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Hy4Smelt

Deliverable 2.1 - Hy4Smelt use case specifications

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Disclaimer: This report contains a preliminary list of use cases which are defined at the start of the project, but which may change throughout the course of the project given development and operation of the plant. This may lead to adjustment of both the number and character of use cases.

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1 Introduction

Hy4Smelt is a research project with a TRL 8 industrial-scale demonstration plant for hot metal production in a sustainable process with green hydrogen, electricity and secondary carbon carriers (Biochar). Besides sustainability, a focus of Hy4Smelt is the processability of iron ore ultra-fines of all qualities, enabling highest flexibility in input material selection. This is possible because of the groundbreaking combination of novel technologies HYFOR and Smelter. HYFOR is a fluidized bed process that enables reduction of ultra-fine iron ores with hydrogen. The Smelter is a continuous electric smelting process under reducing atmosphere enabling processing of direct reduced iron at lower metallization degrees and higher gangue content than electric arc furnaces.

1.1 Purpose of this Document

Work Package 2 (WP2), Task 2.1 of the Hy4Smelt project has the objective to detail the aims and execution of the individual use case of the operational phase, which are going to be performed in WP4 “Research and technology demonstration of Hy4Smelt”. This document, deliverable D2.1, details the specifications of these use cases, which will be composed of a representative selection of iron ores of various qualities and operational conditions. Use case 1 will be used for start-up and initial operation of the plant to gain process understanding while use cases 2 to 8 cover a variety of operational conditions.

1.2 Abbreviations, Acronyms, Units,

Table 1: Abbreviations

Abbreviation	Meaning
HYFOR	Hydrogen based fine ore reduction
Fe_{tot}	Total iron content
Fe_3O_4	Magnetite
Fe_2O_3	Hematite
CaO	Calcium Oxide / quicklime / burnt lime
MgO	Magnesium Oxide / Magnesia
SiO_2	Silicon Oxide / Silica
Al_2O_3	Aluminum Oxide / Alumina
MnO	Manganese Oxide
TiO_2	Titanium Dioxide / Titania
Na_2O	Sodium Oxide
K_2O	Potassium Oxide
P_2O_5	Phosphorus Pentoxide
SO_3	Sulphur Trioxide
LOI	Loss on ignition
H_2	Hydrogen
PEM	Proton Exchange Membrane or Polymer Electrolyte Membrane
DRI	Direct Reduced Iron
B_2	Slag basicity, ratio of CaO to SiO
D_{50}	Median particle size

Table 2: Units

Unit	Meaning
°C	Temperature in Celsius
Nm^3	Norm cubic meters
h	Hours
MW	Megawatts
t	Tons

2 Use case selection

In order to develop a representative selection of iron ores results from prior projects (lab scale, pilot scale) and input from project partners was combined. The chemical compositions of iron ores and the available hydrogen from H2FUTURE [1] were used together with a process simulation done by the partner Primetals Technologies Austria GmbH to define all required parameters. Key among these and presented in the following sections are composition and ratios of ore, hydrogen, produced DRI, other iron-bearing additions and carbon. Furthermore, information regarding slag-forming additives is provided.

2.1 Iron ore selection

Iron ores in the form of various mineral compositions, particle sizes and grades (iron content) are selected as a representative of globally and domestically relevant iron ores. Figure 1 shows globally traded iron ores, showcasing the tremendous potential of sustainably processing medium and low-grade iron ores.

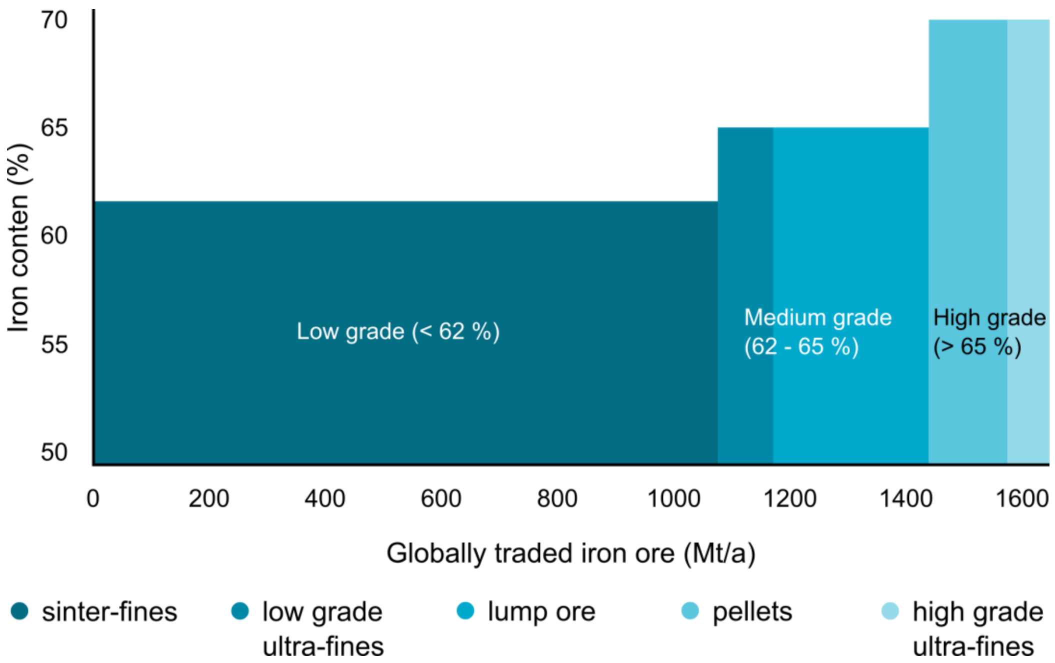

Figure 1: Globally traded iron ores and pellets [2].

The following two tables give a detailed chemical analysis of the selected iron ores.

Table 3: Iron ore composition.

Ore Type	Fe_{tot}	Fe_3O_4	Fe_2O_3	CaO	MgO	SiO_2	Al_2O_3
High grade magnetite sinter feed	66.35	28.36	65.52	0.45	0.45	4.55	0.17
High grade magnetite pellet feed	69.22	39,10	58.53	0.46	0.46	0.81	0.17
Low grade hematite 1	56.10	0	80.21	0.20	0.16	5.00	2.90
Low grade hematite 2	61.60	0	88.07	0.09	0.10	3.70	2.30
Low grade siderite	33.56	-	-	6.88	3.72	5.20	1.02
Medium grade hematite	63.21	-	89.92	0.1	0.37	5.87	2.55

Table 4: Iron ore composition cont.

Ore Type	MnO	TiO_2	Na_2O	K_2O	P_2O_5	SO_3	LOI*
High grade magnetite sinter feed	0.222	0.05	-	-	0.019	0.003	0.20
High grade magnetite pellet feed	0.21	0.05	-	-	0.019	0.003	0.20
Low grade hematite 1	0.16	0.16	-	-	0.073	0.062	11.10
Low grade hematite 2	0.155	0.09	-	-	0.229	0.062	5.20
Low grade siderite	2.47	-	0.025	0.35	0.062	0.06	35.91
Medium grade hematite	0.06	-	0.01	0.22	0.115	0.04	-

The target particle size for all ores is smaller than 1 mm with an optimum range of > 20 µm and < 500 µm. By using a fluidized bed process for the reduction, the energy-intensive agglomeration (sintering, pelletizing) can be omitted. Pellet feed (ultra fines) is already fine material at the required particle size after beneficiation processes, while other feed types (lump, sinter fines) require grinding at an estimated energy requirement of one tenth of that of agglomeration for reduction in shaft processes.

2.2 Overview of use cases

2.2.1 Use Case 1

Use Case 1 is based on a magnetitic sinter feed iron ore. It has a high content of iron (66 %) and a particle size distribution that requires milling. It has been selected as the first use case because it is readily available and allows testing of the grinding setup as well as the oxidation step during pre-heating before the reduction with H_2. The standard hydrogen flowrate of 1200 Nm^3/h is applied. DRI production is expected to be 1.79 t/h at a metallization degree of 85 %. A net-addition of 170 kg carbon is required for reduction and carburization in the Smelter.

2.2.2 Use Case 2

Use case 2 uses the same parameters and additives as use case 1 with exception of no addition of bauxite in the Smelter process.

2.2.3 Use Case 3

Use case 3 uses the same parameters and additives as use case 1 with exception of biochar instead of fossil carbon in the Smelter process.

2.2.4 Use Case 4

Use case 4 uses the same parameters and additives as use case 1 with exception of the addition of iron carriers or recycling material. However, iron carriers are defined by shredded scrap and HBI, recycling material as EAF slag, BOF slag, pelletized BF dust and mill scale.

2.2.5 Use Case 5

Use case 5 uses high grade magnetitic pellet feed. This is a very fine material with a D_{50} of 27 µm. Therefore, it does not require a grinding step. However, it will be a test and showcase of the capability to directly handle ultra-fine iron ores without agglomeration. Due to the highest content of iron at 69.22 % this use case also has the lowest demand carbon due to highest achievable metallization of the DRI resulting in expected 1.63 t/h of DRI and 1.64 t/h of hot metal.

2.2.6 Use Case 6

Use case 6 uses the same parameters and additives as use case 5. However, for a short period the H2FUTURE plant can provide for a short time 1500 Nm^3/h of H2. This results in a higher amount of DRI and hot metals of 2.14 t/h resp. 2.14 t/h

2.2.7 Use Case 7

Use case 7 uses a low-grade hematite with an iron ore content of 56 %. The standard hydrogen flowrate of 1200 Nm^3/h is applied. DRI production is expected to be 2.09 t/h at a metallization degree of 85 %. A net-addition of 190 kg carbon is required for reduction and carburization in the Smelter.

2.2.8 Use Case 8&9

Use case 7&8 uses a low-grade hematite with an iron ore content of 61 %. The standard hydrogen flowrate of 1200 Nm^3/h is applied in one case and 1500 Nm^3/h in the other case. DRI production is expected to be 2.00 resp. 2.60 t/h at a metallization degree of 85 %. A net-addition of 190 resp. 250 kg carbon is required for reduction and carburization in the Smelter.

2.2.9 Use Case 10

Use case 10 is a blend of Austrian domestic iron ore (low grade siderite) and medium grade hematite ore, whereas the blend may be adjusted according to the data generated during operation. This is of special interest for some of the project's industry partners and gives detailed insight in the calcination behavior of $FeCO_3$ during pre-heating. A 1:1 blend will result in 2.35 t/h of DRI and 1.84 t/h of hot metal. Due to the low-grade siderite ore this will also be the use case with the highest amount of slag produced at up to 0.71 t/h.

2.2.10 All use cases

It is essential for all use cases to investigate the ore preprocessing (grinding, pre-heating, oxidation, calcination). Key parameter for the direct reduction with hydrogen are hydrogen pressure, ore and gas temperature, particle dwell time in the reactor and on the product side the reduction and metallization degree. From the direct reduction two pathways to the Smelter are possible. Direct charging of the DRI fines and a compacting step with a briquetting press. This allows investigation of behavior of compacted and fine material in the Smelter, mixing of two material streams, as well as independent operation of HYFOR and Smelter. Various carbon addition strategies will be investigated as well as different carbon carriers. After smelting the product qualities will be evaluated. Hot Metal carburization is of special interest because it is a requirement for downstream steelmaking. The slag will be investigated regarding re-use as binder in the cement sector as an alternative to blast furnace slag. In use cases 1 through 7 slag additives are added to achieve a basicity of B_2 = 1.1. In use case 8 the slag is adjusted to a basicity of B_2 = 0.9 with the basicity being

$$B_2 = \frac{CaO}{SiO_2}$$

In the following tables 5 and 6 all use cases are summarized.

Table 5: Summary of HYFOR use cases.

Use Case	Ore Type	HYFOR				
		Ore (t/h)	Hydrogen (Nm^3/h)	DRI (t/h)	Metallization (%)	Temperature Hydrogen (°C)
1	Magnetitic sinter feed	2.45	1200	1.79	85	720
2		2.45	1200	1.79	85	720
3		2.45	1200	1.79	85	720
4		2.45	1200	1.79	85	720
5	Magnetitic pellet feed	2.32	1200	1.63	94	720
6		3.04	1500	2.14	94	720
7	Low grade hematite 1	3.15	1200	2.09	85	780
8	Low grade hematite 2	2.90	1200	2.00	85	780
9		3.78	1500	2.60	85	780
10	Siderite + hematite blend	3.70	1200	2.35	85	780

Table 6: Summary of Smelter use cases.

Use Case	Ore Type	Smelter				
		Recycling material/iron carrier (t/h)	Carbon (t/h)	Power (MW)	Hot metal (t/h)	Slag (t/h)
1	Magnetitic sinter feed	0	0.17	1.6	1.66	0.30
2		0	0.16	1.5	1.66	0.24
3		0	0.20[1]	1.6	1.66	0.29
4		0.45[2]	0.19	1.9	2.12	0.30
5	Magnetitic pellet feed	0	0.12	1.2	1.64	0.10
6		0	0.16	1.5	2.14	0.13
7	Low grade hematite 1	0	0.19	1.9	1.82	0.48
8	Low grade hematite 2	0	0.19	1.9	1.82	0.40
9		0	0.25	2.3	2.37	0.52
10	Siderite + hematite blend	0	0.19	2.0	1.84	0.71

[1] Biochar instead of fossil carbon
[2] Iron carriers are defined as scrap and HBI, recycling materials as EAF slag, BOF slag, pelletized BF dust and mill scale

3 Conclusion

The use cases were selected as a representation of relevant iron ore types of various particle sizes. During the next 24 month for the installation of the Hy4Smelt demonstration plant, some technological modifications and discussions with iron ore suppliers can lead to an adapted test program, which will be communicated. With this a wide range of operational parameters can be tested, ranging from grinding conditions, temperatures of ore and DRI, gases and melts all the way to product handling and product properties such as carburization of hot metal, FeO content of the slag and slag properties for use in the cement sector. Some of these are KPIs which are defined in the deliverable "D2.2 List of KPIs".

4 References

[1] H2FUTURE: a flagship project for the generation of green hydrogen, https://www.h2future-project.eu/en, funded by "Fuel Cells and Hydrogen 2 Joint Undertaking" under grant agreement No 735503, website accessed 16.06.2025

[2] Mitsubishi RTM, 2021

[3] United States Geological Survey, Mineral Commodity Summaries 2025 – Iron Ore, https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-iron-ore.pdf, accesses 18.06.2025