I consider that the Leaching Technical Report could be used by Dr Winther-Jensen and any recipient of the document to develop a leaching process in competition with Fortescue, with significantly less time and/or resources than would otherwise be needed in the absence of that document. The Leaching Technical Report provides the limits of Fortescue's testing (upper and lower temperatures), and is useful for understanding the limits of what leaching will do at the top and bottom of the temperature range, and could assist Dr Winther-Jenssen or any other recipient to focus on a smaller temperature window to optimise their own process.

134. My concern in that regard is heightened because, the Element Zero PCT Application filed by Element Zero discusses leaching of iron ores in a temperature range of 160 °C up to 350 °C. The Element Zero PCT Application also discusses nickel and manganese containing ores. The Leaching Technical Report discusses operation of leaching at 100 °C in a caustic solution, and leaching and roasting of ores with caustic at 750 °C. As such, the temperature window described in the Element Zero PCT Application falls within the window of temperatures tested and analysed in Fortescue's Leaching Technical Report.

I.2 Iron Ore Leaching Update

135. Shown to me and marked **Confidential Annexure AIB-32** are copies of two Microsoft Excel spreadsheets titled, '211014_FFI Green Steel_Ore Leach_ASH_XRF results.csv' and '211014_FFI Green Steel_Ore Leach_ASH_ICP results.csv', and an email chain to which the spreadsheets are attached dated 1 November 2021 (together, these documents are referred to as the **Iron Ore Leaching Update**). As can be seen from **Confidential Annexure AIB-32,** Dr Winther-Jensen received the Iron Ore Leaching Update on 1 November 2021, and forwarded it to his personal email on 10 November 2021 (two days before leaving Fortescue). I again note that the covering email forwards an email chain from Dr Shrestha dated 1 November 2021 at 9:37am, but otherwise contains no text.

136. The first email in the email chain in the Iron Ore Leaching Update explains that the attachments to that email contain the results of Fortescue's '*recent set of leaching experiments. The leaching experiments were designed to understand the fundamental limitations that may exist using NaOH as a leaching agent (e.g. aluminosilicate solubility and reactivity of silica and alumina species in ore). In addition, the use of ICP* ["Inductively Coupled Plasma spectroscopy"] *as a potential analytical method was also tested.*

137. The spreadsheets in the Iron Ore Leaching Update contain raw data for the abovementioned leaching experiments.

138. Further, the covering email chain contains discussion between Dr Shrestha and Mr White regarding the results of the leaching experiments and the details of the roasting process for iron ore.

139. I reasonably estimate it would have taken Dr Shrestha two weeks to create the spreadsheets in the Iron Ore Leaching Update. I reasonably estimate the experiments the subject of the spreadsheets would have taken Dr Shrestha four months to perform. Additionally, as Dr Winther-Jensen was supervising Dr Shrestha and signed off on the report above, I expect that he would have utilised around two weeks of his time in that role.

140. I reasonably estimate the total cost to Fortescue of preparing the Iron Ore Leaching Update, including all experiments which were the subject of the results, to be approximately $100,000–200,000 including salary costs and overheads, equipment, and test work, amongst other costs.

141. I consider the information in the Iron Ore Leaching Update could assist Dr Winther-Jensen and any recipient of the document to develop a leaching process in competition to Fortescue, with significantly less time and/or resources than would otherwise be needed in the absence of that document.

I.3 TEA Sheet and Email

142. Shown to me and marked **Confidential Annexure AIB-33** is a copy of a Microsoft Excel spreadsheet titled 'Technical Evaluation' (**TEA Sheet**) and a covering email dated 4 November 2021 attaching the TEA Sheet (**TEA Email**).

143. As can be seen in **Annexure AIB-33,** Dr Winther-Jensen forwarded the TEA Email, attaching the TEA Sheet, to his personal email address on 5 November 2021.

144. I am informed by David White, an employee of Fortescue whose role at the time was Senior Chemical Engineer — R&D Technology at Fortescue that:

    (a) He prepared the TEA Sheet on 4 November 2021.

    (b) On the same day, Mr White sent the TEA Email to several Fortescue staff, including Dr Winther-Jensen.

    (c) That the assumptions that went into the TEA Sheet resulted from months of extensive research and development (discussed below).

145. The TEA Sheet contains economic analysis of the technologies required to process [redacted] iron ore into iron using the Fortescue Process at full scale. The body of the TEA Email contains assumptions used for the calculations in the TEA Sheet and observations about the TEA Sheet.

146. The TEA Sheet developed on 4 November 2021 would have been a culmination of all the data generated by the Fortescue Project to date and a best guess as to what the commercial system would look like. A TEA Sheet is used as a guide to justify the commercial viability of a research technology. Where the analysis in a TEA Sheet indicates the technology would be commercially viable, recommendations are made to further develop the technology, whereas if the TEA analysis looks less promising, the technology further research and development will be required. This is the first of several technical evaluation assessments that are required to develop a project from lab scale to commercial scale, and secure funding from potential investors.

147. To progress with any independent research and development project in this industry, a TEA Sheet would have to be prepared, particularly if funding is to be obtained. I estimate the total cost of preparing the TEA Sheet, if prepared by an independent consultant (including the cost of trials and experimentation needed before preparing the TEA Sheet), may have been around $500,000.

148. The TEA Sheet contains valuable confidential information. In particular, the TEA Sheet contains:

   (a) a breakdown of the end-to-end steps and technologies needed to process [redacted] iron ore into iron using the Fortescue Process at full scale;

   (b) assumptions for the calculations in the TEA Sheet, which are supplemented by the assumptions in the TEA Sheet Email (together, the **TEA Sheet Assumptions**);

   (c) dimensions, metrics, and specifications of products and technologies used in the Fortescue Process (for example, leach tank volume is a specific number of m^3); and

   (d) brand names and specifications of products needed to set up a green iron plant per the TEA Sheet.

149. By reference to the TEA Sheet Assumptions and the steps and specifications in the TEA Sheet, I consider that the TEA Sheet and TEA Email contain information that was useful for the design of an electrowinning pilot plant. For example, the TEA Sheet and TEA Sheet Email could be used to:

   (a) understand the end-to-end steps and technologies needed to process [redacted] [redacted] iron ore into iron using the Fortescue Process at full scale, in order to emulate the Fortescue Process or create a similar process;

   (b) understand the dimensions, metrics, and specifications of products and technologies, from start to finish, in the Fortescue Process, in order to emulate the Fortescue Process or create a similar process;

   (c) create a 'shopping list' of the specific products needed to set up a electrowinning pilot plant; and

   (d) adapt the TEA Sheet assumptions to produce desired results for a process that is different from the Fortescue Process.

I.4 Fortescue Green Iron Provisional Application

150. Shown to me and marked **Confidential Annexure AIB-34** are copies of the specifications and drawings, as filed on 24 May 2021, of Australian provisional patent application no. 2021901547 entitled 'Apparatus and process for producing iron' in the name of Fortescue Future Industries Pty Ltd (**Fortescue Green Iron Provisional Application**), and a

covering email attaching Fortescue Green Iron Provisional Application which Dr Winther-Jensen sent to his personal email on 11 November 2021. Again, the covering email contains no text save for a forwarded email.

151. I am informed by DCCL, that the complete application associated with the Fortescue Green Iron Provisional Application, being Australian standard patent application no. 2021215184, was filed on 11 August 2021. The complete application was open to public inspection, i.e., has an Australian OPI date, of 8 December 2022. Shown to me and marked **Annexure AIB-35** is a copy of the IP Australia AusPat online record for Australian standard patent application no. 2021215184 and the complete specification, which has the number 'AU 2021215184 A1' (**Fortescue Green Iron Complete Application**).

152. Dr Winther-Jensen is a named inventor in the Fortescue Green Iron Complete Application.

153. I have read and considered the Fortescue Green Iron Provisional Application and Fortescue Green Iron Complete Application. I have compared the two applications in light of my knowledge of the Fortescue Process. I consider that the patent applications each accurately describes the Fortescue Process.

154. I am informed by DCCL that provisional applications, such as the Fortescue Green Iron Provisional Application, are not made open for public inspection by IP Australia before the OPI date.

155. In light of the above information, I understand the Fortescue Green Iron Provisional Application contains valuable confidential information belonging to Fortescue that would not have otherwise been available to Dr Winther-Jensen and Element Zero prior to it becoming publicly available on 8 December 2022.

J. Missing material

156. I have been provided access to, and reviewed the following material and information in Fortescue's business records:

    (a) The SharePoint Folder; and

    (b) Fortescue raw data files, such as experiment/test results, in which Dr Winther-Jensen is identified as the author.

157. I note from Fortescue's books and records that during the period from February to November 2021, Dr Winther-Jensen was supervising a team of around four scientists. My review of the SharePoint Folder identified only five documents in which Dr Winther-Jensen is named as an author.

158. Dr Winther-Jensen was a senior employee in the Fortescue Project team from February to November 2021. Having reviewed Dr Winther-Jensen's curriculum vitae, it is apparent he

is a well-established scientist, prolific publisher of articles, and named inventor on patents. In light of the above, I would have expected Dr Winther-Jensen to have produced and saved a significantly greater amount of work output to be produced and saved on the SharePoint folder for the green output team.

159. Given the above matters and those set out in Part I above, I am extremely concerned that Dr Winther-Jensen took work output (including Fortescue's confidential information) with him when he left Fortescue.

K. Consideration of the expertise of Dr Winther-Jensen and Dr Kolodziejczyk

K.1 Consideration of the expertise of Dr Winther-Jensen

160. I am familiar with Mr Winther-Jensen by reputation only. I cannot recall meeting him at any time during or after his employment with Fortescue.

161. I commenced employment with Fortescue after Mr Winther-Jensen had stopped working at Fortescue. My evidence in this **Part K.1** is based upon my review of Fortescue's business records, discussions with Fortescue employees and my own internal investigations.

162. Shown to me and annexed to this affidavit and marked **Annexure AIB-36** is a copy of Mr Winther-Jensen's curriculum vitae, current as at 2020, which forms part of Fortescue's business records. From this document, it is apparent to me that:

    (a) Mr Winther-Jensen' expertise is in solar, hydrogen, water cracking and electrochemistry;

    (b) Mr Winther-Jensen's experience does not include Green Iron Technology;

    (c) although "Aqueous electrodeposition of iron directly from ore" is listed under "Research and Development Interests and Expertise", I understand that most of Mr Winther-Jensen's electrochemistry experience is not in respect of the electrochemical reduction of iron ore; and

    (d) Mr Winther-Jensen's PhD thesis was on 'Micro-patterning of conducting polymers', which I understand is not relevant to Green Iron Technology.

163. From the internal investigations I conducted on or about 23 April 2024, I understand that:

    (a) on 15 February 2021, Mr Winther-Jensen commenced working at Fortescue (specifically, FMG Personnel Services Pty Ltd, a wholly owned subsidiary of FMG);

    (b) on 3 November 2021, Mr Winther-Jensen resigned from Fortescue.

    (c) on 12 November 2021, Mr Winther-Jensen worked his final day at Fortescue; and

(d) during the time Mr Winther-Jensen was working in the Fortescue green iron team (February to November 2021) his title was Technology Development Lead. His role was to develop an Electrochemical Green Iron Technology process.

164. Based upon the matters in paragraphs 162 and 163 above, I consider that Mr Winther-Jensen would have had to educate himself extensively with respect to iron ore electrolysis in the period from February to November 2021. Iron ore is a specific field for application of electrolysis, and in my view Dr Winther-Jensen's prior expertise would not have fully equipped him to work in this field.

K.2 Consideration of the expertise of Dr Kolodziejczyk

165. I am familiar with Dr Kolodziejczyk by reputation only. I cannot recall meeting him at any time during or after his employment with the Applicant companies.

166. I commenced employment with Fortescue after Dr Kolodziejczyk had stopped working at Fortescue. My evidence in this **Part K.2** is in part based upon my review of the Applicants' business records annexed in this **Part K.2**.

167. Shown to me and annexed to this affidavit at **Annexure AIB-37** is a copy of Dr Kolodziejczyk's curriculum vitae, sent on 25 November 2019, which forms part of Fortescue's business records. From this document, it is apparent to me that:

(a) Dr Kolodziejczyk's expertise is in electropolymers, materials science, hydrogen, solar and electrochemistry.

(b) Dr Kolodziejczyk's experience does not include Green Iron Technology.

(c) Dr Kolodziejczyk lists his role with Fortescue as Hydrogen Specialist and does not mention iron ore.

(d) Dr Kolodziejczyk's PhD thesis was on 'Novel light enhanced electrocatalysts for energy applications', which is not relevant to Green Iron Technology.

168. From the internal investigations I conducted in or around 23 April 2024, I understand that:

(a) On 25 March 2019, Dr Kolodziejczyk commenced working at Fortescue (specifically, FMG Personnel Services Pty Ltd, a wholly owned subsidiary of FMG).

(b) On 22 October 2021, Dr Kolodziejczyk resigned from Fortescue.

(c) On 5 November 2021, Dr Kolodziejczyk worked his final day at Fortescue.

(d) During the time Dr Kolodziejczyk was working in the Fortescue green iron team (25 March 2019 to November 2021) his titles included Hydrogen Specialist, Chief

Scientist – Energy, and Chief Scientist. Part of his role was to develop an Electrochemical Green Iron Technology process.

169. Based upon the matters in paragraphs 167 and 168 above, I consider that Dr Kolodziejczyk would have had to educate himself extensively with respect to iron ore electrolysis in the period from 25 March 2019 to November 2021. Iron ore is a specific field for application of electrolysis, and in my view Dr Kolodziejczyk's prior expertise would not have fully equipped him to work in this field.

Affirmed by Dr Anand Indravadan Bhatt)
at Perth)
in Western Australia)
on 1 May 2024)
Before me:)

Signature of Dr Anand Indravadan Bhatt

Signature of witness

[Name and qualification of witness]
Olivia Campana
An Australian legal practitioner within the
meaning of the Legal Profession Uniform Law (WA)
[* Delete if inapplicable]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-1

This is the annexure marked **AIB-1** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

CURRICULUM VITAE

ANAND INDRAVADAN BHATT

D. O. B: [redacted]/1976 **Sex: Male** **Age: [redacted]**

[redacted]
Bullsbrook,
WA 6084, Australia

Tel: +61 (0)3 9545 8[redacted]
Mob: +61 (0)416 523 [redacted]
Email: Anand.Bhatt@csiro.au

EDUCATION

2010	Diploma of Management - People Management, Australian Institute of Management, Australia
2000 – 2004	PhD, Centre for Radiochemistry Research, The University of Manchester, UK *Thesis title: f-elements in ionic liquids: a synthetic, spectroscopic and electrochemical study*
1994 – 1999	2:1 BSc. (Honours) Chemistry, The University of Leicester, UK

WORK EXPERIENCE

2022 – present	Manager Minerals Research and Development, Fortescue Leading the development of zero emission green iron and green minerals processing technologies
2021 – 2022	Lead Scientist, VSPC Leading VSPCs efforts to commercialise lithium iron phosphate cathode manufacturing
2012 – 2021	Research Team Leader for the Electrochemical Energy Storage Team, Energy Business Unit, CSIRO, Australia Leading CSIRO’s efforts in battery evaluation, integration and application research and battery recycling technologies development with a focus on lithium-ion technologies. Managing and developing a team of full-time scientists, experimentalists plus visiting scientists and postgraduate students.
2008 – 2012	Research Scientist, Division of Energy Technology, CSIRO, Australia investigating novel battery technologies Research focused on development of next generation lithium battery technology and testing and evaluation of lithium batteries
2006 – 2007	Research Fellow, Monash University, Australia
2005 – 2006	Royal Society Research Fellowship, Monash University, Australia
2004 – 2005	Post Doctoral Research Associate, The University of Manchester, UK
2003 – 2004	Post Doctoral Research Associate, UMIST, UK

SKILLS

- Experienced electrochemist and materials scientist with a focus on electrochemical minerals processing, battery storage and integration to renewable electricity generation and battery recycling.
- Project leadership and management of large-scale research projects (1-20 Million plus),
people development and new research field development from concept to large scale activities and commercialisation.

TRAINING

- DEMERS Type B gas inspector
- Purposeful conversations, diversity and inclusion, leadership essentials
- Mental health awareness for managers, anti-bullying and harassment
- Writing winning scientific proposals, influencing and persuasion, HSE for leaders

PROFESSIONAL EXPERIENCE

- Trained in Incident management, fire warden and chief fire warden (PUAFER005), Fire extinguisher training (PUAFER008).
- Editor for Energies (MDPI)
- Member of the Review Editorial Board of Frontiers in Chemical Engineering
- Peer reviewer for Materials Chemistry and Physics (Electrochemistry and Batteries expertise), Electrochimica Acta, Journal of the Electrochemical Society, Journal of Physical Chemistry, Inorganica Chimica Acta, ACS Applied Energy Materials, ACS Energy letters, Australian journal of Chemistry, Journal of Materials Chemistry A, PhysChemChemPhys amongst others.
- Member of the Electrochemical Society and American Chemical Society

OTHER EXPERIENCE

- CSIRO Energy Business Unit representative for Critical Metals Mission development
- CSIRO Energy business Unit representative for Lithium Battery Recycling Future Science Platform development
- Member of Clean Energy Council working group to investigate safety standards, performance standards and testing methods for residential battery products
- Member of multi partner, BNFL science team working on the application of ionic liquids as an alternative means of nuclear fuel processing, collaborating with scientists and technologists from the fields of ionic liquids, chemical engineering, electrochemistry and fuel plant processing managers

ORAL PRESENTATIONS

Numerous invited presentations at small to large scale conferences.

PEER REVIEWED PUBLICATIONS LIST

In 2024, I was the author on over 65 journal articles with over 2800 citations and an individual h-factor of 26. A full list of publications is available on request.

PATENTS

- Bhatt A. I., Ruther T. I., Electrolyte Recovery, Australian Provisional Patent Application 2020902099, June 2020
- Best, A. S., Bhatt, A. I., Hollenkamp, A. F., Ruether, T. R., Snook, G. S., Bentley, C., Electrolytes for Energy Storage Devices, provisional patent filed 22 April 2013
- Lane, G. H., Best, A. S., Bhatt A. I., Shekibi, Y. S., Clare, B. R., Ionic Liquids for Batteries. WO/2011/113111A1
- Best, A. S., Hollenkamp, A. F., Bhatt, A. I., Lithium energy storage device. WO/2009/003224
- Best, A. S., Bhatt, A. I., Kyratzis L., Helmer, R., Petersen, P., Snook, G., Redox electrodes for flexible devices, WO/2009/127006 A1
- Bhatt A. I., Behrens, S., Best, A. S., McGarry, S., Flexible Electrical Connectors for Electrochemical Devices, Provisional patent being written at present

INDUSTRY PUBLICATIONS

- Australian landscape for lithium-ion battery recycling and reuse in 2020 - current status, gap analysis and industry perspectives, CSIRO and FBI CRC (Zhao Y., Ruether T., Bhatt A. I., Staines J.), Feb 2021
- Recommended Information for BESS and Battery Safety Information Sheets, Bhatt A. I., Hollenkamp A. F., Vecchio-Sadus A.
- Australian Battery Performance Standard Industry Best Practice Guideline, DNVGL (Liebrich F., Mendis N.), CSIRO (Bhatt A. I., Munnings C., Hollenkamp A. F.), Smart Energy Council (Smith W.), June 2020
- Proposed Australian Battery Performance Testing Standard - for PV connected residential/small-scale commercial systems, DNVGL (Liebrich F., Mendis N.), CSIRO (Bhatt A. I., Munnings C., Hollenkamp A. F., Trezise A., Huynh T., Kao P., Haigh N.), Smart Energy Council (Smith W.), submitted to Standards Australia - June 2020
- Gap Analysis of Existing Battery Energy Storage System Standards - Summary Report, DNVGL (Liebrich F., Mendis N.), CSIRO (Bhatt A. I., Munnings C.), Smart Energy Council (Smith W.), June 2019
- Lithium Battery Recycling in Australia – current status and opportunities, CSIRO (S. King, N. Boxall, A. I Bhatt), 2018
- Energy storage safety: Responsible installation, use and disposal of domestic and small commercial systems, CSIRO and CEC, (K. Cavanagh, S. Behrens, C. Price, O. Lim, N. Haigh, A. Fleming, E. Oliver, A. Mankad, A. I. Bhatt), 2015, Report for the Clean Energy Council's Energy Storage Safety Study
- Electrical Energy Storage: Technology Overview and Applications, CSIRO and AEMC (K. Cavanagh, J. K. Ward, S. Behrens, A. I. Bhatt, E. Ratnam, E. Oliver, J. Hayward), 2015, Report for Australian Energy Market Commision

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-2

This is the annexure marked **AIB-2** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From: Bart Kolodziejczyk
Sent: Wednesday, 5 August 2020 3:58 PM
To: [redacted]
Subject: [redacted]

Dear [redacted],

By way of introduction, Fortescue Metals Group Ltd (Fortescue) is a global leader in the iron ore industry, recognised for our culture, innovation, and industry-leading development of world-class infrastructure and mining assets in the Pilbara, Western Australia.

Fortescue is one of the largest global iron ore producers and is focussed on a vision of being the safest, lowest cost, most profitable mining company. Consistently shipping around 170 million tonnes of iron ore per annum, Fortescue is the lowest cost provider of seaborne iron ore to China with revenues last year reaching US$10.0 billion and a net profit of US$3.2 billion.

In addition to growing our iron ore business, Fortescue is diversifying domestically and internationally into other mineral resources. As part of our commitment to decarbonise our operations, we are exploring various low-emission technologies.

I came across your project titled [redacted]
Would you have time for an introductory call to briefly discuss this project and its current TRL? I am available next week if this suits you.

Best regards,

Bart Kolodziejczyk
Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace East Perth WA 6004

Mobile: +61 437 947 164 **Web:** www.fmgl.com.au
Twitter: @FortescueNews I **www.fmgl.com.au**

Fortescue
The New Force in Iron Ore

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-3

This is the annexure marked **AIB-3** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Thursday, 13 August 2020 7:58 AM
To: [redacted]
Cc: [redacted]
Subject: [redacted]

Hi [redacted],

Apologies for this. I emailed [redacted] last night to let her know that I won't be able to join. I woke up at 5 am yesterday to attend some other calls, and this morning, I had another early call that I had to attend. I was simply falling asleep last night at around 10 pm.

Can we please reschedule this introductory call? I am happy to have a chat in a week, two or more, if that will allow us to find a better time. I will be in Europe in September so we could find a more suitable time then.

In preparation for our call I have also noticed your interests in developing green ammonia pathways. Green ammonia, fertilisers and explosives are also of interest to us.

Apologies again,
Bart

From: [redacted]
Sent: Wednesday, August 12, 2020 9:34:59 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: [redacted]
Subject: [redacted]

Hi Bart,

I just wanted to let you know that I am currently logged into the link below for our meeting at 9:30 AM ET - I'll stick around for a few more minutes:

[redacted]

In case there was any misunderstanding in scheduling, please let me know and we can find another time to meet. I look forward to our discussion.

Best,
[redacted]

On Wed, Aug 5, 2020 at 8:30 AM [redacted] wrote:

> Hi Bart,
>
> Thanks for your email, and I would be delighted to chat with you further. I am CC'ing [redacted] who can help us find time.
>
> Best,
> [redacted]
>
> On Wed, Aug 5, 2020 at 3:58 AM Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au> wrote:

Dear [redacted],

By way of introduction, Fortescue Metals Group Ltd (Fortescue) is a global leader in the iron ore industry, recognised for our culture, innovation, and industry-leading development of world-class infrastructure and mining assets in the Pilbara, Western Australia.

Fortescue is one of the largest global iron ore producers and is focussed on a vision of being the safest, lowest cost, most profitable mining company. Consistently shipping around 170 million tonnes of iron ore per annum, Fortescue is the lowest cost provider of seaborne iron ore to China with revenues last year reaching US$10.0 billion and a net profit of US$3.2 billion.

In addition to growing our iron ore business, Fortescue is diversifying domestically and internationally into other mineral resources. As part of our commitment to decarbonise our operations, we are exploring various low-emission technologies.

I came across your project titled [redacted]
Would you have time for an introductory call to briefly discuss this project and its current TRL? I am available next week if this suits you.

Best regards,

Bart Kolodziejczyk

Fortescue Metals Group Ltd

Level 2, 87 Adelaide Terrace East Perth   WA 6004

Mobile: +61 437 947 164 **Web:** www.fmgl.com.au

Twitter: @FortescueNews I **www.fmgl.com.au**

Fortescue
The New Force in Iron Ore

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-4

This is the annexure marked **AIB-4** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: [redacted]
Sent: Monday, 21 September 2020 11:50 PM
To: Bart Kolodziejczyk
Cc: [redacted]
Subject: [redacted]
Attachments: [redacted]

Hi Bart,

We received a request for an NDA to begin discussions between [redacted] and Fortescue Metals. Please find our standard NDA attached for your review. If you have any questions or edits, please direct them to my attention for review.

We look forward to engaging with you and your colleagues.

Thanks,
[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-5

This is the annexure marked **AIB-5** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From:	Bart Kolodziejczyk
Sent:	Tuesday, 22 September 2020 8:28 PM
To:	Tamahra Dempsey
Cc:	Julie Shuttleworth;Emily Ward
Subject:	[redacted]
Attachments:	[redacted]

Hi Tamahra,

Under Chairman's request, I have approached a team at [redacted] to explore opportunities for [redacted] [redacted] and low-temperature oxide (predominantly iron ore) reduction technology.

Can you please email Fortescue Non-Compete NDA to [redacted]? Having a non-compete NDA in place is of the highest importance to our Chairman.

The approved purpose for this NDA would be:

[redacted]

Thank you,
Bart

From: [redacted]
Sent: Monday, 21 September 2020 11:50 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: [redacted]
Subject: [redacted]

Hi Bart,

We received a request for an NDA to begin discussions between [redacted] and Fortescue Metals. Please find our standard NDA attached for your review. If you have any questions or edits, please direct them to my attention for review.

We look forward to engaging with you and your colleagues.

Thanks,
[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-6

This is the annexure marked **AIB-6** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Tuesday, 13 October 2020 5:34 PM
To: [redacted];Emily Ward
Cc: [redacted]
Subject: [redacted]
Attachments: [redacted]

Hi [redacted],

Please find attached executed NDA. Apologies again for delays.

[redacted], would you have time for another call this or next week to discuss project(s) scope?

Best regards,
Bart

From: [redacted]
Sent: Wednesday, 30 September 2020 2:38 AM
To: Emily Ward <eward@fmgl.com.au>
Cc: [redacted]; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: [redacted]

Hi Emily,

[redacted] executed NDA attached.

Thanks,
[redacted]

[redacted]

From: Emily Ward <eward@fmgl.com.au>
Sent: Sunday, September 27, 2020 10:00 AM
To: [redacted]
Cc: [redacted]; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: RE: Confidentiality Agreement - MIT / FFI

Hi [redacted],

I have attached an updated version of our Agreement.

I have been able to accept most changes as you will see. Where a change has not been accepted, I have simply rejected the mark-up.

I will explain to our team that all correspondence and discussions will need to be prefaced with a statement or note identifying whether the contents are confidential.

Does the University have a legal entity name?

Many thanks,

Emily.

From: [redacted]
Sent: Thursday, 24 September 2020 5:56 PM
To: Emily Ward <eward@fmgl.com.au>
Cc: [redacted]; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: [redacted]

Hi Emily,

Please find my requested edits in the attached.

Thanks,
[redacted]

[redacted]

From: Emily Ward <eward@fmgl.com.au>
Sent: Wednesday, September 23, 2020 4:43 AM
To: [redacted]
Cc: [redacted]; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: [redacted]

Dear [redacted],

Further to your discussions with my colleague Bart Kolodziejczyk, please find attached a Confidentiality Agreement for your review and signature.

If you have any questions, please do not hesitate to ask.

Many thanks,

Emily Ward
Legal Manager – International Operations
Fortescue Metals Group Limited
Level 2, 87 Adelaide Terrace
East Perth WA 6004

Direct: +61 8 6218 8[redacted]
Mobile: +61 40 277 6[redacted]

Main: +61 8 6218 8888
Email: eward@fmgl.com.au

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-7

This is the annexure marked **AIB-7** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Wednesday, 21 October 2020 8:50 PM
To: [redacted]
Subject: [redacted]

Hi [redacted],

Apologies for my bad connection. Luckily, we have discussed everything regarding [redacted].

I will draft a quick overview of preliminary work that we have done in ionic liquids and low temperature iron ore reduction and share it with you shortly.

I am looking forward to receiving [redacted].

Thank you,
Bart

Get Outlook for Android

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
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ANNEXURE AIB-8

This is the annexure marked **AIB-8** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: [redacted]
Sent: Tuesday, 10 November 2020 7:27 AM
To: Bart Kolodziejczyk
Cc: Ryan Lenegan; [redacted]
Subject: [redacted]

Hi Bart,

I am glad to hear our proposed work lines up well with Fortescue's interests and ongoing efforts. Submitting 2-3 reports a year works well for us. We will have the involvement of myself (PI), a graduate student, and a postdoc. Tasks 1 and 2 will be started in Year 1 (continuing through Years 2 and 3), with efforts initiating on Task 2 in Year 2 (and continuing through Year 3). I am CC'ing [redacted] [redacted], who helps facilitate corporate partnerships for [redacted] and can help provide guidance on IP and any other topics that we need to clarify.

Best,
[redacted]

On Mon, Nov 9, 2020 at 12:52 PM Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au> wrote:

> Hi [redacted],
>
> I have reviewed your proposal. The provided proposal is clear and aligns well with what Fortescue Future Industries is looking for in terms of low-temperature [redacted].
>
> You might be aware that Fortescue is currently exploring for lithium, which adds just another degree of relevance to your proposed pathway.
>
> To move forward, I propose a milestone-based approach, where every year, project progress is evaluated and the decision made to continue or abandon the project.
>
> In terms of governance, I would like to be closely involved in the project. We would also expect two to three project progress reports per year. As mentioned before, your two-step approach fits very well with our internal endeavours, where Fortescue develops a new type of electrolyser which could be integrated with your [redacted].
>
> I've got only two questions related to your proposal:

- Can you please clarify how many researchers will be involved in this project and their research seniority (PI, Postdoctoral researcher, Ph.D. student, etc.)?
- Will all three proposed tasks be undertaken simultaneously or one at a time?

I have CC'ed Ryan who will help to agree on T&Cs for this project including IP ownership.

Best regards,

Bart

From: [redacted]
Sent: Wednesday, 28 October 2020 12:39 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: [redacted]

Hi Bart,

I hope your travels are going well. I wanted to share with you a first draft of the proposal on [redacted]. It would be great to hear your feedback and thoughts, based on which we can make modifications.

The only prior IP we have in this space is a patent on [redacted]. This was supported by the National Science Foundation and our own department's internal funds, so there are no restrictions on licensing by Fortescue.

I look forward to continuing our discussions.

Best,

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
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Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-9

This is the annexure marked **AIB-9** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Thursday, 10 December 2020 6:13 AM
To: Michael Masterman;Julie Shuttleworth;Michaela Johnstone
Subject: Re: [redacted] - Call with CEOhop

B

Get Outlook for Android

From: Michael Masterman <mmasterman@squadronenergy.com>
Sent: Thursday, December 10, 2020 5:15:35 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Julie Shuttleworth <jshuttleworth@fmgl.com.au>; Michaela Johnstone <mjohnstone@fmgl.com.au>
Subject: RE: [redacted]- Call with CEOhop

Bart
Got it – remember you explaining to me (the Bjorn had me thinking Sweden and Abba)
Agree could be a great fit
I will give him a call – what is his mobile

M

Michael Masterman

SQUADRON ENERGY

M +61 429 957 831
P +61 8 6460 4949
E mmasterman@squadronenergy.com

PO Box 3155, Broadway Nedlands
WA 6009 Australia
squadronenergy.com

A company of Tattarang

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Wednesday, 9 December 2020 10:23 PM
To: Julie Shuttleworth <jshuttleworth@fmgl.com.au>; Michael Masterman <mmasterman@squadronenergy.com>; Michaela Johnstone <mjohnstone@fmgl.com.au>
Subject: RE: [redacted] - Call with CEOhop

Hi Michael,

Bjorn is currently semi-retired and living in Thailand. Him and his wife had to take care of his wife's niece and adopt her. Until recently, he was working part-time as a professor at Waseda University in Tokyo and travelled back and forth every three months. After a couple of years of living in Thailand, they are ready to move back to Australia. He is an Australian citizen and can move back as quickly as 3+ months.

Bart

From: Julie Shuttleworth
Sent: Wednesday, 9 December 2020 5:47 PM
To: Michael Masterman <mmasterman@squadronenergy.com>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Michaela Johnstone <mjohnstone@fmgl.com.au>
Subject: RE: [redacted] - Call with CEOhop

Bart
Please answer MM's query. Is Bjorn in Singapore.?

From: Michael Masterman <mmasterman@squadronenergy.com>
Sent: Wednesday, 9 December 2020 4:49 PM
To: Julie Shuttleworth <jshuttleworth@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Michaela Johnstone <mjohnstone@fmgl.com.au>
Subject: RE: [redacted]- Call with CEOhop

Julie
Ok we will action

Where is Bjorn based?   We do need to bring the technical team together – initially in Perth

Happy to give him a call

Will bring Aaron on a contract basis.

Michael

Michael Masterman

SQUADRON ENERGY

M +61 429 957 831
P +61 8 6460 4949
E mmasterman@squadronenergy.com

PO Box 3155, Broadway Nedlands
WA 6009 Australia
squadronenergy.com

A company of Tattarang

From: Julie Shuttleworth <jshuttleworth@fmgl.com.au>
Sent: Wednesday, 9 December 2020 6:47 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Michaela Johnstone <mjohnstone@fmgl.com.au>; Michael Masterman <mmasterman@squadronenergy.com>
Subject: FW: [redacted] - Call with CEOhop

Hi Bart and Michael

Just answering this email. Happy for you to proceed with Aaron, since you have already done the interview.

I am also happy for you to bring Bjorn on board, once Michael has had a quick interview with him to check FFI values. Michael, Paul Scott and Cameron have offered to join the call if you want either of them to do so. Otherwise, happy for you to have this chat by yourself MM.

We are recruiting for a Manufacturing Manager, however that may take 2 months until onboard. Therefore, I am happy for these two new positions to temporarily report to Michael. Bart and Michael we will involve you in the interviews for that position.

Does that work for everyone? Happy for any other ideas.

Will have a call on manufacturing next week when I am in quarantine, and make sure we really get this cranked up. Having a good discussion on the plane now with Rod, Paul S and Rod.

Cheers
Julie

Julie Shuttleworth

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Monday, 7 December 2020 10:50 AM
To: Julie Shuttleworth <jshuttleworth@fmgl.com.au>
Cc: Michael Masterman <mmasterman@fmgl.com.au>; Michaela Johnstone <mjohnstone@fmgl.com.au>
Subject: RE: [redacted]- Call with CEOhop

Hi Julie,

We've already got your support. That's super helpful.

Please find attached CVs of Aaron and Bjorn.

Bjorn is my PhD supervisor, who is semi-retired and currently in Thailand. He is probably the best electrochemist I know. His involvement in this would be essential. He is also very hands-on, and I have already discussed it with him without revealing too many details. Before he got his PhD, Bjorn has developed several processes which are deployed commercially. Same time, Bjorn would probably have to report to Michael M, Paul Scott, or someone else.

Best regards,
Bart

From: Julie Shuttleworth
Sent: Monday, 7 December 2020 10:43 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: Michael Masterman <mmasterman@fmgl.com.au>; Michaela Johnstone <mjohnstone@fmgl.com.au>
Subject: Re: [redacted] - Call with CEOhop

Hi team

Please proceed with high speed on this

Please get Michaela In the loop so we can get it organised.

Please send me his CV.

What else do you need from me?

Thanks
Julie

Julie Shuttleworth
Fortescue Metals Group
Fortescue Future Industries
+61 439918677

On 6 Dec 2020, at 19:43, Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au> wrote:

Hi Julie,

I agree with Michael. We will need someone to drive this while we do 100s other things and having a quick chat with Aaron. He seems like a great candidate.

Aaron is currently in the process of getting our NDA signed. We will have a more detailed follow-up call with him, but getting him on board asap would definitely help and take some of the work burden from us.

Bart

From: Michael Masterman
Sent: Monday, 7 December 2020 9:35 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Julie Shuttleworth <jshuttleworth@fmgl.com.au>
Subject: RE: [redacted] - Call with CEOhop

Julie
We need someone practical who has a can do attitude and is great at setting up mechanical and material operations.

Bart and I have spoken to Aaron Szumilak (Polish background born in Canada) who worked on the Iron Bridge project and was pivotal in making the HPGR work and overall project innovation. Paul Scott has had a look at the resume. He knows the FMG/FFI values.

He is also very practical and frugal and can work with speed. (not recommending it but he could probably weld up the [redacted]pod we saw [redacted] and get the kiln brick installation going before [redacted] close their term sheet)

Andrew is agitating on all this work. If we bring Aaron on with a contract we can get the arms and legs to start the process.

Michael

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Sunday, 6 December 2020 7:22 PM
To: Andrew Forrest - [redacted]; Michael Masterman <mmasterman@fmgl.com.au>; John Paul Olivier <jolivier@fmgl.com.au>
Cc: John Hartman <jhartman@tattarang.com>; Julie Shuttleworth <jshuttleworth@fmgl.com.au>; Alan Krause <akrause@fmgl.com.au>
Subject: RE: [redacted]- Call with CEOhop

Hi Andrew,

I am in Malaysia and this is exactly what I am doing this week while in quarantine.

We will do it better. It will be low-temperature processing from ionic liquids.

Bart

From: Andrew Forrest - [redacted]
Sent: Saturday, 5 December 2020 11:44 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Michael Masterman <mmasterman@fmgl.com.au>; John Paul Olivier <jolivier@fmgl.com.au>
Cc: John Hartman <jhartman@tattarang.com>; Julie Shuttleworth <jshuttleworth@fmgl.com.au>; Alan Krause <akrause@fmgl.com.au>
Subject: Re: [redacted]- Call with CEOhop

Bart

So set up a decent testing facility in Perth and properly prove or disprove the concept so I can set up a steel manufacturing facility.

A

Sent via BlackBerry Hub+ Inbox for Android

Andrew Forrest

From: bkolodziejcz@fmgl.com.au
Sent: 4 December 2020 15:01
To: mmasterman@fmgl.com.au; jolivier@fmgl.com.au; [redacted]
Cc: jhartman@tattarang.com; jshuttleworth@fmgl.com.au; akrause@fmgl.com.au
Subject: RE: [redacted] - Call with CEO

Hi Michael,

The idea makes sense. Having one step-process which can be easily controlled by tunning applied voltage is definitely preferred over solid-state reduction using green hydrogen or ammonia. It merely makes it easier and potentially cheaper.

In terms of energy intensity, the process uses roughly 4 MWh/tonne of steel. Hence, with 500 MW of hydropower and uninterrupted operation, we would get nearly 1.1 million tonnes of steel per year. While it seems not much, we need to remember that there is a reason why steelmaking is one of the major contributors to global carbon emissions, contributing roughly 7% of global CO2 emissions. The steelmaking process is very energy-intensive. The energy contained in coal used to process iron ore via traditional pathways contains around 5.3 MWh/tonne of steel. On average 0.8 tonnes of coal is used to produce 1 tonne of steel.

Bart

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-10

This is the annexure marked **AIB-10** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Tuesday, 15 December 2020 10:58 AM
To: Andrew Forrest - ([redacted]);Michael Masterman;John Hartman
Cc: John Paul Olivier
Subject: [redacted]

Andrew, this is exactly what will keep us busy in 2021. We are getting our manufacturing and R&D facilities set up and this work will proceed shortly.

Same time I agree with Michael. We need to look at both hydrogen and ammonia. To convert existing blast furnaces. Green ammonia can be used a carbon-free reductant and it is easier to ship than hydrogen.

Bart

From: Andrew Forrest - [redacted]
Sent: Tuesday, 15 December 2020 10:55 AM
To: Michael Masterman <mmasterman@squadronenergy.com>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; John Hartman <jhartman@tattarang.com>
Cc: John Paul Olivier <jolivier@fmgl.com.au>
Subject: [redacted]

Or build our own mini plant in Freo and shortly after a commercial scale pilot plant in Port Hedland.

Sent from my BlackBerry — the most secure mobile device

Andrew Forrest

From: mmasterman@squadronenergy.com
Sent: 15 December 2020 11:53
To: bkolodziejcz@fmgl.com.au; jhartman@tattarang.com; [redacted]
Cc: jolivier@fmgl.com.au
Subject: [redacted]

We probably also need to understand how a steel mill like Posco would practically use H2 as a reductant to replace coking coal in a sinter furnace or blast furnace

Might be smoking drugs but is there anything we could do at the Bluescope steel works at Port Kembla

M

Michael Masterman

SQUADRON ENERGY

M +61 429 957 831
P +61 8 6460 4949
E mmasterman@squadronenergy.com

PO Box 3155, Broadway Nedlands
WA 6009 Australia
squadronenergy.com

A company of Tattarang

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Tuesday, 15 December 2020 1:46 PM
To: Michael Masterman <mmasterman@squadronenergy.com>; John Hartman <jhartman@tattarang.com>; Andrew Forrest - [redacted]
Cc: John Paul Olivier <jolivier@fmgl.com.au>
Subject: [redacted]

Hi Michael,

Sounds good. We'll do it at low temperature using ionic liquids as iron ore solvents. Low temperature electrochemical reduction will allow us to switch on and off our "iron ore electrolyser" within seconds or minutes and as such we will be able to operate with highly intermittent power supply like wind and solar.

[redacted]

I am available any time this week.

Bart

From: Michael Masterman <mmasterman@squadronenergy.com>
Sent: Tuesday, 15 December 2020 10:40 AM
To: John Hartman <jhartman@tattarang.com>; Andrew Forrest - ([redacted])
<[redacted]>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: John Paul Olivier <jolivier@fmgl.com.au>
Subject: [redacted]

Will keep to ourselves

JP, Bart
Lets have a call on expediting Green Steel (as you can imagine its on the top of Andrews priority list)

M

Michael Masterman

SQUADRON ENERGY

M +61 429 957 831
P +61 8 6460 4949
E mmasterman@squadronenergy.com

PO Box 3155, Broadway Nedlands
WA 6009 Australia
squadronenergy.com

A company of Tattarang

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-11

This is the annexure marked **AIB-11** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ……………………

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FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-12

This is the annexure marked **AIB-12** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Tuesday, 22 December 2020 10:06 AM
To: 'Andrew Forrest';Michael Masterman
Subject: RE: The batteries that could make fossil fuels obsolete - BBC Future

I will do my best, Andrew.

By May, we will definitely have a good idea and a working prototype in our Perth facility. Having a large(er) commercial-scale plant in Pilbara by June 30 might be very challenging. Anyway, challenge accepted.

On the same note, I am currently working on a patent application for our low-temperature electrochemical ores reduction in ionic liquid electrolytes.

This patent application is based on my initial work done a couple of years ago, where I have managed to produce iron from iron oxides, copper from copper complexes, and nickel from nickel oxides. I would like Michael and you to be listed as co-inventors. We wouldn't be doing this work if not for your push. Are you ok with being on that patent?

Bart

From: Andrew Forrest
Sent: Tuesday, 22 December 2020 9:55 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Michael Masterman <mmasterman@squadronenergy.com>
Subject: Re: The batteries that could make fossil fuels obsolete - BBC Future

Well done and thank you.

I need you testing in the Pilbara before June 30 Bart.

A

Sent from my BlackBerry — the most secure mobile device

From: bkolodziejcz@fmgl.com.au
Sent: 22 December 2020 9:06 am
To: [redacted]; mmasterman@squadronenergy.com
Subject: RE: The batteries that could make fossil fuels obsolete - BBC Future

Hi Andrew,

I think batteries have a role to play.

Michael M and I looked at battery ships to send electricity from Pilbara to Japan (and elsewhere) directly in the form of electricity contained in batteries on a vessel. Batteries are so heavy and bulky that using the best batteries today, we would be able to ship only 9% of the energy per shipment compared to energy contained in today's LNG shipping vessels.

Highest performing batteries today are lithium-sulfur batteries. Their energy densities reach 0.55 kWh/L, and specific energy is in the range of 0.5 kWh/kg. For comparison, liquid hydrogen is 2.7 kWh/L and 39.4 kWh/kg. Ammonia gives 3.2 kWh/L and 5.1 kWh/kg.

Batteries will be used for stationary energy storage. Hydrogen and ammonia will be used to ship energy globally.

We are very happy to be out with families.

Very busy 2021 ahead we will be doing work over Christmas to establish our Perth manufacturing in early 2021. We need to have working electrolysers and low-temperature electrochemical iron ore processing plants. Testing in Pilbara to commence in late 2021.

Bart

From: Andrew Forrest
Sent: Monday, 21 December 2020 8:04 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Michael Masterman <mmasterman@squadronenergy.com>
Subject: The batteries that could make fossil fuels obsolete - BBC Future

"The batteries that could make fossil fuels obsolete - BBC Future"
https://www.bbc.com/future/article/20201217-renewable-power-the-worlds-largest-battery

Trust you guys are enjoying some super well deserved freedom. Love to both of you and your families.

A

Sent via BlackBerry Hub+ Inbox for Android

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-13

This is the annexure marked **AIB-13** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From: Bart Kolodziejczyk
Sent: Tuesday, 22 December 2020 4:08 PM
To: Robert Grant
Subject: Low-temperature electrochemical ores reduction in ionic liquids
Attachments: 22122020 Patent Assessment Form (Electrochemical ore reduction).pdf

Hi Rob,

I hope you're doing well. I have attached a patent assessment form for the intended patent application covering low-temperature electrochemical ores reduction in ionic liquids. Applying Fortescue stretch targets, we are aiming to test it in Pilbara by June 30, 2021.

The technology is proven. I have developed this method and tested it in a small scale laboratory setting before. Now we need to scale it up and couple it with a green power source.

If you don't have any comments, can you please approve the form? I will be working over Christmas to finalise a draft for this application.

Bart

Bart Kolodziejczyk
Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace East Perth WA 6004

Mobile: +61 437 947 164 **Web:** www.fmgl.com.au
Twitter: @FortescueNews I **www.fmgl.com.au**

INTELLECTUAL PROPERTY TEAM **100-FR-LE-0003**

PATENT ASSESSMENT FORM

PURPOSE

The purpose of this form is to assist Fortescue's personnel to determine whether or not an invention or innovation should be patented.

The information in this document is strictly private and confidential and must not be publicly disclosed until a patent application has been filed or a decision has been made not to seek patent protection.

The Guidance Notes at the back of this form provides additional information in relation to some of the items.

INVENTION DETAILS

Inventor's Name (Guidance Note 1)	Bartlomiej Piotr KOLODZIEJCZYK
Inventor's Manager's Name	Robert GRANT
Department	Fortescue Future Industries
Title of Invention	Low-temperature Electrochemical Ore Reduction
Summary of Invention	The invention revolves around the use of ionic solvents and electrochemical devices for the low-temperature reduction of ores and oxides, including but not limited to iron ores and nickel ores. Careful selection of ionic liquid or mixture of ionic liquids allows to dissolve ores at low-temperatures. The electrochemical window of ionic liquid or ionic mixtures is selected so that the applied electrochemical potential required to reduce ores does not damage the ionic electrolyte.
Benefit of Invention (Guidance Note 2)	Today's steelmaking accounts for roughly 6 - 7% of global carbon dioxide emissions. Steelmaking processes require the use of coal as an iron ore reductant. Decarbonisation of this process would significantly reduce global carbon dioxide emissions while creating a new commodity – green steel. Proposed carbon-free alternatives are complex and require a multi-step approach, where green hydrogen or green ammonia are used as reductants. In addition, thermochemical processes tend to operate at high temperatures and are challenging to sustain using an intermittent power supply, like wind or solar energy. The low-temperature one-step electrochemical process would overcome those limitations by providing modular and scalable approaches that could operate with a higher degree of flexibility than intermittent renewable energy sources.
Specific Inventive Element (Guidance Note 3)	There are a couple of inventive steps to this process. Firstly, ionic liquids, their mixtures, and composition ratio are innovative. The application of ionic liquids in metal oxide reduction is innovative by itself. In addition, the selection of electrode materials and cell design are novel and unique.
What is the Status of the Invention? Has it been Designed? Constructed? Tested? Used?	The concept has been tested in a laboratory setting and is intended to be scaled up to a commercial system in 2021.
Any Other Comments	NA

Inventor's Email Address	bkolodziejcz@fmgl.com.au, kolodziejczyk.bartlomiej@gmail.com
Inventor's Mobile Phone Number	+61 416 833 585, +61 437 947 164
Date	22/12/2020

PATENT ASSESSMENT

Patents

A patent is a legally enforceable right for a device, substance, method or process. A patent gives Fortescue the right to stop others from using the invention without Fortescue's permission.

When granted, a patent will give Fortescue exclusive commercial rights to the invention for 20 years for a standard patent, or 8 years for an innovation patent.

To be patentable, an invention must be new, useful and inventive or innovative.

Prior to filing the patent application, the invention must be kept confidential. If the invention is disclosed to the public or commercially used before a patent application is filed, there is a risk that the patent will not be granted. If disclosure is required to a third party, the IP Team can assist you to put in place a confidentiality agreement to ensure that information about the invention is kept confidential.

Fortescue has access to an international patent search database and is able to carry out searches to ensure that the invention is not already covered by another patent. Please request the IP Team to carry out searches if you are unsure if the invention is new.

As a general estimate, the initial cost of applying for a patent are in the range of $6,000 to $9,000 with maintenance and ancillary costs bringing the total cost over a five year period up to $30,000 depending on the particular circumstances.

Key Considerations

If in your view the invention or innovation is patentable, the following must be considered:

- what is the objective of protecting the invention? For example:
  - to obtain a commercial advantage over Fortescue's competitors because:
    - the invention improves Fortescue's efficiency/productivity;
    - the invention reduces Fortescue's costs; or
    - the invention may be used in negotiations with a third party to gain another advantage;
  - to commercialise the invention and create a financial return for Fortescue (i.e., through licensing or sale of technology);
  - to ensure Fortescue has the freedom to use and operate that invention without restriction; or
  - to create marketing or business development benefits for Fortescue.
- do the benefits of patent protection outweigh the time, effort and cost (including filing and maintenance costs of the patent) required to file and maintain the patent?

INVENTOR'S DECLARATION

- I have reviewed and considered the information provided in this Patent Assessment Form and in my view the invention should be considered for patent protection by Fortescue's IP Team.
- I acknowledge and agree that the invention and the patent are the sole and exclusive property of Fortescue Metals Group.

What is the objective of patenting the invention?	The objective is to protect the initial invention and enable further scale-up and commercial deployment in Pilbara and elsewhere.

Do the benefits of patenting the invention outweigh the time, effort and costs?	No, the production of green metals, including green iron, green steel, green nickel, and green copper, among other metal commodities, is at the core business of Fortescue Future Industries. Protecting this development will give FFI a competitive advantage in this growing industry space.
Are searches required of the patent database? If yes, please provide search terms and the countries which the searches should cover (i.e., **"remote dozing" in Australia**) **(Guidance Note 4)**	Patent searches have been performed, and search results will be presented in a longer write up. Technology that is similar to the current proposal is that of Boston Metal, a spin-off from MIT. The difference is that Boston Metal technology uses molten oxide electrolyte and operates at very high temperatures, up to 1,500 ^{o}C.
Has this invention been discussed with others? If yes, with whom? Was the invention developed in co-operation or collaboration with outside parties? If yes, please give details of any such parties.	No
Has the invention or information relating to the invention been made publically available or disclosed to third parties? If so, please provide details of the disclosure. **(Guidance Note 5)**	No, invention has not been publicly disclosed. All information related to this invention is kept internally within Fortescue Future Industries.
Inventor's Name	Bartlomiej Piotr KOLODZIEJCZYK
Inventor's Signature	Bartlomiej Kolodziejczyk
Date	22/12/2020
Inventor's Manager's Name	Robert GRANT
Inventor's Manager's Signature	
Date	

NEXT STEPS

If you consider that the invention or innovation should be patented, please complete this Patent Assessment Form and submit it to Fortescue's IP Team at the following email address: ip@fmgl.com.au

If you have any queries, please do not hesitate to contact Simon Yamchikov on 0428 164 830 or ip@fmgl.com.au

GUIDANCE NOTES

1. **Inventor's Name:** There can be more than one inventor. If contractors or consultants have been involved with the invention, please make a note of this as well the role which they have played. If the consultant or contractor was engaged under an agreement, please provide details of that agreement.

2. Benefit of Invention: The benefits of the invention are not limited to being financial benefits or cost savings. The benefits of the invention can include safety improvements, the potential to use the intellectual property as bargaining power with another supplier or to gain an advantage over a competitor.
3. Specific Inventive Element: What inventive or innovative feature of the device, substance, method or process distinguishes the invention from existing devices, substances, methods or processes? The inventive element might be a structural feature or a function of the invention or it may be a number of different features, improvements or modifications.
4. Searches: In order to be patentable, the invention must be new. The IP Team can carry out patent searches to ensure that the invention is new when compared with the prior art base and has not been previously patented.
5. Public Disclosure: Disclosure includes contractors inspecting the invention, Fortescue discussing the invention at a presentation or providing information in a publically available document. All communication should be carefully managed and confidentiality agreement should be used wherever possible to ensure that the invention is not disclosed to the public prior to the filing of the patent.

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-14

This is the annexure marked **AIB-14** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ……………………………

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Wednesday, 23 December 2020 8:20 AM
To: Julie Shuttleworth
Subject: RE: green steel plant Pilbara

Hi Julie,

Sure. It would be great to have a presentation or a pitch deck.

I will ask Chloe to work on this. Her economics background, together with what she has learned during our trips, should be good enough to do this task. I will work with Chloe to make sure that everything is aligned with Fortescue's vision.

We are proposing the development of two green steel technologies. One will be low-temperature electrochemical ore reduction in ionic liquids. The second one will be the electrolysis of iron ore in molten carbides. I am drafting R&D roadmaps for both of those technologies. Those roadmaps and write-ups will subsequently be used for patent applications.

I will give you a call later today to quickly discuss how we can try something up to scale in Pilbara by June 30, 2021. We need to get equipment for our manufacturing and R&D facility, and we don't have time to wait. My idea is to start getting chemicals, flasks, and other R&D equipment even before our facility is established. I will work with procurement on this. So that by the end of January, we can start hands-on work.

Bart

From: Julie Shuttleworth
Sent: Tuesday, 22 December 2020 8:48 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: RE: green steel plant Pilbara

Hi Bart
Thanks for the info.
Only a few days ago Andrew again mentioned doing green steel in the Pilbara. He is asking [redacted] and others if they want to partner with us to do green steel in the Pilbara.

I still think we need to follow up and get some slides together with numbers etc.
I can ask Rob Grant to find someone to get onto this if you don't have time, I know you have a lot of things on

Let me know, and feel free to call if you wish

Regards
Julie

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Monday, 21 December 2020 10:09 AM
To: Julie Shuttleworth <jshuttleworth@fmgl.com.au>
Subject: RE: green steel plant Pilbara

Hi Julie,

Michael and I have had a number of calls with Andrew on this. Hence, I have assumed that this was closed.

[redacted]

We are getting NDAs signed with [redacted] and [redacted] to understand CAPEX and OPEX of hydrogen-powered DRI plants. Also, something to have in mind is that our ores probably have too high silica content to work with DRI. Once, NDAs are signed we will ship our ores to [redacted] and [redacted] for trials.

Bart

From: Julie Shuttleworth
Sent: Saturday, 19 December 2020 2:43 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: green steel plant Pilbara

Bart
Just going through some older emails

The below in yellow. What help do you need with this?
Don't want you to think you havre to do this one all by yourself.

Cheers
Julie

From: Andrew Forrest (Minderoo) [redacted]>
Sent: Sunday, 15 November 2020 3:59 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Julie Shuttleworth <jshuttleworth@fmgl.com.au>
Subject: Fw: Shared from BBC:The new fuel to come from Saudi Arabia

Bart your views please.

This is similar to what we are going to do in the Pilbara right?

Bart

IF you can find the time...

I need you to do a quick scoping study on making our own steel in Port Headland please.

I want a rough idea on capex and open per million tonnes produced.

Aiming for a [redacted] plant.

Are you up for it?

A

Sent from my BlackBerry — the most secure mobile device

From: chasbrooke@runbox.com
Sent: 14 November 2020 14:38
To: [redacted]
Subject: Shared from BBC:The new fuel to come from Saudi Arabia

https://www.bbc.com/future/article/20201112-the-green-hydrogen-revolution-in-renewable-energy?ocid=ww.social.link.email

A
I am sure you have probably read this !
all the best and safe travels
Charlie
Kind regards
Charlie
Sent from my iPhone

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-15

This is the annexure marked **AIB-15** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From:	Bart Kolodziejczyk
Sent:	Wednesday, 6 January 2021 2:15 PM
To:	Chris Mcmahen;John Paul Olivier;Michael Masterman
Cc:	Danny Goeman
Subject:	RE: Report from [redacted]

Hi Chris,

Thank you for sharing this draft. It provides some valuable insights into the MOE process.

We are currently developing an R&D roadmap where a number of challenges outlined in this report will be addressed. The major challenge is MOE's high operating temperature, which requires specialised materials, often based on noble and expensive metals. The system's high thermal inertia is also a challenge when running the MOE process with highly intermittent wind and solar power supply.

[redacted]

In our development, we are looking at using solvents capable of dissolving iron ore at low temperatures < 300 deg C and/or using molten carbonate electrolyte, which would allow the dissolution of iron ore at temperatures ranging between 700 and 800 deg C. Same time allowing to use less exotic and less expensive materials and making the entire process more compatible with intermittent power supply. Same time we are open to testing MOE too.

Based on your description, Joe seems like a valuable potential employee. However, I know too little about your previous engagement to be able to comment on any future engagement with Joe.

[redacted]

Best regards,
Bart

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-16

This is the annexure marked **AIB-16** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From: Bart Kolodziejczyk
Sent: Wednesday, 6 January 2021 2:39 PM
To: Shanta Barley
Subject: RE: [redacted]

Hi Shanta,

We are working internally at Fortescue on alternative processes that would utilise lower temperatures and direct electrochemical reduction of iron ore into iron and further steel.

The electrochemical reduction is done in a liquid phase. Hence iron ore has to be dissolved in the electrolyte prior to being electrolysed. High temperature helps iron ore dissolution but poses certain technical challenges, especially when running the intermittent power supply process. With the intermittency of wind and solar energy supply, it becomes challenging to maintain the high temperature of the process.

We are working to overcome this issue.

Other than the above, I am not aware of alternatives.

As we have discussed before, we could use green hydrogen as an iron ore reductant instead of using coal as a reductant (traditional steel making process uses coal). But this is different from using direct current.

Bart

From: Shanta Barley <sbarley@minderoo.org>
Sent: Wednesday, 6 January 2021 2:17 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: [redacted]

Dear Bart,

I was wondering if you know of a good alternative to [redacted] for the sentence below:

[redacted] to turn iron oxide into steel. This is a radical step change that does away, not only with coal, but with blast furnaces.

Thanks!
Shanta

Shanta Barley
Minderoo Foundation • Research

M +61 439 485 [redacted]
P +61 8 6460 4949
E sbarley@minderoo.org
L Perth (GMT+8)

PO Box 3155, Broadway Nedlands
WA 6009 Australia
minderoo.org/research

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-17

This is the annexure marked **AIB-17** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Friday, 22 January 2021 11:41 AM
To: Ashlee Crabbe;Chris Mcmahen;Geoff Beros
Cc: Danny Goeman;Alison Terry;Stephanie Vanicek;Julie Shuttleworth
Subject: RE: For review: Media enquiry AFR green steel pilot

Hi Ashlee,

The way I interpret Chairman's Boyer Lecture is that Fortescue is interested in exploring green steel opportunities. Production of green steel would be a natural extension to our vertically integrated value chain and fits well with Fortescue's decarbonisation strategy.

In terms of a pilot plant in Pilbara, the lecture does not talk about that plant's size. It could be 10 tonnes/day, but it could be 100 kg/day. We are exploring various existing technologies, but we are also developing internally enabling technologies for iron ore processing to produce green commodities.

It is going to be a small scale pilot plant.

As discussed over the phone, please find links to four existing technologies that use hydrogen as a green reductant for iron ore processing.

https://www.thyssenkrupp-steel.com/en/company/sustainability/climate-strategy/

https://www.hybritdevelopment.com/

https://www.midrex.com/technology/midrex-process/midrex-h2/

https://www.energiron.com/hydrogen/

Internally, we are developing a process that will allow us to take green electricity produced from wind, solar, hydropower, etc., and apply this green electricity to electrochemically reduce Fortescue's iron ore dissolved in a unique electrolyte. In other words, green electricity will be used to separate oxygen from iron. The selection of electrolyte, electrode material, and other materials used in the process is proprietary, and at this point, Fortescue's trade secret. In the future, we are aiming to file a series of patents covering this development.

[redacted]

Please let me know if this explanation is suitable? I am happy to provide feedback on your reply draft.

Bart

From: Ashlee Crabbe
Sent: Friday, 22 January 2021 10:28 AM
To: Chris Mcmahen <cmcmahen@fmgl.com.au>; Geoff Beros <gberos@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: Danny Goeman <dgoeman@fmgl.com.au>; Alison Terry <aterry@fmgl.com.au>; Stephanie Vanicek <svanicek@fmgl.com.au>
Subject: RE: For review: Media enquiry AFR green steel pilot

Hi all,

Are you please able to give an estimate of when I can get any info on this, or if it is available?

We have had a follow up from the journalist and I need to run any information past Elizabeth for approval asap.

Kind regards
Ashlee

From: Ashlee Crabbe
Sent: Friday, 22 January 2021 8:58 AM
To: Chris Mcmahen <cmcmahen@fmgl.com.au>; Geoff Beros <gberos@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: Danny Goeman <dgoeman@fmgl.com.au>
Subject: RE: For review: Media enquiry AFR green steel pilot

Thank you all

From: Danny Goeman <dgoeman@fmgl.com.au>
Sent: Friday, 22 January 2021 8:57 AM
To: Ashlee Crabbe <acrabbe@fmgl.com.au>
Cc: Geoff Beros <gberos@fmgl.com.au>
Subject: RE: For review: Media enquiry AFR green steel pilot

Hi Ashlee

Yes, this information is even available on the internet. Perhaps best to coordinate with Geoff/Chris/Bart - they are the technical experts.

Danny

From: Ashlee Crabbe <acrabbe@fmgl.com.au>
Sent: Friday, 22 January 2021 8:53 AM
To: Danny Goeman <dgoeman@fmgl.com.au>
Cc: Chris Mcmahen <cmcmahen@fmgl.com.au>; John Paul Olivier <jolivier@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; John Paul Olivier <jolivier@fmgl.com.au>; Alison Terry <aterry@fmgl.com.au>; Stephanie Vanicek <svanicek@fmgl.com.au>; Ben Kuchel <bkuchel@fmgl.com.au>
Subject: RE: For review: Media enquiry AFR green steel pilot

Thanks Danny,

I think what Brad is hoping to receive, is some basic information about how the processes work for people (like me) who aren't across the technical process.

Are there any summaries available on these two processes?

Ash

From: Danny Goeman <dgoeman@fmgl.com.au>
Sent: Friday, 22 January 2021 8:52 AM
To: Ashlee Crabbe <acrabbe@fmgl.com.au>
Cc: Chris Mcmahen <cmcmahen@fmgl.com.au>; John Paul Olivier <jolivier@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; John Paul Olivier <jolivier@fmgl.com.au>; Alison Terry <aterry@fmgl.com.au>; Stephanie Vanicek <svanicek@fmgl.com.au>; Ben Kuchel <bkuchel@fmgl.com.au>
Subject: RE: For review: Media enquiry AFR green steel pilot

Hi Ashlee,

What Andrew is referring to here is (i) reducing/removing coal in the steel making process in the BF and replacing it with hydrogen, and (ii) direct reduction of iron ore by using electricity to create steel. We don't have an agreed commercial design/solution on how to achieve either at this stage. That said, we are engaging/collaborating with a number of parties in the steel making industry and elsewhere to pursue solutions.

Chris/Geoff/Bart (copied) are across the details of discussions/progress to date, but I am not sure we necessarily want to reveal who we are engaging - for obvious reasons. Between Bart/Chris/Geoff we can dig up some high-level generic information to explain the concepts.

Regards,

Danny

From: Ashlee Crabbe <acrabbe@fmgl.com.au>
Sent: Friday, 22 January 2021 8:42 AM
To: Geoff Beros <gberos@fmgl.com.au>; Danny Goeman <dgoeman@fmgl.com.au>
Cc: Alison Terry <aterry@fmgl.com.au>; Stephanie Vanicek <svanicek@fmgl.com.au>
Subject: For review: Media enquiry AFR green steel pilot

Hi Geoff and Danny,

Following our Chairman's Boyer Lecture last night, Brad Thompson from the Australian Financial Review has asked us for background information on the two green steel processes Andrew referenced in the speech.

Do we have any background information to hand, which I could edit and provide to the AFR?

> From the Chairman's speech, there are two ways:
>
> - In one, you replace coal in the furnace with green hydrogen. You get steel – but instead of emitting vast clouds of CO2, you produce nothing more than water vapour.
>   To strengthen the steel, you simply add the carbon separately. It bonds into the metal rather than dispersing into the atmosphere.
> - The other way to make green steel is to scrap the blast furnace altogether and just zap the ore with renewable electricity.

Brad is working to an East Coast deadline for the AFR, so would be great to get this as soon as possible. Please feel free to call me for further clarification 0439 941 [redacted].

Thank you
Ashlee

Ashlee Crabbe

Senior Media and Corporate Affairs Specialist
Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace East Perth WA 6004

Phone: +61 8 2930 1855 | **M:** 0439 941 [redacted]

E: acrabbe@fmgl.com.au

Twitter: @FortescueNews I **www.fmgl.com.au**

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-18

This is the annexure marked **AIB-18** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From: Bart Kolodziejczyk
Sent: Wednesday, 27 January 2021 5:29 PM
To: bjorn winther-jensen
Subject: RE: Out of quarantine yet ?

Hi Bjorn,

Yes, we've got money for R&D. Additional, [redacted] will go towards scale up and pilot plant.

Yes, I have read many of those NaOH papers. Another option, potentially in the future would be using molten carbonate or ionic liquids.

Do you want to have a call to discuss this, this or next week? It is much easier than emails.

Also apologies for late reply, I am swamped with "urgent" emails.

Talk soon,

Bart Kolodziejczyk
Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace East Perth WA 6004

Mobile: +61 437 947 164 **Web:** www.fmgl.com.au
Twitter: @FortescueNews I **www.fmgl.com.au**

From: bjorn winther-jensen <bjornwj@gmail.com>
Sent: Sunday, 24 January 2021 5:33 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: Out of quarantine yet ?

Hi Bartek,

Are you guys out of the quarantine ?
(Maybe the real question is if you are back to "normal" work tomorrow ?)

You wrote: "the idea is to ask for [redacted] for green steel R&D and a pilot project in Pilbara". Are there any decisions made for a plan regarding this ?
I understand the need for doing/achieving something fast (pilot project) and on the other hand I see the need for "buying" a fair bit of time for R&D.
So, here is a suggestion (although that I should not involve myself in politics...):
The most obvious possibility, I think, to do something (meaningful) fast is to suggest that the pilot project should be on solid state electrochemical reduction of magnetite from the Iron Bridge site. The product coming out of Iron Bridge is expected to be (in press releases etc.) 67% Fe. When water/moisture is subtracted that means almost pure Fe_3O_4. In other words, the electrochemical process does not need to include removal of other oxides - and can

therefore be a solid state process. The conductivity of magnetite is relatively high (compared to other iron oxides), which will also be an advantage to a solid state process.
There are numerous reports on performing such solid state electrochemical reduction in concentrated NaOH (which suppress the hydrogen evolution and also means that the same anode material intended for electrolysis can be used here). Potentials below 2V at reasonably high current densities have been achieved at around 100 degC (which suppress/eliminate the crossover reaction from dissolved oxygen).
Getting that going could (maybe) allow some time to find some smarter approaches to tackle hematite - which understandably is the higher aim.
This suggestion clearly needs decisions on the highest level - where understandably, there are other issues to take into account (e.g. that Iron Bridge has minority owners...).

Think about it and maybe we should arrange a call soonish.

Cheers
Bjorn

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-19

This is the annexure marked **AIB-19** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Susanne Hantos

From:	Bart Kolodziejczyk
Sent:	Wednesday, 27 January 2021 5:42 PM
To:	bjorn winther-jensen
Subject:	RE: contract signed...

Hi Bjorn,

We have visited [redacted] roughly two months ago.

[redacted]

I have looked at water, ionic liquids, and molten carbonate.

[redacted]

Suggest any supplier globally, I am having a meeting with our procurement team to prepare them form what is coming and make it clear to them that their traditional procurement approaches won't work.

Bart

From: bjorn winther-jensen <bjornwj@gmail.com>
Sent: Wednesday, 20 January 2021 5:47 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: Re: contract signed...

Hi Bartek

Thanks for the info and the report.

I can see the industrial appeal in the MOE process, but man, it is not at all "elegant" or even efficient (I even think that the energy efficiency calculation in the report is overestimating the efficiency...).
Unfortunately it looks like they are ahead of any other technology for CO2 free steel.
Is it correctly understood that the molten iron (or other metal) is separated from the electrolyte by "simple" phase separation (helped by gravity) ?
At the current state, do they do batch processing or can they do continuous operation ?

I have been looking at many (MANY) papers and technical reports on dissolving iron ore. (Notably, magnetite seems to be quite easy to dissolve - especially compared to Hematite). All these reports have one thing in common: They intend to dissolve the ore in water.
Have you seen any reports on attempting dissolution in (polar) organic solvents ?
The point is that many iron(II)and iron(III) salts have higher solubility in e.g.alcohols than in water. So it is quite curious that there seems to be no attempts in that direction... (ILs not counting !)

On the lab equipment and chemicals shopping: Does Fortescue have "prefered suppliers" ? Or can I suggest products from any supplier in Australia/Perth ?

Cheers
Bjorn

On Mon, Jan 18, 2021 at 3:17 PM Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au> wrote:

> Wow, sounds good. Yes, we will start ordering chemicals as soon as we have the facility.
>
> It is also great that you're making a list of things that we will need. I am working with Emily and our procurement team to simplify and expedite procurement processes to get the necessary equipment asap.
>
> I have attached a report draft from tests on Fortescue ores using Molten Oxide Electrolysis.
>
> [redacted]
>
> We are having a board meeting in February, the idea is to ask for [redacted]. With further funds in "the next grant round" for scale up.
>
> ---
>
> **Bart Kolodziejczyk**
>
> **Fortescue Metals Group Ltd**
>
> Level 2, 87 Adelaide Terrace East Perth WA 6004
>
> **Mobile:** +61 437 947 164 **Web:** www.fmgl.com.au
>
> **Twitter:** @FortescueNews I **www.fmgl.com.au**

From: bjorn winther-jensen <bjornwj@gmail.com>
Sent: Monday, 18 January 2021 3:47 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: Re: contract signed...

I also got the signed NDA back, today.

I have been trying to make "shopping lists" for both lab-equipment and chemicals. So if you need input, please let me know (also before 15th of Feb..,).

Also been looking for possible passes for the ore to iron process. Have got some possible good ideas that will be easy to try out. Am considering doing initial trials while here in Thailand to test viability. I should be able to do it with the gear we have here...

Cheers

Bjorn

On Mon, Jan 18, 2021 at 2:34 PM Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au> wrote:

> That's great! I am happy that you didn't have to start as contractor. Enjoy your "holidays" 😊
>
> From: bjorn winther-jensen <bjornwj@gmail.com>
> Sent: Monday, 18 January 2021 3:12 PM
> To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
> Subject: Re: contract signed...
>
> Starting date is 15th of Feb. - there are "things" here that need time to be resolved before I can focus 38 hours a week on FFI work... 😬
>
> I will be employed directly by Fortescue from the 15th of Feb. Having an Australian taxfile number and an Australian bank account apparently solves the issue.
>
> We hope to be able to make the move to Perth in mid-April. FIngers crossed.
>
> Cheers
>
> Bjorn

> > On Mon, Jan 18, 2021 at 1:58 PM Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au> wrote:
> >
> > > No worries. Congrats!
> > >
> > > When is your start day? Are you going to be initially engaged as a contractor working form Thailand?
> > >
> > > From: bjorn winther-jensen <bjornwj@gmail.com>
> > > Sent: Monday, 18 January 2021 2:55 PM
> > > To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
> > > Subject: contract signed...
> > >
> > > Hi Bartek,
> > >
> > > I got, signed and returned the contract today ! 😎
> > >
> > > Thanks for initiating this whole process.
> > >
> > > Cheeers
> > >
> > > Bjorn

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-20

This is the annexure marked **AIB-20** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From:	Bjorn Winther-jensen
Sent:	Tuesday, 23 February 2021 10:51 AM
To:	Bart Kolodziejczyk
Subject:	Research plan for Green Steel
Attachments:	Electrochemical Green Steel.docx

Hi Bartek,

Before I go much further with the time-line for the research activities, personnel etc. , I would kindly ask you to have a look at the attached *draft* research plan (sorry for the repetitive structure of the document…) to see if there are any significant areas that I have overlooked or over/under prioritized.
Also where possible, provide input to perspective collaborative research groups you know of and/or have already been in contact with.

Cheers
Bjorn

Electrochemical Green Steel - Starting from iron ore

General background and considerations

Roadmap and research plan for Electrochemical Green Steel (EC Green Steel)

Generally, the process of converting iron ore to steel contains two tasks:

- To reduce iron oxides to steel
- To remove a sufficient level of impurities/oxides

In traditional industrial practice carbon is employed for the reduction, itself being oxidized to CO_2 in a high-temperature blast furnace process. The removal of impurities – in this case mainly excess carbon as well as silicium- and metal oxides from the ore are removed in a subsequent high-temperature process through the formation of slag.

The obvious drive for developing an alternative reduction process is to stop the CO_2 release. However, a new route must also be able to manage the removal of impurities to an appropriate level, such that the resulting Green Steel products are optimized to suit the subsequent steel-making process overseas.

As such three major theoretical routes can be outlined:

Molten Iron Route.

- From dissolved ore at high-temperature, purification through phase separation of molten iron form the electrolyte ([redacted] type)

Dissolved Iron Route.

- Dissolution of ore in chelating or coordinating electrolytes, purification through non-solution of impurities. Followed by electrochemical (EC) reduction

Solid-state Route.

- Through solid-state electrochemistry, purification of ore prior to or after electrochemical operation

For all scenarios, the counter electrode (anode) process is oxygen evolution

Main details, requirements and limitations for these possibilities are listed below.

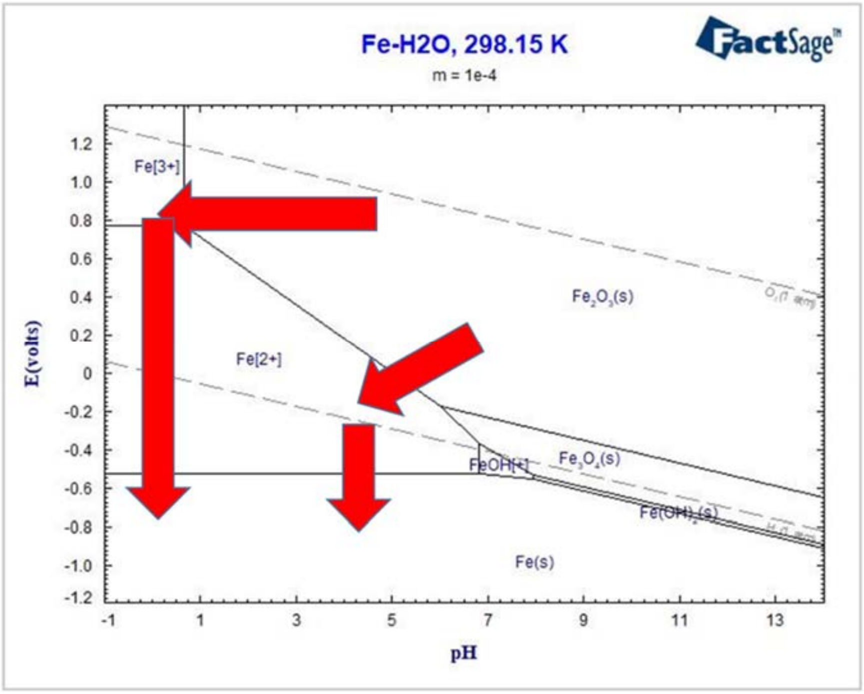
Molten Iron Route.
From dissolved/melted ore at high temperature above the melting temperature of (carbon-free) iron, i.e. in the 1500°C range.

- Electrolyte. molten oxides ([redacted] model), other possibilities may include carbonates or molten salts
- Current ore qualities can be used directly. However, water and other volatiles have to be removed in a pre-melting step (presumably to avoid steam explosions in the electrolyte !)

- Not very compatible with intermittent power supply from solar and wind.
- Expected Power Efficiencies in the 20 – 30% range
- Apparent long development time-line
- The iron is separated from the electrolyte in the molten state by gravity assisted phase separation. Impurities (SiO_2 and metal oxides) thus remain in the electrolyte => electrolyte “cleaning” needed

Dissolved Iron Route(s)
Dissolution of ore in chelating or coordinating electrolytes, purification through non-solution of impurities

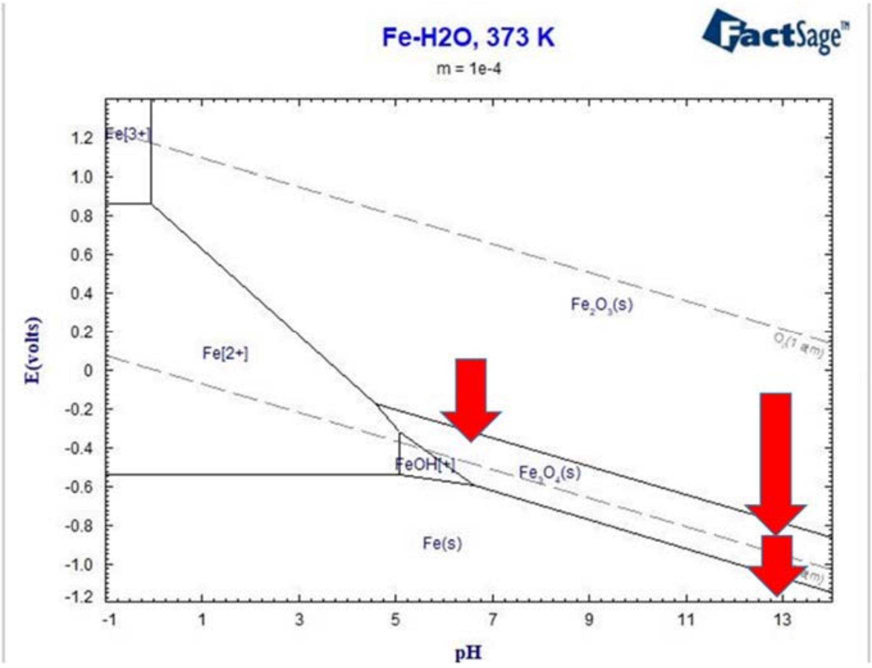
- Dissolution of hematite is generally very slow
- The chelating/coordination is increasing the potential required for iron deposition
- The chelating/coordination is allowing a wider range of pH and solvents.
- Expected Power Efficiencies in the 30 – 60 % range
- Deposition is limited by the concentration of iron in solution – which may be low in these systems
- Impurities remain in the electrolyte => electrolyte “cleaning” needed
- Significant research has been conducted but without any clear “winner” technology.
- New possibilities may emerge from “medium” temerature options using ionic liquids, molten salts or molten carbonates (300 – 800°C)
- Apparent long development time-line
- Dissolution of magnetite is significantly easier that hematite. However, it seems a detour when solid-state reduction of magenetite concentrate could give a Green Steel product directly



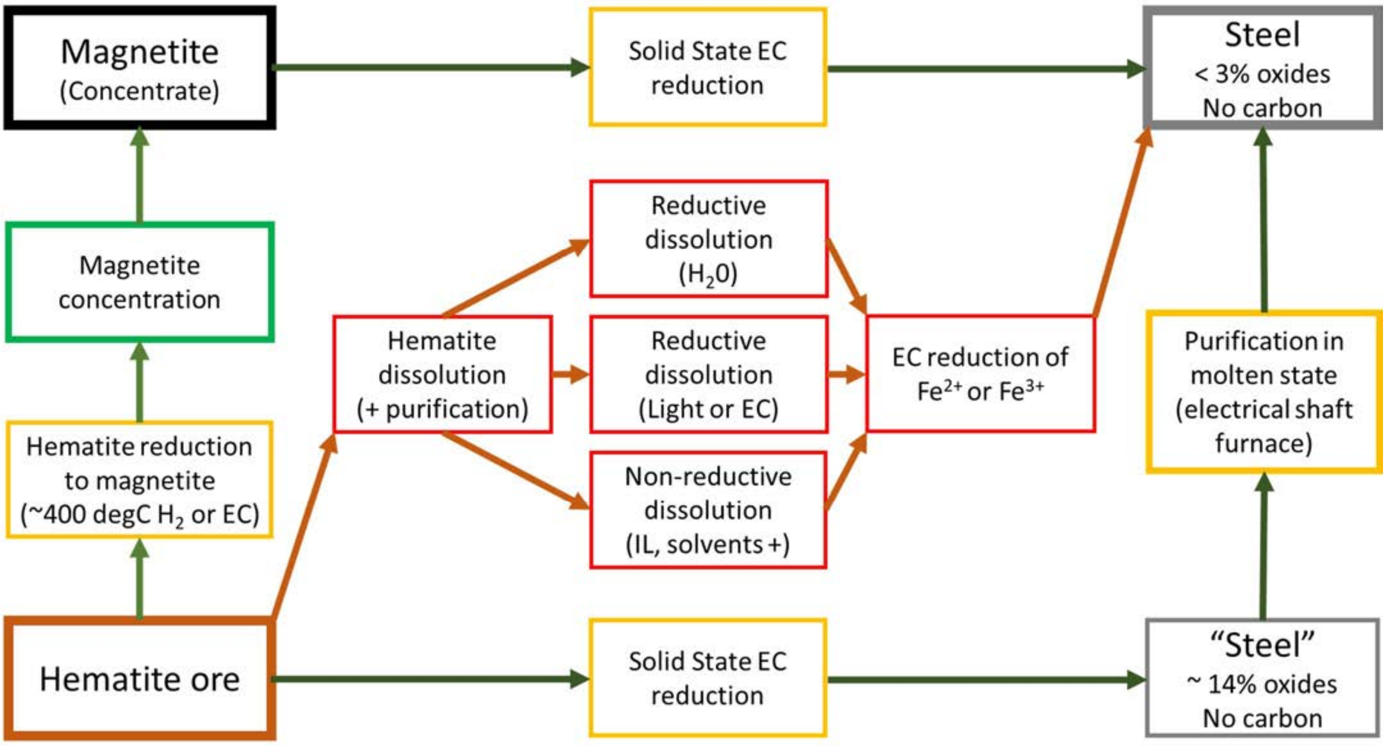
Solid-state Route(s)

The electrochemistry is resempling the “Edison cell” in charging mode where magnetite is reduced to metalic iron through a $Fe(OH)_2$ intermidiate. At temperature above ~85°C, the $Fe(OH)_2$ intemediate becomes thermodynamically unstabel and the conversion from magnetite to iron can proceed directly and significanltly faster.

- Impurities are not removed trough the process => requires pure enough ore concentrates to produce a meaningful product or a post-reduction process e.g. in molten state for slag formation
- Cheap electrolyte (high pH NaOH or KOH solutions)
- Impurities are not deposited in the electrolyte => longer electrolyte lifetime
- Expected Power Efficiencies in the > 60 % range
- High deposition rates at temperature above 85 °C
- Apparent short development time-line
- Magnetite Concentrate could be a starting material, producing a pig iron quality product (without carbon)
- Large scale conversion of hematite to magnetite has been reported with hydrogen as reductant in fluidbed setups
- Direct solid-state reduction of hematite is possible. However, resulting in a “steel” product with ~ 14% oxides (based on existing ore qualities from FMG)



Flow diagram for dissolved iron (red) and solid-state (green) routes of iron ore reduction



Green frame indicates well-known, unscaled process. Yellow frame indicates well-documented research at (at least) pilot-scale level. Red frame indicates solely research level.

Alignment

In order to make a meaningful R&D planning, communication with other parts of FMG should be established to ensure that the products R&D are aiming for are aligned with "the market" and that there are agreements in place to "allow" the use of different ore types. i.e. can we suggest to firstly aim for magnetite concentrate conversion and later move to hematite ?

Below some of the questions regarding the requirements to Green Steel products out of Port Headland – to qualify to be a "product". => Anticipating the product is a type of "raw" or intermediate material in the steel production process

- Maximum level of impurities (oxides; SiO_2, Al_2O_3 etc.)
  - Is steel with 14% oxides a product ?
  - How will price be related to the level of impurities –> what impurity level is it worth aiming for ?
- Porosity / Bulk density
- Preferred physical form (bars, "pigs", rolls, plates etc.)
- Estimate for max. production cost to be profitable

Preferred scenario from a R&D viewpoint

- *Priority*. Reduction of magnetite concentrate

  To get prototype and pilot facility established based on solid-state reduction of magnetite concentrate to steel, where no further purification is needed to meet specs within "product range".

  - Justification.
    - The fundamentals of this process are known and tested
    - I see this as the most viable and economic (i.e. high volume) route to obtain a commercial Green Steel product on a short timescale.
    - Magnetite (concentrate) as starting material is preferred due to purity and electrical conductivity
    - It will give valuable knowhow also for possible solid-state reduction of hematite
    - It will broaden the possibilities for reduction of hematite. i.e. the hematite reduction may be carried out in two steps. Firstly, to magnetite, where concentration can proceed with known technology, secondly from magnetite to steel through the solid-state process.
- *Parallel research* with longer lead-time, maybe to be pursued in collaboration with universities and/or research institutions.
  1. Dissolution of hematite. The reaction rate is a main and general issue for both the dissolution and the deposition step.
     a. Reductive dissolution (chelating with use of solvents)
     b. Chelating (non-reductive) dissolution of hematite
     c. Light induced/assisted dissolution of hematite
        - These three routes have all been reported previously without any serious scale-up. However, all with either low rates, low end-concentration and/or with unknown possibilities for recycling the media.
        - A method for electrodeposition of iron will depend on the "liquid" used for the dissolution. i.e. starting electrodeposition studies without having a dissolution route is therefore meaningless. The dissolution process must produce significant iron concentrations to allow appreciable deposition rates of metallic iron.
        - Shifting to "medium-high" temperatures (300-850°C) with molten salt or molten carbonate electrolytes could help the rate issues, but it is quite early days.

  2. Reduction of hematite to magnetite.
     a. By hydrogen reduction of hematite (e.g. in a fluid bed setup at ~300 - 450 degC). This is well-documented and at least pilot-scale has been demonstrated

   b. Reduction of hematite, using metallic iron as reducing agent.

3. On-shore post-purification of “raw” Green Steel to export quality Green Steel.

Priority. Reduction of magnetite concentrate through a solid state process

A 67% Fe magnetite concentrate should produce a ~ 92.5% Fe Green Steel (without including the calculation of the removal of water/moisture, which would indeed be removed in the process – am awaiting a more detailed composition of the magnetite concentrate(s) existing and expected). This is approximately the iron content in pig iron.

The solid-state reduction of magnetite is less researched than that of hematite (except for the Edison cell !). The high(er) conductivity of magnetite should help limiting the ohmic loss in the process.

[redacted]

Research topics

a) *Testing the reduction on relevant, available magnetite ore concentrates.* Most reports have been using synthetic magnetite (or synthetic hematite) so adjusting to large-scale reality is needed.
b) *Optimization of electrolyte.* Traditional [redacted] NaOH electrolytes have been used with success. The NaOH electrolytes have high conductivity and low water activity, which is needed to suppress hydrogen evolution. However, there is merit in revisiting the electrolyte composition. During the reduction process, the released oxygen ions are reacting with water (not OH^-) and thus a lower pH could be an advantage. The very high pH is in principal not helping the reaction to “escape” the hydrogen evolution potential (see Pourbaix diagram at 100°C above) and low water activity could alternatively be obtained by adding significant amounts of [redacted] (It is acknowledged that high pH is an advantage to the oxygen evolution reaction on the anode).
c) *Securing 100% conversion of ore.* Particle size and distribution, reactor layout and dimensions, operational parameters (voltage and current density), The possibility of multiple reduction steps (by changing the operational parameters) as well as the dimensions of the magnetite layer, all have to be optimized.

[redacted]

g) *Reactor design for upscaling, eventually continuous operation*.
   - Operating at 90°C or higher ([redacted]). Possible “co-heating” through pre-heating (drying of raw magnetite concentrate is needed to control the

electrolyte composition in a more continuous operation) of the magnetite concentrate by microwave or inductive heating.

- Efficient removal of produced oxygen from the anode and reactor closed to atmospheric oxygen to avoid oxygen reduction as cross reaction.

[redacted]

Parallel research with longer lead-time.

1. Dissolution of hematite.
   We don't have a clear direction here. There is surely no apparent method that can provide appreciable dissolution rates. Pure aqueous systems are, in my opinion, not worth revisiting.

Research topics

[redacted]

c) Molten salts, Molten carbonates. Iron dissolution and deposition has been reported from these medium-high temperature electrolytes. E.g. from $CaCl_2$-KF @ 825°C. My suggestion would be to seek "proof of concept" projects (with clear scale-up passes) with relevant groups experienced in these systems, before setting up facilities in Perth. One such collaborator could be Professor Geir Martin Haarberg, Department of Materials Science and Engineering, Faculty of Natural Sciences, NTNU in Norway, geir.martin.haarberg@ntnu.no, +47 73594036. His group has been working on both molten salt and molten carbonate systems for various metals.

d) Ionic Liquids. Here I suggest to search for systems/research groups that have shown reasonable dissolution rates of iron ore (hematite). I have not found any convincing reports yet (!). If there is indeed merit for dissolution in the temperature range below 300°C, then we should pursue collaborative research projects until scaling has been verified.

2. Reduction of hematite to magnetite.

Research topics

a) Reduction of hematite to magnetite is a well-documented field using either hydrogen, carbon (CO) or siderite (CO) as reducing agents. Pursuing one of these routes should not require further research on the R&D level but be on pilot plant level in collaboration with a fluid-bed-equipment manufacture.

[redacted]

3. On-shore post-purification of “raw” Green Steel to export quality Green Steel.
   Many in FMG and elsewhere will know much more about the possibilities and ultimately this topic may be well outside the R&D facility’s business.

   Research topics

a) Using traditional high-temperature, molten iron processes for the removal of SiO_2 and metal oxides. E.g. Open-hearth process, Bessemer converter or Electric shaft furnace.
   Several patents have been filed in the area, e.g. US2693411A - Method of purifying molten pig iron, and EP2530171A1 - Method for removing impurities in molten cast iron.

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-21

This is the annexure marked **AIB-21** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From: Bjorn Winther-jensen
Sent: Wednesday, 24 February 2021 3:02 PM
To: Bart Kolodziejczyk
Subject: Iron Ore samples

Hi Bartek,

The outcome of my last two hours considerations, given the current situation/state of facilities etc., etc.:
I cannot commit to produce any meaningful "something" (understood as solid iron samples made by electrochemical reduction of FMG iron ore) by the end of June 2021.
I don't mind challenges but this is out of proportion.

I guess the fastest way to "something" is by reduction of hematite with hydrogen at high temperature (700 – 900 degC) followed by removal of oxides in the molten state (1500 degC). These processes are well outside my expertize and a more appropriate person should be appointed for pursuing such path.

Cheers
Bjorn

From: Bjorn Winther-jensen
Sent: Wednesday, 24 February 2021 1:08 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bartek,

Better be today after 5pm (which is only 4pm here, I presume)

B

From: Bart Kolodziejczyk
Sent: Wednesday, 24 February 2021 1:03 PM
To: Bjorn Winther-jensen <bjorn.wintherjensen@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bjorn, can do only after 5 pm, or tomorrow.

From: Bjorn Winther-jensen
Sent: Wednesday, 24 February 2021 1:57 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bartek,

When would you have time to talk ?

Cheers
Bjorn

From: Bart Kolodziejczyk
Sent: Wednesday, 24 February 2021 12:41 PM
To: Bjorn Winther-jensen <bjorn.wintherjensen@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bjorn,

Yes, I talked to Deputy Vice-Chancellor of UWA. We'll get overarching R&D agreement this or early next week. You will be able to use any equipment at UWA.

Bart

From: Bjorn Winther-jensen
Sent: Wednesday, 24 February 2021 11:25 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bartek,

I see…

In that case I guess that we cannot wait for our own lab to be up running.
Somehow we have to get started in somebody's else lab. Hmmm

Bjorn

From: Bart Kolodziejczyk
Sent: Wednesday, 24 February 2021 10:07 AM
To: Bjorn Winther-jensen <bjorn.wintherjensen@fmgl.com.au>
Subject: RE: Iron Ore samples

Sounds good. We had this Think Tank last two days, I was just told that we need to have something to show by June 30, 2021. The pressure is not only on us, but also others to decarbonise FMG operations.

On a positive note, Malcolm Turnbull was appointed FFI Australia Chairman.

From: Bjorn Winther-jensen
Sent: Wednesday, 24 February 2021 11:02 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bartek,

Am aware of the issues at Iron Bridge and that material may not be available on the short term. However, there must be data available e.g. from the pilot project at iron bridge and I would like to be able to at least consider the possibilities of using magnetite.

Cheers
Bjorn

From: Bart Kolodziejczyk
Sent: Wednesday, 24 February 2021 9:54 AM
To: Bjorn Winther-jensen <bjorn.wintherjensen@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bjorn,

I am not sure if you get any magnetite at this point.

Iron Bridge has been suspended last week due to cost blow out. Magnetite projects have been highly unsuccessful globally.

[redacted]

Bart

From: Bjorn Winther-jensen
Sent: Wednesday, 24 February 2021 10:51 AM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Uu Vuu <tvuu@fmgl.com.au>; Simon Campbell-Hardwick <scampbellhardwick@fmgl.com.au>; Christopher Counsell <ccounsell@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>; Benjamin Brun <bbrun@fmgl.com.au>; !RS-QA <RS-QA@fmgl.com.au>
Subject: RE: Iron Ore samples

Dear all,

- Thanks Bart for getting me in the loop.

I am currently investigating the overall possibilities for Green Steel processes. As help to evaluate these possibilities I need input regarding the composition and particle size of the available and "possible" ore qualities.
For the hematite ores, I already have sufficient data.
For the magnetite concentrate(s), data for "typical" composition and particle size distribution would be very helpful.
I presume that these data already exist and can be made available to me.

Kind regards
Bjorn WJ

From: Bart Kolodziejczyk
Sent: Wednesday, 24 February 2021 8:42 AM
To: Uu Vuu <tvuu@fmgl.com.au>; Simon Campbell-Hardwick <scampbellhardwick@fmgl.com.au>; Christopher Counsell <ccounsell@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>; Benjamin Brun <bbrun@fmgl.com.au>; !RS-QA <RS-QA@fmgl.com.au>; Bjorn Winther-jensen <bjorn.wintherjensen@fmgl.com.au>
Subject: RE: Iron Ore samples

Thank you, Tuu.

I have CC'ed Bjorn who also had questions regarding particle size and distribution would be helpful.

Bjorn is leading R&D on our green steel effort.

Thank you,
Bart

[redacted]

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Friday, 19 February 2021 11:33 AM
To: Simon Campbell-Hardwick <scampbellhardwick@fmgl.com.au>; Christopher Counsell <ccounsell@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>; Benjamin Brun <bbrun@fmgl.com.au>; !RS-QA <RS-QA@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Simon and Ben,

Thank you for your package. We have received it just now.

Can you please tell us more about the composition of this sample, if that information is available?

Thank you and have a great weekend,
Bart

From: Simon Campbell-Hardwick
Sent: Tuesday, 16 February 2021 4:56 PM
To: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>; Christopher Counsell <ccounsell@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>; Benjamin Brun <bbrun@fmgl.com.au>; !RS-QA <RS-QA@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Bart,

Nice to e-meet you too. Ben will be sending it to you via Express Post. It should arrive by the end of this week.

Cheers,
Simon

From: Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Sent: Tuesday, 16 February 2021 3:11 PM
To: Simon Campbell-Hardwick <scampbellhardwick@fmgl.com.au>; Christopher Counsell <ccounsell@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>; Benjamin Brun <bbrun@fmgl.com.au>; !RS-QA <RS-QA@fmgl.com.au>
Subject: RE: Iron Ore samples

Hi Simon,

Nice e-meeting you.

That's a great news. Can we get it all sent to Level 2, 6-8 Bennett Street, East Perth?

Thank you,
Bart

From: Simon Campbell-Hardwick
Sent: Tuesday, 16 February 2021 1:56 PM
To: Christopher Counsell <ccounsell@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>; Benjamin Brun <bbrun@fmgl.com.au>; !RS-QA <RS-QA@fmgl.com.au>
Subject: RE: Iron Ore samples

G'day Chris,

It looks like there is a 5kg duplicate of the WP (NJ1677).

Where would you like it sent?

Cheers,
Simmo

From: Christopher Counsell <ccounsell@fmgl.com.au>
Sent: Tuesday, 16 February 2021 12:40 PM
To: Simon Campbell-Hardwick <scampbellhardwick@fmgl.com.au>; Bart Kolodziejczyk <bkolodziejcz@fmgl.com.au>
Cc: Aaron Szumilak <aszumilak@fmgl.com.au>
Subject: Iron Ore samples

Gday Simmo

Bart is after 1kg sample of Iron ore for Electrolysis test work. Have we still got splits from the [redacted] test work? If so can we get a 1kg split of the WPF sample please?

Cheer

Chris

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

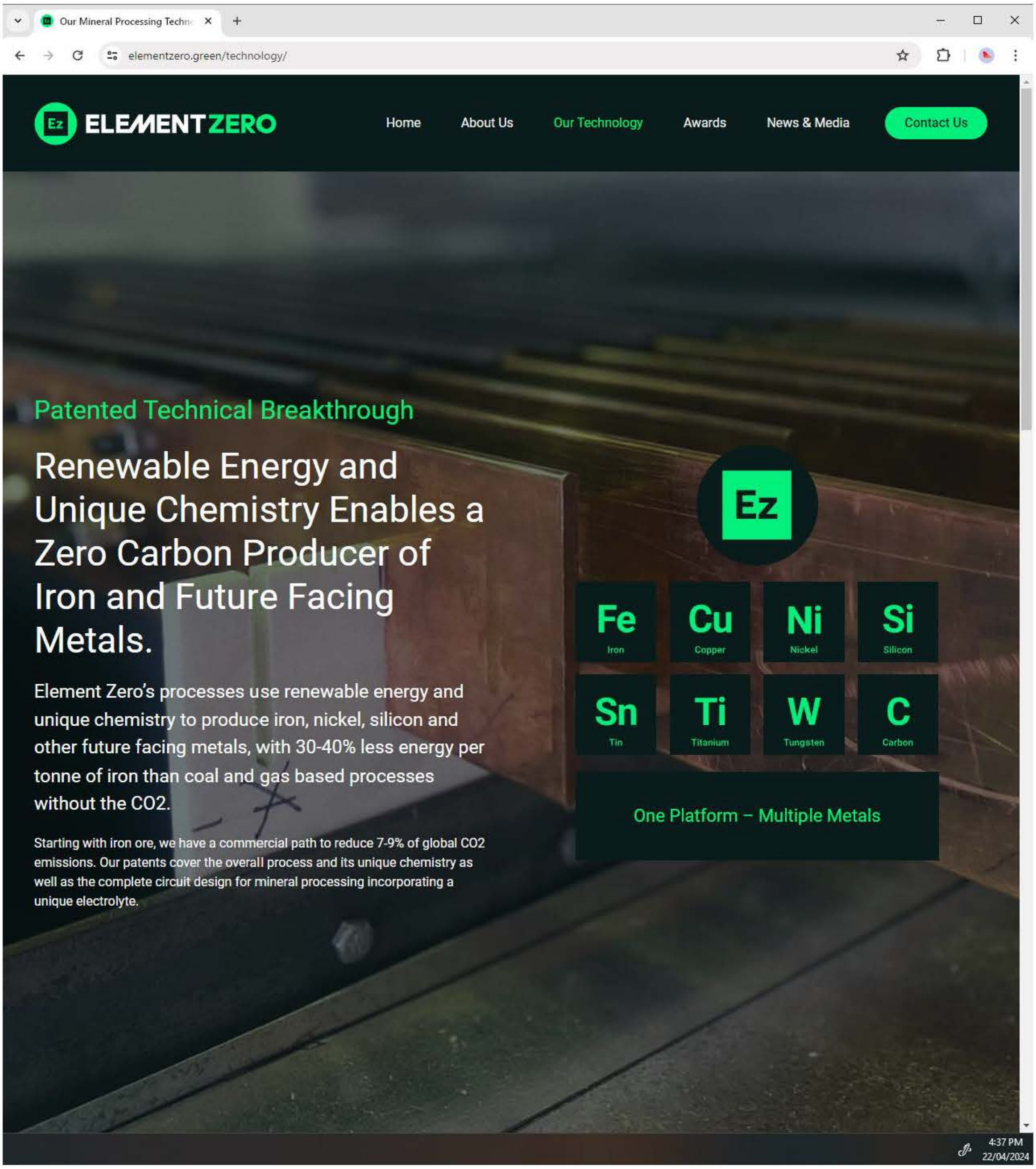
ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-22

This is the annexure marked **AIB-22** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....



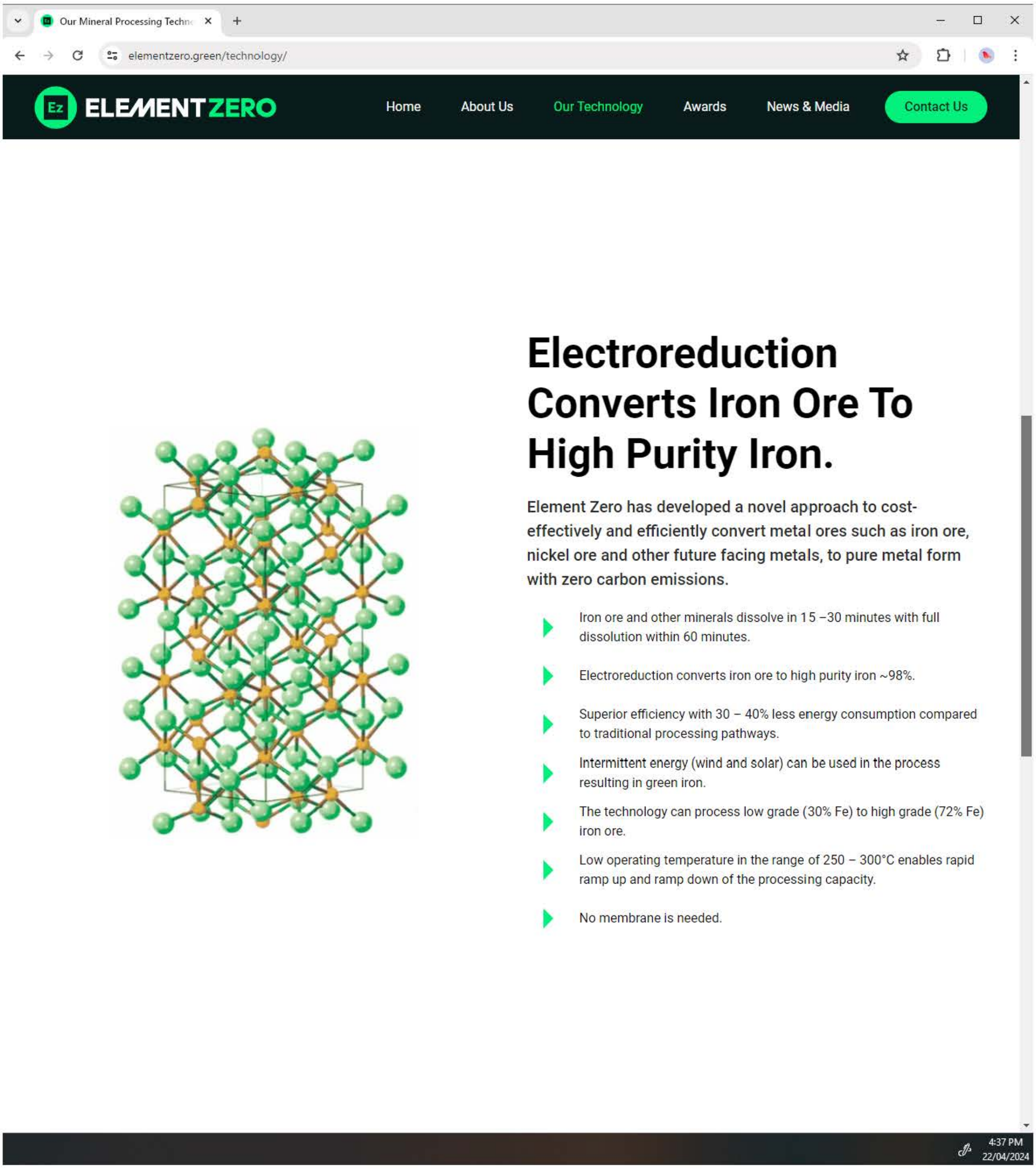
Patented Technical Breakthrough

Renewable Energy and Unique Chemistry Enables a Zero Carbon Producer of Iron and Future Facing Metals.

Element Zero's processes use renewable energy and unique chemistry to produce iron, nickel, silicon and other future facing metals, with 30-40% less energy per tonne of iron than coal and gas based processes without the CO2.

Starting with iron ore, we have a commercial path to reduce 7-9% of global CO2 emissions. Our patents cover the overall process and its unique chemistry as well as the complete circuit design for mineral processing incorporating a unique electrolyte.

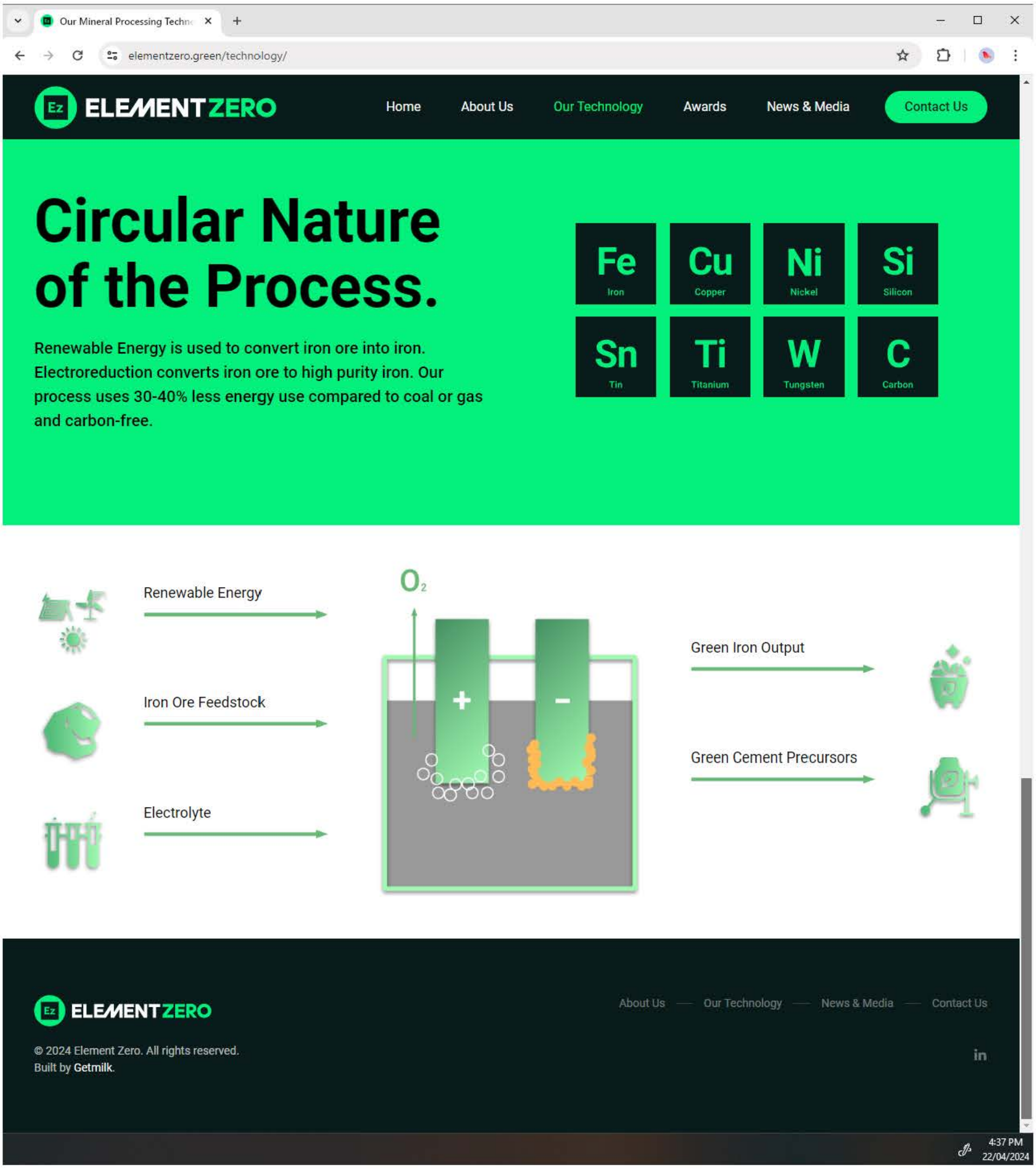
One Platform – Multiple Metals



Electroreduction Converts Iron Ore To High Purity Iron.

Element Zero has developed a novel approach to cost-effectively and efficiently convert metal ores such as iron ore, nickel ore and other future facing metals, to pure metal form with zero carbon emissions.

- Iron ore and other minerals dissolve in 15 –30 minutes with full dissolution within 60 minutes.
- Electroreduction converts iron ore to high purity iron ~98%.
- Superior efficiency with 30 – 40% less energy consumption compared to traditional processing pathways.
- Intermittent energy (wind and solar) can be used in the process resulting in green iron.
- The technology can process low grade (30% Fe) to high grade (72% Fe) iron ore.
- Low operating temperature in the range of 250 – 300°C enables rapid ramp up and ramp down of the processing capacity.
- No membrane is needed.



Circular Nature of the Process.

Renewable Energy is used to convert iron ore into iron. Electroreduction converts iron ore to high purity iron. Our process uses 30-40% less energy use compared to coal or gas and carbon-free.

© 2024 Element Zero. All rights reserved.
Built by Getmilk.

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-23

This is the annexure marked **AIB-23** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

Former Fortescue duo in breakaway green iron dream

Peter Ker *Resources reporter*

Jan 17, 2024 – 5.00am

Listen to this article
6 min

Two of the original architects behind Fortescue’s clean energy pivot [https://www.afr.com/companies/energy/fortescue-to-pump-billions-into-clean-energy-venture-20210218-p573rt] believe their start-up can solve the carbon footprint of the Australian iron ore industry without using the hydrogen [https://www.afr.com/policy/energy-and-climate/the-fire-within-fortescue-s-clean-energy-mission-20211018-p590yj] and membrane [https://www.afr.com/rear-window/andrew-forrest-insane-in-the-membrane-20230219-p5clq7] technology popularised by their former employer.

One of Fortescue chairman Andrew Forrest’s [https://www.afr.com/companies/mining/executive-chairman-forrest-he-always-was-20220518-p5am9t] most senior lieutenants of the past 25 years, Michael Masterman [https://www.afr.com/life-and-luxury/how-joan-masterman-became-earth-mother-of-tasmanias-ecotourism-boom-20160314-gni3b5], has joined forces with former Fortescue chief scientist Bart Kolodziejczyk to create a metals processing start-up that is already turning iron ore into pure iron at laboratory scale.

Bart Kolodziejczyk (left) and Michael Masterman were early leaders of Fortescue's clean energy pivot. Now they're trying to beat their alma mater at its own game. **Eamon Gallagher**

Dubbed Element Zero, the new company has a patented method of "electro-reduction" that uses an alkaline solution and electric current to separate pure iron from the waste products in iron ore such as silica, alumina and oxygen.

Mr Masterman and Mr Kolodziejczyk say Element Zero's patented process can work for the hematite ores that dominate the Australian iron ore industry, plus other metals like nickel.

"Everything we do was developed after Fortescue and doesn't bring anything from Fortescue," said Mr Kolodziejczyk.

RELATED QUOTES

FMG **$25.025** ▲ 0.10%

1 year 1 day

Updated: Apr 18, 2024 – 4.09pm. Data is 20 mins delayed.

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BHP **$45.055** ▲ 1.38%

RIO **$131.570** ▲ 2.21%

Element Zero is part of a rush to develop "green iron" technologie [https://www.afr.com/companies/mining/shift-to-green-steel-challenges-future-of-australian-iron-ore-20230302-p5covz]s that could help Australian miners reduce the scope 3 emissions created when their customers cook iron ore and coking coal together to make steel.

The oxygen in iron ore combines with the carbon in coking coal during the steel-making process to make carbon dioxide.

Big miners Rio Tinto, Fortescue and BHP are investigating future options to export pure iron from Western Australia rather than iron ore, by removing the oxygen and other waste products in ore.

Pure iron has traditionally been extracted from iron ore in some parts of the world using the potent greenhouse gas methane, under a process called direct reduced iron. Miners like Fortescue have studied [https://www.afr.com/policy/energy-and-climate/the-fire-within-fortescue-s-clean-energy-mission-20211018-p590yj] whether they can make carbon-free DRI by using green hydrogen rather than methane to remove the oxygen.

But experts have warned that converting the Pilbara iron ore industry to hydrogen DRI would be extremely expensive [https://www.afr.com/companies/mining/shift-to-green-steel-challenges-future-of-australian-iron-ore-20230302-p5covz], costing up to $30 billion and requiring the installation of enough renewables to double Australia's power generation capacity.

Hydrogen DRI also struggles to work on the hematite ores that dominate the Australian export industry.

Part of the breakthrough at Element Zero "is being able to show that we can process the iron ore of all the majors and all the magnetite miners," said Mr Masterman, adding that the company had trialled ore from several miners, including Fortescue.

"Importantly for Australia's future, because iron ore grades are coming down, our technology works very efficiently on the currently sub-economic, sub 55 per cent iron ores."

Under Element Zero's process, iron ore is dissolved into a clear, alkaline solution that does not include water. When renewable electricity is passed through the solution, the pure iron plates onto a cathode, from where it can be collected for sale.

Element Zero is commissioning a green iron pilot plant in the Perth suburb of Malaga, where 100 kilograms of iron ore will be fed into the process each day.

Mr Kolodziejczyk received an Order of Australia in 2022 for services to hydrogen energy science. But he said the lack of hydrogen in Element Zero's process was an advantage because it lowered capital costs and allowed for a more direct and efficient use of renewable power.

Fortescue announced last February that it had developed a method for making green iron without requiring hydrogen, but Dr Forrest said that breakthrough was based on Fortescue's secret membrane technology [https://www.afr.com/companies/mining/fortescue-lab-succeeds-in-green-iron-experiment-20230323-p5cuol].

Mr Masterman said he believed technologies reliant on membranes would be hard to scale up, and stressed that Element Zero did not use membranes.

"If you want to build a plant that is say 5 million tonnes per year, you can't pass 5 million tonnes a year through a very expensive piece of plastic," he said, in reference to membranes.

Mr Masterman's association with Dr Forrest goes back to the late 1990s when he was the finance boss at troubled miner Anaconda Nickel.

He later held senior roles at Fortescue, including as international projects boss, before serving as chief financial officer and chief investment officer within Fortescue's Future Industries division between 2020 and 2022.

He also served as chairman of Dr Forrest's private company Squadron Energy until late 2021; Squadron is now Australia's biggest owner of renewable power assets.

During their time at FFI, Mr Masterman and Mr Kolodziejczyk were among the small group that spent most of 2020 travelling on Dr Forrest's private jet to more than 30 nations [https://www.afr.com/companies/mining/forrest-fmg-team-dodge-deadly-terrorist-attack-20200913-p55v4h] on the hunt for clean energy projects.

Mr Masterman said exiting Fortescue better enabled him to focus on a smaller number of projects.

"There became a point in time where, for me, [there were] too many time zones; let's come back and focus. So I stepped back in 2022 and focused on where there are opportunities for very, very large-scale decarbonisation," he said.

Some of the green iron technologies being pursued by Fortescue were developed by Mr Kolodziejczyk during his time at the company, and his name is still on some Fortescue patents.

Asked why he did not pursue Element Zero's electro-reduction method while working at Fortescue, Mr Kolodziejczyk said the idea had not dawned on him until later.

"You actually had to step out of Fortescue to brainstorm, ideate and develop a pathway," he said. "We tested it in our garage initially to make sure it works.

"We can move significantly faster being a small start-up company."

Mr Masterman said he hoped Element Zero could have a good working relationship with Fortescue in the future.

“We need a broad church to be successful here. There are enormous incentives for the major iron ore companies to solve this problem and enormous incentives for the major steel companies to solve this problem,” he said.

“We want to be in a position, with the support of the full industry, to be able to deploy at scale quickly.”

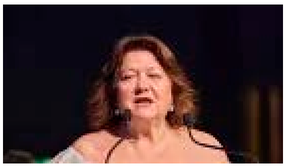
Element Zero was registered with ASIC in December 2022 and raised $US9 million from US venture capital fund Playground Global [https://www.afr.com/technology/meet-the-aussie-who-gave-elon-musk-his-first-job-20230324-p5cuy7] in August.

The money was part of a $US10 million raising that will help fund studies on a larger plant that would consume a tonne of iron ore per day.

RELATED

Shift to green steel challenges future of Australian iron ore

https://www.afr.com/companies/mining/shift-to-green-steel-challenges-future-of-australian-iron-ore-20230302-p5covz



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Rinehart’s common sense crucial to green mining transition

https://www.afr.com/companies/mining/rinehart-s-common-sense-crucial-to-green-mining-transition-20231212-p5equ6

Peter Ker covers resource companies for The Australian Financial Review, based in Melbourne. *Connect with Peter on Twitter. Email Peter at pker@afr.com*

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

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ANNEXURE AIB-24

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businesswire
A BERKSHIRE HATHAWAY COMPANY

ELEMENT ZERO

Element Zero Raises US$10M Seed Funding Led by Playground Global to Scale up Green Materials Platform, Decarbonize Iron and Other Critical Metals Production

- *Transformative process fundamentally changes the economics of steel production making green steel as affordable as grey steel*
- *Scaling up from 100 kg of iron per day prototype to pilot plant that can process one tonne per day*
- *Operational by second half of 2024 and millions of tonnes by the end of the decade*

January 17, 2024 11:05 AM Eastern Standard Time

PERTH, Australia--(BUSINESS WIRE)--Element Zero, a green materials platform company, announced today that it has raised US$10 million in seed funding led by Playground Global. The company has developed a novel approach to cost-effectively convert metal ores, such as iron, nickel, and other future-facing materials, to pure metals with zero carbon emissions. The low energy consumption and the ability to operate using intermittent renewable energy underpins the company's capability to reduce carbon emissions on a global scale. Element Zero will use the funding to grow R&D, engineering, and project development teams and scale the development of a pilot iron plant. Peter Barrett, Co-Founder and General Partner at Playground Global, has joined the company's board of directors.

"Element Zero will help transform Western Australia from the world's mine into the world's foundry, dramatically reducing carbon emissions in the process," said Playground Global's Peter Barrett. "Australia is poised to become a leader in resilient and sustainable global prosperity – its natural wealth in minerals and renewable energy blended with innovation in electrochemistry and new materials will cement its leadership in the energy transformation. Element Zero is a major catalyst in this shift and the Pilbara region in the north of Western Australia stands as the premier location globally to showcase the company's potential."

Initial Focus on Converting Iron Ore to Iron with Novel Processing Platform

Element Zero has created a low-temperature mineral processing platform that utilizes renewable energy to convert iron ore to iron. This non-aqueous electrochemical process allows Element Zero to process the full spectrum of iron ores; this includes the core 95% of Australian and Brazilian global trade in iron ore. Currently, lower grade iron ore cannot be processed using hydrogen-fed direct iron reduction or other lower carbon processing technologies. The technology has been tested successfully on iron ore, nickel, and other future facing metals. The lower temperature also allows Element Zero to run this process on intermittent renewables like wind, solar, and hydropower.

The current Element Zero prototype is capable of producing 100 kg of zero-carbon iron per day while offering superior product purity – a testimony of the team's capabilities and the simplicity and scalability of the process itself. Most notably, Element Zero:

- Achieved this milestone in 18 months, while proponents of other electrochemical technologies spent nearly a decade reaching a similar scale.
- Completed a detailed engineering design for one metric ton per day and is in the midst of a procurement and manufacturing process while a 100 kg per day prototype is being tested and optimized using iron ore feed from major iron ore producers.
- Aims for the next scale-up to be completed and commissioned by end of 2024.

Addressing Urgent Need for Global Decarbonization

The production of iron, steel, and other metals is an energy and carbon-intensive process, with steel production accounting for over 30% of carbon emissions from materials and more than 8% of global carbon emissions alone. With demand for these materials expected to double by 2050, there is a clear and urgent need to decarbonize. However, current approaches in this sector are energy-intensive and can only use very high-grade iron ore in their process; they cannot use renewable energy sources to power their plants due to the high temperature required. Element Zero's platform will also serve as a cost-effective approach for decarbonizing heavy metals. As the price of high-grade iron ore continues to rise, Element Zero will be able to process low-grade iron ore, which is widely accessible.

"Our processing platform will, for the first time, allow cost-effective and scalable production of carbon-free metals crucial to the iron and steel and critical metals industries," said Michael Masterman, Founder and CEO of Element Zero. "We are excited to have Playground Global join our journey to tackle the decarbonization of hard-to-abate sectors. Support from Playground Global goes way beyond financial investment, and we are already in deep discussions about developing green iron and green silicon value chains in the U.S. We are also working with major iron ore miners and iron and steel companies globally."

Based in Perth and the north of Western Australia, adjacent to the largest iron ore ports in the world responsible for exporting nearly 55% of the world's seaborne iron ore supply, Element Zero plans to develop five million tonnes per year of iron ore feed, producing around 2.7 million tonnes of high purity iron.

A World-Class Team of Energy, Materials, and Financial Experts

The Element Zero team comprises experienced leaders in the energy and materials industries with electrochemistry, engineering, metallurgy, project deployment, and fundraising expertise: https://elementzero.green/

- Co-founder and Chief Executive Officer **Michael Masterman** previously served as Executive Chairman of Squadron Energy, Australia's largest renewable energy company. Prior to that, he was the Chief Financial Officer and Chief Investment Officer of Fortescue Future Industries, driving the company's evolution from startup to global expansion and scale. He is a founding shareholder in several multi-billion dollar startups.
- Fellow co-founder and Chief Technology Officer **Bart Kolodziejczyk** served as Director of Hydrogen and Clean Technologies at Boston Consulting Group and Chief Scientist at Fortescue Metals Group.

About Element Zero

Element Zero is a green materials platform company working towards zero-carbon iron and steel and other future-facing metal production. Headquartered in Australia, the company has developed a cost-effective and efficient pathway to convert iron ore and other minerals into their pure metal form with zero carbon emissions. The modular approach of the Element Zero process aims to address 8% of global carbon dioxide emissions from iron and steelmaking. Element Zero is developing a portfolio of projects to accelerate market adoption, the first of which will be located in the north of Western Australia, the world's largest source and holder of iron ore reserves. Learn more at elementzero.green.

About Playground Global

Playground Global is an early-stage venture capital firm investing in entrepreneurs who have developed breakthroughs in frontier technologies that will transform existing industries and create entirely new verticals. Founded in 2015 and headquartered in Palo Alto, CA, and with over $1.2 billion of AUM, Playground invests across deep tech and science, including automation, infrastructure, engineered biology, and decarbonization — all underpinned by the next generation of compute. Playground's bench of technical and operational experts supports founders in developing their deep tech technical breakthroughs into transformational businesses. Playground has been an early – and frequently the first investor – in companies like d-Matrix, Ideon, MosaicML, PsiQuantum, Relativity Space, Strand Therapeutics, Ultima Genomics, and Universal Hydrogen. Learn more at playground.vc.

Contacts

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No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-25

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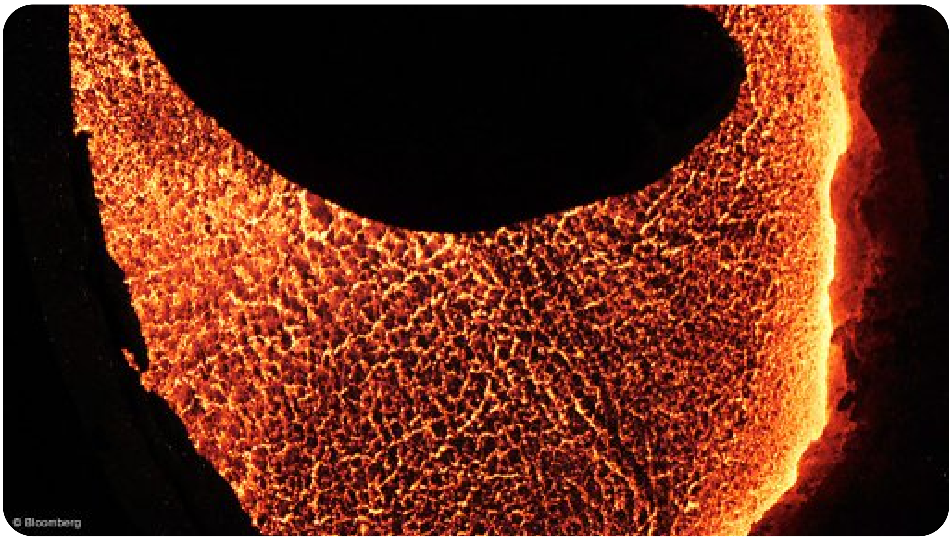
https://www.miningweekly.com/article/start-up-aims-to-transform-wa-from-worlds-mine-into-worlds-foundry-2024-01-19

Startup aims to transform WA from world’s mine into world’s foundry

19TH JANUARY 2024 BY: MARIAAN WEBB - CREAMER MEDIA SENIOR DEPUTY EDITOR ONLINE



Perth-headquartered Element Zero, a green materials platform company launched by former Fortescue executives, has raised $10-million in seed funding for its pioneering zero-carbon metal conversion technology.

The funding, led by Playground Global, will be used to grow research and development, engineering and project development teams and scale the development of a pilot iron plant.

Cofounded by former Fortescue Future Industries CFO and chief investment officer **Michael Masterman** and former Fortescue Metals Group chief scientist **Bart Kolodziejczyk**, Element Zero has created a low-temperature mineral processing platform that uses renewable energy to convert iron-ore to iron.

“Our processing platform will, for the first time, allow cost-effective and scalable production of carbon-free metals crucial to the iron and steel and critical metals industries,” said Masterman.

The non-aqueous electrochemical process allows Element Zero to process the full spectrum of iron ores; this includes the core 95% of Australian and Brazilian global trade in iron-ore. Currently, lower grade iron-ore cannot be processed using hydrogen-fed direct iron reduction or other lower carbon processing technologies.

Element Zero said the technology had been tested successfully on iron-ore, nickel, and other future-facing metals. The lower temperature also allows Element Zero to run this process on intermittent renewables like wind, solar and hydropower.

Based adjacent to the largest iron-ore ports in the world, responsible for exporting nearly 55% of the world’s seaborne iron-ore supply, Element Zero plans to develop five-million tonnes a year of iron-ore feed, producing about 2.7-million tonnes of high purity iron.

“Element Zero will help transform Western Australia from the world's mine into the world's foundry, dramatically reducing carbon emissions in the process,” said Playground Global cofounder **Peter Barrett**, who has joined the Element Zero board.

“Australia is poised to become a leader in resilient and sustainable global prosperity – its natural wealth in minerals and renewable energy, blended with innovation in electrochemistry and new materials, will cement its leadership in the energy transformation. Element Zero is a major catalyst in this shift and the Pilbara region in the north of Western Australia stands as the premier location globally to showcase the company's potential," added Barrett.

Phone: +27 (0)11 622 3744
Email: newsdesk@engineeringnews.co.za
Website: www.miningweekly.com

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Applicants

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ANNEXURE AIB-26

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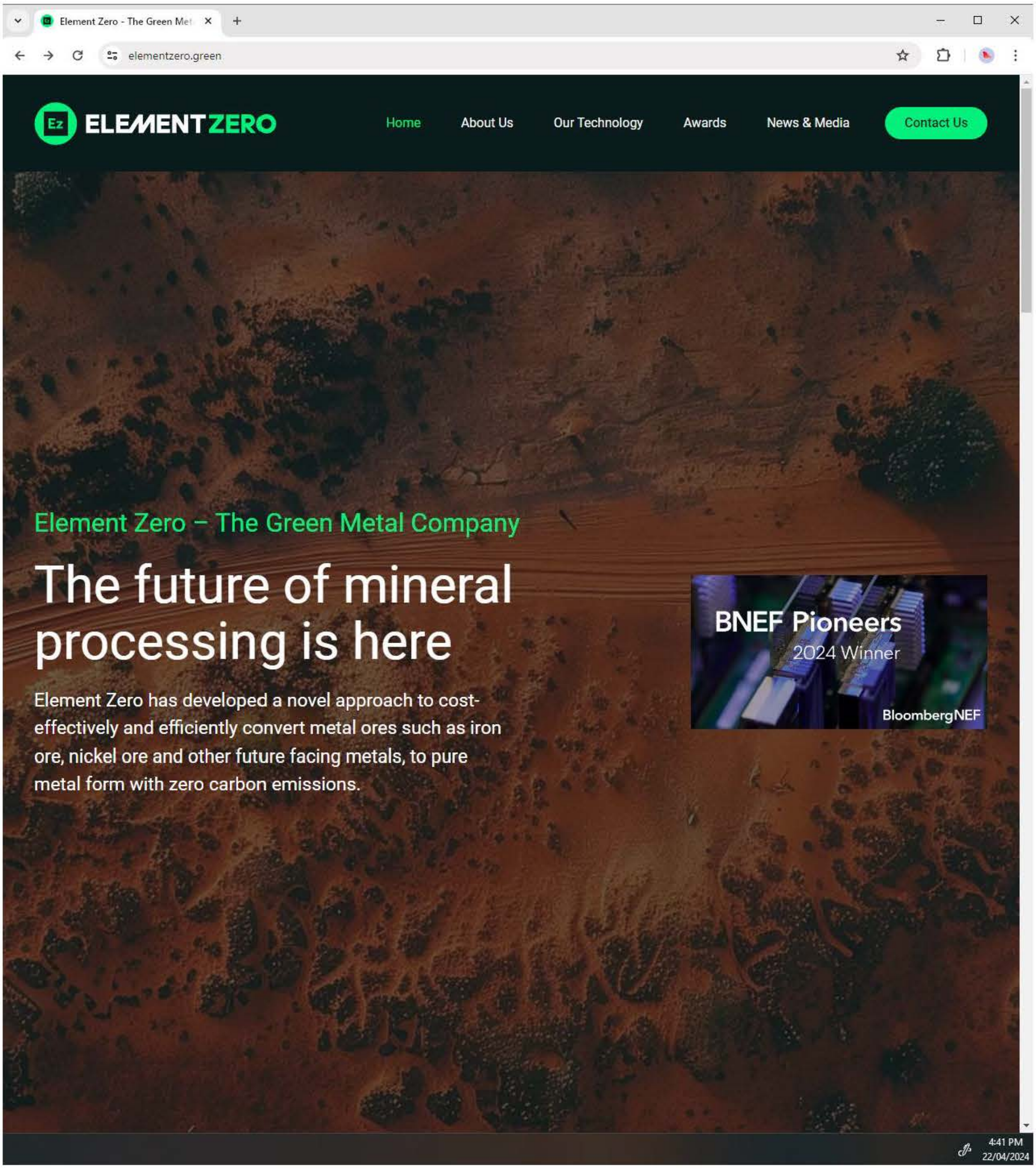
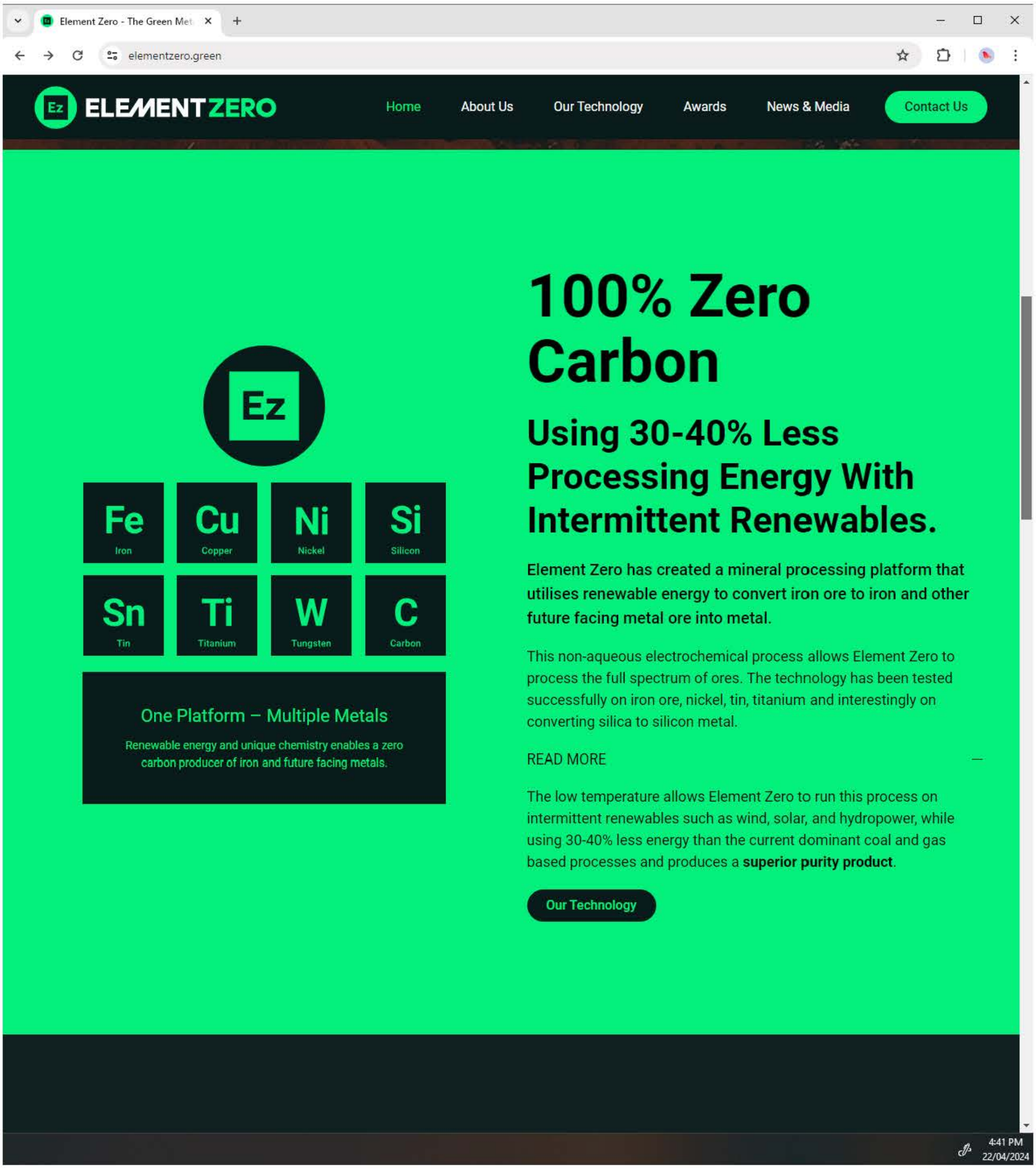


Element Zero – The Green Metal Company

The future of mineral processing is here

Element Zero has developed a novel approach to cost-effectively and efficiently convert metal ores such as iron ore, nickel ore and other future facing metals, to pure metal form with zero carbon emissions.



One Platform – Multiple Metals

Renewable energy and unique chemistry enables a zero carbon producer of iron and future facing metals.

100% Zero Carbon

Using 30-40% Less Processing Energy With Intermittent Renewables.

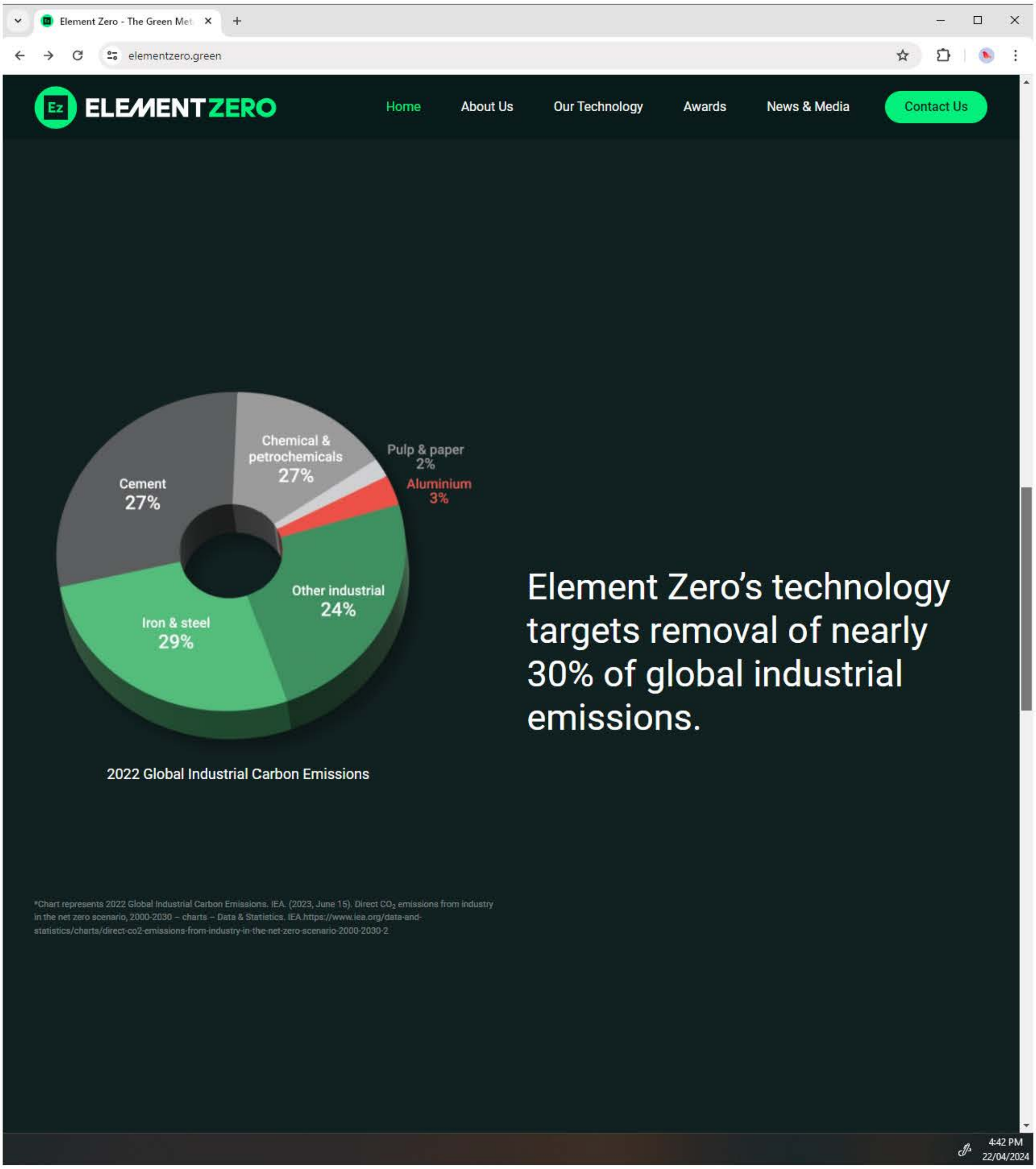
Element Zero has created a mineral processing platform that utilises renewable energy to convert iron ore to iron and other future facing metal ore into metal.

This non-aqueous electrochemical process allows Element Zero to process the full spectrum of ores. The technology has been tested successfully on iron ore, nickel, tin, titanium and interestingly on converting silica to silicon metal.

READ MORE —

The low temperature allows Element Zero to run this process on intermittent renewables such as wind, solar, and hydropower, while using 30-40% less energy than the current dominant coal and gas based processes and produces a **superior purity product**.

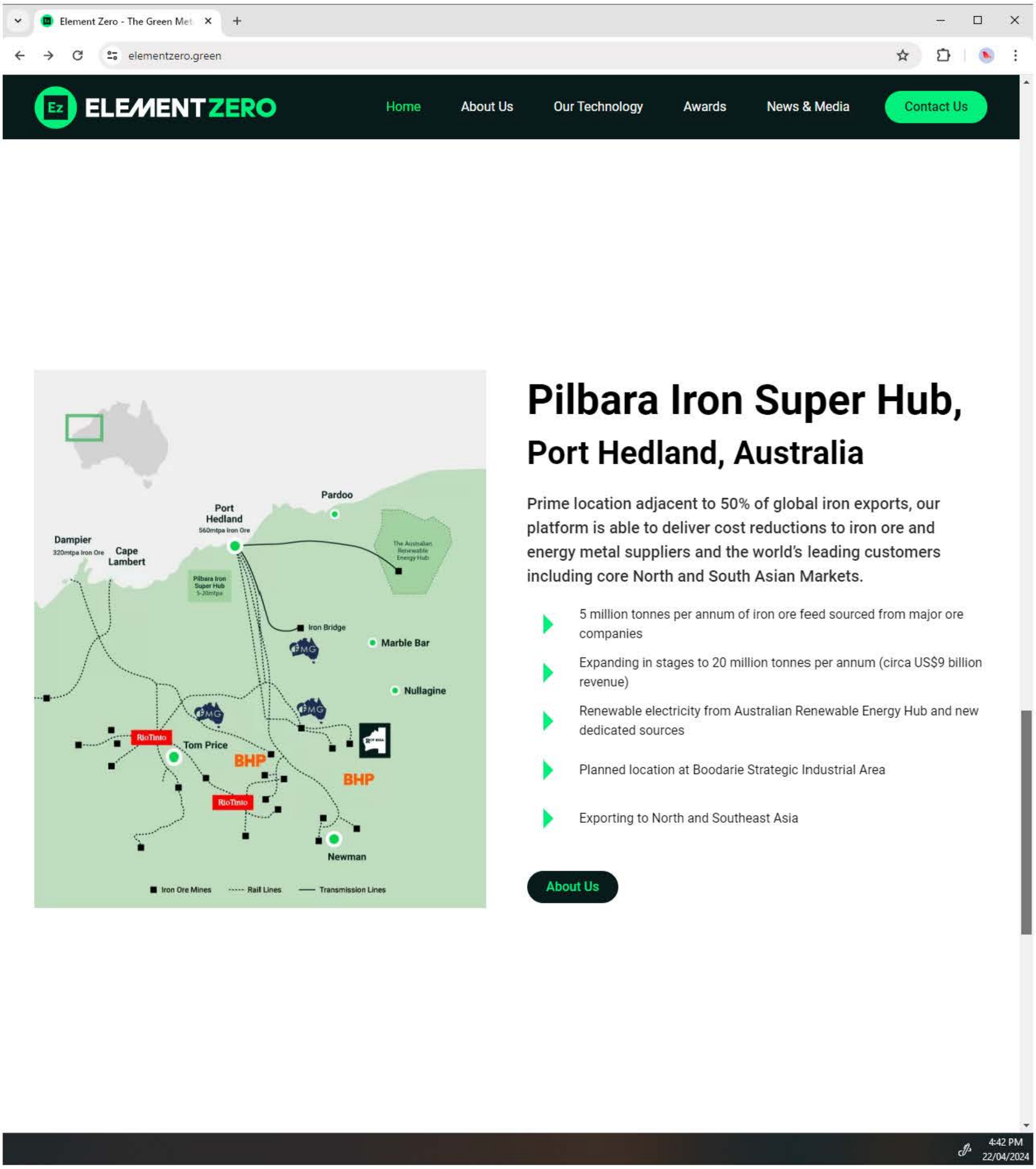
Our Technology



2022 Global Industrial Carbon Emissions

Element Zero's technology targets removal of nearly 30% of global industrial emissions.

*Chart represents 2022 Global Industrial Carbon Emissions. IEA. (2023, June 15). Direct CO_2 emissions from industry in the net zero scenario, 2000-2030 – charts – Data & Statistics. IEA.https://www.iea.org/data-and-statistics/charts/direct-co2-emissions-from-industry-in-the-net-zero-scenario-2000-2030-2

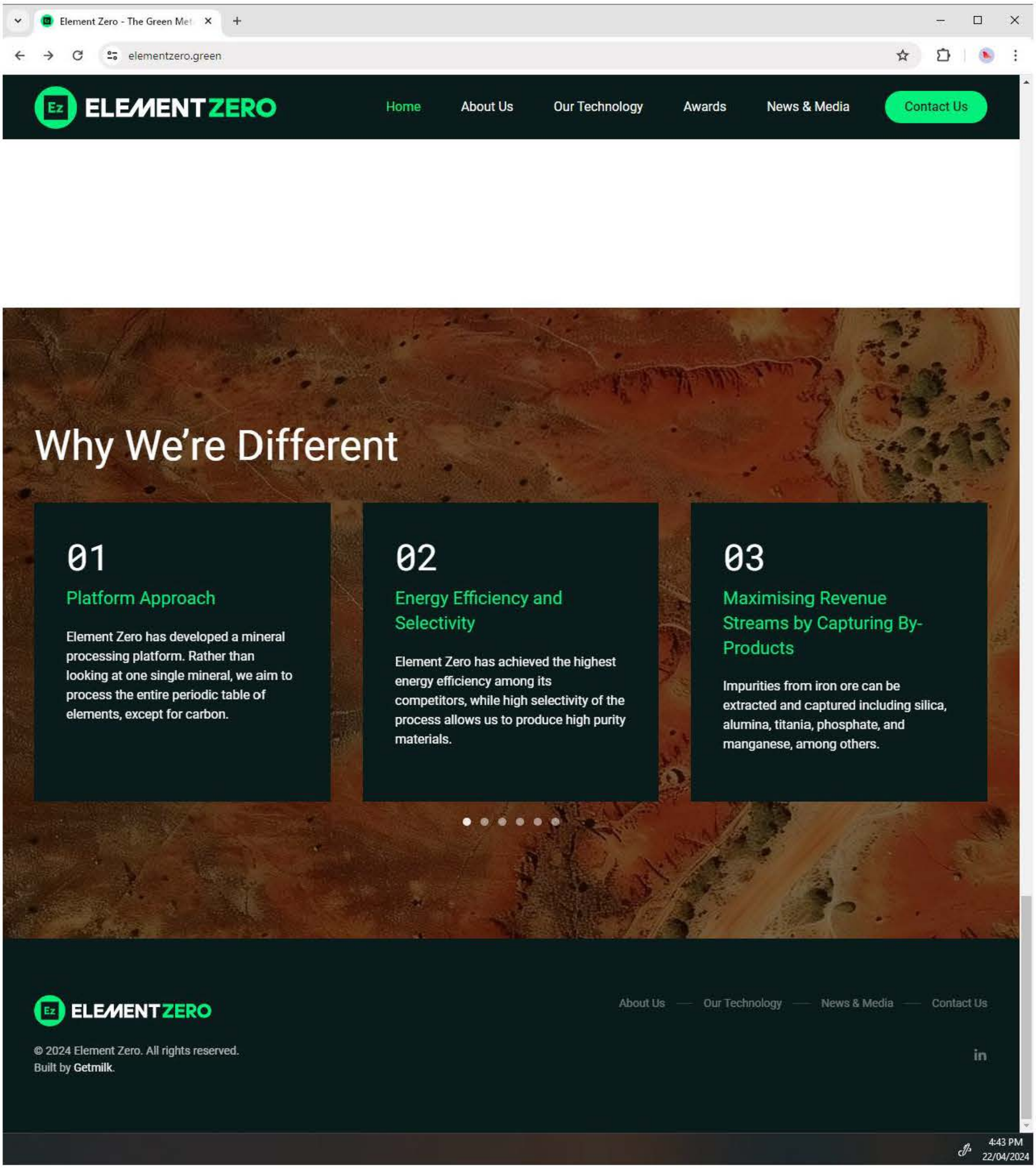


Pilbara Iron Super Hub,

Port Hedland, Australia

Prime location adjacent to 50% of global iron exports, our platform is able to deliver cost reductions to iron ore and energy metal suppliers and the world's leading customers including core North and South Asian Markets.

- 5 million tonnes per annum of iron ore feed sourced from major ore companies
- Expanding in stages to 20 million tonnes per annum (circa US$9 billion revenue)
- Renewable electricity from Australian Renewable Energy Hub and new dedicated sources
- Planned location at Boodarie Strategic Industrial Area
- Exporting to North and Southeast Asia



Why We're Different

01

Platform Approach

Element Zero has developed a mineral processing platform. Rather than looking at one single mineral, we aim to process the entire periodic table of elements, except for carbon.

02

Energy Efficiency and Selectivity

Element Zero has achieved the highest energy efficiency among its competitors, while high selectivity of the process allows us to produce high purity materials.

03

Maximising Revenue Streams by Capturing By-Products

Impurities from iron ore can be extracted and captured including silica, alumina, titania, phosphate, and manganese, among others.

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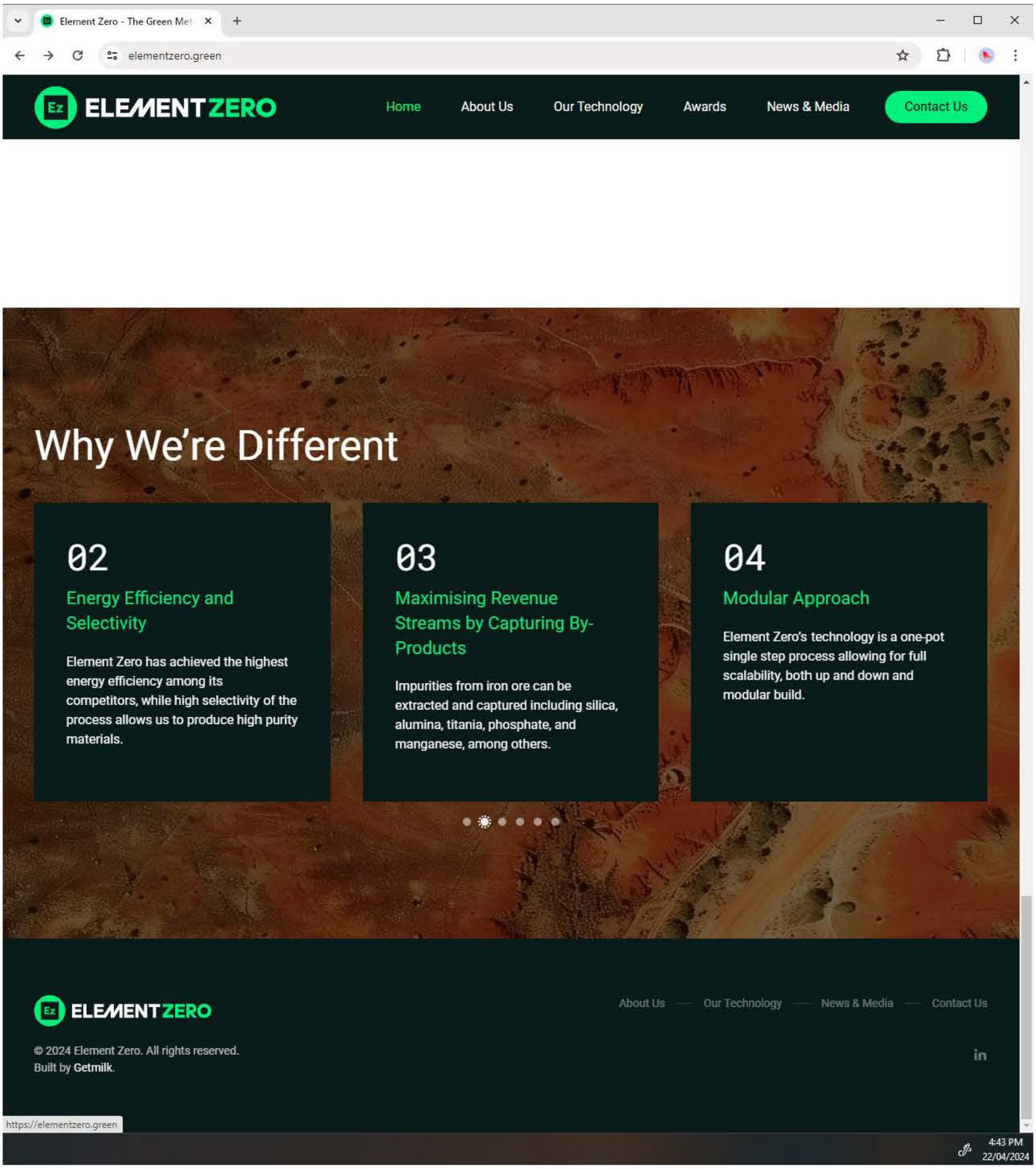

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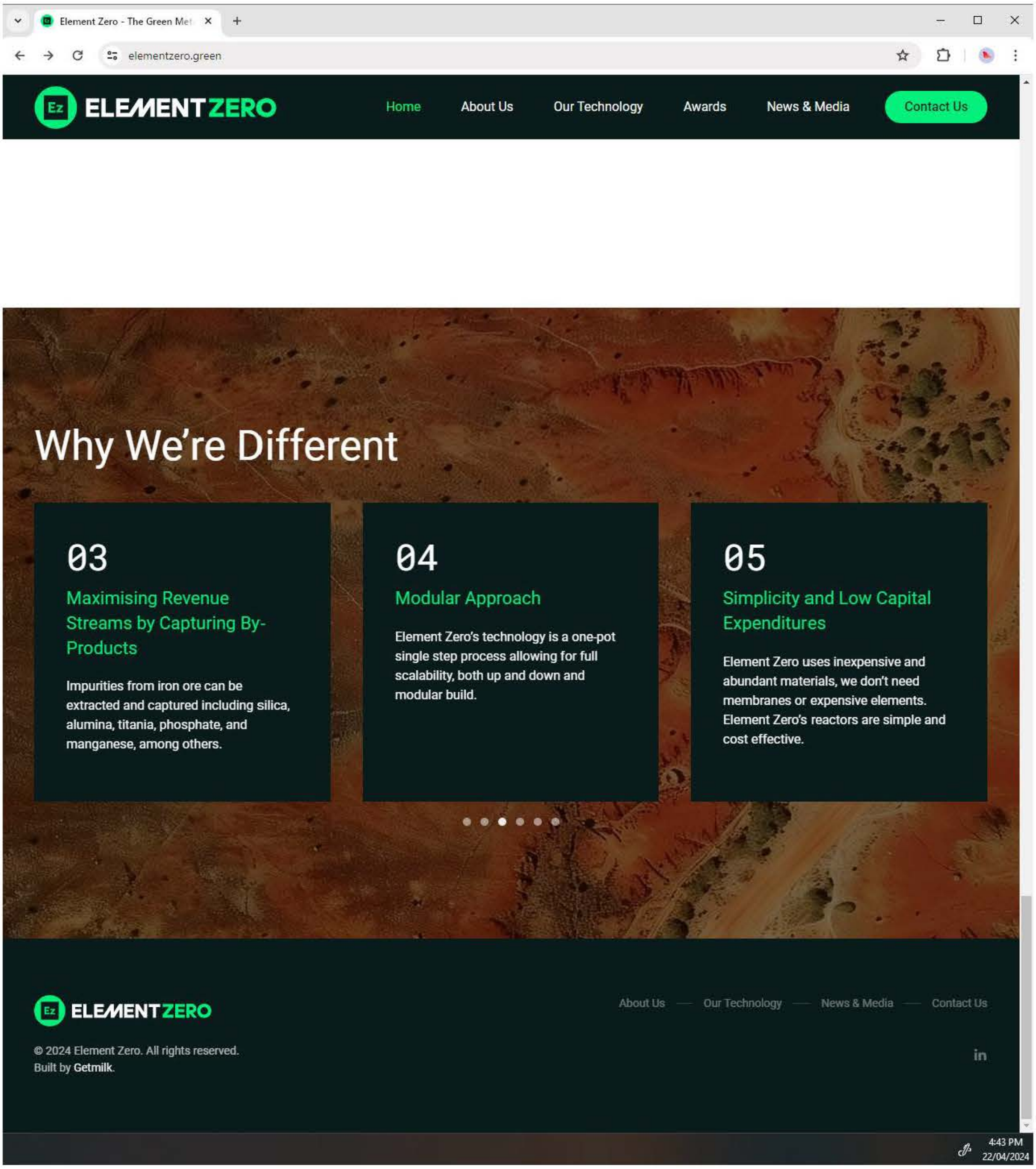

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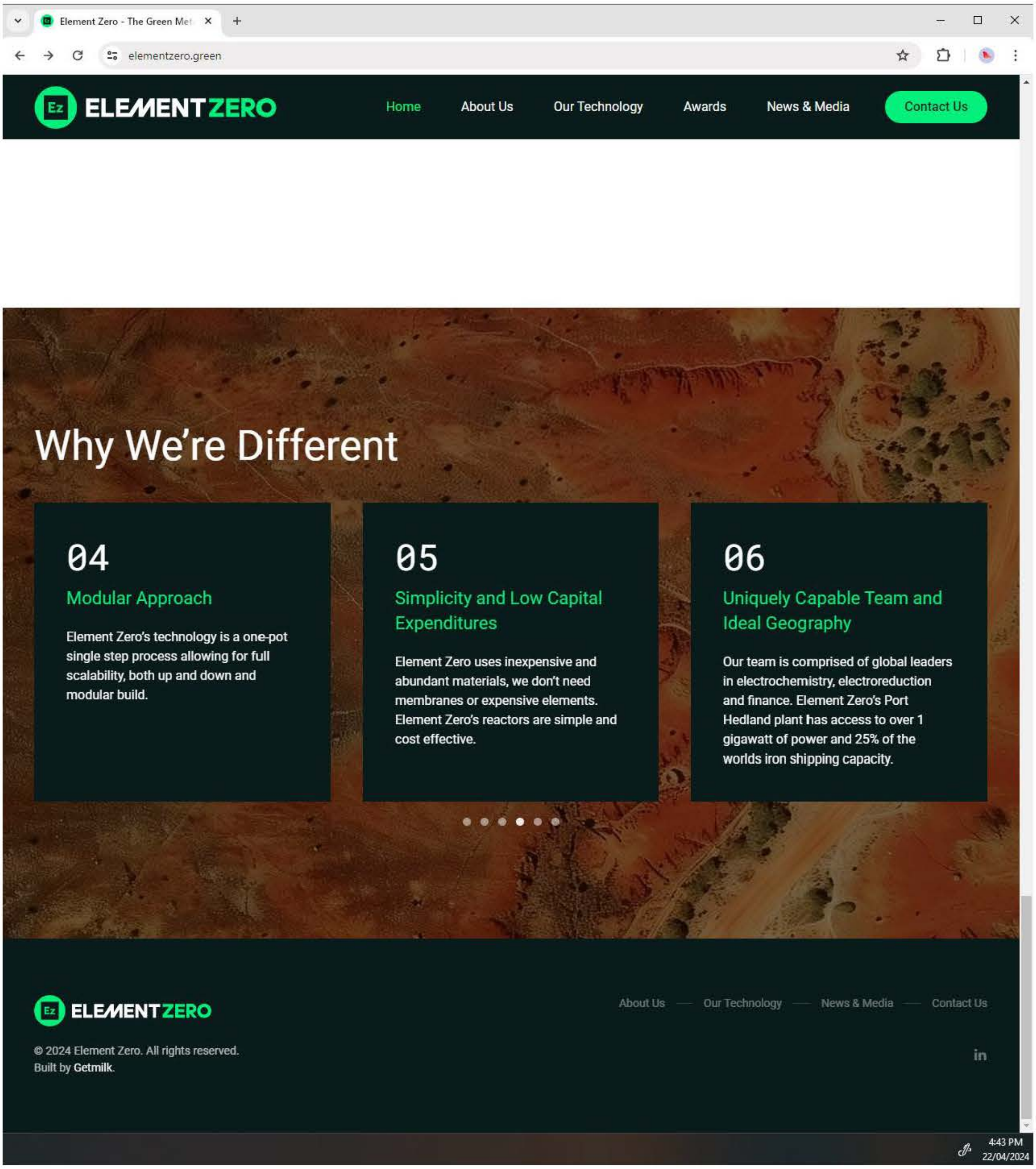

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Uniquely Capable Team and Ideal Geography

Our team is comprised of global leaders in electrochemistry, electroreduction and finance. Element Zero's Port Hedland plant has access to over 1 gigawatt of power and 25% of the worlds iron shipping capacity.

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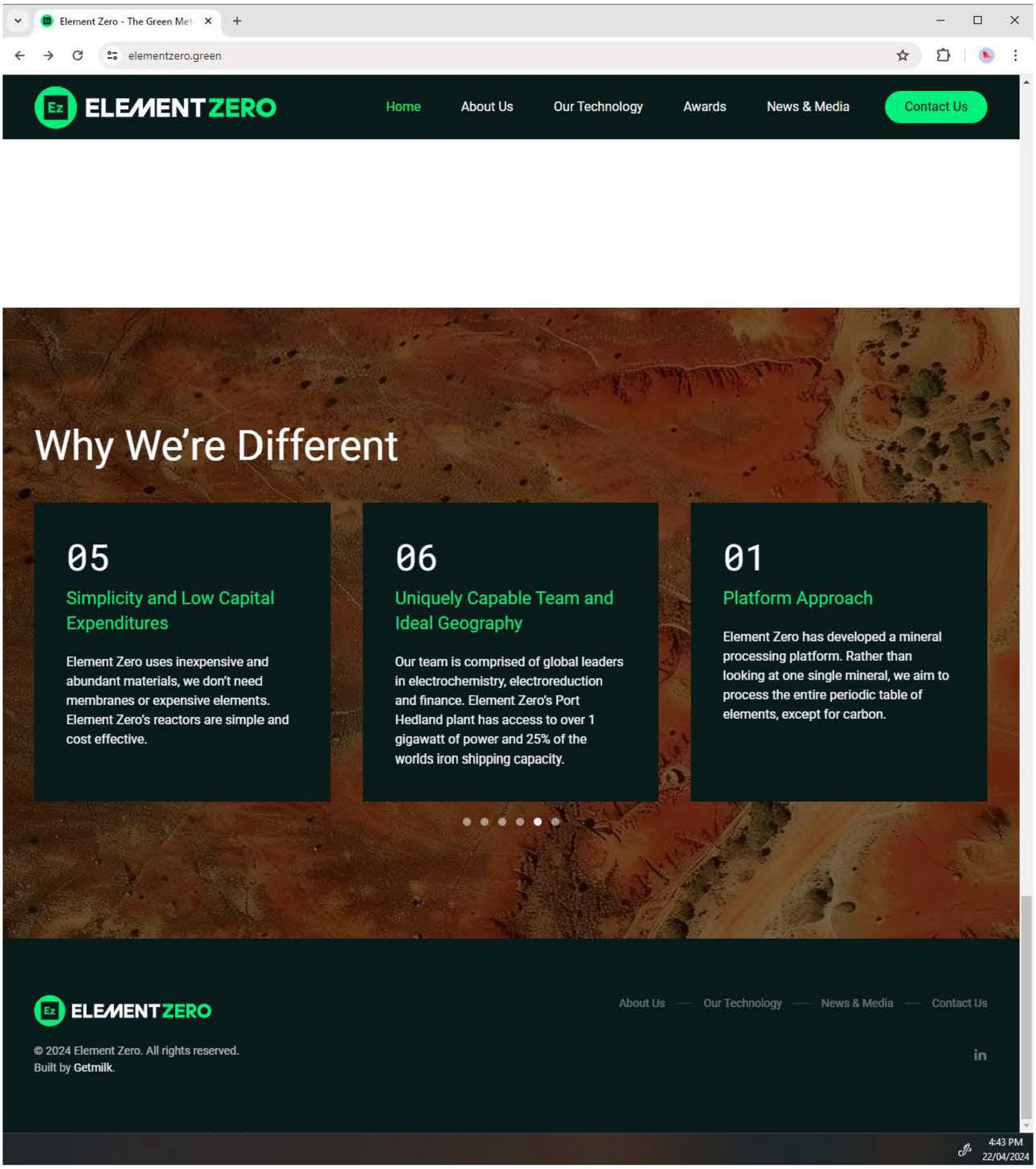

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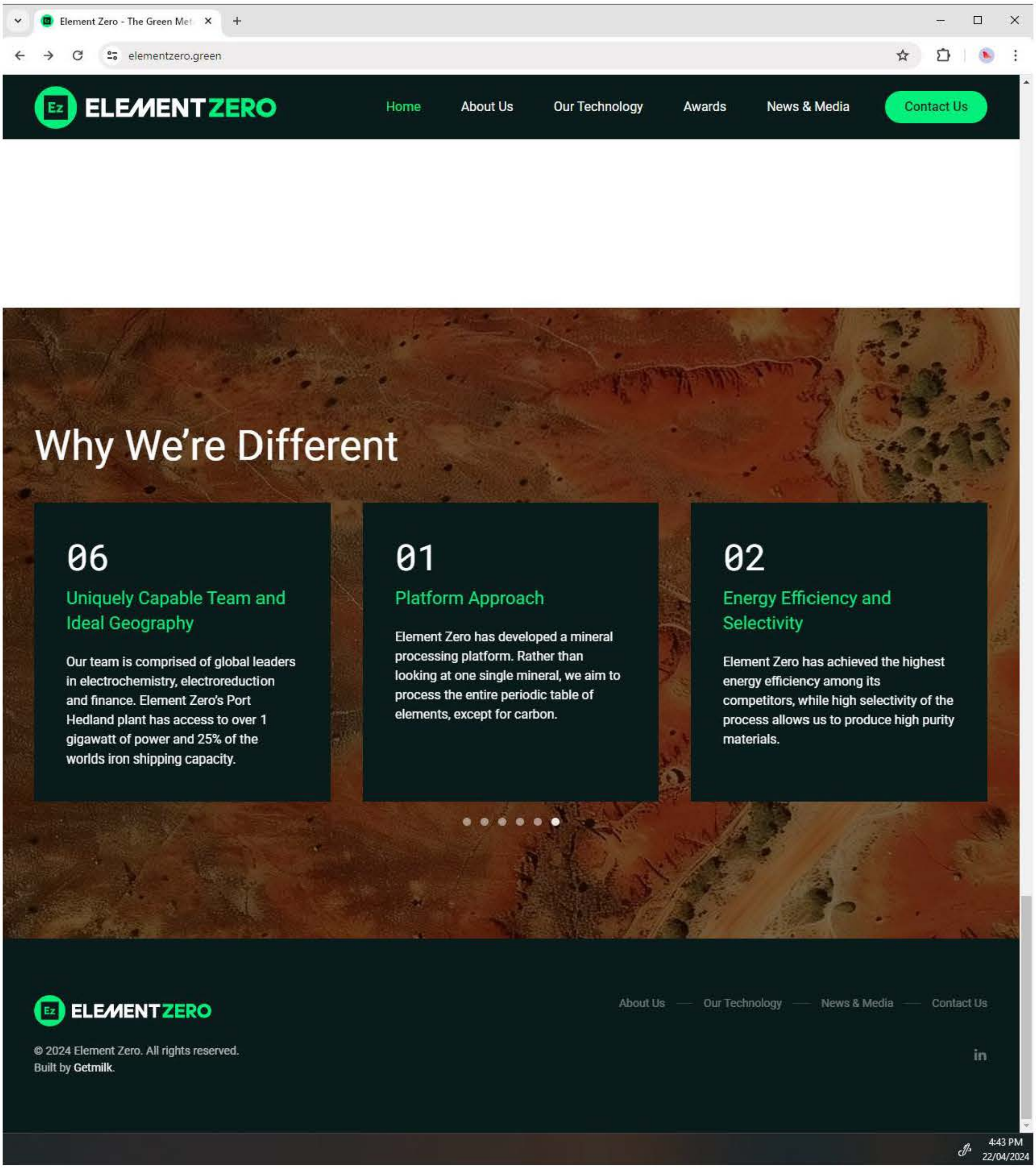

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ANNEXURE AIB-27

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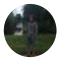
INTERACTION OF OXIDES AND MOLTEN ALKALIS, PRODUCTS OF REACTION AND APPLICATION

Conference Paper · October 2015

1 author:



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INTERACTION OF OXIDES AND MOLTEN ALKALIS, PRODUCTS OF REACTION AND APPLICATION

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Keywords: Molten Salts.

ABSTRACT

The science of chemistry includes a study of properties, composition, and structure of matter, the changes in structure and composition which matter undergoes, and the accompanying energy changes. To learn to use to the full the chemical reaction products is a present-day problem of chemistry. To obtain kinetic energy, the use of chemical reactions with are not combustion reaction and the complete utilization of the products of these reactions are possible. One of these reactions is interaction of oxides with molten alkalis. This reaction is eco-friendly and economically advantageous.

INTRODUCTION

The science of chemistry includes a study of properties, composition, and structure of matter, the changes in structure and composition which matter undergoes, and the accompanying energy changes. To learn to use to the full the chemical reaction products is a present-day problem of chemistry. The simplest combustion reaction (Table I, reaction 1) is used in many areas of human life. This reaction is used every day, for example in the operating principle of internal-combustion engine or in operating of steam engine, where fuel is burnt, the evolved heat heats water to boiling, and the kinetic energy of steam moves the locomotive. A problem of this simplest chemical reaction is its being not eco-friendly. Oxygen burns up, and the carbon dioxide contain of the atmosphere increases. Incomplete combustion involving carbon monoxide formation (Table I, reaction 2) and evaporation of impurities in the fuel are possible. All this leads to environmental pollution.

Kinetic energy can be extracted from other chemical reactions. Therefore, the idea was to utilize a chemical reaction with innocuous gaseous product. This reaction may be interaction of an alkali with oxides (silica, alumima or boric acid). Gibbs energy indicated that exothermal (Table I, reactions 3-5) and endothermal (Table I, reactions 6) reactions proceed from left to right. Thermodynamic properties of pure phases are taken from handbook[1].

Table I Thermodynamic properties of reactions at 600 K

	Reaction	$\Delta H^0_{600\ K}$/kJ	$\Delta G^0_{600\ K}$/kJ
1	$C(graphite)+O_2(g)=CO_2(g)$	-393.7	-395
2	$2C(graphite)+O_2(g)=2CO(g)$	-220.2	-329
3	$2NaOH(l)+SiO_2(s) =Na_2SiO_3(s)+H_2O(g)$	-82.6	-95
4	$2NaOH(l)+Al_2O_3(s) =2NaAlO_2(s)+H_2O(g)$	-26.3	-43
5	$NaOH(l)+B_2O_3(s)=NaBO_2(s)+H_2O(g)$	-111.8	-136
6	$NaOH(l)+H_3BO_3(s) =NaBO_2(s)+2H_2O(g)$	41	-127

RESULTS AND DISCUSSION

The melting point of the equimolar mixture NaOH-KOH is 170^0C; at this temperature, water is in the form of steam. On addition of silica to the NaOH-KOH melt, one mole of water is formed, whose steam energy can be used as kinetic one.

It follows that this reaction can be used instead of the petrol combustion process in internal-combustion engine. The space containing alkalis is heated through electricity to temperature above the melting point of alkalis (>200^0C); then an oxide mixtures is thrown in, the pressure rises, and the pistons move; then the next portion of oxides is thrown in, and process repeats. This reaction can also be used for water production. Another product, sodium or potassium silicate, is a raw material for glass industry.

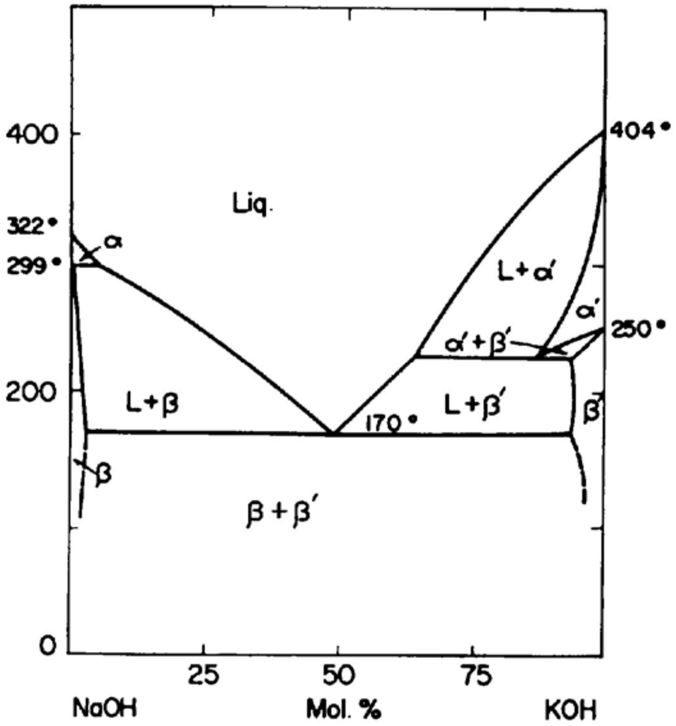

Fig.1. Phase diagram NaOH-KOH [2]

When up to 10% silicate is formed in the system, the NaOH-KOH melt begins to crystallize through silicate formation; to renew reaction 3, it is necessary either to raise the melt temperature or to remove silicate from the melt. Addition of boric acid to the NaOH-KOH melt leads to the formation of two moles of water, hence the steam pressure is higher than in the case with silica. This reaction is endothermal, therefore heat supply is needed. The saturation of the melt by borax takes place at a concentration of over 50%. But as boric acid is lighter the melt (Table II), it floats on the melts surface and retards the reaction. Therefore, it is worth-while to add a boric acid –silica mixture to the melt; the density of this mixture must be higher than that of the melt. Also γ-Al_2O_3 mixed with boric acid may be used instead of silica; since γ-Al_2O_3 also contain water, this will lead to an increase in vapor pressure. Properties of molten salts and oxides (Table II) are taken from handbooks[3-5].

Table II Density of salts at 600 K	
Salt	ρ/g cm^{-3}
NaOH-KOH(l)	1.77
SiO_2(s)	2.53
Al_2O_3(s)	3.90
B_2O_3(s)	1.84
H_3BO_3(s)	1.43

CONCLUSION

To obtain kinetic energy, the use of chemical reactions with are not combustion reaction and the complete utilization of the products of these reactions are possible. One of these reactions is interaction of oxides with molten alkalis. This reaction is eco-friendly (green chemistry) and economically advantageous.

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No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

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Characterization of Li2K(OH)3 as material for thermal energy storage at high temperature

Conference Paper · May 2015

Fouzia Achchaq
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C/T/E Energy Storage – 02

Characterization of $Li_2K(OH)_3$ as material for thermal energy storage at high temperature

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Keywords: THERMO-PHYSICAL PROPERTIES, energy density, phase diagram

SUMMARY

$Li_2K(OH)_3$ is proposed as a candidate for thermal energy storage in power plants providing saturated steam around 300°C. Its selection among other salts was done with FactSage 6.4® software. Key thermophysical properties of $Li_2K(OH)_3$ were determined using differential scanning calorimeter (DSC) and a γ-ray based method. As expected, $Li_2K(OH)_3$ has a very high enthalpy of formation. It also shows an appreciable thermochemical stability. However, the enthalpy of formation is 10% lower than the predicted value. This issue is discussed in the paper and the use of Carbon-$Li_2K(OH)_3$ composites have been proposed to maximize heat recovery on cooling.

INTRODUCTION

The success of solar power plants using direct steam generation (DSG) depends on the effectiveness of thermal energy storage modules (Feldhoff et al. 2012) and particularly on those which are able to provide saturated steam at almost constant temperature (~310°C) and pressure (~100 bars) (Seitz et al. 2014). Latent heat storage (LHS) is hence considered as an appropriate storage solution for this application. Extensive work has been reported in the literature on selection and/or characterization of phase change materials (PCM) for high temperature LHS (Kenisarin 2010; Liu et al. 2012; Pielichowska et al. 2014). Inorganic anhydrous salts have attracted more interest than metals and metallic alloys because they are cheaper. The cations are mainly alkali (e.g. Li, Na, K) and alkali earth metals (e.g. Ca, Mg). Anions which are considered include nitrates, nitrites, hydroxides, bromides, carbonates, chlorides, sulphates and fluorides. Many anhydrous salts are miscible and this results in a large variety of potential single salts or eutectic salts. Regarding PCMs with melting point closed to 300°C, only four have been studied with deep analysis of their long-term stability: $NaNO_3$ (Zheng et al.), $Li_2CO_3/K_2CO_3/Na_2CO_3$ (Liu et al. 2015), Al/Mg/Zn (Sun J.Q. et al 2007) and Mg/Zn (Blanco-Rodriguez et al. 2014). $NaNO_3$ is the most widely used in prototypes so far and the only one seriously considered for the development of a LHS technology for DSG applications (Steinmann and Eck 2006; Laing et al. 2011). The melting point and the latent heat of $NaNO_3$ are 309°C and 176J/g, respectively.

Even if LiOH/KOH-based material was already listed in databases and considered as one of very promising materials (Ozawa 1985; Liu et al. 2012; Cardenas and Leon 2013), only one experimental characterization has been done until now to our knowledge (Ozawa 1985). However this characterization involves the eutectic mixture of LiOH/KOH, which has a latent heat (184 J/g) closed to those of $NaNO_3$ but a melting point (222°C) far below what required for the intended application. The stoiechiometric compound $Li_2K(OH)_3$, which is form on cooling by reaction of the LiOH/KOH liquid phase with LiOH(s), is proposed and studied in this paper. This material has never been proposed before for thermal energy storage.

METHODS

LiOH/KOH mixture composition selection

FactSage 6.4® software has been used for selecting the composition of the LiOH/KOH mixture. This software, established on Calphad method (Saunders and Miodownik 1998), allows the calculation of phase diagrams and the related thermodynamic functions and parameters using Gibbs free energies.

$Li_2K(OH)_3$ synthesis and composite materials elaboration

Binary mixtures were prepared using anhydrous powders of LiOH and KOH respectively supplied by Acros Organics and Fischer Scientific. Their purity were, respectively, of 98% and 85%. Different ratios of each compound were weighed accurately and milled in a marble mortar into a glove-box under Argon controlled atmosphere to avoid any oxydation or hydration of mixtures. The mixture of powders (~20 mg) was then placed inside a closed crucible (stainless steel) and heated inside a furnace (Nabertherm 30-3000°C) at 350°C for several hours up to the melting of mixture. Before cooling, crucibles were stirred for several minutes to enhance the melted phase homogenisation. Once cooled (cooling rate: 0.3 °C/min), end products obtained were sampled and tested.

Two types of carbon-salt composites have been prepared to study the effect of the crystallization of the LiOH on the formation of $Li_2K(OH)_3$. The first one is obtained by addition and dispersion of small particles (micrometric size) of vitreous carbon into the molten salt. The second one consists in a graphitic carbon foam (KFOAM® L1 125 from Koppers Inc. coated with PyC) infiltrated with $Li_2K(OH)_3$. The foam has a cellular structure, 82% of open porosity and apparent density equal to 0.24 g/cc (Canseco et al. 2014). It was put with $Li_2K(OH)_3$ in powder into a stainless steel crucible and heated in the furnace at 350°C for hours. Afterwards, the foam impregnation was done under vacuum within a desiccator. The infiltration rate was checked by calculating the ratio volume of salt (liq.) inside the foam divided by the porosity of this latter. It reached a value superior to 95%.

$Li_2K(OH)_3$ & composite materials characterization methods

Differential scanning calorimeter (TG-DSC 111 Setaram) was used for the determination of melting temperatures, enthalpies of solid/liquid transitions and corresponding heat capacities. The DSC calibration was checked using indium, tin and lead. Powder samples, of approximately 80mg each, were poured into stainless steel open crucibles and heated with a scanning rate of 0.5°C/min under dry Ar flow (20ml/min) into the DSC furnace. The program temperature varied from 280 to 360°C. DSC measurements (heat flow versus temperature) were repeated at least three times for each sample.

Densities and volume expansion were measured using a γ-ray based method described in (Sommier A. et al 2011). The principle is based on the assessment of intensity attenuation of a mono-energetic γ radiation collimated beam after passing through the sample. Samples were put into an insulated beaker of 35 mm of diameter. The beaker is thermally controlled allowing the solid/liquid transitions of materials.

RESULTS & DISCUSSION

The phase diagram of LiOH/KOH binary system was calculated at atmospheric pressure and the result is depicted in Fig. 1. It can be seen that in addition to LiOH(s) and KOH(s), a third solid phase can appear. This is the stoiechiometric compound $Li_2K(OH)_3$, which is formed on cooling by reaction of the liquid phase with LiOH(s). The reaction is reversible and takes place at constant temperature (314.8°C) in mixtures with compositions in the interval [0, 58%wt] KOH/(KOH+LiOH). The solid formed upon cooling is only $Li_2K(OH)_3$ for a mixture of 53.9%wt KOH whilst a mixture of LiOH and $Li_2K(OH)_3$ is formed for the other compositions. The phase diagram also shows the presence of a eutectic mixture (83.7%wt KOH) with a melting point of 225.7 °C. The melting temperature of LiOH and KOH are, respectively, 477.0°C and 403.9°C.

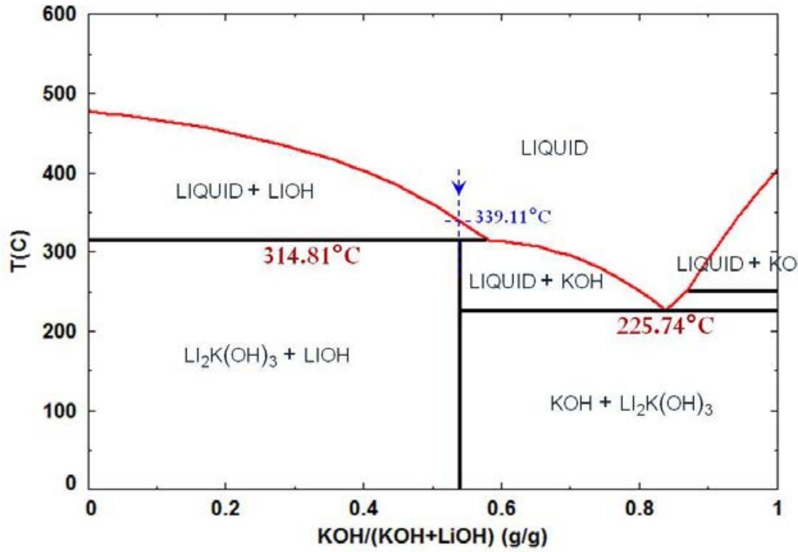

Figure 1. Theoretical phase diagram of KOH/LiOH binary system (liquidus line in red)

Fig. 2. shows the theoretical enthalpy function of four specific compositions of LiOH/KOH system: i) pure component LiOH, ii) pure component KOH, iii) eutectic mixture and iv) the composition 53.9%wt KOH (referred as $Li_2K(OH)_3$ in the following). Despite an interesting heat of fusion (359 J/g), the eutectic mixture (blue line) is discarded because its melting temperature is far from 300°C (225.74°C). $Li_2K(OH)_3$ is formed at 314.81°C with an enthalpy of formation of 534 J/g (ca. 3 times higher than the latent heat of $NaNO_3$), which makes it a really attractive material for thermal energy storage for DSG applications.

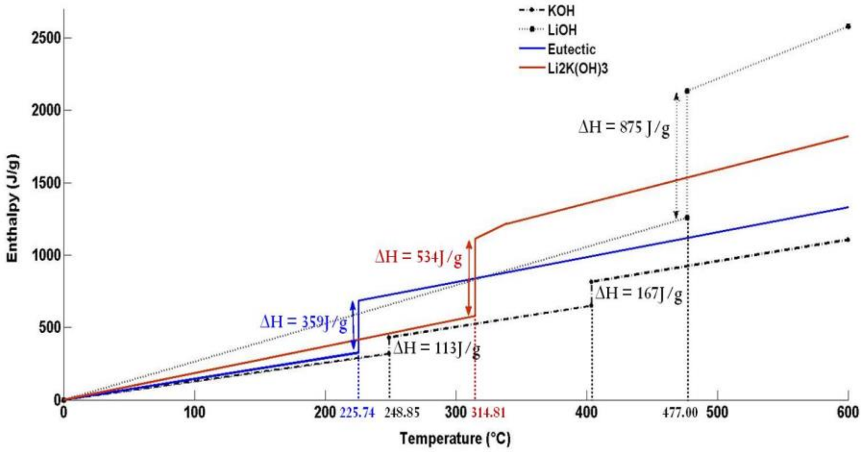

Figure 2. Enthalpy function of several LiOH/KOH mixtures.

To further demonstrate the interest of $Li_2K(OH)_3$, 190 salt-based binary systems were also investigated using FactSage 6.4®. Table 1 presents all eutectic mixtures and pure substances found out with melting point close to 300°C and with improved performances compared to

$NaNO_3$ (higher latent heat and lower or comparable volume expansion). By paying attention to a kind of balance between the highest energy density and the lowest volume expansion possible, $Li_2K(OH)_3$ stands out clearly from the other salts.

Table 1. Candidates for the saturated-steam storage unit

Binary system A/B	[A] (%wt)	T_m (°C)	ΔH (J/g)	ΔV/V (%)
LiOH/KOH	46.1	314.81	534	7
$NaOH/Na_2SO_4$	81.6	294.31	287	15
$FeCl_3$	100	303.85	266	n.a
$NaOH/ NaNO_3$	40.6	267.91	245	15
$LiOH/NaNO_3$	3.15	297.13	214	15
$NaCl/NaNO_3$	4.69	297.49	189	15
$NaBr/NaNO_3$	10.9	291.01	186	15
$NaF/NaNO_3$	1.78	302.96	185	16
$Na_2CO_3/NaNO_3$	2.27	306.55	181	16
$NaNO_3$	100	309.85	179	10

$Li_2K(OH)_3$ thermophysical characterization

Because of impurities presence in raw chemicals used, an experimental screening over a composition range varying from 46 to 49%wt LiOH were carried out to determine the right composition for $Li_2K(OH)_3$ formation. The highest value of enthalpy change (484J/g) is obtained for 48%wt LiOH composition as can be seen in Fig. 3, whilst it varies between 340 and 370J/g for the other compositions. The 52%wt KOH/(LiOH+KOH) composition was thus selected for all upcoming experiments.

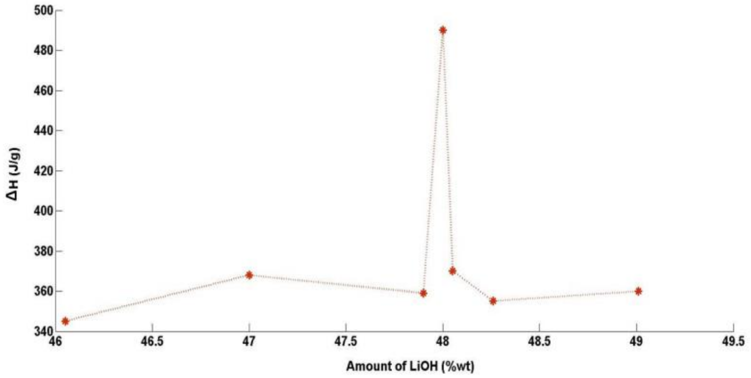

Figure 3. Influence of the amount of LiOH on the enthalpy change associated to the solid-liquid transformation of $Li_2K(OH)_3$

Fig. 4. shows the DSC curves obtained for a $Li_2K(OH)_3$ sample subjected to three melting/solidification cycles. It can be seen that the melting process is perfectly reproducible and the undercooling observed is negligible (< 6°C for a sample of ~80 mg). The onset temperature is 312°C and corresponding enthalpy change is 484 J/g. In both cases, the standard deviation of measurements is less than 1%.

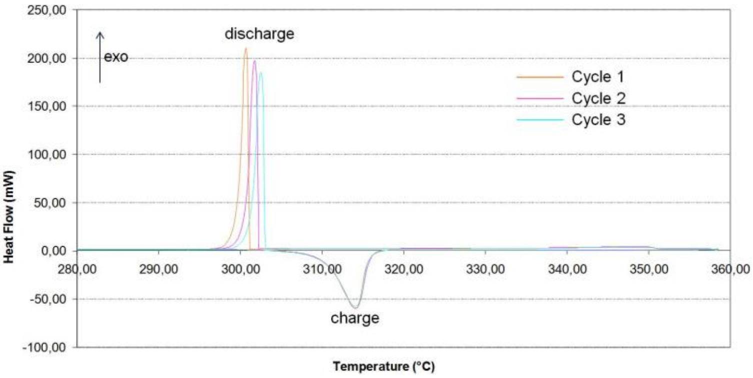

Figure 4. DSC thermogram of one sample . Scanning rate:0.5 °C/min; 3 melting/crystallization cycles

The thermodynamic properties measured are gathered in Table 2. For specific heat, density and volume expansion, there is a quite good agreement between the measurements and the values foreseen by FactSage. However, the measured transition temperature is 2°C below the transition temperature predicted by FactSage and the enthalpy is ca. 10% lower.

Table 2. Thermophysical properties of LiOH/KOH (48/52%wt)mixture

	FactSage 6.4® values	DSC measurements
Transition temperature (°C)	315	312
Heat of formation (J/g)	534	484
Specific heat of solid phase (J/kg.°C) (~270°C)	2021	2169
Specific heat of liquid phase (J/kg.°C) (~330°C)	4323	4544
Volume expansion (%)	7	6
Density of liquid phase (kg/m^3) (350°C)	1583	1634

Preliminary tests of thermochemical stability were performed by applying 50 successive melting/crystallization cycles to a sample. The results show a noticeable enthalpy stability (Fig. 4.). The onset temperature remains unchanged over the 50 cycles as well.

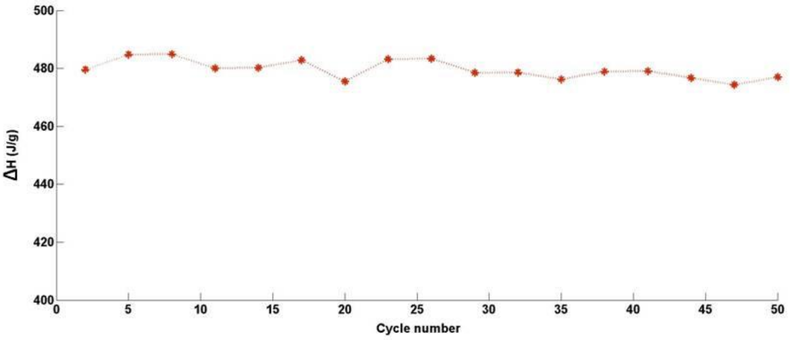

Figure 4. Measured enthalpy evolution of $Li_2K(OH)_3$ by melting

Enthalpy enhancement

The difference observed between the enthalpy of formation of $Li_2K(OH)_3$ predicted by FactSage and the measurements in DSC is ca. 10% and cannot hence be only explained by impurities of raw chemicals used. The reason of this discrepancy is related to low diffusion rates of atoms in the solid phases. Let us recall how $Li_2K(OH)_3$ is formed when cooling the

LiOH/KOH mixture (46%wt KOH) from a temperature above the liquidus. Assuming thermodynamic equilibrium, LiOH(s) starts to nucleate once the liquid phase reaches the liquidus temperature (339.1°C, see Fig. 1) and then the nuclei grow up to 314.8°C where they react chemically with the remaining liquid phase to form $Li_2K(OH)_3$. At the beginning, the three phases - liquid, LiOH(s) and $Li_2K(OH)_3$ - are in contact each other and the reaction progresses fast and forms a layer of $Li_2K(OH)_3$ that isolates the LiOH(s) from the liquid. From now onwards, the growth of $Li_2K(OH)_3$ takes place by long-range atoms diffusion through the $Li_2K(OH)_3$ layer. If diffusion coefficients are infinite (both in the liquid and in the solid phase), the material will be in thermodynamic equilibrium at all temperatures and the $Li_2K(OH)_3$ formed, as well as corresponding enthalpy changes, will follow the blue curve in Fig. 5 (calculated according to the lever rule). However, the solute diffusion into the solid phase is sluggish compared with diffusion into the liquid phase leading to chemical segregation. Therefore, the end product obtained is out of equilibrium, with not complete annihilation of LiOH(s), explaining why the enthalpy change is inferior to the theoretical value. The evolution of the enthalpy and the composition with temperature have been calculated using Scheil-Gulliver model, which considers infinite diffusivity in the liquid and zero diffusivity in the solid. The results are depicted in Fig. 5 (green line). It can be seen that the maximum amount of $Li_2K(OH)_3$ produced is of only 80% at the end of Scheil-Gulliver cooling, and enthalpy changes are lower than those predicted by the lever rule for temperatures below 315°C.

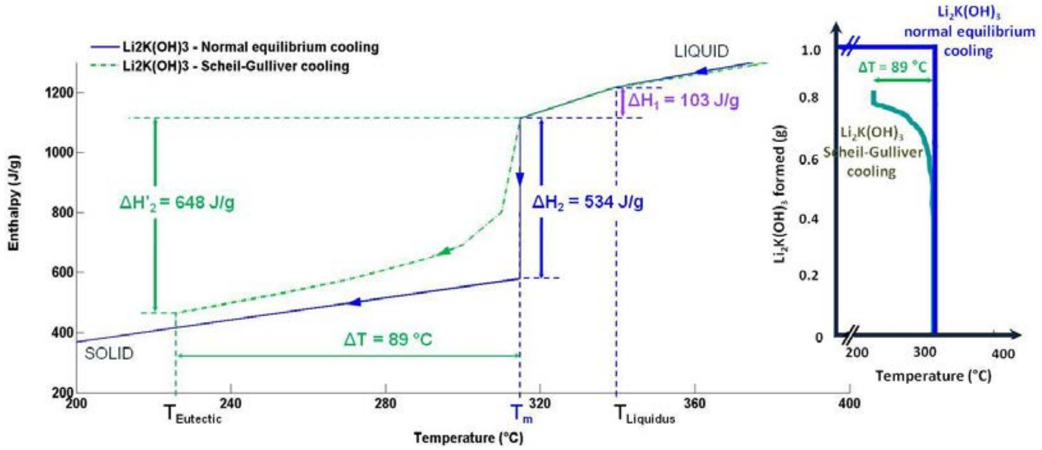

Figure 5. Theoretical enthalpy evolution of $Li_2K(OH)_3$ when subjected to ideal equilibrium (blue line) and to nonequilibrium conditions (dashed green line)

One solution to overcome this drawback and to approach as much as possible the enthalpy theoretical limit consists in providing appropriate sites for heterogeneous nucleation of the LiOH(s), so that this solid phase has a finer distribution. This will result in increased specific surface area between the reactants, namely the liquid phase and the LiOH(s), and therefore the relative weight of the chemical reaction in the whole transformation will be enhanced. The heterogeneous nucleation of LiOH(s) could be achieved either by using porous structures to host the storage material or by dispersing fillers within the storage material. Two types of carbon-salt composites have been prepared to proof the concept. The first one is obtained by dispersion of small particles (micrometric size, 20%wt) of vitreous carbon into the molten salt. The second one consists in a graphitic carbon foam (82% porosity, 0.24 g/cc apparent density) filled with $Li_2K(OH)_3$. Both composites have been submitted to 100 successive cycles of heating/cooling in a DSC. It has been observed that the onset temperature remains unchanged over the 100 cycles whilst the composite enthalpy change is improved and tends even to increase with cycling (Fig. 6.).

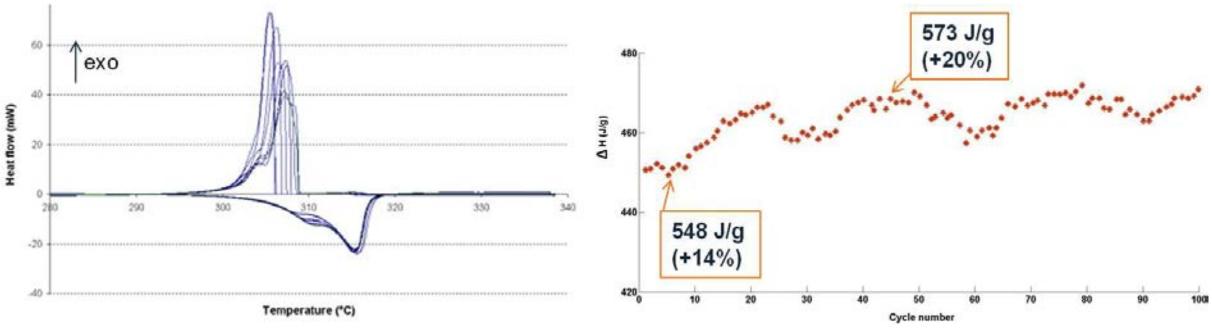

Figure 6. DSC curves of PyC-coated CGC foam/$Li_2K(OH)_3$ composite when subjected to 10 successive heating/cooling cycles - enthalpy evolution by melting after 100 cycles - values in the boxes correspond to the energy density per unit mass of $Li_2K(OH)_3$

CONCLUSIONS

In this paper, $Li_2K(OH)_3$ was selected and studied as material for thermal energy storage in saturated steam operated power plants working at ca. 100 bars. The temperature at which $Li_2K(OH)_3$ is formed/decomposed is 312°C and corresponding enthalpy change is 480J/g. The gravimetric energy density of $Li_2K(OH)_3$ is hence three times higher than that of $NaNO_3$. Also, $Li_2K(OH)_3$ has lower volume changes than $NaNO_3$. Furthermore, key thermodynamic parameters (transition temperature and corresponding enthalpy change) remain unchanged over 50 melting/solidification cycles. All these make $Li_2K(OH)_3$ a really attractive material for thermal energy storage for DSG applications. It has also been shown that enhanced energy density can be achieved either by using carbon porous structures to host the $Li_2K(OH)_3$ or by dispersing carbon fillers within the storage material. Carbon surfaces probably provide active sites for heterogeneous nucleation of the LiOH(s), thus leading to a finer distribution of the solid phase that enhance the relative weight of the chemical reaction in the global transformation. Obviously, much research is required for understanding the impact of walls on the whole enthalpy change and to optimize composites. Also, chemical compatibility with materials used for containment tanks and heat exchangers should be also studied.

ACKNOWLEDGEMENT

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No. NSD of 2024

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ANNEXURE AIB-29

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Before me: ....

Concept Number	Keywords searched in Fortescue sharepoint between 9-16 April 2024
1	flow diagram **OR** process flow diagram **OR** PFD OR flowsheet **OR** process flow sheet **OR** PFS **OR** process & instrumentation diagram **OR** P&ID **OR** process instrumentation diagram **OR** PID **OR** model **OR** modelling **OR** Aspen (i.e. software used to genera PFD, P&ID, models)
2	plant **OR** pilot **OR** Bumblebee **OR** Bumble Bee **OR** seacontainer **OR** sea container **OR** shipping container **OR** bund **OR** bunded **OR** bunding (i.e. cavity in bottom of shipping container to contain leaks)
3	ore **OR** iron **OR** Fe **OR** iron oxide **OR** hematite **OR** haematite **OR** Fe2O3 **OR** Fe203 **OR** goethite **OR** gangue **OR** silica **OR** SiO2 **OR** alumina **OR** Al2O3 **OR** Al203 **OR** Christmas **OR** Christmas Creek **OR** CC **OR** CCSS **OR** Cloudbreak **OR** Kings **OR** Fortescue Blend **OR** FMG blend **OR** Super Special **OR** West Pilbara Fines **OR** WBF **OR** tailings
4	grind **OR** grinding **OR** mill **OR** milling **OR** milled **OR** IsaMill (supplier of milling equipment) **OR** Cedric Walstra (IsaMill employee)
5	leach **OR** leaching **OR** leached **OR** alkaline **OR** caustic **OR** NaOH **OR** MESA Mining Engineering (supplier of leach tank) **OR** Craig Jovanovic (MESA employee) **OR** thickener **OR** thickeners **OR** thickening
6	filter **OR** filter press **OR** belt filter **OR** effluent
7	electrolysis **OR** electrolyser **OR** electrolysor **OR** electrolyzer **OR** electrolyzor **OR** low temperature electrolysis **OR** LTE **OR** cathode **OR** anode **OR** bipolar plate **OR** stack **OR** cells
8	electrolyte **OR** catholyte **OR** anolyte **OR** alkaline **OR** caustic **OR** sodium hydroxide **OR** NaOH **OR** potassium hydroxide **OR** KOH
9	inline product separation **OR** inline separation **OR** magnet **OR** magnetic **OR** mag **OR** demag **OR** low intensity magnetic separation **OR** LIMS **OR** wet high intensity magnetic separation **OR** WHIMS **OR** Eriez Magnetics (WHIMS supplier) **OR** Brian Blythe (employee of WPE Process Equipment which was an Eriez stockist) **OR** Davis tube
10	briquette **OR** briquettes **OR** bricket **OR** brickettes **OR** briquetted **OR** bricketted **OR** briquetting **OR** bricketting **OR** pellet **OR** pellets **OR** pelletisation **OR** pelletization **OR** pelleting **OR** green iron **OR** green steel

Search conducted on R&D sharepoint site, Fortescue Future Industries - FFI Science and Technology - All Documents (sharepoint.com). Search was performed by using keyword/concept listed and then scanning files between January 2021 to November 2021. Likely files were then opened and read by Anand Bhatt and evaluated in context of being useful for developing a pilot plant for green iron technology.

Based on the searching, there are a number of documents listed below which can be helpful to construct a pilot plant for green iron technology. This list is not comprehensive, but provides an indication of the type of documentation that was available to anyone with access to the aforementioned sharepoint site.

The following documents can be used to assist in designing a pilot plant and choosing the basis of design parameters:

- Example Flow Diagrams 22_2_21.docx
- Electrochemical ore reduction Figures and flow diagram (002).pptx
- FFI-Green_Steel_Process_Overview_Memo_v1.docx
- 570CBC0001-02007-BD-EG-0001_1_US.pdf
- FFICGreen_Steel_Process_Overview_Memo_v2.docx
- Southdown Flowsheet 4_5_21.docx
- Pilot Plant Basis of Design - Mechanical.docx
- Engineering Diary Week 36_21 12_9_21.docx
- FFI INNOVATION CENTRE Engineering Diary Week 42_21 22_10_21 DJA input.docx
- FFI0302-8100-EG-BOD-0001_A.docx
- BumbleBee FFI0301-10000-00-EG-BOD-0001_A.docx
- Pilot Plant Basis of Design - Mechanical.docx

- FFI-Green_Steel_Process_Overview_Memo_v1.docx
- Pilot Plant Workshop_Outputs.pptx
- Pilot Plant Basis of Design - Mechanical.docx
- FFI-Green_Steel_Process_Overview_Memo_v1.docx
- FFI-Green_Steel_Process_Overview_Memo_v2.docx
- Pilot Plant Assumptions.xlsx
- BumbleBee FFI0301-10000-00-EG-BOD-0001_A.docx
- FFI0302-8100-EG-TNN-0001 - Questions.docx

The following documents can be used for detailed design of a pilot plant, for example developing piping and instrument diagrams or flowsheets which can then be used as the basis documents for construction process:

- Green_Steel_PFD_Example_Overview_BWJ_16-07-21_Comments.pdf
- Green_Steel_PFD_Example_Overview_NOT_FOR_USE.pdf
- FFI0301-0001-00-DR-PR-0001_rA GS RIG OVERALL BLOCK DIAGRAM.pdf
- 2. FFI Pilot - concept flowsheet REV0.pdf
- Pilot Plant MEL draft.xlsx
- PTHPSM01_3BF00564-PTH_PRN_Belmont_0576_001.pdf
- Multiple Aspen software files located within the folder named Models
- GreenSteel_ProcessFlow_Schematic_v4.pdf
- FFI0001-0001-00-DR-PR-0004_rA_LEACHING STAGE - CHECK.pdf
- FFI0001-0001-00-DR-PR-0002_rA_COMMINUTION STAGE - CHECK.pdf
- Bumblebee PID markups 26_10_21.pdf
- Bumblebee layout.docx
- Green_Steel_PFD_Example_Overview_BWJ_16-07-21_Comments.pdf
- Pilot Plant Technical Workshop .potx
- Pilot Plant Workshop_Outputs.pptx
- Green_Steel_PFD_Rev1_v2_Example.png
- GS_PFD.png

The following can be used to identify equipment suppliers to provide parts and components for a pilot plant:

- 2020 IsaMill Compendium of Papers.pdf
- IsaMill_Technology_Used_in_Effecient_Grinding_Circuits.pdf
- Supplier Options.docx
- Tank Review 1_6_21 expanded .docx
- TOTAL CONTAINERS Open Side Container Brochure -3.pdf
- A22314 - ISAMill SigPlot Report Final.pdf
- MESA Q1030.pdf
- MESA Quote 1029.pdf
- filter press concepts 22_3_21.pdf
- SGS Filter Press review 29_03_21.docx
- filter press conversion.pdf
- Filter Press tesfa.docx
- tanks.xlsx

- Isamill call 28_4_21docx.docx
- Isamill purchase review.pdf
- IsaMill Budget Quote ETM 2120 6721.pdf

The following documents can be used for estimation of costs or economics:

- 2. FFI pilot plant (Project Chameleon).msg

Help with research and development for a pilot plant which informs the engineering required for pilot plant design and construction:

- Effluent stream potentials.docx
- 211004_Leaching experimental design_ASH.xlsx
- ULT_Green Steel_u330327.a_Alkali roasting_Diff NaOH trial+Wash trial.csv
- Leaching results_Rob.xlsx
- Ore composition after drying.xlsx
- green iron quick intro.pptx
- Pilot Plant Workshop_Outputs.pptx
- 211029_Iron ore leaching_Report_ASH.R1.docx
- 211004_Leaching experimental design_ASH.xlsx
- ULT_Green Steel_u330327.b_ICP_Bjorn Leach solution.csv
- 210827_Leaching project draft plan_NTH_ASH edits.docx
- Test Plan for leaching variables.docx
- Brief notes on processing product from ‘filter press’ test rig 10_6_21.docx
- 210920_Update presentation_ASH.pptx
- SWI RS-WI-MT-0101 Wet Low Intensity Magnetic Sperarator (Rev 0) SG.doc
- FFI0303-8100-EG-PLN-0002 Comminution Testing Plan.xlsx
- A22314 - SigPlot Report Final edit.xlsx
-

Contain information regarding Fortescue ore specifications and green iron business plans which allows for a market positioning exercise to build a green iron business:

- V1.0_Estimated Grade_Logging_Template_8mm_Sample__Post_Scrub_20201216 AL.xlsx
- Green Iron Update (10.09.2021) v1.pdf
- Solomon_Stratigraphy_Geo-Met_GE.pptx
- SOL DID Rc chip polished blocks grades_JCedits final.xlsx
- 20210813 All Operations Tailings Chemistry to Current_SCH.xlsx
- Tailings stream potentials.docx
- Christmas Creek OPF2 Mass Balance.xlsx

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-30

This is the annexure marked **AIB-30** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

[redacted]

From: Bjorn Winther-jensen
Sent: Monday, 8 November 2021 12:53 PM
To: bjornwj@gmail.com
Subject: FW: Technical Report- Leaching experiments (Iteration- 1)
Attachments: 211029_Iron ore leaching_Report_ASH.R1.docx

From: Aabhash Shrestha <aabhash.shrestha@fmgl.com.au>
Sent: Monday, 8 November 2021 9:39 AM
To: !FFI - Innovation Centre <FFIInnovationCentre@fmgl.com.au>
Cc: Rachelle Doyle <racdoyle@fmgl.com.au>
Subject: Technical Report- Leaching experiments (Iteration- 1)

Hello Team,

We have completed the 1st iteration of the leaching experiments and I have prepared a draft of technical report for your review. The 1st iteration was designed to understand the mechanism (and/or limitations) of the leaching process. Please find the attached document. The document is also located at:
Technical Reports

The leaching experiments will be an on-going effort with further iterations to explore other relevant variables. I will be glad to have your feedback and suggestions.

Cheers,
AS

Aabhash Shrestha
Electrochemist, Energy

Fortescue Future Industries Pty Ltd
Level 1, 6 Bennett Street, East Perth WA 6004

P: +61 8 6218 8888 I M: 0 420 510 [redacted]
E: aabhash.shrestha@fmgl.com.au
Twitter: @FortescueNews I www.ffi.com.au | www.fmgl.com.au

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[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-31

This is the annexure marked **AIB-31** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-32

This is the annexure marked **AIB-32** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

[redacted]

From: Bjorn Winther-jensen
Sent: Wednesday, 10 November 2021 11:46 AM
To: bjornwj@gmail.com
Subject: FW: Iron ore leaching- update
Attachments: 211014_FFI Green Steel_Ore Leach_ASH_XRF results.csv; 211014_FFI Green Steel_Ore Leach_ASH_ICP results.csv

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others
Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others
Respondents

ANNEXURE AIB-33

This is the annexure marked **AIB-33** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

[redacted]

From: Bjorn Winther-jensen
Sent: Friday, 5 November 2021 12:55 PM
To: bjornwj@gmail.com
Subject: FW: Technical Evaluation of Green Iron process
Attachments: Technical Evaluation.xlsx

[redacted]

[redacted]

[redacted]

[redacted]

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-34

This is the annexure marked **AIB-34** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

From: Bjorn Winther-jensen <bjorn.wintherjensen@fmgl.com.au>
Sent on: Thursday, November 11, 2021 8:43:12 AM
To: bjornwj@gmail.com
Subject: FW: PROVISIONAL APPLICATION FILED || Australian Provisional Patent Appln 2021901547 || YRef: Green iron || DCC: 35557986/JPN [ITUSEONLY-DCC.FID1199841]
Urgent: High

Attachments: 35557986AU- Specification as filed (35557986).pdf (163.88 KB), 35557986AU - Drawings as filed (35557986).pdf (302.99 KB)

From: Bjorn Winther-jensen
Sent: Thursday, 11 November 2021 1:26 PM
To: Robert Kerr <robert.kerr@fmgl.com.au>; Sienna Mohammadzadehmoghadam <sienna.mohammadzadehmoghadam@fmgl.com.au>; Aabhash Shrestha <aabhash.shrestha@fmgl.com.au>
Subject: FW: PROVISIONAL APPLICATION FILED || Australian Provisional Patent Appln 2021901547 || YRef: Green iron || DCC: 35557986/JPN [ITUSEONLY-DCC.FID1199841]
Importance: High

Hi

FYI, the provisional patent application as filed.

Bjorn

[redacted]

APPARATUS AND PROCESS FOR PRODUCING IRON

FIELD OF THE INVENTION

The present invention relates to an apparatus and process for producing iron and, more generally but not exclusively, to a method of producing steel with zero-emissions energy.

BACKGROUND TO THE INVENTION

It is well-known to produce iron from iron ore, however the present applicant has identified that the typical processes for producing iron from iron ore require intense and sustained energy input. In particular, the applicant has identified that existing processes for producing iron from iron ore would not be suitable for use with a highly intermittent power supply such as from renewable energy sources including wind and solar energy.

In traditional steelmaking processes, approximately two tonnes of carbon dioxide are produced for every tonne of steel produced. The term "green steel" (or "green iron”) has been given to steel (or iron) which is produced with less carbon dioxide being generated in the process.

Examples of the present invention seek to provide an apparatus and process for producing iron which alleviates or at least ameliorates one or more disadvantages of existing processes for producing iron.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, there is provided an apparatus for producing iron, wherein the apparatus includes an electrochemical reactor for reducing iron ore to iron.

Preferably, the electrochemical reactor is in the form of a fluid-bed reactor. More preferably, the fluid bed reactor has a primary catholyte chamber having a cathode and a primary anolyte chamber having an anode. Even more preferably, the primary catholyte chamber contains iron ore powder suspended in a catholyte.

In one form, the fluid bed reactor has an ion-conducting membrane separating the primary catholyte chamber from the primary anolyte chamber. In other forms, the fluid bed reactor may operate without a membrane.

Preferably, the electrochemical reactor is in the form of an electrochemical flow reactor. More preferably, the electrochemical reactor has a primary catholyte chamber for containing catholyte on one side of an electrochemical cell and a primary anolyte chamber for containing anolyte on another side of the electrochemical cell.

Preferably, the catholyte is in the form of a powder slurry having suspended ore powder, circulated over a cathode. More preferably, the apparatus includes a pump for circulating the catholyte. Even more preferably, the apparatus includes a first pump for circulating the catholyte and a second pump for circulating the anolyte.

In a preferred form, the pump forms part of a pumping system external to the primary catholyte chamber. The pumping system may include a secondary catholyte chamber. The plurality of catholyte chambers may provide multiple electrochemical cells whereby reduction of the ore powder is extended over the plurality of cells to achieve complete reduction. Multiple electrochemical cells may be stacked to allow increasing the capacity of the system while minimising a footprint of the required system.

Preferably, the flow reactor includes a separator for separation/extraction of reduced iron particles. More preferably, the flow reactor includes a magnetic separator for magnetic separation of reduced iron particles. More preferably, the magnetic separator allows non-reduced iron ore particles to continue to flow for further reduction cycles. The applicant has determined that different separator techniques may be used, particularly those which may be suitable for use with magnetite iron ore.

In one form, the flow reactor includes a source of iron ore particles for metered introduction of iron ore particles into the flow of the catholyte.

Preferably, a cathodic potential is applied to the magnetic separator to force a complete reduction.

In a preferred form, the iron ore is in the form of iron ore powder. More preferably, the iron ore is in the form of iron ore powder having a particle size of less than or equal to 20 µm, and more preferably 10 µm or smaller. The applicant has identified that a narrow distribution of the particle size is important, as having different particle sizes in the system will require different reduction rates/times.

Preferably, the apparatus includes a cathode formed of a material selected to have inferior catalytic properties for a water reduction reaction and good charge-transfer properties to iron ore particles. More preferably, the cathode is formed of a glassy carbon material. In another form, the cathode may be formed simply from steel. Even more preferably, the cathode is formed to prevent adhesion of iron particles to the cathode. In one form, the apparatus includes sonication, pulsed electrical currents, and/or high-speed catholyte flow to prevent iron particles from adhering to the cathode.

It is preferred that the apparatus is adapted to perform the reaction at a temperature less than 130 °C. More preferably, the apparatus is adapted to perform the reaction at a temperature between 85 °C and 130 °C. Even more preferably, the apparatus is adapted to perform the reaction at a temperature between 100 °C and 110 °C.

Preferably, the apparatus is arranged to provide electrochemical parameters of between 1.5 V and 2.5V and 0.1 to 1 A/cm^2. More preferably, the apparatus is arranged to provide electrochemical parameters of between 1.5 V and 1.9V and 0.1 to 0.3 A/cm^2. More preferably still, the apparatus is adapted to provide electrochemical parameters of 1.66 V and 0.2 A/cm^2.

In accordance with another aspect of the present invention, there is provided a method of producing iron, wherein the method includes the step of using an electrochemical reactor for reducing iron ore to iron.

Preferably, the iron ore is in the form of iron ore powder. More preferably, the iron ore is in the form of particles dispersed in a highly concentrated aqueous hydroxide solution. Even more preferably, the solution includes up to 50% sodium hydroxide (NaOH). It will be appreciated by those skilled in the art that other forms of hydroxide may be used as alternatives to sodium hydroxide. For example, aqueous potassium hydroxide (KOH) may be used, or mixtures of KOH and NaOH.

The iron ore may be pre-treated before, after or between different steps in the grinding process to remove impurities that may otherwise accumulate in the electrolyte during the electrochemical reduction process or may complicate the post-treatment of reduced iron powder to an export grade of iron or steel. Examples of these impurities are alkali chlorides, alumina, silica and sulphur species. The pre-treatment process may include exposure of the iron ore to acidic or alkaline solutions at elevated temperature and pressure to enhance the removal of the impurities. In particular, pre-treatment in a highly alkaline environment to remove alumina and silica (by dissolution) from the ore, in line with the well-known Bayer Process, is suitable for preparing the iron ore powder for the electrochemical reduction process as well as providing a route to a higher-grade iron end-product.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described, by way of a non-limiting example only, with reference to the accompanying drawings in which:

Figure 1 shows a flow chart for production of green iron and green steel;

Figure 2 shows a fluidised bed layout for ore reduction;

Figure 3 shows a flow reactor for ore reduction (first iteration);

Figure 4 shows a flow reactor for ore reduction (second iteration); and

Figure 5 shows a flow reactor for ore reduction (third iteration).

DETAILED DESCRIPTION

With reference to Figures 1 to 5, there are described examples of electrochemical reactors, together with methods of producing iron from iron ore, in accordance with embodiments of the present invention. Advantageously, examples of the present invention may provide superior efficiency compared to other technologies for producing iron, as well as low operating temperatures which allow coupling the process to a highly intermittent power supply, such as a power supply from renewable energy (for example, wind and/or solar). The applicant has identified that efficiency is linked to the low operating temperature enabled by examples of the present invention. Furthermore, low temperature operation may also advantageously provide the ability to switch on and off the system more quickly, for example, within minutes/seconds.

More specifically, Figure 1 shows a flow chart for the production of green steel using an electrochemical reactor 10 for the reduction of hematite iron ore to metallic iron. In particular, a mill 56 is used in iron ore powder manufacturing with a particle size of 10 micrometres being the target size. Subsequently, the iron ore powder from the mill 56 may be fed to the electrochemical reactor 10 which electrochemically reduces the iron ore powder to metallic iron. The raw hematite ore powder from the mill 56 may contain around 5 – 30%, or more, of impurities. These impurities are up-concentrated during the reduction of hematite to iron at the electrochemical reactor 10, due to removal of oxygen from the ore. This relatively high level of impurities has to be removed in the steel-making process (where the iron has to be melted anyway). This process can either be done onshore or at the export destination. The flowchart shows that the metallic iron from the electrochemical reactor 10 may be either exported as raw green iron (see reference 58 representing export of raw green iron), or may undergo purification/steelmaking onshore (see reference 60) with the addition of carbon in an electrical shaft furnace or similar to reduce the impurities to 1 to 3%. Export of green steel with 1 to 3% impurities is represented by reference 62.

Turning to Figure 2, showing a fluidised bed layout for ore reduction, there is provided an apparatus 12 for producing iron, the apparatus 12 including an electrochemical reactor 10 for reducing iron ore to iron. In this example, the electrochemical reactor 10 is in the form of a fluid-bed reactor 14. The fluid bed reactor 14 has a primary catholyte chamber 16 having a cathode 18 and a primary anolyte chamber 20 having an anode 22. The primary catholyte chamber 16 contains iron ore powder 24 suspended in a catholyte 26.

The fluid-bed reactor 14 has an ion-conducting membrane 28 separating the primary catholyte chamber 16 from the primary anolyte chamber 20. In other examples, the fluid-bed reactor may operate without a membrane.

In the electrochemical fluid-bed reactor layout, the hematite ore powder is kept fluidized in the same reactor volume 16 until the reduction to iron has occurred. The powder 24 is kept fluidized by circulation the catholyte 26 from bottom to top of the reactor 14. As such, the fluid bed reactor layout provides a batch process.

By using e.g., magnetic separation for continuous or sequential removal of the iron powder product and by simultaneously adding fresh hematite powder to the reactor, the process can be made continuous.

With reference to Figure 3, in another example, the electrochemical reactor 10 is in the form of an electrochemical flow reactor 30 for ore reduction. The electrochemical flow reactor 30 has a primary catholyte chamber 32 for containing catholyte 26 on one side of an electrochemical cell 34 and a primary anolyte chamber 36 for containing anolyte 38 on another side of the electrochemical cell 34. In the example shown, the catholyte 26 is in the form of a powder slurry 40 having suspended ore powder 24, circulated over a cathode 18. The apparatus 12 includes a pump 42 for circulating the catholyte 26. In particular, the apparatus 12 includes a first pump 42 for circulating the catholyte 26 and a second pump 44 for circulating the anolyte 38.

As shown in Figure 3, the pump 42 forms part of a pumping system 46 external to the primary catholyte chamber 32. Example flow reactors in accordance with embodiments of the invention may implement features used in electrochemical flow reactors used for molecular reactions on pilot and industrial scales.

The applicant has determined that, for the reduction of powders, one can visualise a flow reactor 30 layout as a way to upscale a fluid-bed reactor 14, where the powder slurry 40 is circulated over the cathode 18 and through the external pumping system 46. Multiple cells can be connected in series or parallel (which may be an advantage of flow reactors), so the reduction of powder can be extended over a series of cells to secure complete reduction (in this case to iron) and/or to increase quantity of produced commodity while maintaining minimal system’s footprint.

Figure 4 shows a flow reactor for iron ore reduction (second iteration). In an electrolyser, hydrogen gas is separated from a electrolyte in a liquid/gas separator. The applicant has identified that, in a similar manner, for the separation of iron particles one possibility for separation from the electrolyte is to use magnetic separation of reduced, metallic iron particles. The magnetic separation will allow “un-reduced” iron ore particles to continue in the flow for further reduction cycles.

Accordingly, the flow reactor 30 includes a magnetic separator 50 for magnetic separation of reduced iron particles. The magnetic separator 50 allows non-reduced iron ore particles to continue to flow for further reduction cycles.

As shown in Figure 4, the flow reactor 30 may include a source 52 of iron ore particles 54 for metered introduction of iron ore particles 54 into the flow of the catholyte 26.

Figure 5 shows a flow reactor 30 for iron ore reduction (third iteration) having multiple cells. The applicant has identified that there exists a real possibility that hematite particles can be partially reduced to magnetite in the flow reactor 30 (i.e., incomplete reduction). Such magnetite particles would be captured by the magnetic separation at the magnetic separator 50 and it may be an advantage to add a cathodic potential to the magnetic separator 50 to force a complete reduction of the magnetite (containing) particles. A practical setup contains multiple cells (extended pass way) to secure as complete reduction as possible in the (first) step before magnetic separation, so the amount of reduction reaction required on the magnetic separator 50 would be minimal.

In the example shown in Figure 5, the pumping system 46 includes a secondary catholyte chamber 48. The plurality of catholyte chambers 32,48 may provide multiple electrochemical cells 34 whereby reduction of the ore powder 24 is extended over the plurality of cells 34 to achieve complete reduction.

The iron ore may be in the form of iron ore powder 24. In particular, the iron ore may be in the form of iron ore powder 24 having a particle size of less than or equal to 20μm.

The cathode 18 may be formed of a material selected to have inferior catalytic properties for a water reduction reaction and good charge-transfer properties to iron ore particles 54. In one form, the cathode 18 may be formed of a glassy carbon material. The cathode 18 may be formed to prevent adhesion of iron particles 54 to the cathode 18. The apparatus 12 may use sonication, pulsed electrical currents, and/or high-speed catholyte flow to prevent iron particles 54 from adhering to the cathode 18.

The apparatus 12 may be adapted to perform the reaction at a temperature less than 130°C. More specifically, the apparatus 12 may be adapted to perform the reaction at a temperature between 85 °C and 130 °C. In one particular form, the apparatus 12 may perform the reaction at a temperature between 100 °C and 110 °C.

Also, the apparatus 12 may be arranged to provide electrochemical parameters of between 1.5 V and 2.5 V and 0.1 to 1 A/cm^2. More particularly, the apparatus 12 may be arranged to provide electrochemical parameters of between 1.5 V and 1.9 V and 0.1 to 0.3 A/cm^2. In one form, the apparatus 12 may provide electrochemical parameters of 1.66 V and 0.2 A/cm^2.

As will be appreciated from the above, another aspect of the invention provides a method of producing iron, wherein the method includes the step of using an electrochemical reactor 10 for reducing iron ore to iron. The iron ore may be in the form of iron ore powder 24. More specifically, the iron ore may be in the form of particles dispersed in a highly concentrated aqueous sodium solution. The solution may include up to 50% sodium hydroxide. As mentioned above, the applicant has determined that other forms of hydroxide may be used for electrolyte, such as KOH and the like.

PROCESS DESCRIPTION

In one example, the iron ore may be in the form of hematite iron ore. In this case, hematite iron ore particles 54 are ground to 1 – 20 μm size and fed into the reactor 10. The process may be performed in a close autoclave-like reactor, with graphite cathode electrode and ultra-pure (99.999%) nickel mesh anode electrode. Ultra-fine hematite particles will be dispersed in a highly concentrated aqueous sodium hydroxide solution (up to 50% NaOH). The reaction will be performed at 100 to 110 °C (below the boiling point of the electrolyte).

The electrochemical parameters of the process are 1.5 to 2.5 Volts and 0.1 to 1 A/cm^2. More specific electrochemical parameters of the process are 1.5 to 1.9 Volts and 0.1 to 0.3 A/cm^2. However, optimal parameters are likely to be 1.66 V and 0.2 A/cm^2. The reaction will be performed with a stirrer or agitator to keep the iron ore particles 54 uniformly dispersed within the electrolyte 40.

For 1 kg of green iron per day production, a 460 cm^2 electrode is required. Approximately 3.6 kWh of energy is required to produce 1 kg of iron (3.6 MWh/tonne of iron), but the applicant foresees that this could be reduced further. For comparison, existing technology based on molten oxide electrolysis (at 1,500 ºC) requires >4.0 kWh/kg, while energy contained in coal used in traditional steelmaking processes can range from between 5.2 to 5.6 kWh/kg of iron. Accordingly, the present invention has the potential to greatly reduce the amount of energy required to produce iron.

The applicant has also made significant advances in electrode technology and specifically in relation to electrode materials. The applicant has determined that the cathode may potentially be made of glassy carbon or simply steel/iron. Several candidates for higher performance anode electrodes have been identified that could allow to reduce overpotential. The applicant foresees that the same process can also be deployed for the reduction of magnetite and goethite.

The main advantages of this process may include:

- continuous operation,
- superior efficiency compared to other technologies; and
- low operating temperature, which allows coupling this process with a highly intermitted power supply, including wind and solar.

The solid-state electrochemical process ($Fe_xO_y \rightarrow xFe + \frac{1}{2}yO_2$) under alkaline conditions has been used previously as a cathode process in batteries. The applicant recognises that $Fe(OH)_x$ plays a limiting role as intermediate for the reaction at temperatures below ~80 °C.

For the applicant, a solid-state reduction of the current hematite ore qualities would produce a “raw” green steel with about 14% oxide impurities (mainly from SiO_2 and Al_2O_3). Reduced magnetite concentrates would have around 10% oxide impurities. This suggests that a down-stream process for the removal of impurities would be appropriate in order to obtain a high-quality export product. This consideration allows to revisit the physical-form-requirement for the product coming out of the electrochemical reduction of ore; if the product goes into a down-stream molten-state process, there is not much need for the product to be a coherent steel plate – it could just as well be in the form of raw iron powder. The applicant has determined that this widens the possibilities for upscaling the process.

Design Details

The following design details have been identified by the applicant:

- *Cathode material.* The water reduction reaction is a likely competing reaction to the reduction of iron ore to metallic iron. i.e., the thermodynamic reduction potentials are very similar in the alkaline regime. This indeed has been one of the main hurdles in achieving high efficiencies in all electrochemical iron deposition attempts from solution as well as in the solid state – with effectively iron electrodes, hydrogen has been a significant by-product. In the case of a flow-reactor setup, the intention is that no deposition should occur on the cathode (the reduced particles should remain in dispersion), which means that the properties of the cathode material, in principal, remains unchanged during operation. This gives the opportunity to select materials with inferior catalytic properties for the water reduction reaction but with good charge-transfer properties to iron ore particles. One such material could be glassy carbon, which provides large overpotential for the water reduction process and otherwise good charge-transfer properties.

- *The prevention of iron particles adhering to the cathode is a potential issue.* Having a vertical cathode arrangement is a reasonable first point to apply. A second point is suitable choice of cathode materials (or cathode coatings/structure) that help prevent adhesion. A third point includes active methods to remove particles from the cathode surface. Here sonication, pulsed (electrical) currents and high-speed flow could be added during/part of the operation.

- *Periodical electrochemical removal of deposited.* Periodical electrochemical removal of deposited iron on the cathode material may be included in the maintenance schedule for the equipment. Such electrochemical dissolution can be achieved by applying a more positive potential – above the thermodynamical equilibrium potential of iron – to the electrode, preferably with a neutral or acidic electrolyte solution dedicated for the maintenance procedure.

- *Electrolyte composition.* Generally high concentrations (10 – 20 M) of NaOH have been used. It is anticipated that there can be used alternative electrolyte compositions, where a mixture of alkali-hydroxides are used (i.e., NaOH, KOH and LiOH). Such mixed electrolytes have indeed been adopted for the closely related “Edison” cell (Fe-Ni battery) on a commercial scale. A further possibility is to use high concentration of an otherwise neutral alkali salt (e.g., LiCl) in combination with alkali-hydroxides to obtain a so-called “water-in salt” electrolyte. The combined salt-concentrations should possibly remain in the 10 – 15 M range to provide similar properties as for the common NaOH electrolytes.

- *Operating temperature.* The operation temperature must be above 85 °C to avoid the formation of $Fe(OH)_x$ species on the surface of the iron ore powder. $Fe(OH)_x$ acts as an inhibitor for the (further) reduction but becomes unstable at temperatures above 85 °C. Most reports use temperatures in the 100 – 110 °C range. However, the high concentration electrolytes have boiling points (well) above 120 °C so there could be room for also operating in the 110 – 130 °C range.

- *Operating pressure.* There is no reason to pressurize the electrolyte system other than what is needed to overcome pressure-loss in flow-system itself. The possible need for high flow-rates to avoid adherence of powder to the cathode may require a substantial electrolyte pressure at the inlet of the flow-reactor.

- *Membrane.* The sketched layouts are all containing ion conducting membranes to separate the electrolytes on the anode and cathode side. Thereby re-oxidation of iron particles on the anode is avoided as well as crossover of produced oxygen to the cathode. The particles are kept in one flow stream which will simplify the (magnetic) separation of iron particles from the electrolyte. However, the membrane adds a resistive element to the system and layouts could be developed to omit the membrane in the flow configuration. The membrane family distributed under the Agfa and ZIRFON trademarks have been identified as one potential membrane candidate. The list of possible membranes is not limited to those distributed under the Agfa trademark.

- *Direction of electrolyte flow*. For simulating conditions in the fluid bed reactor, a vertical electrolyte flow “from ground up” may be applied. In this case, the size distribution of the iron ore power must be sufficiently narrow and/or the electrolyte flow high enough to avoid that larger particles are accumulated in the cell. It may therefore be an advantage to have a flow-direction following gravity, so particle accumulation is avoided.

- *Increase of electrode contact area.* Electrode patterning to increase contact area and hence performance of the cell.

- *The separation of iron particles from the electrolyte.* The separation can be performed on the low-pressure side of the flow-reactor and be by magnetic or by other means (e.g., cyclone separation). The electrolyte should be removed from the iron powder without exposing the iron power to oxidizing environments such as the combination of neutral water and air – using an inert atmosphere (e.g., nitrogen gas) may be optimal.

- *Purification*. The impurities from the ore will largely remain in the metallic iron product. Preferably, the metallic iron particles should be transferred to a melting and purification step immediately after the flow-reactor to minimize re-oxidation of the particles in contact with air.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described exemplary embodiments.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

LISTING OF REFERENCE NUMERALS

10	Electrochemical reactor
12	Apparatus for producing iron
14	Fluid-bed reactor
16	Primary catholyte chamber
18	Cathode
20	Primary anolyte chamber
22	Anode
24	Iron ore powder
26	Catholyte
28	Ion-conducting membrane
30	Electrochemical flow reactor
32	Primary catholyte chamber
34	Electrochemical cell
36	Primary anolyte chamber
38	Anolyte
40	Powder slurry
42	Pump
44	Second pump
46	Pumping system
48	Secondary catholyte chamber
50	Magnetic separator
52	Source of iron ore particles
54	Iron ore particles
56	Mill
58	Export of raw green iron
60	Purification/steelmaking onshore
62	Export of green steel

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An apparatus for producing iron, wherein the apparatus includes an electrochemical reactor for reducing iron ore to iron.

2. An apparatus as claimed in claim 1, wherein the electrochemical reactor is in the form of a fluid-bed reactor.

3. An apparatus as claimed in claim 2, wherein the fluid bed reactor has a primary catholyte chamber having a cathode and a primary anolyte chamber having an anode.

4. An apparatus as claimed in claim 3, wherein the primary catholyte chamber contains iron ore powder suspended in a catholyte.

5. An apparatus as claimed in claim 3 or claim 4, wherein the fluid bed reactor has an ion-conducting membrane separating the primary catholyte chamber from the primary anolyte chamber.

6. An apparatus as claimed in claim 1, wherein the electrochemical reactor is in the form of an electrochemical flow reactor.

7. An apparatus as claimed in claim 6, wherein the electrochemical reactor has a primary catholyte chamber for containing catholyte on one side of an electrochemical cell and a primary anolyte chamber for containing anolyte on another side of the electrochemical cell.

8. An apparatus as claimed in claim 7, wherein the catholyte is in the form of a powder slurry having suspended ore powder, circulated over a cathode.

9. An apparatus as claimed in claim 8, wherein the apparatus includes a pump for circulating the catholyte.

10. An apparatus as claimed in claim 9, wherein the apparatus includes a first pump for circulating the catholyte and a second pump for circulating the anolyte.

11. An apparatus as claimed in claim 9, wherein the pump forms part of a pumping system external to the primary catholyte chamber.

12. An apparatus as claimed in claim 11, wherein the pumping system includes a secondary catholyte chamber.

13. An apparatus as claimed in claim 12, wherein the plurality of catholyte chambers provide multiple electrochemical cells whereby reduction of the ore powder is extended over the plurality of cells to achieve complete reduction.

14. An apparatus as claimed in any one of claims 11 to 13, wherein the flow reactor includes a magnetic separator for magnetic separation of reduced iron particles.

15. An apparatus as claimed in claim 14, wherein the magnetic separator allows non-reduced iron ore particles to continue to flow for further reduction cycles.

16. An apparatus as claimed in any one of claims 11 to 15, wherein the flow reactor includes a source of iron ore particles for metered introduction of iron ore particles into the flow of the catholyte.

17. An apparatus as claimed in claim 14, wherein a cathodic potential is applied to the magnetic separator to force a complete reduction.

18. An apparatus as claimed in any one of claims 1 to 17, wherein the iron ore is in the form of iron ore powder.

19. An apparatus as claimed in claim 18, wherein the iron ore is in the form of iron ore powder having a particle size of less than or equal to 20 μm.

20. An apparatus as claimed in any one of claims 1 to 19, wherein the apparatus includes a cathode formed of a material selected to have inferior catalytic properties for a water reduction reaction and good charge-transfer properties to iron ore particles.

21. An apparatus as claimed in claim 20, wherein the cathode is formed of a glassy carbon material.

22. An apparatus as claimed in claim 20 or claim 21, wherein the cathode is formed to prevent adhesion of iron particles to the cathode.

23. An apparatus as claimed in any one of claims 20 to 22, wherein the apparatus includes sonication, pulsed electrical currents, and/or high-speed catholyte flow to prevent iron particles from adhering to the cathode.

24. An apparatus as claimed in any one of claims 1 to 23, wherein the apparatus is adapted to perform the reaction at a temperature less than 130 °C.

25. An apparatus as claimed in claim 24, wherein the apparatus is adapted to perform the reaction at a temperature between 85 °C and 130 °C.

26. An apparatus as claimed in claim 25, wherein the apparatus is adapted to perform the reaction at a temperature between 100 °C and 110 °C.

27. An apparatus as claimed in any one of claims 1 to 26, wherein the apparatus is arranged to provide electrochemical parameters of between 1.5 V and 2.5 V and 0.1 to 1 A/cm^2.

28. An apparatus as claimed in claim 26, wherein the apparatus is adapted to provide electrochemical parameters of 1.66 V and 0.2 A/cm^2.

29. A method of producing iron, wherein the method includes the step of using an electrochemical reactor for reducing iron ore to iron.

30. A method of producing iron as claimed in claim 29, wherein the iron ore is in the form of iron ore powder.

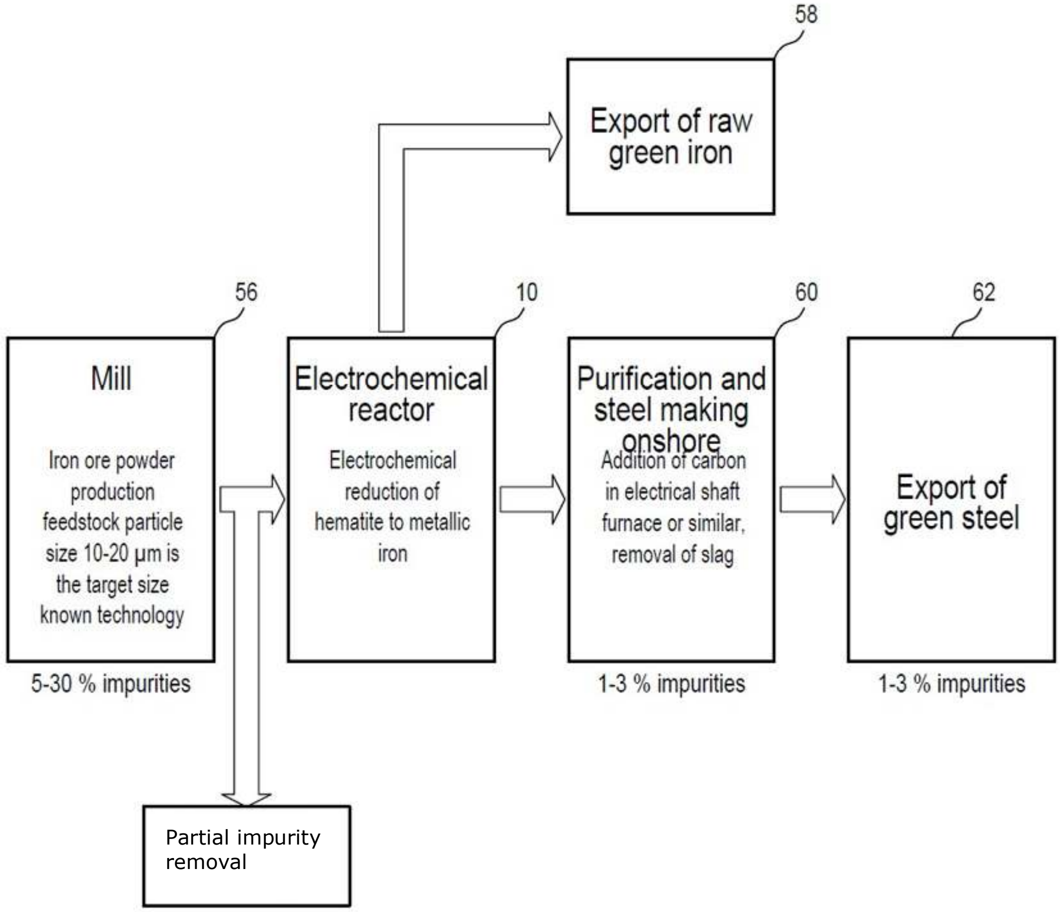
31. A method of producing iron as claimed in claim 29 or claim 30, wherein the iron ore is in the form of particles dispersed in a highly concentrated aqueous hydroxide solution.

32. A method of producing iron as claimed in claim 31, wherein the solution includes up to 50% sodium hydroxide.

ABSTRACT

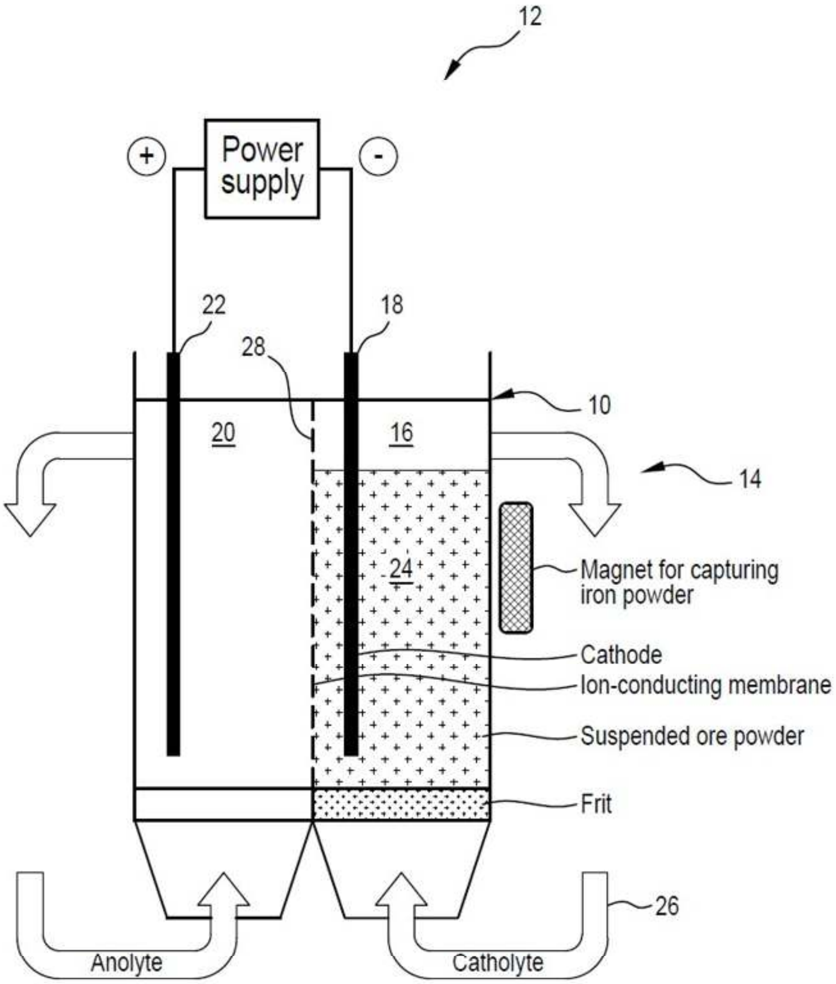
An apparatus for producing iron, wherein the apparatus includes an electrochemical reactor for reducing iron ore to iron. The electrochemical reactor may be in the form of a fluid-bed reactor. Alternatively, the electrochemical reactor may be in the form of an electrochemical flow reactor. The electrochemical reactor may have a primary catholyte chamber for containing catholyte on one side of an electrochemical cell and a primary anolyte chamber for containing anolyte on another side of the electrochemical cell.

A method of producing iron, wherein the method includes the step of using an electrochemical reactor for reducing iron ore to iron. The iron ore may be in the form of iron ore powder. The iron ore may be in the form of particles dispersed in a highly concentrated aqueous sodium hydroxide solution.



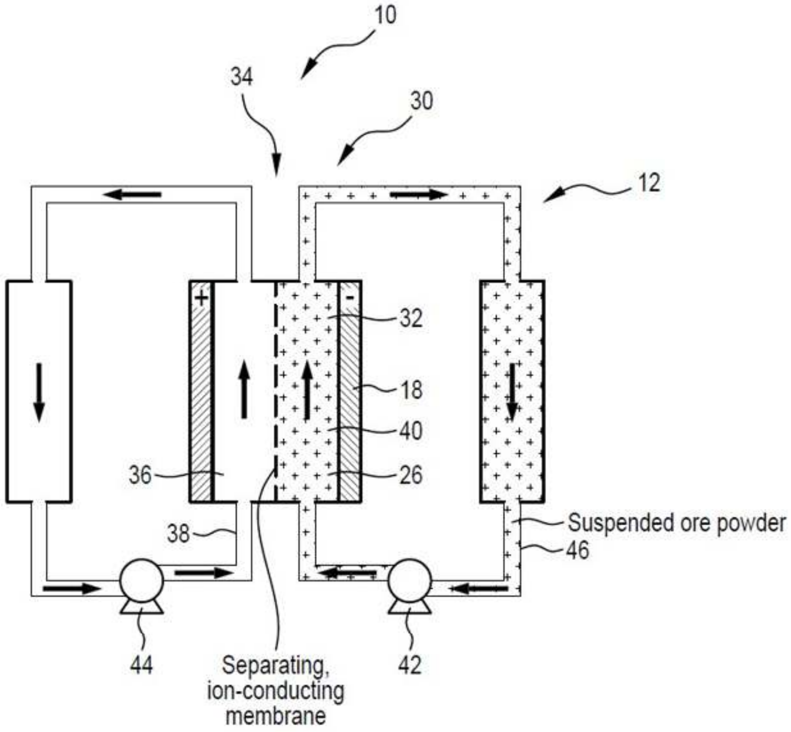
Flow chart for green iron and steel

Figure 1



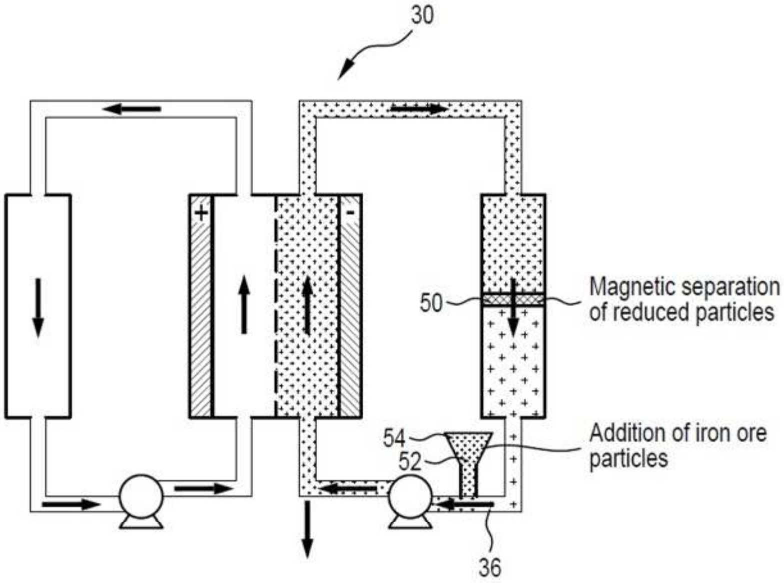
Fluidized bed layout for ore reduction

Figure 2



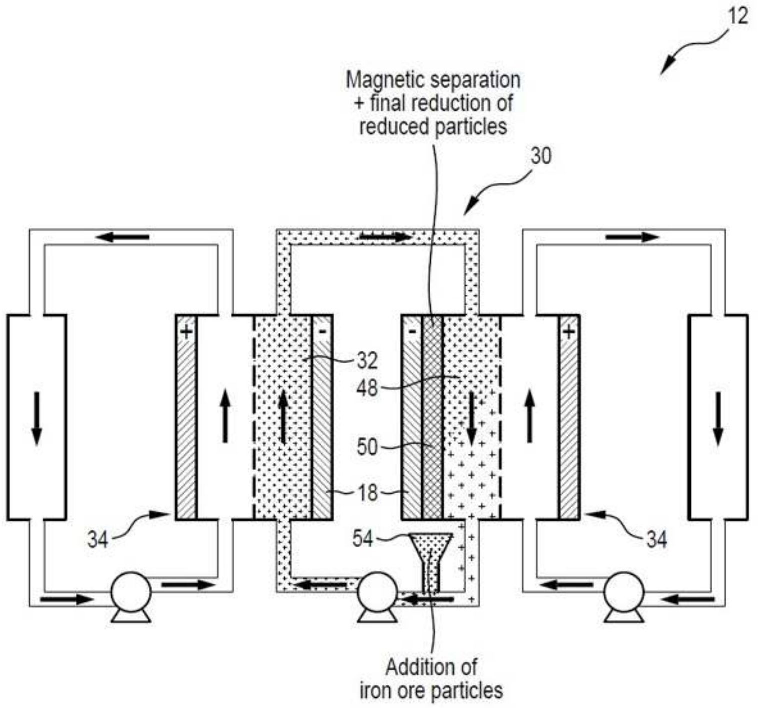
Flow reactor for ore reduction, first iteration

Figure 3



Flow reactor for ore reduction, second iteration

Figure 4



Flow reactor for ore reduction, third iteration

Figure 5

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-35

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Application Details

2021215184
: Apparatus and process for producing iron

BIBLIOGRAPHIC DATA

Application details

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Currently under opposition	No	**Proceeding type(s)**			
Invention title	Apparatus and process for producing iron				
Inventor(s)	KOLODZIEJCZYK, Bartlomiej Piotr ; WINTHER-JENSEN, Bjorn				
Agent name	Davies Collison Cave Pty Ltd	**Address for legal service**	VIC 3000 Australia	show full address	
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Applicant details

Applicant	FORTESCUE FUTURE INDUSTRIES PTY LTD	**Applicant address**	WA 6004 Australia
Old name(s)			

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History of Published Specifications: Download Specification(AU-A1)

Explanation of Specification Codes

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Document Date	Document Title	Document Type	Document Status	File Size (KB)
2022-11-25	Abstract OPI.pdf	ABSTRACT	FILED	95
2021-09-21	Application Complies with Formalities 21-09-2021	CORRO OUT	FILED	120
2021-09-20	Cover Sheet Formalities Response 20-09-2021 AMCZ-2110461739	OTHER	FILED	5
2021-09-20	Formalities Response 20-09-2021 AMCZ-2110461739	OTHER	FILED	129
2021-08-16	Formalities Report 16-08-2021	CORRO OUT	FILED	134
2021-08-16	Standard Patent Application Filing Receipt 16-08-2021	CORRO OUT	FILED	157
2021-08-11	Abstract 11-08-2021 AMCZ-2110351834	ABSTRACT	FILED	26
2021-08-11	Claim 11-08-2021 AMCZ-2110351834	CLAIM	FILED	137
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2021-08-11	Description 11-08-2021 AMCZ-2110351834	DESCRIPTION	FILED	688
2021-08-11	Drawing 11-08-2021 AMCZ-2110351834	DRAWING	FILED	302
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Allowance date	**Allowance published date**	

Current Oppositions and Disputes

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Re-examination

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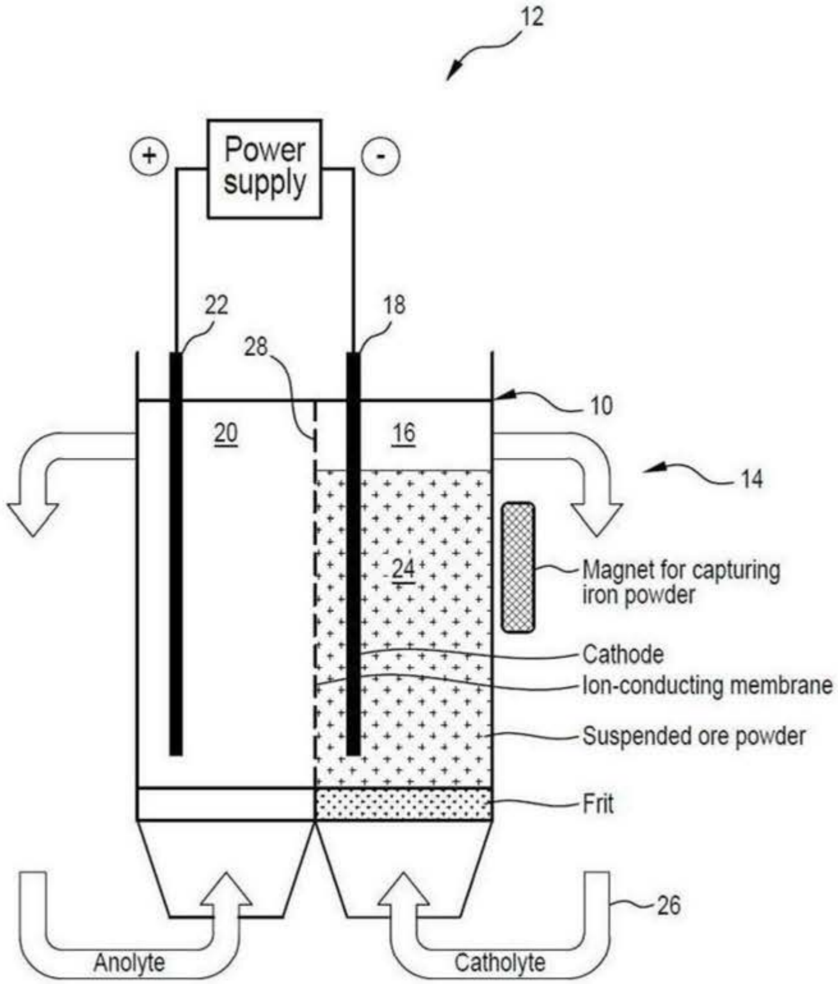
ABSTRACT

An apparatus for producing iron, wherein the apparatus includes an electrochemical reactor for reducing iron ore to iron. The electrochemical reactor may be in the form of a fluid-bed reactor. Alternatively, the electrochemical reactor may be in the form of an electrochemical flow reactor. The electrochemical reactor may have a primary catholyte chamber for containing catholyte on one side of an electrochemical cell and a primary anolyte chamber for containing anolyte on another side of the electrochemical cell.

A method of producing iron, wherein the method includes the step of using an electrochemical reactor for reducing iron ore to iron. The iron ore may be in the form of iron ore powder. The iron ore may be in the form of particles dispersed in a highly concentrated aqueous sodium hydroxide solution.



Fluidized bed layout for ore reduction

Figure 2

APPARATUS AND PROCESS FOR PRODUCING IRON

FIELD OF THE INVENTION

The present invention relates to an apparatus and process for producing iron and, more generally but not exclusively, to a method of producing steel with zero-emissions energy.

BACKGROUND TO THE INVENTION

It is well-known to produce iron from iron ore, however the present applicant has identified that the typical processes for producing iron from iron ore require intense and sustained energy input. In particular, the applicant has identified that existing processes for producing iron from iron ore would not be suitable for use with a highly intermittent power supply such as from renewable energy sources including wind and solar energy.

In traditional steelmaking processes, approximately two tonnes of carbon dioxide are produced for every tonne of steel produced. The term "green steel" (or "green iron”) has been given to steel (or iron) which is produced with less carbon dioxide being generated in the process.

Examples of the present invention seek to provide an apparatus and process for producing iron which alleviates or at least ameliorates one or more disadvantages of existing processes for producing iron.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention, there is provided an apparatus for producing iron, wherein the apparatus includes an electrochemical reactor for reducing iron ore to iron.

Preferably, the electrochemical reactor is in the form of a fluid-bed reactor. More preferably, the fluid bed reactor has a primary catholyte chamber having a cathode and a primary anolyte chamber having an anode. Even more preferably, the primary catholyte chamber contains iron ore powder suspended in a catholyte.

In one form, the fluid bed reactor has an ion-conducting membrane separating the primary catholyte chamber from the primary anolyte chamber. In other forms, the fluid bed reactor may operate without a membrane.

Preferably, the electrochemical reactor is in the form of an electrochemical flow reactor. More preferably, the electrochemical reactor has a primary catholyte chamber for containing catholyte on one side of an electrochemical cell and a primary anolyte chamber for containing anolyte on another side of the electrochemical cell.

Preferably, the catholyte is in the form of a powder slurry having suspended ore powder, circulated over a cathode. More preferably, the apparatus includes a pump for circulating the catholyte. Even more preferably, the apparatus includes a first pump for circulating the catholyte and a second pump for circulating the anolyte.

In a preferred form, the pump forms part of a pumping system external to the primary catholyte chamber. The pumping system may include a secondary catholyte chamber. The plurality of catholyte chambers may provide multiple electrochemical cells whereby reduction of the ore powder is extended over the plurality of cells to achieve complete reduction. Multiple electrochemical cells may be stacked to allow increasing the capacity of the system while minimising a footprint of the required system.

Preferably, the flow reactor includes a separator for separation/extraction of reduced iron particles. More preferably, the flow reactor includes a magnetic separator for magnetic separation of reduced iron particles. More preferably, the magnetic separator allows non-reduced iron ore particles to continue to flow for further reduction cycles. The applicant has determined that different separator techniques may be used, particularly those which may be suitable for use with magnetite iron ore.

In one form, the flow reactor includes a source of iron ore particles for metered introduction of iron ore particles into the flow of the catholyte.

Preferably, a cathodic potential is applied to the magnetic separator to force a complete reduction.

In a preferred form, the iron ore is in the form of iron ore powder. More preferably, the iron ore is in the form of iron ore powder having a particle size of less than or equal to 20 µm, and more preferably 10 µm or smaller. The applicant has identified that a narrow distribution of the particle size is important, as having different particle sizes in the system will require different reduction rates/times.

Preferably, the apparatus includes a cathode formed of a material selected to have inferior catalytic properties for a water reduction reaction and good charge-transfer properties to iron ore particles. More preferably, the cathode is formed of a glassy carbon material. In another form, the cathode may be formed simply from steel. Even more preferably, the cathode is formed to prevent adhesion of iron particles to the cathode. In one form, the apparatus includes sonication, pulsed electrical currents, and/or high-speed catholyte flow to prevent iron particles from adhering to the cathode.

It is preferred that the apparatus is adapted to perform the reaction at a temperature less than 130 °C. More preferably, the apparatus is adapted to perform the reaction at a temperature between 85 °C and 130 °C. Even more preferably, the apparatus is adapted to perform the reaction at a temperature between 100 °C and 110 °C.

Preferably, the apparatus is arranged to provide electrochemical parameters of between 1.5 V and 2.5V and 0.1 to 1 A/cm^2. More preferably, the apparatus is arranged to provide electrochemical parameters of between 1.5 V and 1.9V and 0.1 to 0.3 A/cm^2. More preferably still, the apparatus is adapted to provide electrochemical parameters of 1.66 V and 0.2 A/cm^2.

In accordance with another aspect of the present invention, there is provided a method of producing iron, wherein the method includes the step of using an electrochemical reactor for reducing iron ore to iron.

Preferably, the iron ore is in the form of iron ore powder. More preferably, the iron ore is in the form of particles dispersed in a highly concentrated aqueous hydroxide solution. Even more preferably, the solution includes up to 50% sodium hydroxide (NaOH). It will be appreciated by those skilled in the art that other forms of hydroxide may be used as alternatives to sodium hydroxide. For example, aqueous potassium hydroxide (KOH) may be used, or mixtures of KOH and NaOH.

The iron ore may be pre-treated before, after or between different steps in the grinding process to remove impurities that may otherwise accumulate in the electrolyte during the electrochemical reduction process or may complicate the post-treatment of reduced iron powder to an export grade of iron or steel. Examples of these impurities are alkali chlorides, alumina, silica and sulphur species. The pre-treatment process may include exposure of the iron ore to acidic or alkaline solutions at elevated temperature and pressure to enhance the removal of the impurities. In particular, pre-treatment in a highly alkaline environment to remove alumina and silica (by dissolution) from the ore, in line with the well-known Bayer Process, is suitable for preparing the iron ore powder for the electrochemical reduction process as well as providing a route to a higher-grade iron end-product.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will be described, by way of a non-limiting example only, with reference to the accompanying drawings in which:

Figure 1 shows a flow chart for production of green iron and green steel;

Figure 2 shows a fluidised bed layout for ore reduction;

Figure 3 shows a flow reactor for ore reduction (first iteration);

Figure 4 shows a flow reactor for ore reduction (second iteration); and

Figure 5 shows a flow reactor for ore reduction (third iteration).

DETAILED DESCRIPTION

With reference to Figures 1 to 5, there are described examples of electrochemical reactors, together with methods of producing iron from iron ore, in accordance with embodiments of the present invention. Advantageously, examples of the present invention may provide superior efficiency compared to other technologies for producing iron, as well as low operating temperatures which allow coupling the process to a highly intermittent power supply, such as a power supply from renewable energy (for example, wind and/or solar). The applicant has identified that efficiency is linked to the low operating temperature enabled by examples of the present invention. Furthermore, low temperature operation may also advantageously provide the ability to switch on and off the system more quickly, for example, within minutes/seconds.

More specifically, Figure 1 shows a flow chart for the production of green steel using an electrochemical reactor 10 for the reduction of hematite iron ore to metallic iron. In particular, a mill 56 is used in iron ore powder manufacturing with a particle size of 10 micrometres being the target size. Subsequently, the iron ore powder from the mill 56 may be fed to the electrochemical reactor 10 which electrochemically reduces the iron ore powder to metallic iron. The raw hematite ore powder from the mill 56 may contain around 5 – 30%, or more, of impurities. These impurities are up-concentrated during the reduction of hematite to iron at the electrochemical reactor 10, due to removal of oxygen from the ore. This relatively high level of impurities has to be removed in the steel-making process (where the iron has to be melted anyway). This process can either be done onshore or at the export destination. The flowchart shows that the metallic iron from the electrochemical reactor 10 may be either exported as raw green iron (see reference 58 representing export of raw green iron), or may undergo purification/steelmaking onshore (see reference 60) with the addition of carbon in an electrical shaft furnace or similar to reduce the impurities to 1 to 3%. Export of green steel with 1 to 3% impurities is represented by reference 62.

Turning to Figure 2, showing a fluidised bed layout for ore reduction, there is provided an apparatus 12 for producing iron, the apparatus 12 including an electrochemical reactor 10 for reducing iron ore to iron. In this example, the electrochemical reactor 10 is in the form of a fluid-bed reactor 14. The fluid bed reactor 14 has a primary catholyte chamber 16 having a cathode 18 and a primary anolyte chamber 20 having an anode 22. The primary catholyte chamber 16 contains iron ore powder 24 suspended in a catholyte 26.

The fluid-bed reactor 14 has an ion-conducting membrane 28 separating the primary catholyte chamber 16 from the primary anolyte chamber 20. In other examples, the fluid-bed reactor may operate without a membrane.

In the electrochemical fluid-bed reactor layout, the hematite ore powder is kept fluidized in the same reactor volume 16 until the reduction to iron has occurred. The powder 24 is kept fluidized by circulation the catholyte 26 from bottom to top of the reactor 14. As such, the fluid bed reactor layout provides a batch process.

By using e.g., magnetic separation for continuous or sequential removal of the iron powder product and by simultaneously adding fresh hematite powder to the reactor, the process can be made continuous.

With reference to Figure 3, in another example, the electrochemical reactor 10 is in the form of an electrochemical flow reactor 30 for ore reduction. The electrochemical flow reactor 30 has a primary catholyte chamber 32 for containing catholyte 26 on one side of an electrochemical cell 34 and a primary anolyte chamber 36 for containing anolyte 38 on another side of the electrochemical cell 34. In the example shown, the catholyte 26 is in the form of a powder slurry 40 having suspended ore powder 24, circulated over a cathode 18. The apparatus 12 includes a pump 42 for circulating the catholyte 26. In particular, the apparatus 12 includes a first pump 42 for circulating the catholyte 26 and a second pump 44 for circulating the anolyte 38.

As shown in Figure 3, the pump 42 forms part of a pumping system 46 external to the primary catholyte chamber 32. Example flow reactors in accordance with embodiments of the invention may implement features used in electrochemical flow reactors used for molecular reactions on pilot and industrial scales.

The applicant has determined that, for the reduction of powders, one can visualise a flow reactor 30 layout as a way to upscale a fluid-bed reactor 14, where the powder slurry 40 is circulated over the cathode 18 and through the external pumping system 46. Multiple cells can be connected in series or parallel (which may be an advantage of flow reactors), so the reduction of powder can be extended over a series of cells to secure complete reduction (in this case to iron) and/or to increase quantity of produced commodity while maintaining minimal system’s footprint.

Figure 4 shows a flow reactor for iron ore reduction (second iteration). In an electrolyser, hydrogen gas is separated from a electrolyte in a liquid/gas separator. The applicant has identified that, in a similar manner, for the separation of iron particles one possibility for separation from the electrolyte is to use magnetic separation of reduced, metallic iron particles. The magnetic separation will allow "un-reduced" iron ore particles to continue in the flow for further reduction cycles.

Accordingly, the flow reactor 30 includes a magnetic separator 50 for magnetic separation of reduced iron particles. The magnetic separator 50 allows non-reduced iron ore particles to continue to flow for further reduction cycles.

As shown in Figure 4, the flow reactor 30 may include a source 52 of iron ore particles 54 for metered introduction of iron ore particles 54 into the flow of the catholyte 26.

Figure 5 shows a flow reactor 30 for iron ore reduction (third iteration) having multiple cells. The applicant has identified that there exists a real possibility that hematite particles can be partially reduced to magnetite in the flow reactor 30 (i.e., incomplete reduction). Such magnetite particles would be captured by the magnetic separation at the magnetic separator 50 and it may be an advantage to add a cathodic potential to the magnetic separator 50 to force a complete reduction of the magnetite (containing) particles. A practical setup contains multiple cells (extended pass way) to secure as complete reduction as possible in the (first) step before magnetic separation, so the amount of reduction reaction required on the magnetic separator 50 would be minimal.

In the example shown in Figure 5, the pumping system 46 includes a secondary catholyte chamber 48. The plurality of catholyte chambers 32,48 may provide multiple electrochemical cells 34 whereby reduction of the ore powder 24 is extended over the plurality of cells 34 to achieve complete reduction.

The iron ore may be in the form of iron ore powder 24. In particular, the iron ore may be in the form of iron ore powder 24 having a particle size of less than or equal to 20μm.

The cathode 18 may be formed of a material selected to have inferior catalytic properties for a water reduction reaction and good charge-transfer properties to iron ore particles 54. In one form, the cathode 18 may be formed of a glassy carbon material. The cathode 18 may be formed to prevent adhesion of iron particles 54 to the cathode 18. The apparatus 12 may use sonication, pulsed electrical currents, and/or high-speed catholyte flow to prevent iron particles 54 from adhering to the cathode 18.

The apparatus 12 may be adapted to perform the reaction at a temperature less than 130°C. More specifically, the apparatus 12 may be adapted to perform the reaction at a temperature between 85 °C and 130 °C. In one particular form, the apparatus 12 may perform the reaction at a temperature between 100 °C and 110 °C.

Also, the apparatus 12 may be arranged to provide electrochemical parameters of between 1.5 V and 2.5 V and 0.1 to 1 A/cm^2. More particularly, the apparatus 12 may be arranged to provide electrochemical parameters of between 1.5 V and 1.9 V and 0.1 to 0.3 A/cm^2. In one form, the apparatus 12 may provide electrochemical parameters of 1.66 V and 0.2 A/cm^2.

As will be appreciated from the above, another aspect of the invention provides a method of producing iron, wherein the method includes the step of using an electrochemical reactor 10 for reducing iron ore to iron. The iron ore may be in the form of iron ore powder 24. More specifically, the iron ore may be in the form of particles dispersed in a highly concentrated aqueous sodium solution. The solution may include up to 50% sodium hydroxide. As mentioned above, the applicant has determined that other forms of hydroxide may be used for electrolyte, such as KOH and the like.

PROCESS DESCRIPTION

In one example, the iron ore may be in the form of hematite iron ore. In this case, hematite iron ore particles 54 are ground to 1 – 20 μm size and fed into the reactor 10. The process may be performed in a close autoclave-like reactor, with graphite cathode electrode and ultra-pure (99.999%) nickel mesh anode electrode. Ultra-fine hematite particles will be dispersed in a highly concentrated aqueous sodium hydroxide solution (up to 50% NaOH). The reaction will be performed at 100 to 110 °C (below the boiling point of the electrolyte).

The electrochemical parameters of the process are 1.5 to 2.5 Volts and 0.1 to 1 A/cm^2. More specific electrochemical parameters of the process are 1.5 to 1.9 Volts and 0.1 to 0.3 A/cm^2. However, optimal parameters are likely to be 1.66 V and 0.2 A/cm^2. The reaction will be performed with a stirrer or agitator to keep the iron ore particles 54 uniformly dispersed within the electrolyte 40.

For 1 kg of green iron per day production, a 460 cm^2 electrode is required. Approximately 3.6 kWh of energy is required to produce 1 kg of iron (3.6 MWh/tonne of iron), but the applicant foresees that this could be reduced further. For comparison, existing technology based on molten oxide electrolysis (at 1,500 ºC) requires >4.0 kWh/kg, while energy contained in coal used in traditional steelmaking processes can range from between 5.2 to 5.6 kWh/kg of iron. Accordingly, the present invention has the potential to greatly reduce the amount of energy required to produce iron.

The applicant has also made significant advances in electrode technology and specifically in relation to electrode materials. The applicant has determined that the cathode may potentially be made of glassy carbon or simply steel/iron. Several candidates for higher performance anode electrodes have been identified that could allow to reduce overpotential. The applicant foresees that the same process can also be deployed for the reduction of magnetite and goethite.

The main advantages of this process may include:

- continuous operation,
- superior efficiency compared to other technologies; and
- low operating temperature, which allows coupling this process with a highly intermitted power supply, including wind and solar.

The solid-state electrochemical process ($Fe_xO_y \rightarrow xFe + \frac{1}{2}yO_2$) under alkaline conditions has been used previously as a cathode process in batteries. The applicant recognises that $Fe(OH)_x$ plays a limiting role as intermediate for the reaction at temperatures below ~80 °C.

For the applicant, a solid-state reduction of the current hematite ore qualities would produce a “raw” green steel with about 14% oxide impurities (mainly from SiO_2 and Al_2O_3). Reduced magnetite concentrates would have around 10% oxide impurities. This suggests that a down-stream process for the removal of impurities would be appropriate in order to obtain a high-quality export product. This consideration allows to revisit the physical-form-requirement for the product coming out of the electrochemical reduction of ore; if the product goes into a down-stream molten-state process, there is not much need for the product to be a coherent steel plate – it could just as well be in the form of raw iron powder. The applicant has determined that this widens the possibilities for upscaling the process.

Design Details

The following design details have been identified by the applicant:

- *Cathode material.* The water reduction reaction is a likely competing reaction to the reduction of iron ore to metallic iron. i.e., the thermodynamic reduction potentials are very similar in the alkaline regime. This indeed has been one of the main hurdles in achieving high efficiencies in all electrochemical iron deposition attempts from solution as well as in the solid state – with effectively iron electrodes, hydrogen has been a significant by-product. In the case of a flow-reactor setup, the intention is that no deposition should occur on the cathode (the reduced particles should remain in dispersion), which means that the properties of the cathode material, in principal, remains unchanged during operation. This gives the opportunity to select materials with inferior catalytic properties for the water reduction reaction but with good charge-transfer properties to iron ore particles. One such material could be glassy carbon, which provides large overpotential for the water reduction process and otherwise good charge-transfer properties.

- *The prevention of iron particles adhering to the cathode is a potential issue.* Having a vertical cathode arrangement is a reasonable first point to apply. A second point is suitable choice of cathode materials (or cathode coatings/structure) that help prevent adhesion. A third point includes active methods to remove particles from the cathode surface. Here sonication, pulsed (electrical) currents and high-speed flow could be added during/part of the operation.

- *Periodical electrochemical removal of deposited.* Periodical electrochemical removal of deposited iron on the cathode material may be included in the maintenance schedule for the equipment. Such electrochemical dissolution can be achieved by applying a more positive potential – above the thermodynamical equilibrium potential of iron – to the electrode, preferably with a neutral or acidic electrolyte solution dedicated for the maintenance procedure.

- *Electrolyte composition.* Generally high concentrations (10 – 20 M) of NaOH have been used. It is anticipated that there can be used alternative electrolyte compositions, where a mixture of alkali-hydroxides are used (i.e., NaOH, KOH and LiOH). Such mixed electrolytes have indeed been adopted for the closely related "Edison" cell (Fe-Ni battery) on a commercial scale. A further possibility is to use high concentration of an otherwise neutral alkali salt (e.g., LiCl) in combination with alkali-hydroxides to obtain a so-called "water-in salt" electrolyte. The combined salt-concentrations should possibly remain in the 10 – 15 M range to provide similar properties as for the common NaOH electrolytes.

- *Operating temperature.* The operation temperature must be above 85 °C to avoid the formation of $Fe(OH)_x$ species on the surface of the iron ore powder. $Fe(OH)_x$ acts as an inhibitor for the (further) reduction but becomes unstable at temperatures above 85 °C. Most reports use temperatures in the 100 – 110 °C range. However, the high concentration electrolytes have boiling points (well) above 120 °C so there could be room for also operating in the 110 – 130 °C range.

- *Operating pressure.* There is no reason to pressurize the electrolyte system other than what is needed to overcome pressure-loss in flow-system itself. The possible need for high flow-rates to avoid adherence of powder to the cathode may require a substantial electrolyte pressure at the inlet of the flow-reactor.

- *Membrane.* The sketched layouts are all containing ion conducting membranes to separate the electrolytes on the anode and cathode side. Thereby re-oxidation of iron particles on the anode is avoided as well as crossover of produced oxygen to the cathode. The particles are kept in one flow stream which will simplify the (magnetic) separation of iron particles from the electrolyte. However, the membrane adds a resistive element to the system and layouts could be developed to omit the membrane in the flow configuration. The membrane family distributed under the Agfa and ZIRFON trademarks have been identified as one potential membrane candidate. The list of possible membranes is not limited to those distributed under the Agfa trademark.

- *Direction of electrolyte flow.* For simulating conditions in the fluid bed reactor, a vertical electrolyte flow "from ground up" may be applied. In this case, the size distribution of the iron ore power must be sufficiently narrow and/or the electrolyte flow high enough to avoid that larger particles are accumulated in the cell. It may therefore be an advantage to have a flow-direction following gravity, so particle accumulation is avoided.

- *Increase of electrode contact area.* Electrode patterning to increase contact area and hence performance of the cell.

- *The separation of iron particles from the electrolyte.* The separation can be performed on the low-pressure side of the flow-reactor and be by magnetic or by other means (e.g., cyclone separation). The electrolyte should be removed from the iron powder without exposing the iron power to oxidizing environments such as the combination of neutral water and air – using an inert atmosphere (e.g., nitrogen gas) may be optimal.

- *Purification.* The impurities from the ore will largely remain in the metallic iron product. Preferably, the metallic iron particles should be transferred to a melting and purification step immediately after the flow-reactor to minimize re-oxidation of the particles in contact with air.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. It will be apparent to a person skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the present invention should not be limited by any of the above described exemplary embodiments.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

LISTING OF REFERENCE NUMERALS

10	Electrochemical reactor
12	Apparatus for producing iron
14	Fluid-bed reactor
16	Primary catholyte chamber
18	Cathode
20	Primary anolyte chamber
22	Anode
24	Iron ore powder
26	Catholyte
28	Ion-conducting membrane
30	Electrochemical flow reactor
32	Primary catholyte chamber
34	Electrochemical cell
36	Primary anolyte chamber
38	Anolyte
40	Powder slurry
42	Pump
44	Second pump
46	Pumping system
48	Secondary catholyte chamber
50	Magnetic separator
52	Source of iron ore particles
54	Iron ore particles
56	Mill
58	Export of raw green iron
60	Purification/steelmaking onshore
62	Export of green steel

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An apparatus for producing iron, wherein the apparatus includes an electrochemical reactor for reducing iron ore to iron.

2. An apparatus as claimed in claim 1, wherein the electrochemical reactor is in the form of a fluid-bed reactor.

3. An apparatus as claimed in claim 2, wherein the fluid bed reactor has a primary catholyte chamber having a cathode and a primary anolyte chamber having an anode.

4. An apparatus as claimed in claim 3, wherein the primary catholyte chamber contains iron ore powder suspended in a catholyte.

5. An apparatus as claimed in claim 3 or claim 4, wherein the fluid bed reactor has an ion-conducting membrane separating the primary catholyte chamber from the primary anolyte chamber.

6. An apparatus as claimed in claim 1, wherein the electrochemical reactor is in the form of an electrochemical flow reactor.

7. An apparatus as claimed in claim 6, wherein the electrochemical reactor has a primary catholyte chamber for containing catholyte on one side of an electrochemical cell and a primary anolyte chamber for containing anolyte on another side of the electrochemical cell.

8. An apparatus as claimed in claim 7, wherein the catholyte is in the form of a powder slurry having suspended ore powder, circulated over a cathode.

9. An apparatus as claimed in claim 8, wherein the apparatus includes a pump for circulating the catholyte.

10. An apparatus as claimed in claim 9, wherein the apparatus includes a first pump for circulating the catholyte and a second pump for circulating the anolyte.

11. An apparatus as claimed in claim 9, wherein the pump forms part of a pumping system external to the primary catholyte chamber.

12. An apparatus as claimed in claim 11, wherein the pumping system includes a secondary catholyte chamber.

13. An apparatus as claimed in claim 12, wherein the plurality of catholyte chambers provide multiple electrochemical cells whereby reduction of the ore powder is extended over the plurality of cells to achieve complete reduction.

14. An apparatus as claimed in any one of claims 11 to 13, wherein the flow reactor includes a magnetic separator for magnetic separation of reduced iron particles.

15. An apparatus as claimed in claim 14, wherein the magnetic separator allows non-reduced iron ore particles to continue to flow for further reduction cycles.

16. An apparatus as claimed in any one of claims 11 to 15, wherein the flow reactor includes a source of iron ore particles for metered introduction of iron ore particles into the flow of the catholyte.

17. An apparatus as claimed in claim 14, wherein a cathodic potential is applied to the magnetic separator to force a complete reduction.

18. An apparatus as claimed in any one of claims 1 to 17, wherein the iron ore is in the form of iron ore powder.

19. An apparatus as claimed in claim 18, wherein the iron ore is in the form of iron ore powder having a particle size of less than or equal to 20 μm.

20. An apparatus as claimed in any one of claims 1 to 19, wherein the apparatus includes a cathode formed of a material selected to have inferior catalytic properties for a water reduction reaction and good charge-transfer properties to iron ore particles.

21. An apparatus as claimed in claim 20, wherein the cathode is formed of a glassy carbon material.

22. An apparatus as claimed in claim 20 or claim 21, wherein the cathode is formed to prevent adhesion of iron particles to the cathode.

23. An apparatus as claimed in any one of claims 20 to 22, wherein the apparatus includes sonication, pulsed electrical currents, and/or high-speed catholyte flow to prevent iron particles from adhering to the cathode.

24. An apparatus as claimed in any one of claims 1 to 23, wherein the apparatus is adapted to perform the reaction at a temperature less than 130 °C.

25. An apparatus as claimed in claim 24, wherein the apparatus is adapted to perform the reaction at a temperature between 85 °C and 130 °C.

26. An apparatus as claimed in claim 25, wherein the apparatus is adapted to perform the reaction at a temperature between 100 °C and 110 °C.

27. An apparatus as claimed in any one of claims 1 to 26, wherein the apparatus is arranged to provide electrochemical parameters of between 1.5 V and 2.5 V and 0.1 to 1 A/cm^2.

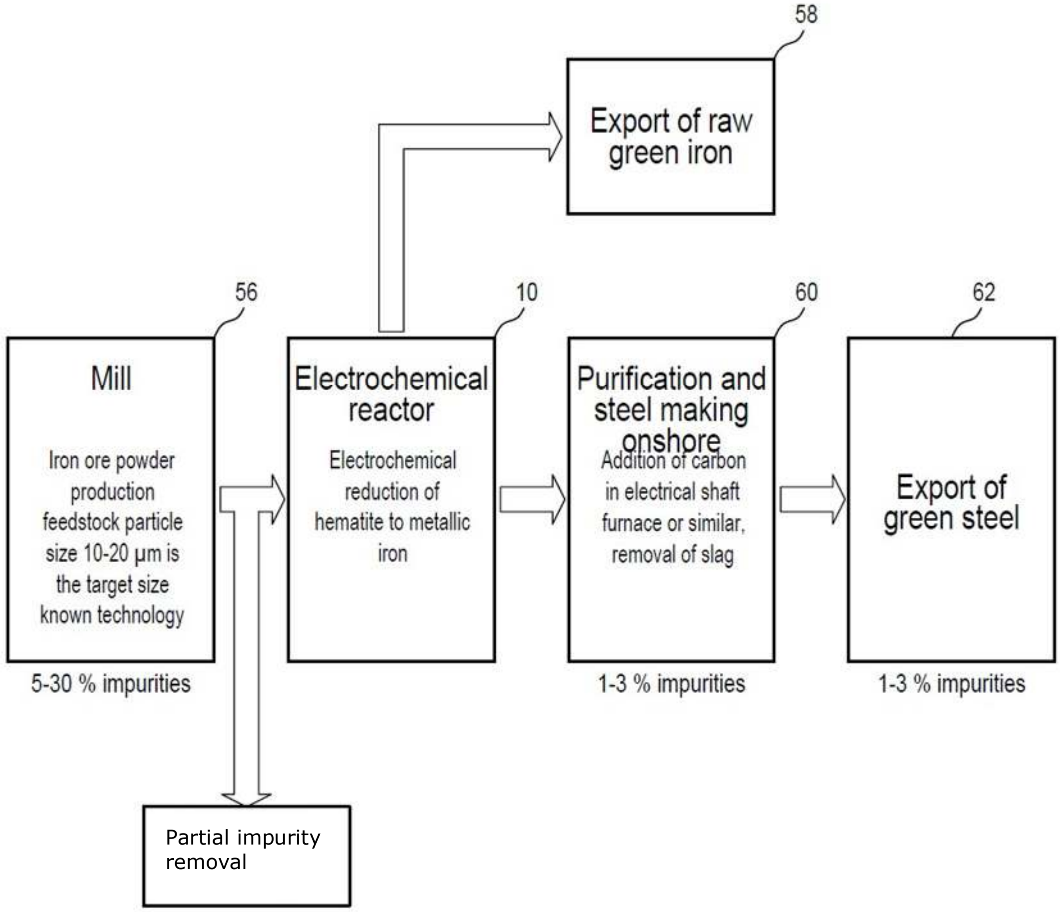
28. An apparatus as claimed in claim 26, wherein the apparatus is adapted to provide electrochemical parameters of 1.66 V and 0.2 A/cm^2.

29. A method of producing iron, wherein the method includes the step of using an electrochemical reactor for reducing iron ore to iron.

30. A method of producing iron as claimed in claim 29, wherein the iron ore is in the form of iron ore powder.

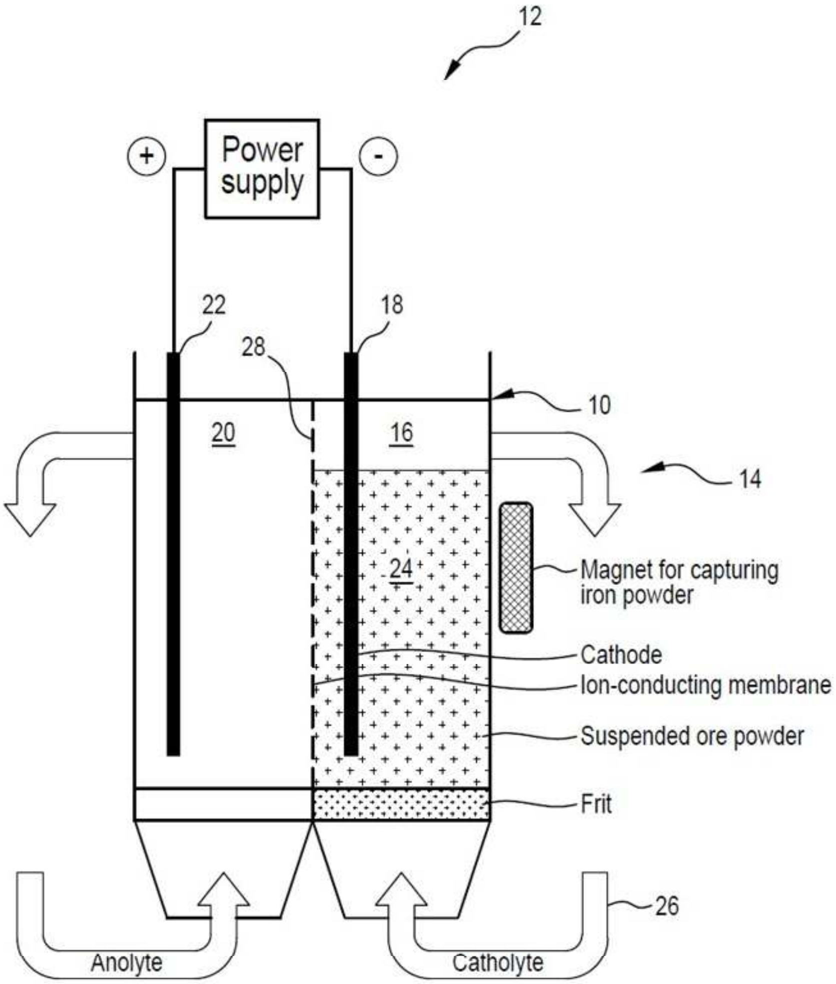
31. A method of producing iron as claimed in claim 29 or claim 30, wherein the iron ore is in the form of particles dispersed in a highly concentrated aqueous hydroxide solution.

32. A method of producing iron as claimed in claim 31, wherein the solution includes up to 50% sodium hydroxide.



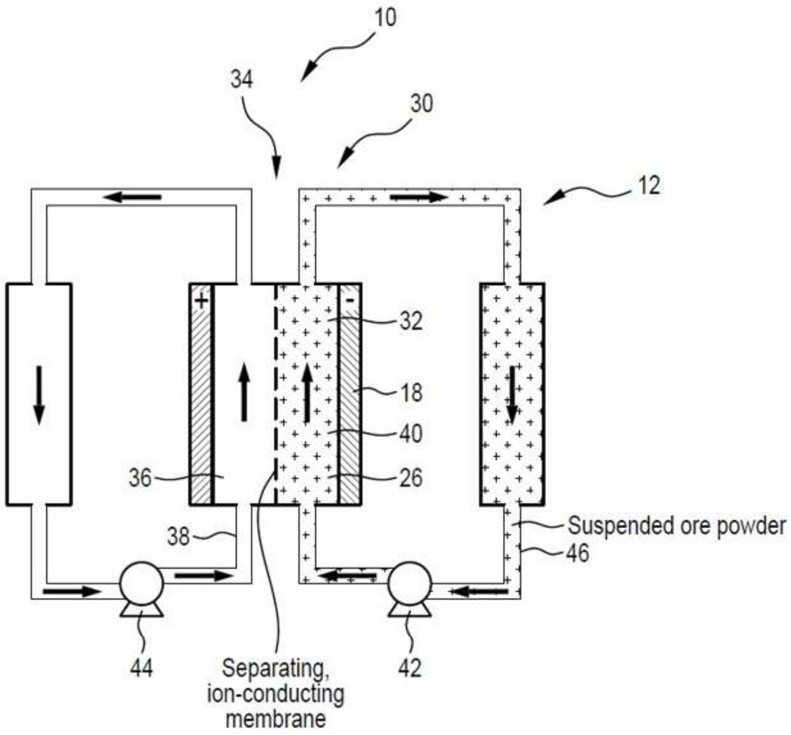
Flow chart for green iron and steel

Figure 1



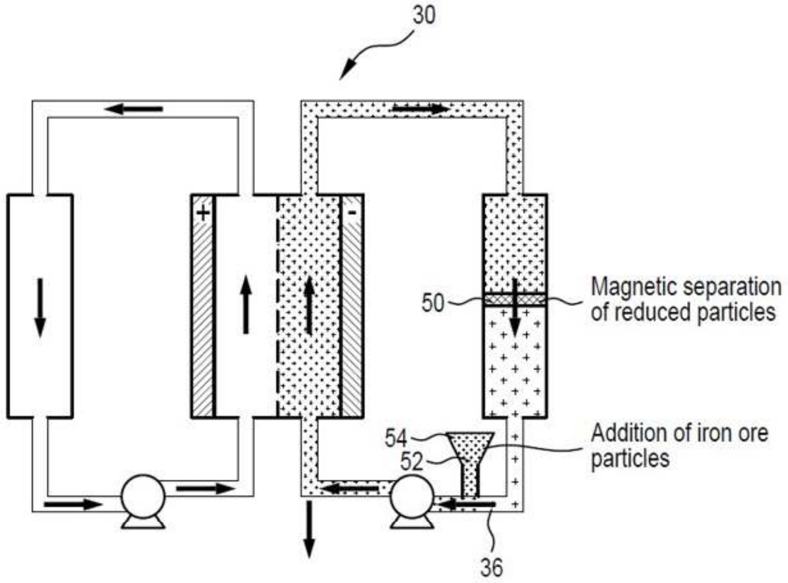
Fluidized bed layout for ore reduction

Figure 2



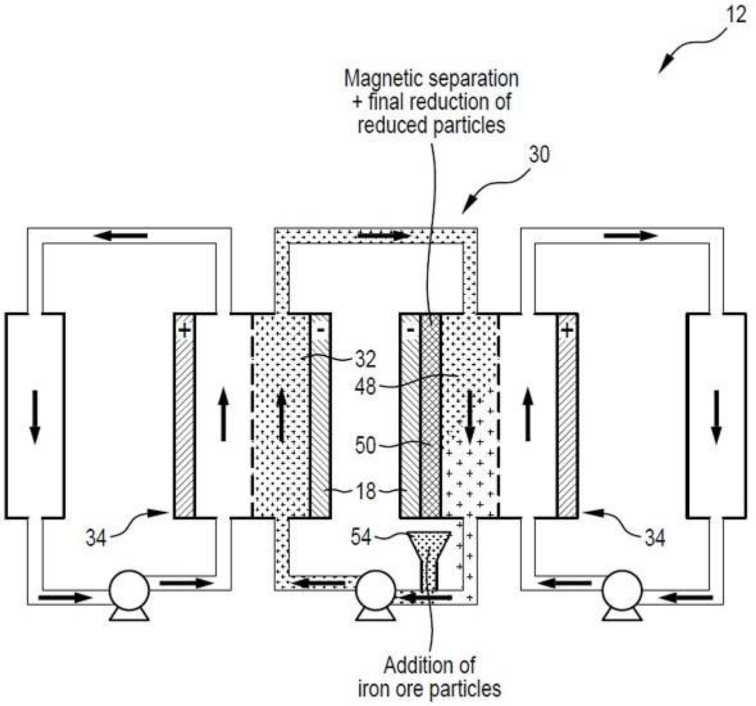
Flow reactor for ore reduction, first iteration

Figure 3



Flow reactor for ore reduction, second iteration

Figure 4



Flow reactor for ore reduction, third iteration

Figure 5

No. NSD of 2024

Federal Court of Australia
District Registry: New South Wales
Division: General

FORTESCUE LIMITED (ACN 002 594 872) and others

Applicants

ELEMENT ZERO PTY LIMITED (ACN 664 342 081) and others

Respondents

ANNEXURE AIB-36

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Before me: ....

Curriculum Vitae

Bjorn Winther-Jensen

Date of birth: April 9. 1960 (Gladsaxe, Denmark)
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Private address: 33/1 Moo 4 Simahaphot, 25140 Prachin Buri, Thailand
Email: bjornwj@gmail.com and b.wintherjensen@kurenai.waseda.jp

Professional Education

2001-2004: Ph.D. from the Department of Chemical Engineering, The Technical University of Denmark (Towards Micro-patterning of conducting polymers).
1991-1995: Chemical Engineer from The Danish Engineering Academy, The Technical University of Denmark.

Employment

2019-	Research Associate at Waseda University, Research Institute for Science and Engineering, Tokyo, Japan
2015-2019	Professor at Waseda University, Department for Advanced Science and Engineering, Tokyo, Japan
2010-2015	Associate Professor at Monash University, Materials Science and Engineering, (2010-2013 ARC Future Fellow).
2007-2009	APD Research Fellow at Monash University, Materials Science and Engineering.
2006-2007	Research Fellow at Monash University, Materials Science and Engineering.
2005-2006:	Researcher at University of Wollongong, Intelligent Polymer Research Institute (IPRI).
2004-2005:	Post Doc at Risø National Laboratory, Denmark
2001-2006:	Technology Advisor for Nanon A/S, Denmark.
1995-2001:	Research Engineer and Project Manager at NKT Research Center A/S, Denmark.
1986-1991:	Area manager in HUMANA Kleiderhandel GmbH. Start up and run of the section in Cologne, Germany; containing 3 shops and one storage facility, total 20 employees.
1985-1986:	Start up and run of the restaurant "Mettes Cafeteria" in Århus, Denmark.
1980-1985	Work in companies within the Danish wood and metal industry.

Research and Development Interests and Expertise

Electrochemistry and Electrolysis

- Electrochemical hydrogen and hydrogen peroxide production
- Scalable porous electrodes with optimized three phase interface
- (Photo) Electrocatalysis on conducting polymers
- Water oxidisation on Nickel alloys at high pH
- Aqueous electrodeposition of iron directly from ore

Conducting polymers:

- Vapour phase polymerisation
- Composites of both conducting and non-conducting materials
- High volume application methods (printing, spaying etc.)
- Novel photo-electrochemical materials

Plasma polymerisation:

- Low power plasma induced radical polymerisation
- Surface design for interfacing between biological and synthetic materials
- Design and construction of low power plasma systems

Research support, teaching, commercialization and research output

2007-2009 Dr. Winther-Jensen held an APD fellowship funded by The Australian Research Council (ARC)

2010-2014 Future-Fellowship: “Electro-Catalytic Conjugated Polymers”.

2011 ARC Discovery Grant: “Novel Fuel-Cell Structures based on Electroactive Polymers”

2013 ARC Discovery Grant: “Bio-inspired electro catalysts for gas reduction reactions: towards electrochemical ammonia production under ambient conditions”.

From 2008-2012 Dr. Winther-Jensen also obtained five minor grants from the Faculty of Engineering at Monash University (2008: “Novel Conducting Polymer Air Electrode”, 2009: “Novel nano-scale Plasma-Polymerised Proton-Conducting (PP-PC) membranes for potential Fuel-Cell applications”, 2010: “Conducting polymer composites with tuned electro-catalytic activity”, 2011: "Deciphering the electro-catalytic mechanisms on conducting polymers", 2012: Quantitative gas detection from electrochemical and photochemical water splitting”).

From 2007 to 2015 Dr. Winther-Jensen participated in the teaching at the Faculty of Engineering at Monash University by lecturing the polymer part of MTE2545 and from 2012 he started as lecture in the new course MTE4599 “Materials for Energy applications” (later MTE5884). From 2015 to 2019 Dr. Winther-Jensen has been teaching “Materials for Energy applications” at Waseda University for postgraduate students.

Dr. Winther-Jensen was accredited research supervisor (level 2) from Monash University and has supervised more than 10 PhD students to successful completion.

In 1999 and 2000 two spin-off companies (Nanon A/S) and Scandinavian Micro Biodevices) were started in the field of plasma polymerization from NKT Research Center. The technology underpinning these companies were largely based on patents and techniques developed by Dr Winther-Jensen.

In December 2012 four patents from Dr. Winther-jensen’s portfolio in the water-splitting field made a significant part of Monash University’s contribution (of a total five patents) that was licensed to the start-up company “Aquahydrex”, which was 100% financed by the US based venture capital company TrueNorth.

A list of peer-reviewed publications (108) and patents (26) is attached in a separate file.

References

Professor Maria Forsyth

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Professor Hiroyuki Nishide

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No. NSD of 2024

Federal Court of Australia
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ANNEXURE AIB-37

This is the annexure marked **AIB-37** produced and shown to **ANAND INDRAVADAN BHATT** at the time of affirming his affidavit on 1 May 2024.

Before me: ....

BART KOLODZIEJCZYK

PhD, MSc, FRSA, FIEC, FLS, FIET, MRSC, MAAS, CEnv

PERSONAL DETAILS

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Gender	Male

EDUCATION

Sep 2018 to present	University of Gothenburg *Sprängkullsgatan 19, 405 30 Göteborg, Sweden* Studying Executive Master of Arts Programme in European Studies (EMAES) at the Department of Political Science.
Sep 2013 to Feb 2015	Stockholm University *Forum 100, SE-164 40 Kista, Sweden* Earned a Master of Science in IT Project Management from the Department of Computer and System Sciences (DSV).
Aug 2013 to Aug 2015	National Institute of Science and Technology at Saint-Etienne *880, route de Mimet, 13541 Gardanne, France* Earned a Doctor of Philosophy in Bioelectronics from the Microelectronics Center of Provence, Department of Bioelectronics (BEL). Thesis consisted of research on Novel Light Enhanced Electrocatalysts for Energy Applications.
Nov 2011 to Nov 2014	Monash University *Wellington Road, Clayton VIC 3800, Australia* Earned a Doctor of Philosophy in Materials Engineering from the Department of Materials Engineering. Thesis consisted of research on Novel Light Enhanced Electrocatalysts for Energy Applications.
Oct 2010 to Feb 2011	Monash University *Wellington Road, Clayton VIC 3800, Australia* An exchange student for one semester within the Department of Materials Engineering at Monash University.
Feb 2010 to Mar 2011	RES I the School for Renewable Energy Science *Solborg at Nordurslod, IS 600 Akureyri, Iceland* Received a Master of Science in Renewable Energy Science with a specialization in Fuel Cell Systems and Hydrogen. Thesis was the Development of Novel Air Electrode Materials for Fuel Cells – Solar Activated Fuel Cells. The degree was jointly awarded by the University of Iceland & University of Akureyri.
Feb 2009 to Jun 2009	University of Oviedo *Campus de Viesques, 33204 Gijon, Spain* An exchange student for one semester with the Erasmus Programme where I studied in the Mechanical Engineering, Electric, Electronics, Computers and Systems Departments at the University of Oviedo.

Oct 2004 to Feb 2010	Rzeszow University of Technology *Powstancow Warszawy 8, 35-959 Rzeszow, Poland* Studied Mechanical Engineering and Aeronautics and received my Master of Science in Mechanical Engineering with a specialization in Automation and Robotics. The thesis was on Digital Control of Electromagnetic Levitation.

WORK EXPERIENCE

Jan 2017 to March 2019	Hydrogen Specialist Fortescue Metals Group (FMG) Ltd. *Level 2/87 Adelaide Terrace, Perth WA 6004, Australia* Fortescue Metals Group Ltd is an Australian iron ore company. Fortescue is the fourth largest iron ore producer in the world after BHP Billiton, Rio Tinto, and Vale. Developing hydrogen projects and solutions for mining and export.
Jan 2016 to March 2019	Chief Technology Officer (CTO) H2SG Energy (Aus) Pty. Ltd. *Level 19, 15 William Street, Melbourne 3000, Victoria, Australia* H2SG Energy is a leader in high-voltage solar hydrogen production. In my current role, I am responsible for three R&D teams in Singapore, China and Australia, as well as market research and development in Australia and China. Our systems are used for hydrogen generation for applications in hydrogen refueling stations, smart grids, energy storage, power-to-gas (P2G), industrial hydrogen and more. Company was valued at S$300m by PwC Singapore and attracted investment by Kuok Group and other large Asian conglomerates. I was directly and indirectly responsible for 110 staff across four locations, including Singapore, China, Malaysia and Australia.
Jan 2015 to Feb 2016	Co-Founder & Chief Technology Officer (CTO) Glu10 – Gluten Sensing Solutions *5000 Forbes Avenue Pittsburgh, PA 15213, USA* Glu10 is a fast and reliable gluten-sensing platform for people with gluten intolerance and celiac disease. My research at Carnegie Mellon University is being turned into a real product. Glu10 is an early stage startup with working prototype and pending patent. We've been accepted into prestigious NSF I-Corps program and we have secured a place in startup accelerator (Idea Foundry).
Nov 2014 to Dec 2015	Research Fellow Department of Mechanical Engineering, Carnegie Mellon University *5000 Forbes Avenue Pittsburgh, PA 15213, USA* As a Research Fellow, I am involved in the development of novel conducting polymer-biomolecule composites for biosensing and energy applications. At the current stage, I am mostly interested in the development of gluten sensor that will help patients with gluten intolerance and celiac disease (estimated to be 1% of human population).

Jan 2015 to May 2015
Expert & Researcher
United Nations Industrial Development Organization (UNIDO)
SHS Quadra 6, Centro Empresarial Brasil 21 Conj. A, Bloco A, Sala 612, CEP 70.316-102, Brasília, DF, Brazil

I have provided my expertise to advise UNIDO on challenges and opportunities in renewable energy in Latin America. This work resulted in two extensive reports on a novel and promising materials for renewable energy generation and storage; and new investment cycles and mechanisms in renewable energy between China and Latin America.

May 2012 to Dec 2012
Consultant
UNDP Guyana
42 Brickdam & United Nations Place, Stabroek, Georgetown, Guyana

I provided consultancy on off-grid solar power systems for rural areas in Guyana. I also designed photovoltaic systems together with energy storage and tested the systems as well as performed remote efficiency measurements on site in Guyana. I also designed measurement systems and data acquisition software projects in cooperation with the Guyana Energy Agency.

Sep 2009 to Feb 2010
R&D Engineer
Danfoss Solar Inverters A/S,
Jyllandsgade 28, 6400 Sonderborg, Denmark

I served as a Research and Development Engineer designing power electronic products such as solar inverters and developing technology within the solar energy sector. I worked specifically on projects in ORCAD, PSIM, SIMETRIX, MathCAD, Matlab/Simulink, TESTTRACK, SURROUND, and even a solar panel simulator where I used fuzzy logic to design and develop control systems and algorithms for solar and fuel cell inverters

ADVISORY, CASUAL, VOLUNTARY, AND REMOTE ROLES

Jul 2018 to March 2019
Member
International Working Groups, European Commission (EC)'s Scientific Advice Mechanism (SAM)
Rue d'Egmont/Egmontstraat 13, Brussels, Belgium

The EC's SAM provides independent scientific advice to the EC, working with a Group of Chief Scientific Advisors (GCSA) and the European Academies (SAPEA). SAPEA was asked by the GCSA to produce an Evidence Review Report that gives a 'Scientific Perspective on Micro and Nanoplastic Pollution and its Impacts'. This work aims to provide multidisciplinary scientific advice for policy makers, providing the following: (1) a summary of natural sciences MNPs reviews and the latest primary literature, with a look at what could be learned from scientific modelling approaches; (2) a digest of the social and behavioural sciences and humanities knowledge on relevant areas (such as risk perception, the behaviour of stakeholders etc.); and (3) regulatory and legislative aspects from the political and legal sciences perspectives.

Dec 2017 to present **Accelerating Commercialisation Expert**
Department of Industry, Innovation & Science
10 Binara St, Canberra ACT 2601, Australia
In this voluntary role, I provide businesses with access to expert advice in my area of expertise including renewable technology, biotechnology, nanotechnology, business development and commercialization. Additionally, the programme provides matched funding of up to $1 million to cover eligible commercialisation costs to help businesses to take novel products, processes and services to market.

Oct 2017 to present **Expert – Nano and Biotechnology**
World Economic Forum (WEF)
91-93 route de la Capite, CH-1223 Cologny, Switzerland
The World Economic Forum, committed to improving the state of the world, is the International Organization for Public-Private Cooperation. The Forum engages the foremost political, business and other leaders of society to shape global, regional and industry agendas. As a member of the council, I am involved in developments of broadly understood biotechnology. This council will explore how developments in Biotechnology could impact industry (especially agriculture and health), governments and society in the future, and design innovative governance models that ensure that their benefits are maximized, and the associated risks kept under control.

Feb 2017 to present **Task Force Member**
Group of 20 (G20)
A Task Force Member for Think 20 (T20) Summit and Business 20 (B20) Summit. I participated as a member in 2030 Agenda for Sustainable Development Task Force 2017, 2030 Agenda for Sustainable Development Task Force 2018 and Climate Action and Infrastructure for Development Task Force 2018 in Germany (2017) and Argentina (2018), as well as Energy, Resource Efficiency & Sustainability Task Force (2018). I have also authored a series of policy papers.

Oct 2013 to present **Committee Member, Task Force Member**
The International Union for Conservation of Nature (IUCN)
Rue Mauverney 28, 1196 Gland, Switzerland
The International Union for Conservation of Nature is the foremost international organization working in the field of nature conservation and sustainable use of natural resources. Since October 2013, Member of the Commission on Ecosystem Management (CEM). From September 2017, Member of the World Commission on Environmental Law (WCEL). From February 2014, Member of the Task Force on Nanomaterials and Ecosystems. Since February 2018, Member of the Task Force on Synthetic Biology and Biodiversity Conservation. I am also a member of Young Professionals Network.

Mar 2012 to present **Expert, Evaluator & Consultant**
European Commission
Covent Garden, Place Rogier 16, 1210 - Saint-Josse-Ten-Noode, Belgium
For the European Commission, I analyze and evaluate fuel cells, hydrogen & renewable energy, and nanotechnology projects. I did this first under the Seventh Research Framework Programme (7FP) and later under Horizon 2020. I also work closely with other experts on evaluative and analysis procedures to ensure efficient and timely results.

Mar 2014 to Apr 2014 **Expert Evaluator**
United Nations Convention to Combat Desertification (UNCCD)
Platz der Vereinten Nationen 1, 53113 Bonn, Germany
I assisted the UNCCD as an expert reader by screening select project applications against specific criteria, grading them and providing essential feedback.

TEACHING AND OUTREACH EXPERIENCE

April 2017 to present **Mentor**
The Queen's Young Leaders Programme
89 Albert Embankment, London, SE1 7TP, United Kingdom
I serve as a mentor to the Queen's Young Leaders; some of the most promising young leaders in the Commonwealth.

Nov 2015 to Dec 2016 **Lecturer**
Carnegie Mellon University
5000 Forbes Avenue Pittsburgh, PA 15213, USA
I have thought '27-215 - Thermodynamics of Materials' and '27-205 - Introduction to Materials Characterization' to sophomore year undergraduate students at Carnegie Mellon University.

Feb 2012 to Nov 2015 **Teaching Associate**
Department of Materials Engineering, Monash University
Wellington Road, Clayton VIC 3800, Australia
I was a course instructor for the courses 'MTE4599 - Materials for Energy Technologies'; 'ENG1050 - Engineering Materials'; and 'MTE2541 - Crystal Structures, Thermodynamics and Phase Equilibria'. I was responsible for all aspects of the educational experience in these courses including explaining experiments, device, and materials basics, taking care of OHS during experiments, and collecting and marking student's reports and exams.

SELECTED OTHER ACTIVITIES

Aug 2017 to present **Mentor**
Climate-KIC Australia
Building 25, 4-12 Buckland Street, Chippendale, NSW 2008, Australia
As part of Climate-KIC Australia, I have mentored three teams that developed cleantech and climate change mitigation business ideas to participate in the Climate-KIC grand finale in Cyprus. My work commitment was five hours a week on average for a period of two months.

Jan 2017 to present **Ambassador**
MIT Innovators Under 35 Europe
1 Main St, Cambridge, MA 02142
MIT Ambassadors are figures with an ample experience, visibility, and knowledge of the local and regional academic and entrepreneurial environment who are willing to help MIT Technology Review in discovering the most brilliant technologists. Among other opportunities, ambassadors have the opportunity to nominate new members of the international jury panel, experts, and influencers, for the awards and take an active part in a variety of events. They help in expanding the MIT Innovators Under 35 community. Additionally, ambassadors promote the competition in their channels and help to identify top candidates.

LANGUAGES

Polish native | **English** fluent (IELTS 8) | **German** basic | **Spanish** basic

SKILLS

Computer skills Windows | Microsoft Office | AutoCAD | Mechanical Desktop | SolidWorks | Inventor | CATIA | Adobe Photoshop | Matlab and Simulink | LabVIEW

Programming languages C | C++ | Java | HTML | PHP | Assembly

Selected courses

2018 Trademarks, Industrial Designs and Geographical Indications, World Intellectual Property Organization (WIPO)

2017 Software Licensing including Open Source, World Intellectual Property Organization (WIPO)

2017 Promoting Access to Medical Technologies and Innovation - Executive Course on the intersections between public health, intellectual property and trade, World Intellectual Property Organization (WIPO)

2017 Climate Justice, UNESCO

2017 Intellectual Property Management, World Intellectual Property Organization (WIPO)

2017	Collective Management of Copyright and Related Rights for Policy Makers, World Intellectual Property Organization (WIPO)
2016	Global Systems Science and Policy, UNESCO
2016	Introduction to the Patent Cooperation Treaty, World Intellectual Property Organization (WIPO)
2016	Basics of Patent Drafting, World Intellectual Property Organization (WIPO)
2015	Scuba Diver, Scuba Schools International (SSI)
2015	Patent Information Search, World Intellectual Property Organization (WIPO)
2015	Advanced Course on Patents, World Intellectual Property Organization (WIPO)
2014	WSET Level 2 Award in Wines and Spirits, Wine & Spirit Education Trust (WSET)
2013	Building Performance Analysis, Autodesk
2013	General Course on Intellectual Property, World Intellectual Property Organization (WIPO)
2011	Perform CPR (HLTCPR211A), Parasol
2011	Apply First Aid (HLTFA311A), Parasol
2010	Advanced Open Water Diver (AOWD), PADI
2009	Open Water Diver (OWD), PADI
2008	Writing business plans course, Rzeszow University of Technology
2008	Unigraphics NX 5 course, Rzeszow University of Technology

SELECTED AWARDS AND HONORS

2019	Mars Fellowship, Mars Incorporated
2019	Selected to attend 69th Lindau Nobel Laureate Meeting,
2018	Winner, Jagajaga Australia Day Awards, Parliament of Australia
2018	Victoria Fellowship, Victorian Government and Veski
2018	Winner, Austrade – Australia China Alumni Award for Entrepreneurship & Innovation, 2018 Australia China Alumni Awards, Austrade and Australia China Alumni Association
2018	Monash Global Leader by Monash University
2018	Recipient of the 2018 Premier’s Volunteer Champions Awards, Leadership category, Victorian Government
2018	Finalist, Yarra Sustainability Awards 2018, City of Yarra
2018	InnoHealth Australia, Fraunhofer Institute and DAAD
2018	Future Energy Leader (FEL-100), World Energy Council
2017	International Alumnus of the Year 2017, Victorian International Education Awards, Victorian Government
2017	EU-Australia Emerging Leader, European Commission and Australian Department of Foreign Affairs and Trade
2017	WWF Prince Bernhard Scholarships for Nature Conservation, World Wide Fund (WWF)
2017	Young Global Changers Scholarship, G20 Germany 2017
2017	Energy & Fuels Champion for ProteinX project, Bringing Tech & Science Closer to People
2014 – 2017	Global Shaper, the World Economic Forum
2013 – 2017	Listed continuously since 2013 in *Who’s Who in Australia*, an Australian biographical reference publication
2016	Finalist, International Alumni of the Year 2016, Victorian International Education Awards, Victorian Government
2016	100 Visionary Leaders (#1) by Real Leaders Magazine
2016	Future Leader, The Riga Conference (NATO meeting)

2016	MIT Innovator Under 35, MIT Technology Review
2016	Fellow, the Global Young Academy
2015	Future Leader, the World Forum on Ecosystem Governance
2015	International Student of the Year (Postgraduate), Council of International Student Australia (CISA) Excellence Awards
2015	Laureate of Future Ideas Competition, Future Ideas
2015	3rd Award for the Best Commercialization Pitch, ANN ECR Entrepreneurship Workshop
2015	Travel Grant Award, Monash University Office of the Deputy Vice-Chancellor (Global Engagement)
2014 – 2015	Young Nanotechnology Ambassador Award, Australian Nanotechnology Network (ANN)
2014 – 2015	Postgraduate Publication Award (PPA), Faculty of Engineering, Monash University
2014	Victorian International Education Student Awards, International Student of the Year – Research, Victorian Government
2014	Laureate of Australia's Top 100 Most Employable Graduates, GradConnection
2014	3rd Award for the Best Oral Talk at Materials Engineering Summer Postgraduate Conference
2014	2nd Award for the Best Oral Talk at Materials Engineering Winter Postgraduate Conference
2014	Postgraduate Travel Grant Award, Monash University Institute of Graduate Research
2012 – 2014	Faculty of Engineering International Postgraduate Research Scholarship (FEIPRS)
2011 – 2014	Monash Departmental Scholarship (MDS) – Department of Materials Engineering
2012	Volunteer Grants, Department of Families, Housing, Community Services and Indigenous Affairs (FaHCSIA), Australian Government
2010 – 2011	EEA Financial Mechanism Grants (EFTA) Scholarship
2009	Winner of the nationwide competition Student's Nobel
2008	Erasmus Scholarship
2008	Winner of the nationwide competition Primus Inter Pares Student of the Year
2008	Rector's prize for scientific achievements and work in support of the Students Environment at Rzeszow University of Technology
2008	Dean's List (scholarship for study results)

PROFESSIONAL MEMBERSHIP

May 2018 to present	**The Royal Society of Chemistry**, Member
Dec 2016 to present	**International Association of Genocide Scholars**, Member
Sep 2016 to present	**Future Earth**, Member
Jul 2016 to present	**Conservation International**, Member
Jul 2016 to present	**The International Council for Science (ICSU)**, Member
May 2016 to present	**The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)**, Member
Apr 2016 to present	**The World Association of Young Scientists**, Member
Mar 2016 to present	**The National Postdoctoral Association**, Member
Jan 2016 to present	**The International Network for Government Science Advice (INGSA)**, Member
Jan 2016 to present	**The Global Young Academy (GYA)**, Fellow
Dec 2015 to present	**The Kosciuszko Foundation**, National Member, and Pittsburgh Chapter Board Member
May 2015 to present	**Australian Early- and Mid-Career Researcher (EMCR) Forum, Australian Academy of Science**, Member
May 2015 to present	**Photonics21**, Member
Apr 2015 to present	**EuroScience**, Associate Member

Jan 2015 to present	**Global Shapers Community**, Global Shaper
Feb 2014 to present	**European Materials Research Society**, Member
Dec 2013 to present	**Australian Institute of International Affairs**, Member
Oct 2013 to present	**The International Union for Conservation of Nature (IUCN)**, Member of the Commission on Ecosystem Management (CEM) and Member of the World Commission on Environmental Law (WCEL)
May 2013 to present	**The Australian Association for Hydrogen Energy**, Member
Oct 2012 to present	**Australian Institute of Energy (AIE)**, Member
Feb 2012 to present	**Materials Research Society (MRS)**, Member
Jan 2012 to present	**International Association for Hydrogen Energy (IAHE)**, Member
Nov 2011 to present	**Australian Nanotechnology Network (ANN)**, Member
Feb 2012 to Feb 2016	**The Royal Society of Victoria**, Member
Oct 2007 to Sep 2015	**International Association for Exchange of Students for Technical Experience (IAESTE)**, Member
May 2012 to May 2015	**The Golden Key International Honour Society**, Member
Mar 2009 to May 2015	**Rotary International**, Member
Apr 2010 to Apr 2012	**Icelandic Touring Association (Ferðafélag Íslands)**, Member, Touring Club of Akureyri Chapter

SELECTED PATENTS

2016	Kolodziejczyk, B. & Jayan, B. R., Hybrid Materials, Devices, Software, and Platforms for Electrically Responsive Allergen Detection, Monitoring, and Processing.
2014	Kolodziejczyk, B. & Winther-Jensen B., Method and System for Micro Patterning. AU2014902454
2013	Kolodziejczyk, B., Nair, S. S., & Winther-Jensen, B., Nanogenerators and a Method for their Manufacture. AU2013903001, WO 2015017887 A1

SELECTED PUBLICATIONS

Peer-reviewed journal articles

2017	Kolodziejczyk, B., Ng, C.H., Strakosas, X., Malliaras, G. & Winther-Jensen, B. Light sensors and opto-logic gates based on organic electrochemical transistors. Materials Horizons, 2018, 5, 93 – 98, doi:10.1039/C7MH00818J
2017	Kolodziejczyk, B., Mayevsky, D., Winther-Jensen, O., Garvey, C. & Winther-Jensen, B. Polythiophene micro-wires for organic electronics applications. Under revision (Advanced Materials)
2015	Kolodziejczyk, B., Winther-Jensen, O., Pereira, B. A., Nair, S. S. & Winther-Jensen, B. Patterning of conducting layers on breathable substrates using laser engraving for gas sensors. Journal of Applied Polymer Science 132, doi:10.1002/app.42359
2015	Winther-Jensen, B., Kolodziejczyk, B. & Winther-Jensen, O. New one-pot poly(3,4-ethylenedioxythiophene): poly(tetrahydrofuran) memory material for facile fabrication of memory organic electrochemical transistors. APL Materials 3, 014903, doi:doi:http://dx.doi.org/10.1063/1.4900889
2015	Winther-Jensen, O., Hamilton, J. L., Ng, C. H., Kolodziejczyk, B. & Winther-Jensen, B. Miniaturisation and simplification of solid-state proton activity sensors for non-aqueous media and ionic liquids. Analyst 140, 889-894, doi:10.1039/C4AN01556H
2015	Nair, S. S., Kolodziejczyk, B., West, K., Hansen, T.S., Adeloju, S.B., Forsythe, J.S. & Winther-Jensen, B. New junction materials by the direct growth of ZnO NWs on organic semiconductors. RSC Advances 5, 7932-7937, doi:10.1039/C4RA15621H
2015	Kolodziejczyk, B., Winther-Jensen, O., Kerr, R., Firbas, P. & Winther-Jensen, B. Tuning the morphology of electroactive polythiophene nano-structures. Reactive and Functional Polymers 86, 60-66, doi:http://dx.doi.org/10.1016/j.reactfunctpolym.2014.11.010

2014 Ng, C. H., Winther-Jensen, O., Kolodziejczyk, B., Ohlin, C. A. & Winther-Jensen, B. Photo-electrocatalytic H2 evolution on poly(2,2′-bithiophene) at neutral pH. International Journal of Hydrogen Energy 39, 18230-18234, doi:http://dx.doi.org/10.1016/j.ijhydene.2014.09.003

2014 Kolodziejczyk, B., Winther-Jensen, O., Ng, C. H., Lin, S., Bao, Q., & Winther-Jensen, B. Growth of polythiophene nano-walls and their unique electrochemical and optical properties. Materials Horizons 1, 452-460, doi:10.1039/C4MH00016A

2013 Kolodziejczyk, B., Mayevsky, D. & Winther-Jensen, B. Enhanced absorption spectra of conducting polymers co-polymerised from thiophene derivatives. RSC Advances 3, 4568-4573, doi:10.1039/C3RA23120H

2012 Kolodziejczyk, B., Winther-Jensen, O., MacFarlane, D. R. & Winther-Jensen, B. Conducting polymer alloys for photo-enhanced electro-catalytic oxygen reduction. Journal of Materials Chemistry 22, 10821-10826, doi:10.1039/C2JM30992K

Popular science and leadership

2019 Kolodziejczyk, B., et al. The Future of Health 2030, Popular science book under revision.

2019 Kolodziejczyk, B. and Ong, W.-L. Hydrogen power is here to stay. How do we convince the public that it's safe? World Economic Forum, https://www.weforum.org/agenda/2019/04/why-don-t-the-public-see-hydrogen-as-a-safe-energy-source/

2018 Malone, J. and Kolodziejczyk, B. How would international agreements on genetically engineered organisms apply to humans? Brookings Institution, https://www.brookings.edu/blog/techtank/2018/12/18/how-would-international-agreements-on-genetically-engineered-organisms-apply-to-humans/

2018 Horngren, T. and Kolodziejczyk, B. Microplastic and nanoplastic pollution threatens our environment. How should we respond? World Economic Forum, https://www.weforum.org/agenda/2018/10/micro-and-nano-plastics-the-next-global-epidemics/

2018 Kolodziejczyk, B. and Malone, J. Sharing digitized DNA sequences must balance scientific progress with fair use, Brookings Institution, https://www.brookings.edu/blog/techtank/2018/10/05/sharing-digitized-dna-sequences-must-balance-scientific-progress-with-fair-use/

2018 Kolodziejczyk, B. and Perello, E. Catastrophic risk to ecosystems puts biotechnology fixes on the table, Brookings Institution, https://www.brookings.edu/blog/techtank/2018/05/31/catastrophic-risk-to-ecosystems-puts-biotechnology-fixes-on-the-table/

2018 Kolodziejczyk, B., Why do we fail to measure the most innovative countries? Brookings Institution, https://www.brookings.edu/blog/techtank/2018/01/22/why-do-we-fail-to-measure-the-most-innovative-countries/

2017 Kolodziejczyk, B., Do-it-yourself biology shows safety risks of an open innovation movement, Brookings Institution, https://www.brookings.edu/blog/techtank/2017/10/09/do-it-yourself-biology-shows-safety-risks-of-an-open-innovation-movement/

2017 Kolodziejczyk, B., Gamache, W., Reaping the benefits without salting the earth - moving forward with genetically engineered foods, Food and Agriculture Organization of the United Nations, http://www.fao.org/cfs/home/blog/blog-articles/article/en/c/1027560/

2017 Kolodziejczyk, B., Could your next peer review be done by ... a robot? World Economic Forum, https://www.weforum.org/agenda/2017/05/your-next-peer-review-will-be-done-by-a-machine

2017 Kolodziejczyk, B., Why Governments Need Advice From Scientists, Real Leaders, http://real-leaders.com/why-governments-need-advice-from-scientists/

2017 Kolodziejczyk, B., If I was leader of my country, this is what I'd do, World Economic Forum, https://www.weforum.org/agenda/2017/02/if-i-was-leader-of-my-country-this-is-what-i-d-do

2016 Kolodziejczyk, B., Faunce T., Should all roads and buildings make clean fuel from sunlight, water, and air? World Economic Forum, https://www.weforum.org/agenda/2016/08/should-all-roads-and-buildings-make-clean-fuel-food-and-fertilizer-from-sunlight-water-and-air

2016 Kolodziejczyk, B., What is nanowaste and why should we worry about it? World Economic Forum, https://www.weforum.org/agenda/2016/02/what-is-nanowaste-and-how-will-it-affect-us

2015 Kolodziejczyk, B., Smith, P., Will China become a global environment leader? World Economic Forum, https://www.weforum.org/agenda/2015/11/will-china-become-a-global-climate-leader

2015 Kolodziejczyk, B., The 5 next trends in electronics, World Economic Forum, https://www.weforum.org/agenda/2015/08/5-next-trends-in-electronics

Other publications, reports and policy papers

2019 Kolodziejczyk, B., et al. Genetic frontiers for conservation: An assessment of synthetic biology and biodiversity conservation, International Union for the Conservation of Nature (IUCN), https://doi.org/10.2305/IUCN.CH.2019.05.en

2019 Kolodziejczyk, B., et al. Hydrogen an enabler of the Grand Transition, World Energy Council, https://www.worldenergy.org/wp-content/uploads/2019/02/Hydrogen-an-enabler-of-the-Grand-Transition-FEL-WEC-2018-2.pdf

2018 Kolodziejczyk, B., et al. World Energy Trilemma Index 2018, World Energy Council (WEC), https://trilemma.worldenergy.org/reports/main/2018/2018%20Energy%20Trilemma%20Index.pdf

2018 Kolodziejczyk, B., et al. A Scientific Perspective on Microplastics in Nature and Society, Science Advice for Policy by European Academies (SAPEA), https://www.sapea.info/topics/microplastics/

2018 Kolodziejczyk, B. and Koefler, N. UNEP Frontiers 2018, United Nations Environment Programme (UNEP), https://www.unenvironment.org/resources/frontiers-201819-emerging-issues-environmental-concern

2017 Kolodziejczyk, B., Kagansky S., Consolidated G20 synthetic biology policies and their role in the 2030 Agenda for Sustainable Development, G20 Insights, G20 Germany 2017, http://www.g20-insights.org/policy_briefs/unified-g20-synthetic-biology-policies-role-2030-agenda-sustainable-development/

2017 Kolodziejczyk, B., et al., UNMGCY Youth Science Policy Interface Publication – Special Edition: Disaster Risk Reduction: A Road of Opportunities, http://www.preventionweb.net/files/53923_53923unmgcydrreditionmay2017reduced.pdf

2017 Kolodziejczyk, B., Faunce T., Nanowaste: Need for Disposal and Recycling Standards, G20 Insights, G20 Germany 2017, http://www.g20-insights.org/policy_briefs/nanowaste-need-disposal-recycling-standards/

2016 Kolodziejczyk, B., et al., Global Shapers Annual Survey 2016, World Economic Forum, http://shaperssurvey.org/data/report.pdf

2016 Kolodziejczyk, B., et al., WCC-2016-Res-086-EN - Development of IUCN policy on biodiversity conservation and synthetic biology, IUCN

2016 Kolodziejczyk, B., et al., Innovation for 2030 - 2015 Year in Review, UNDP, http://www.undp.org/content/undp/en/home/librarypage/development-impact/2015-year-in-review.html

2016 Kolodziejczyk, B., Dong, J., Cooperation between China and Latin America – New Investment Cycles in Renewable Energy Sector, UNIDO Report

2016 Kolodziejczyk, B., Kerr, R.P., Novel and Promising Materials for Renewable Energy Applications, UNIDO Report

2016	Kolodziejczyk, B. et al., United Nations E-Government Survey 2016, UN Department of Economic and Social Affairs (DESA), http://workspace.unpan.org/sites/Internet/Documents/UNPAN96407.pdf
2016	Kolodziejczyk, B., Nanotechnology, Nanowaste and Their Effects on Ecosystems: A Need for Efficient Monitoring, Disposal, and Recycling, The UN Global Sustainable Development Report (GSDR) 2016, United Nations
2016	Kolodziejczyk, B. et al., UN Global Sustainable Development Report (GSDR) 2016, the United Nations
2015	Kolodziejczyk, B. et al., Beijing Declaration on Ecosystem Governance, the World Forum on Ecosystem Governance
2015	Kolodziejczyk, B. et al., Amman Youth Declaration on Youth, Peace and Security, Global Forum on Youth, Peace and Security

ISO Standards and frameworks

2017	Kolodziejczyk, B. et al., ISO/NP TR 22293 Evaluation of methods for assessing the release of nanomaterials from commercial, nanomaterial-containing polymer composites
2017	Kolodziejczyk, B. et al., ISO/TC229 PWI Nanotechnologies – 3-D tomography in a transmission electron microscope
2016	Kolodziejczyk, B. et al., ISO-IEC/TS 80004-9 Nanotechnologies – Vocabulary - Part 9: Nano-enabled electrotechnical products and systems
2016	Kolodziejczyk, B. et al., ISO/CD TS 16393 Molecular biomarker analysis - Qualitative methods - Validation scheme for binary analytical methods for food and food products
2016	Kolodziejczyk, B. et al., ISO 80004:2016 CP Nanotechnologies—Vocabulary
2016	Kolodziejczyk, B. et al., ISO/CD 20613 Sensory Analysis - Guidelines for application of sensory analysis in food quality control

SELECTED TALKS AND CONFERENCES

Jun 2019	69th Lindau Nobel Laureate Meeting, *Lindau, Germany*
Feb 2019	Workshop on Science, Technology and Innovation for the SDGs, Meeting of the TFM 10-Member group and IATT in preparation of the Multi-Stakeholder, Meeting on Science, Technology and Innovation for the SDGs 2019, *Bangkok, Thailand*
Jan 2019	Globalization: Contents and Discontents, World Bank, *Kuala Lumpur, Malaysia*
Dec 2018	UNEP's Second Meeting of the Ad Hoc Open-Ended Expert Group on Marine Litter and Microplastics, *Geneva, Switzerland*
Nov 2018	Tenth International Forum of NGOs in official partnership with UNESCO "Science as a Common Good of Humankind", ONG-UNESCO Forum, *Moscow, Russia*
Nov 2018	2018 G20 Summit, *Buenos Aires, Argentina*
Nov 2018	INGSA 2018 Meeting, *Tokyo, Japan*
Oct 2018	UNESCO's CILAC Forum, *Panama City, Panama*
Sep 2018	T20 Argentina Summit, *Buenos Aires, Argentina*
May 2018	OECD Forum 2018, *Paris, France*
May 2018	St Petersburg International Economic Forum (SPIEF) and B20 Regional Consultation Forum, *St Petersburg, Russia*
Apr 2018	UN Expert Group Meeting on Exponential Technological Change, Artificial Intelligence, Automation, and Their Policy Implications for Sustainable Development, *Mexico City, Mexico*
Apr 2018	InnoHealth Australia, *Melbourne, Australia*
Mar 2018	Gateway of India Geoeconomic Dialogue: Where geopolitics meets business, Gateway House and the Indian Ministry of External Affairs, *Mumbai, India*

Feb 2018	International Symposium on Youth Employment Challenges 2018 (ISYEC’18), *Kayseri, Turkey*
Feb 2018	The Ninth Session of the World Urban Forum (WUF9), United Nations Habitat, *Kuala Lumpur, Malaysia*
Feb 2018	T20 Argentina Inception Workshop: Vision & Strategies for 2018, *Buenos Aires, Argentina*
Dec 2017	The 2nd Hydrogen and Fuel Cell Industry Development International Summit and ISO/TC197 Strategic Planning Meeting, The 1st International Hydrogen Energy and Fuel Cell Technology and Product Expo, *Foshan, China*
Nov 2017	Fuel Cell Vehicle Congress (FCVC), *Rugao, China*
Nov 2017	World Science Forum (WSF), UNESCO, *Amman, Jordan*
Nov 2017	UN Sustainable Innovation Forum 2017 (SIF17), *Bonn, Germany*
Oct 2017	Assessing the Security Implications of Genome Editing Technology, *Hanover, Germany*
Sep 2017	United Nations Convention to Combat Desertification 13th Conference of Parties (COP13) Land, Youth and Sustainability – Youth Forum, *Ordos, China*
Sep 2017	UNESCO 2017 MAB Youth Forum, *Venice, Italy*
Jul 2017	The UN High-level Political Forum, *New York, USA*
Jul 2017	Emerging Issues in Science and Society, *Melbourne, Australia*
Jun 2017	Pumped Hydro Roadshow (organized by Clean Energy Council), *Sydney, Australia*
Jun 2017	EU-Australia Leadership Forum, *Sydney, Australia*
Jun 2017	Workshop ‘*Policy Impact of Knowledge Organisations: from Understanding Impact towards Measuring it’, Brussels, Belgium*
May 2017	Global Solutions for G20: the Think 20 Summit, *Berlin, Germany*
Mar 2017	Workshop *‘Off-grid energy for rural development in Southeast and South Asia: Closing regional workshop’, Bangkok, Thailand*
Feb 2017	Symposium ‘*Implementing the 2030 Agenda for Sustainable Development and the SAMOA Pathway in Small Island Developing States (SIDS): Equipping Public Institutions and Mobilizing Partnerships*’, *Nassau, the Bahamas*
Nov 2016	Workshop *'Computational Life Sciences @ Bayer*', *Berlin, Germany*
Nov 2016	The World Forum for Democracy 2016 "*Democracy and equality: does education matter?*", *Strasbourg, France*
Dec 2016	Joint IIASA-NERC Conference: Systems Analysis Applied to Environment and Health, *London, United Kingdom*
Oct 2016	The Riga Conference and Future Leaders Forum, *Riga, Latvia*
Oct 2016	EFC Research Forum Conference *“Change Makers – Enabling High-Impact Research” London, United Kingdom*
Sep 2016	The 2nd International Network for Government Science Advice Conference, *Brussels, Belgium*
Jul 2016	The UN High-level Political Forum on Sustainable Development 2016, *New York, USA*
Jun 2016	NATO Summit, *Warsaw, Poland*
May 2016	Annual Meeting of Global Young Academy, *Eindhoven, Netherlands*
Apr 2016	Celiac Disease Foundation National Conference and Gluten-Free EXPO, *Pasadena, USA*
Mar 2016	Carnegie Mellon University Energy Week, *Pittsburgh, USA*
Oct 2015	World Forum on Ecosystem Governance, *Beijing, China*
Jun 2015	Nanotechnology Entrepreneurship Workshop for Early Career Researchers, *Gold Coast, Australia*
Feb 2015	Nanolytica 2015, *Melbourne, Australia*

Nov 2014	Innovative Printed Smart Objects (IPSO)*, Gardanne, France*
Oct 2014	All-Energy Australia 2014, *Melbourne, Australia*
Sep 2014	E-MRS 2014 Fall Meeting, *Warsaw, Poland*
Jun 2013	Cutting Edge Renewable Energy Technologies, *Melbourne, Australia*
Oct 2012	All-Energy Australia 2012, *Melbourne, Australia*
Apr 2012	2012 MRS Spring Meeting & Exhibit, *San Francisco, USA*

INTERESTS

Innovation and cutting-edge technologies | volcano boarding | kitesurfing | scuba diving | traveling; recently visited Malaysia, Thailand, and the Cook Islands