Steel Database Analysis

– How are plant types related?

Ingrid Torstensson

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Bachelor Thesis

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Sammandrag

I detta examensarbete undersöks databasen Plantfacts som innehåller data om stålverk från hela världen. Syftet med detta är att utvärdera om det finns en koppling mellan primärt och sekundärt producerat stål och olika typer av stålverk i downstream-processer. För att utföra detta har databasen formaterats om i Excel med hjälp av Visual Basic for Applications (VBA). Från början var Plantfacts databas sorterad efter "Plant type", men efter omstruktureringen är den istället sorterad på "Site". Databasen har även jämförts med OECD:s databas, som precis som Plantfacts innehåller värden för "Nominal Capacity". Detta för att validera hur riktig Plantfacts data är.

Resultatet visade att den Plantfacts data som var till störst nytta för studien var "Plant type", "Country", "Site" och "Nominal Capacity". Utifrån denna data visade det sig att Kina i särklass var den största producenten, samt att det finns skillnader i vilka stålverkstyper masugnar och ljusbågsugnar är kopplade till. Jämfört med OECD stämmer Plantfacts väl överens för många länder med en medianskillnad på 9,75 %. Ett av de länder som stämmer sämst överens är Kina, där skillnaden mellan databaserna är 45,4 %.

Den nya formen på databasen har givit en bättre överblick över produktionskedjan, då det är enkelt att sammanställa produktionen från samtliga platser. Plantfacts data stämmer väl överens med OECD i flertalet länder, men i bl.a. Kina, Indien och Brasilien skiljer det sig stort. Detta gör att man kan ifrågasätta hur sanningsenlig Plantfacts data är, men eftersom den stämmer bra för exempelvis Tyskland så rekommenderas att detta utvärderas land för land istället för globalt.

Slutsatsen är att det finns skillnader mellan primärt och sekundärt producerat stål och olika typer av stålverk, eftersom masugnar och ljusbågsugnar följs av olika downstream-processer. Det är därför intressant att kartlägga ytterligare hur detta hänger samman för att kunna skapa policyer som uppmuntrar till ökad återvinning och återanvändning av stål. Genom att undersöka vidare de processer där det är egalt om stålet är primärt eller sekundärt, har man på sikt möjlighet att ersätta CO2-krävande produktionssätt mot mer klimatvänliga sådana.

Title and subtitle

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Abstract

In this thesis the Plantfacts database is investigated, which contains data about steel plants from all over the world. The purpose is to evaluate wheter there is a coupling between primary and secondary steel and different types of steel plants in downstream processes. To achieve this, the database has been reformatted using Visual Basic for Applications (VBA) in Excel. Initially, the Plantfacts database was sorted by "Plant type" and after the reformatting it is sorted by "Site". The Plantfacts database is compared with the OECD database, that contains data regarding "Nominal capacity", just as Plantfacts. This is done to validate how the Plantfacts data seems to compare to reality.

The result showed that the columns "Plant type", "Country", "Site" and "Nominal Capacity" were the most useful ones. China is the significantly largest producer in the world and there are differences in which steel plant types blast furnaces and electric arc furnaces are related to. Compared with OECD, Plantfacts is consistent for most countries with the median 9,75 %. One of the countries that has the largest difference is China, where the number is 45,4 %.

The new form of the Plantfacts database results in a better overview over the production for each site. The Plantfacts data compare well with OECD in many countries, but differ in e.g. China, India and Brazil. This makes it questionable how correct the Plantfacts data are, but since it compares well for e.g. Germany, it is recommended to evaluate this by land instead of globally.

The conclusion is that there are differences between primary and secondary steel and steel plant types, because blast furnaces and electric arc furnaces are followed by different downstream processes. Therefore, it would be interesting to further expand this mapping to create policies that enhances recycling and reusing of steel. By investigating downstream processes where the steel used both could be primary or secondary, it would be possible to replace the CO_2-demanding blast furnace steel with more climate friendly steel without too much effort.

Preface

This bachelor thesis has been created during the winter 2019/2020 at the division of Environmental and Energy Systems Studies at the department of Technology and Society, LTH, Lund.

Ingrid Torstensson

March, 2020

Table of Content

1 Introduction

1.1 Background

The steel industry today produces a lot of CO2. In Sweden, the steel industry caused 10% of the country's CO2 emissions in 2018 (Naturvårdsverket, 2019). The steel industry is one of the most high-emitting industries in the world (Naturvårdsverket, 2019). Therefore, a reduction of steel production emissions is crucial to achieve net-zero emissions world-wide.

Blast furnaces (BF) causes the largest part of the emissions from the steel industry since its production requires coke and usually also coal (Fischedick, et al., 2014). An alternative to blast furnaces is electric arc furnaces (EAF) that is driven by electricity (Fischedick, et al., 2014). If the electricity is produced from renewable sources, electric arc furnaces have the potential to become CO2 free (The European Steel Association, 2013).

In blast furnaces, iron ore is needed to produce steel but in electric arc furnaces steel scrap is used instead (Fischedick, et al., 2014). Steel production using iron ore is called primary steel making and production using scrap is called secondary steel making. One limitation of expansion for EAFs is the availability of recycled steel (The European Steel Association, 2013). To increase the amount of recycled steel and thus increase the use of EAFs, policies are needed. The policies could by e.g. adding taxes to blast furnace produced steel, make it more profitable using EAF steel and enhance the development of EAF process. Creating a well-designed policy requires an understanding of what steel products that comes from blast furnaces and EAFs. Therefore, a mapping of steel products is a step on the way for the steel industry to become more sustainable.

To find data for this mapping, the Plantfacts database can be used. The database contains information about steel production sites, their plants and capacities etc. and this database will be examined in this thesis.

1.2 Purpose

The purpose with this thesis is to investigate the Plantfacts database and find whether there is a coupling between primary and secondary steel making and the plant types.

1.3 Research Questions

RQ1: What data from the Plantfacts database can be used?
RQ2: How well does Plantfacts data regarding capacities compare to data from OECD?
RQ3: How is the data structured within that database?
RQ4: What data can be extracted from the database?
RQ5: What plant types are connected to processes with blast furnaces?
RQ6: What plant types are connected to processes with electric arc furnaces?

1.4 Disposition of Report

Chapter 2 summarizes the most important steps in steel production for this report and presents the databases that will be used. Chapter 3 presents the method. In chapter 4 the results are presented in two parts: firstly the structure of the Plantfacts database and secondly a data analysis and validation of that database. Chapter 5 includes a discussion and the last chapter 6 summarizes the answers to the RQ:s and aim.

2 Theory

2.1 Steel Production Processes

Today it is not completely clear how the steel processes are tied together. In Figure 1 it can be seen how the steel is processed in several steps, and how the whole production flow unites in the Secondary Metallurgy. After this step, it is no longer clear from which steel production process the final steel product originates.
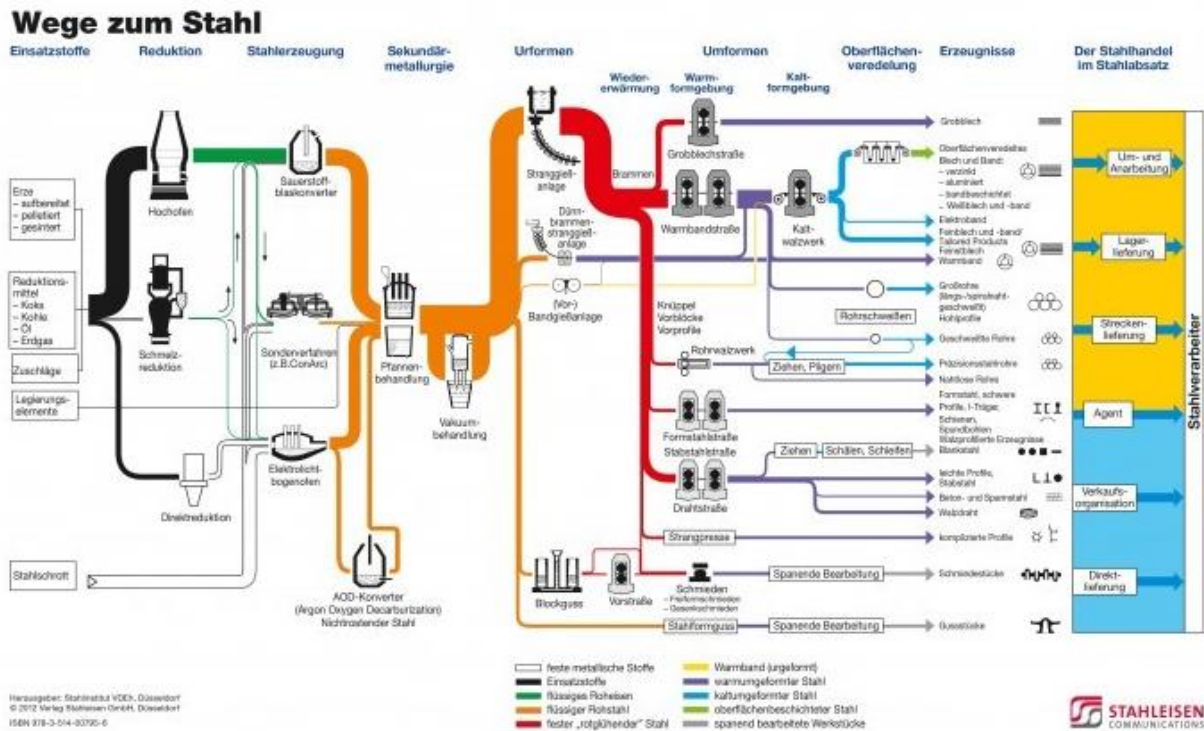
Figure 1. Showing the steel production processes from crude steel to the final product. The orange part shows the Secondary Metallurgy, that vizualises the problem of knowing what steel that is used in different down-stream processes. (Stahlinstitut VDEh, 2012)

The steel used in steel production comes from either iron ore or scrap. It goes through several processes, always including either a blast furnace or an electric arc furnace. The general understanding is that flat products are produced using BFs, while long products are produced by EAFs, but this has not been studied in detail. Flat products include e.g. sheets and plates. Long products mean e.g. bars, tubes and wire products. There are multiple plant types needed for steel production and that are mentioned in this report, but only BF and EAF will be explained in this section because they are the most crucial ones.

2.1.1 Blast Furnaces

Using blast furnaces is the traditional way to create steel from iron ore and since this process requires coke it is highly CO2-consuming (The European Steel Association, 2013). Blast furnaces are fed with iron ore in the form of either sinter, lump ore or pellets (The European Steel Association, 2013). While heating, the iron ore is reduced into liquid iron by adding coke and coal. Then the iron is processed into steel in a basic oxygen furnace (The European Steel Association, 2013), which is called "BOF SHOP" in the Plantfacts database.

2.1.2   Electric Arc Furnaces

Electric arc furnaces are mainly fed by scrap and is driven on electric energy (The European Steel Association, 2013). This means, if the electricity is fossil-free, this process is significantly less CO2-consuming than the BF process (The European Steel Association, 2013). The disadvantages with electric arc furnaces is that they are dependent on the availability of scrap and that the scrap might cause impurities in the produced steel (The European Steel Association, 2013).

There are two types of Electric arc furnaces: AC and DC. An AC is constructed with three electrodes and DC with only one (von Starck, et al., 2005). AC is the traditional one, but since the DC has perks such as a better control of net disturbances (von Starck, et al., 2005). Both are used in modern steelmaking.

2.1.3   Definitions

Primary steel is produced from iron ore and secondary steel is produced from scrap.

Upstream processes will in this report be defined as processes before an EAF or BF, and downstream processes will be defined as the processes after.

Nominal Capacity means the maximal possible capacity for a steel plant (OECD Steel Committee, 2019). This means that the real production from a steel plant probably is lower than this number (OECD Steel Committee, 2019). In the Plantfacts database, nominal capacity is given in the unit 1000 tonnes/year (t/y).

2.2   Data sets

2.2.1   The Plantfacts Database

The Düsseldorf-based Stahlinstitut VDEh gather information about steel and iron production facilities into the Plantfacts database (Steel Institute VDEh, 2014). The database is not public which means a license is needed to access it. The database covers 36 different plant types, from the initial processes, e.g. blast furnace, to the finishing processes, e.g. reversing cold rolling mill. On each sheet in the Plantfacts database, there are all plants of one plant type. Depending on the plant type, the data columns differ since not all data is relevant for all plant types. For analysing which steel production originates from which steel making process, it is necessary to reorganise the database so that all plant types that belong to one site are located on one sheet.

2.2.2   The OECD database

OECD (Organisation for Economic Co-operation and Development) collect data from their member states regarding the Nominal capacity of the steel production (OECD, 2019). The database has public access.

Table 1. The two first columns shows from what plants the OECD data are collected from (OECD Steel Committee, 2019). The third column shows the corresponding plant type in the Plantfacts database.

OECD Type	Code	Plantfacts type
Electric Arc furnace	EAF	Plant type 24 Plant type 26

Energy Optimising furnace	EOF		-
Induction furnace	IF		Plant type 36
LD Basic Oxygen furnace	BOF		Plant type 20
Open Hearth furnace	OHF		Plant type 22
Steelmaking - not specified	STEELMKG		-

The plant types that are included in the nominal capacity definition is shown in Table 1 (OECD Steel Committee, 2019) together with the Plantfacts plant type counterpart.The OECD database covers 126 countries and is available for the years 2000-2018 (OECD, 2019). In this report the latest values will be used, which are from 2018. The data is collected from OECD's website (OECD, 2019).

3 Method

3.1 The reformatting process of the database

The goal of reformatting the Plantfacts database is to sort it on site, instead of plant type. The reformatting of the database proceeded in a few steps.

1. The columns for each plant type was filtered according to Marlene Arens and Valentin Vogls suggestions. Their suggestions were based on what columns they thought was needed the analysis, e.g. country, nominal capacity. The irrelevant columns were sorted out. The relevant columns are presented in section 4.1.2. This filtering improves readability in the database and ensures that all plant types have the same columns.
2. The database was rearranged from sorting by plant type to site. This is the key process. By reformatting the database by site, it becomes clear what plant types that typically are located together.
3. Improve the readability by renaming the sheets to logical site codes and reformatting the look of the database in Excel.

The motivation for this report is to analyse what downstream processes that exist on sites where there are either a BF or an EAF. By the reformatting of the database sorted by site, this information is easy to extract. From this, it is possible to draw conclusions whether certain steel plants are primarily used together with a BF or EAF.

3.2 Plant types related to EAF and BF

To investigate how the plant types are connected to each other, the reformatted database is used. Since it is sorted by site, the data about what plant types frequently occurring together is accessible. The data of interest is sites with EAF, BF or both. For example, when desiring to know what plant types that occur together with an EAF, all sites that does not have an EAF and sites that has an BF are excluded. Vice versa for BF and both EAF and BF. This leads to that sites that has neither a BF nor an EAF will be excluded from this investigation.

The notation in diagrams and tables for different plant types are directly imported from the database, which means they are written in upper case and includes some abbreviations. This makes it easier for the reader to find the data used in the report if also navigating in the database.

Only plants with the status "Operating" are included.

3.3 Comparison with OECD

The OECD data is used to compare the Plantfacts Nominal capacity data and validate its consistency. The Plantfacts countries' nominal capacity is calculated by first sorting out the following plant types: Electric arc furnace, Induction furnace, Basic oxygen furnace and Open hearth furnace. The corresponding plant types in the Plantfacts database can be found in column 3 in Table 1 on page 5. Then only the nominal capacity for all operating plants are sorted on country and summarized. The difference between the OECD and Plantfacts data is calculated as "The Plantfacts value" divided with "OECD value".

Since the nominal capacity of only a smaller amount of plant types will be compared, there might be countries that does not have these plant types. This means that the countries represented from the Plantfacts database might be fewer than from the whole database.

3.4   Software used

The program used for the database analysis is Excel, but Microsoft Access and Plantfacts User Tool were two other candidates. Plantfacts User Tool is an app especially made for the Plantfacts Database where the user asks queries such as a certain site, and the programme generates a table. This gives a good overview of the database, but it is too limited in its table formatting. Access was a good option, but since the database already was in .xlsx-format it made sense to keep it there.

Excel Makro's written in Visual Basic for Applications (VBA) have been used to reformat the database. A Makro can be run as many times as desired and that make it is easy to apply changes on the database without needing to redo work. The Makro's used can be found in Appendix B.

4 Result

4.1 Conversion of the Plantfacts Database

4.1.1 Organization of database

The database is organized by Plant Type, where each Plant Type is one sheet. On each row there is a specific plant and is sorted firstly on the site code and secondly on the unique plant number (DB-Plant-No.).

The data columns differ for each Plant Type. DB-Plant-No., Type of Plant, Company, Site, Country, Manufacturer etc. are found on every plant. Most of the common columns, e.g. Country, are represented in two columns as both "Text" and "Code".

Table 2 shows all plant types in the database and their corresponding plant type number, and also the number of the certain plant in the existing database.

Table 2. Showing all plant types and the amount of them in the Plantfacts database.

Plant type	Plant type	Amount
2	DIRECT OR SMELTING REDUCTION PLANT	197
4	PELLETIZING PLANT	146
6	SINTERING PLANT	428
9	COKING PLANT	858
14	BLAST FURNACE	355
20	BOF SHOP	9
22	OPEN HEARTH MELTSHOP	361
26	AC-ELECTRIC ARC FURNACE	1017
28	DC-ELECTRIC ARC FURNACE	100
30	VACUUM DEGASSING PLANT	583
32	LADLE FURNACE	1060
34	SPECIAL CONVERTER PROCESSES	102
36	INDUCTION MELT FURNACE	65
38	STEEL REMELTING FURNACE	802
42	CONTINUOUS SLAB CASTER	629
44	CONTINUOUS BLOOM CASTER	332
46	CONTINUOUS BILLET CASTER	248
50	BLOOMING AND SLABBING MILL	107
51	BILLET-/HEAVY BAR MILL	297
52	HEAVY SECTION MILL	199
54	MEDIUM SECTION MILL	585
56	LIGHT SECTION AND BAR MILL	310
57	WIRE ROD MILL IN BAR MILL	271
58	WIRE ROD MILL	293
62	HOT STRIP MILL	261
64	TEMPER- / SKIN PASS MILL (HR)	599
66	PLATE MILL	617
72	PICKLING LINE	182
74	REVERSING COLD ROLLING MILL	63

75	TANDEM MILL	303
76	BATCH ANNEALING PLANT	246
77	CONTINUOUS ANNEALING LINE	197
78	TEMPER- / SKIN PASS MILL (CR)	858
82	HOT DIP METAL COATING LINE	113
84	ELECTROLYTIC METAL COATING LINE	83
86	ORGANIC COATING LINE	90

The number of different plant types in Table 2, is visualized in Figure 2. This diagram gives a better overview of all existing plants in the world.
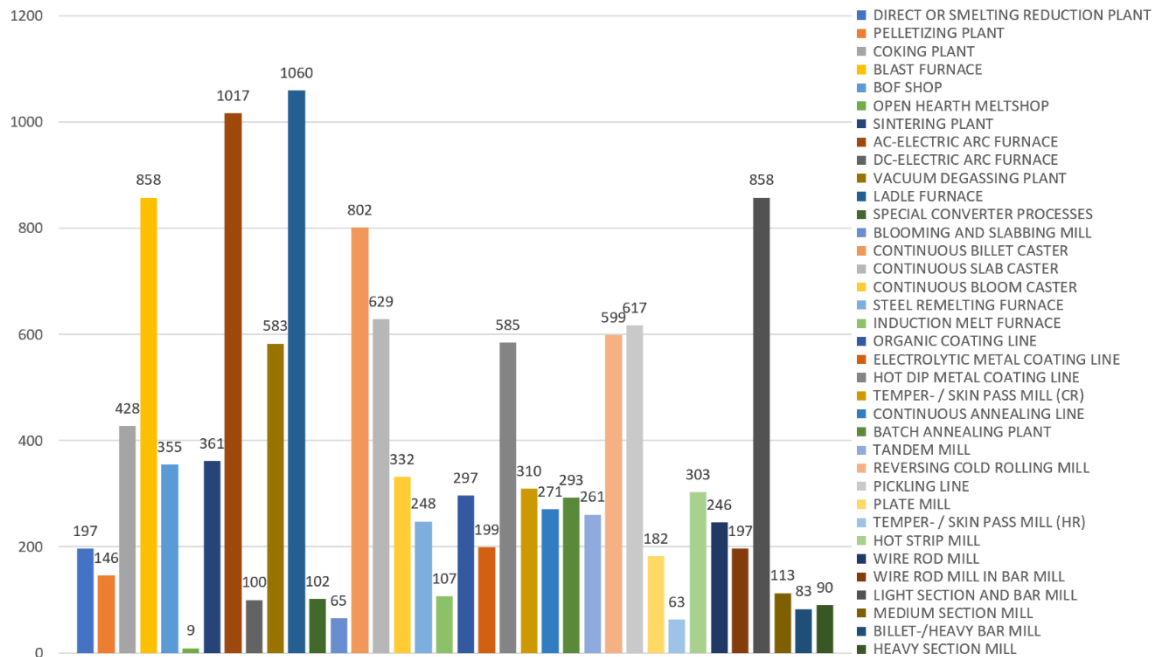
Figure 2. A diagram showing the total number of known plants in the Plantfacts database, distributed into Plant Type.

The plants are distributed in 104 countries all over the world, where India, China, USA and Brazil are some of the largest producers.

4.1.2 Data columns

Here follows a list of the data columns of interest in the Plantfacts database.

- DB-PLANT-No.
- TYPE OF PLANT
- COUNTRY
- COMPANY
- LOCATION/WORKS
- PLANT No.
- STATUS OF THE PLANT
- MANUFACTURER A)
- MANUFACTURER B)
- YEAR OF START UP
- YEAR OF MODERNIZING
- SUPPORTING STEEL PLANT

- INPUT
- PROCESS
- OUTPUT
- NOMINAL CAPACITY

All columns until Manufacturer B) are available for all plant types. The last six are not guaranteed to exist, but Year of start up, Year of modernizing and Nominal capacity usually do.

4.1.3 Result of reorganization

Since not all columns exist for all plant types, the columns in section 4.1.2 was added empty if they were missing. It is necessary when reorganizing the database that the columns are generic to retain the readability and when reorganizing plant types into a new table.

The headings Input, Process and Output did not exist in the original Plantfacts database and thus they have been added. Even if the headings did not exist the information did, but in another column. E.g. "Produced Ingots" in the Steel re-melting furnace (plant type 38) contained data that could be sorted as "Output". In other words, the Input, Process and Output data exist in the database, but for each plant they are named differently. Table 3 shows the columns that have been renamed to Input, Process and Output. How this affect each plant type in detail, see Appendix A.

Table 3. The alternate column names for input, process and output are shown under each heading.

Input	Process	Output
CHARGE: TYPE OF ORE A)	PROCESS	PRODUCT: TYPE
CHARGE: TYPE OF ORE B)	ROASTING EQUIPMENT: TYPE	HOT METAL GRADES
REDUCTION MEDIUM: DERIVATION A)	1.GROUP: TYPE OF FURNACE	SLAG GRANULATION
CHARGED MATERIALS	SUPPORTING STEEL PLANT	CONT. CASTING: TYPE OF SECTIONS
ADDITIONS	TYPE	INGOT CASTING
FUEL FOR ROASTING EQUIPMENT	SUPPORTING MELTING FACILITY	STEEL GRADES A)
COKE GRADES	MACHINE TYPE	STEEL GRADES B)
INJECTION OF REDUCING AGENTS		STEEL GRADES C)
INGOT CASTING		PRODUCED INGOTS
FUELS FOR HEATING		STELL GRADES C)
TYPE OF CHARGE		
ADDITIONAL BURNERS		
OXYGEN BLOWING		
ADDITIONAL FUEL		
CONT. CASTING: TYPE OF SECTIONS		

4.1.4 Example

Here follows an example how a site could look in the database.

DB-PLANT-No.	TYPE OF PLANT	COUNTRY	COMPANY	LOCATION/WORKS	PLANT No.	STATUS OF THE PLANT	MANUFACTURER A)	MANUFACTURER B)	YEAR OF START UP	YEAR OF MODERNIZING	NOMINAL CAPACITY	SUPPORTING STEEL PLANT	PROCESS	INPUT	OUTPUT
101	26 AC-ELECTRIC ARC FURNACE	0 NORDICS	0 Company	0 Site	5	4 OPERATING	0 Manufacturer	0 Manufacturer	1973		200			SCRAP NO	BLOOMS
102	32 LADLE FURNACE	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer			200	5 EAF	SINGLE-LADLE FURNACE LF/LRF		LOW ALLOY STEEL
103	34 SPECIAL CONVERTER PROCESSES	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer	1975	2018	100		1 AOD EAF	BLOOMS INGOT BLOOMS	
104	36 INDUCTION MELT FURNACE	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer							NICKEL-BASE ALLOYS
105	36 INDUCTION MELT FURNACE	0 NORDICS	0 Company	0 Site	21	4 OPERATING	0 Manufacturer	0 Manufacturer							NICKEL-BASE ALLOYS
106	44 CONTINUOUS BLOOM CASTER	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer	1981	1989	150	11 EAF, AOD	VERT/LIQ-BEND	BLOOMS	CARBON STEEL
107	50 BLOOMING AND SLABBING MILL	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer	1954	1996					
108	51 BILLET-/HEAVY BAR MILL	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer	1900	1990	90				
109	56 LIGHT SECTION AND BAR MILL	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer	1973		25				
110	62 HOT STRIP MILL	0 NORDICS	0 Company	0 Site	2	4 OPERATING	0 Manufacturer	0 Manufacturer	2006						
111	72 PICKLING LINE	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer					18 HOT+COLD A&PL		
112	74 REVERSING COLD ROLLING MILL	0 NORDICS	0 Company	0 Site	1	4 OPERATING	0 Manufacturer	0 Manufacturer	1995						
113	74 REVERSING COLD ROLLING MILL	0 NORDICS	0 Company	0 Site	2	4 OPERATING	0 Manufacturer	0 Manufacturer	1997						

Figure 3. The steel plants and production on a site in a Nordic country visualised in the new site-specific database.

4.2 Site-specific Database Analysis

4.2.1 Plant types related to EAF and BF

This section 4.2.1 only handles the Plantfacts database. In all diagrams, the plants are sorted as the order of the plants in the database, see Table 2 on page 9. This corresponds well to the order from upstream to downstream processes.

Since the EAF:s are divided into AC and DC in the Plantfacts database, the normalization is done on the sum of those two. This means that their values together will sum up to the normalized capacity 100 in the figures below. The same for both EAF and BF together, when the normalization is done on AC, DC and BF, see Table 4, page 13. In the table, the nominal capacity in tonnes/year with China excluded is not visualised.

In Table 4 the plant types and their nominal capacity on a site with either an EAF, BF or both from the Plantfacts database are shown. The nominal capacity are also normalized according to the EAF, BF or both in the table, and the same numbers are visualized in Figure 4, Figure 5 and Figure 6. The figures show the world total, with China included.

Table 4. The column "Capacity" shows the nominal capacity in 1000 t/y for different plant types on sites that has either an EAF, BF or both. The column "Normalized" shows the same data, but normalized so that the EAF, BF or both are 100 t/y and the other plants are normalized accordingly. The column "Normalized excl. China" shows the same as "Normalized", but with China excluded.

| Plant type	Capacity (tonnes/year) of all sites in the world categorized on if there are only a BF, only an EAF or both EAF and BF			Normalized (%). E.g. EAF is normalized so that capacities of AC-EAF + DC-EAF = 100			Normalized excluding China (%)		
	BF	EAF	Both	BF	EAF	Both	BF	EAF	Both
DIRECT OR SMELTING RED	5821	65109	17855	0,7	14	7,3	1,2	14,9	12,1
PELLETIZING PLANT	59930	30900	17680	7,2	6,7	7,2	6,5	7,1	7,6
SINTERING PLANT	815539	0	193497	97,4	0	79,1	108	0	72
COKING PLANT	266757	1380	74724	31,9	0,3	30,5	37,2	0,3	30,8
BLAST FURNACE	837028	0	178183	100	0	72,8	100	0	67,8
BOF SHOP	830023	6020	145540	99,2	1,3	59,5	93,9	0,2	46,3
OPEN HEARTH MELTSHOP	7000	110	1100	0,8	0	0,4	1,5	0	0,9
AC-ELECTRIC ARC FURNACE	0	389650	60948	0	84	24,9	0	83,2	31,6
DC-ELECTRIC ARC FURNACE	0	74260	5530	0	16	2,3	0	16,8	0,6
VACUUM DEGASSING PLA	301040	113073	74442	36	24,4	30,4	44,4	22,5	27,2
LADLE FURNACE	275850	374123	125870	33	80,6	51,4	38,9	80	64,9
SPECIAL CONVERTER PROC	350	26742	5180	0	5,8	2,1	0	4,2	3
INDUCTION MELT FURNAC	0	504,2	0	0	0,1	0	0	0,1	0
STEEL REMELTING FURNAC	6	210,9	2	0	0	0	0	0	0
CONTINUOUS SLAB CASTE	609519	131300	131520	72,8	28,3	53,8	80,6	26,2	58,7
CONTINUOUS BLOOM CAS	83565	105204	30880	10	22,7	12,6	10,7	22,4	11
CONTINUOUS BILLET CAST	136245	231345	58160	16,3	49,9	23,8	8,4	51,4	14,3
BLOOMING AND SLABBIN	39190	9040	8200	4,7	1,9	3,4	8,5	2	3,4
BILLET-/HEAVY BAR MILL	20720	21035	4200	2,5	4,5	1,7	4,3	4,4	1,9
HEAVY SECTION MILL	25605	24730	4860	3,1	5,3	2	2,8	5,7	3,3
MEDIUM SECTION MILL	14670	18352	4280	1,8	4	1,7	1,8	4,2	1,9
LIGHT SECTION AND BAR	70980	160973	31970	8,5	34,7	13,1	5,1	36	9,3
WIRE ROD MILL IN BAR MI	600	2400	0	0,1	0,5	0	0	0,6	0
WIRE ROD MILL	61410	26370	17340	7,3	5,7	7,1	3,1	5,8	4,8
HOT STRIP MILL	427315	107275	100540	51,1	23,1	41,1	54,3	21	46,7
TEMPER- / SKIN PASS (HR)	15513	7200	1900	1,9	1,6	0,8	2,7	1,5	0,9
PLATE MILL	86618	17452	27510	10,3	3,8	11,2	8,7	3	10,6
PICKLING LINE	179230	50666	46005	21,4	10,9	18,8	26,2	9,3	22,1
REVERSING COLD ROLLING	9973	16722	5984	1,2	3,6	2,4	1,2	3,2	2
TANDEM MILL	145520	13885	31310	17,4	3	12,8	20,6	2,4	14,8
BATCH ANNEALING PLANT	28053	5473	7160	3,4	1,2	2,9	4,7	1,2	2,5
CONTINUOUS ANNEALING	42851	2408	7619	5,1	0,5	3,1	5,9	0,3	3,2
TEMPER- / SKIN PASS (CR)	44744	9490	8100	5,3	2	3,3	8,6	2,2	3,3
HOT DIP METAL COATING	46926	8302	11619	5,6	1,8	4,7	6,9	1,8	5,7
ELECTROLYTIC METAL COA	12492	330	3717	1,5	0,1	1,5	2,3	0,1	1,8
ORGANIC COATING LINE	4468	1322	2322	0,5	0,3	0,9	0,6	0,3	1
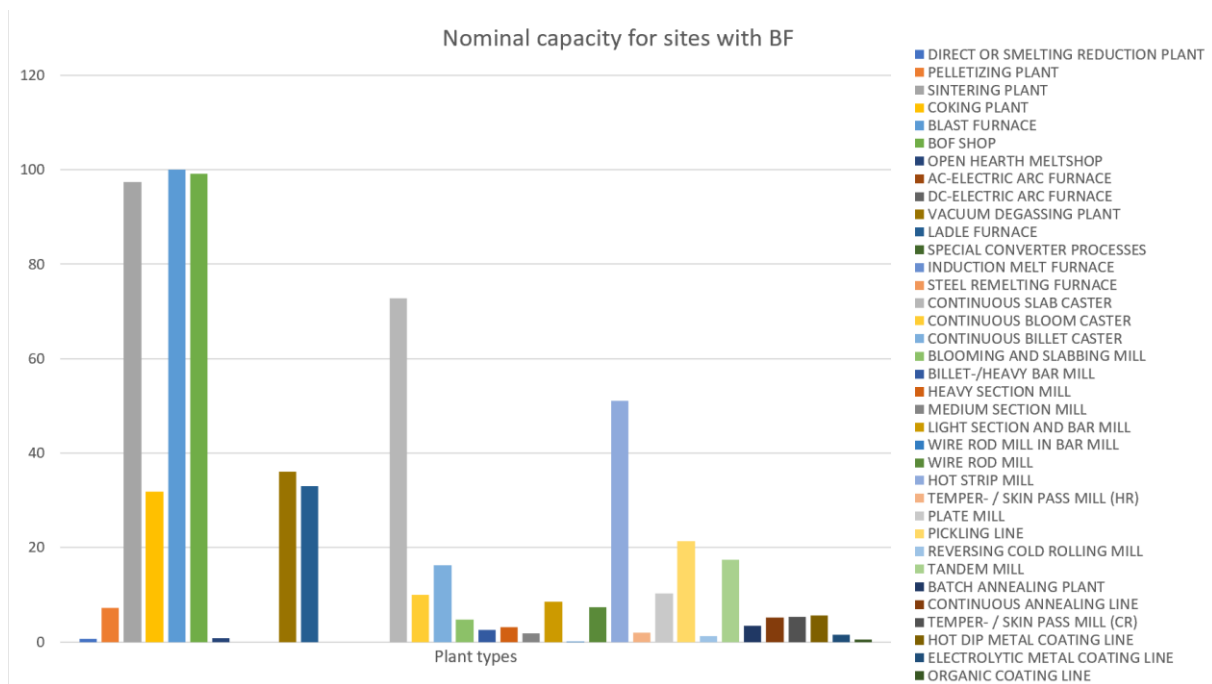
Figure 4. Diagram showing the nominal capacity for different plant types on sites where there are only BFs.
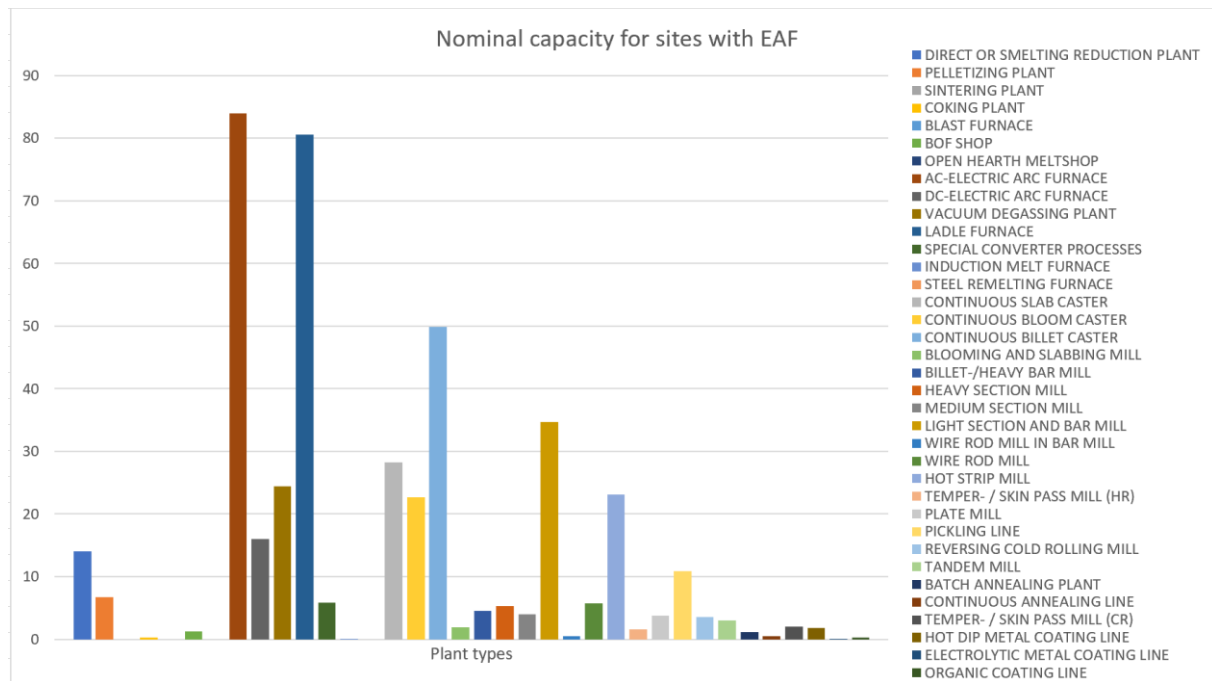

Figure 5. Diagram showing plant types on sites with an EAF. The AC-ELECTRIC ARC FURNACE and DC-ELECTRIC ARC FURNACE sums together up to 100.
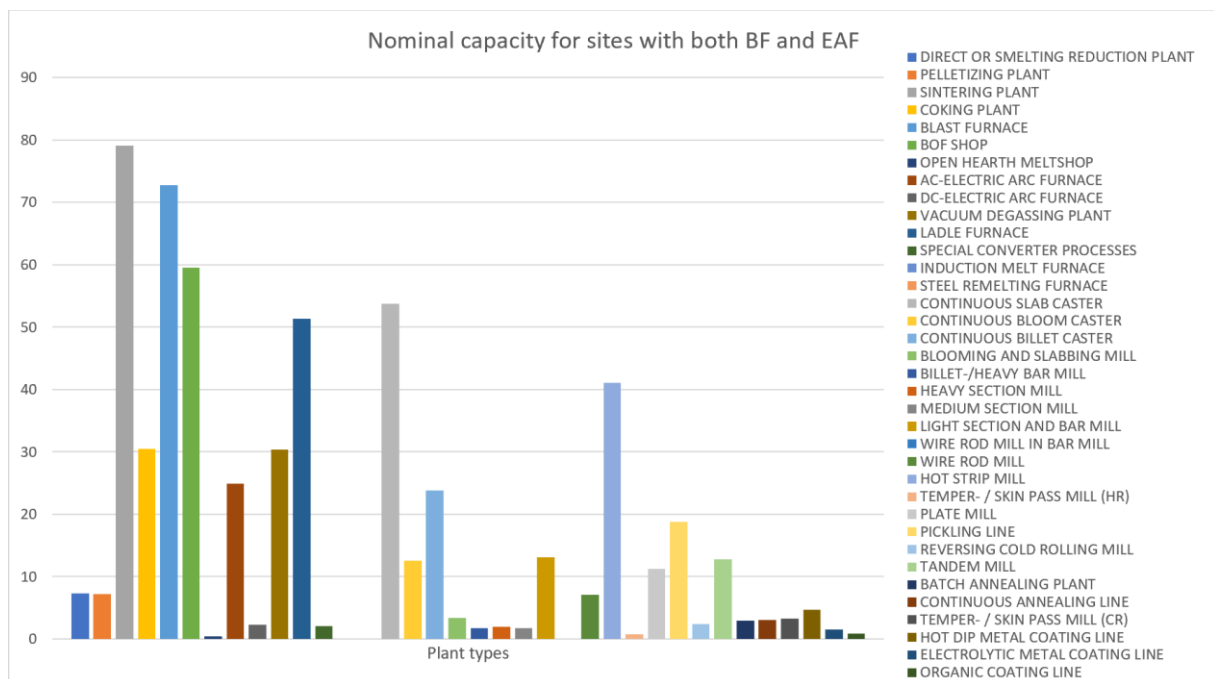
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Figure 6. Diagram showing plant types on sites where there are both at least one EAF and one BF. AC-ELECTRIC ARC FURNACE, DC-ELECTRIC ARC FURNACE and BLAST FURNACE sums together up to 100.

4.2.2 Comparison between Plantfacts database and OECD

In the OECD dataset 126 countries is included and in Plantfacts 89 countries. The lowest nominal capacity in the Plantfacts database was 0.25 (1 000 000 tonnes/year) and in OECD the lowest was 0.0 for 20 countries. The actual steel production as a percentage of the nominal capacity is globally 81,0 % in 2018 (OECD Steel Committee, 2019).

"World" in Table 6 was given in the OECD database. For Plantfacts it has been calculated by summing the nominal capacity of all countries for the plant types BF, AC-EAF and DC-EAF. In the Plantfacts database, 8,3% of the plants has no information about the Nominal capacity. This applies mostly to the five biggest producers in the Plantfacts database, see Table 5.

Here follows a comparison of the largest steel producers according to OECD and the Plantfacts database, see Table 5.

Table 5. Showing the 20 countries that are the largest steel producers. The numbers show nominal capacity in 1 000 000 t/y.

	Largest steel producers according to OECD and Plantfacts			
Rank	OECD		Plantfacts	
1	China	1 023,4	China	558,8
2	Japan	128,1	Japan	123,1
3	India	128,1	United States	106,3
4	United States	112,6	India	85
5	South Korea	87,9	Russia	75,8
6	Russia	84,5	South Korea	71,1
7	Germany	51,9	Germany	49,9
8	Brazil	50,7	Brazil	44,8
9	Turkey	48,9	Turkey	40,4
10	Ukraine	42,5	Ukraine	35,5

11	Italy	34,3	Italy	29,1
12	Iran	33,6	Taiwan	27,4
13	Taiwan	29,4	Iran	27,3
14	Mexico	26,2	Mexico	26,5
15	Spain	21,7	Spain	20,4
16	Vietnam	20,5	France	18,8
17	France	19,1	Canada	16
18	Canada	15,6	Egypt	12,6
19	Egypt	15,3	Poland	12
20	Malaysia	14,2	Indonesia	11,9

Since the 20 largest producers differs for Plantfacts and OECD, the ones from Plantfacts have been selected and the percentual difference between the two can be seen in Table 6.

Table 6. Showing the difference in percent between the 20 largest steel producers and the world production for OECD and Plantfacts.

Difference between the 20 biggest Plantfacts countries			
Countries	OECD	Plantfacts	%
China	1 023,4	558,8	45,4
Japan	128,1	123,1	3,9
United States	112,6	106,3	5,6
India	128,1	85	33,6
Russia	84,5	75,8	10,3
South Korea	87,9	71,1	19,1
Germany	51,9	49,9	3,9
Brazil	50,7	44,8	11,6
Turkey	48,9	40,4	17,4
Ukraine	42,5	35,5	16,5
Italy	34,3	29,1	15,2
Taiwan	29,4	27,4	6,8
Iran	33,6	27,3	18,8
Mexico	26,2	26,5	-1,1
Spain	21,7	20,4	6
France	19,1	18,8	1,6
Canada	15,6	16	-2,6
Egypt	15,3	12,6	17,6
Poland	12,1	12	0,8
Indonesia	10,9	11,9	-9,2
World	2 233,7	1568,3	29,8
World except China	1210,3	1009,5	16,6

The median difference of the countries is 9,75 % and the average difference is 12,35 % in Table 6. When China is excluded, the same numbers are 9,2 % and 10,6 %.

5 Discussion

5.1 Use of the restructured database

The new structure of the Plantfacts database makes it is easier to find how the upstream and downstream processes are connected, by looking at what plant types generally occur together. When all plant types have the same columns, it is easier to process the data into diagrams and draw conclusions.

Another perk is that it is easier to get an overview over different sites. From the Plantfacts User tool it is easy to generate an Excel sheet of the plants in one site, but in this new structure the sites do not need to be chosen and generated, since the data already has the right format. Additionally, all plant types have the same columns, which results in a more compact sheet.

The input, process and output columns could improve the readability. Firstly, to make it easier to find what processes are connected to each other on a certain site. Secondly, by looking at a chosen plant type and being able to compare e.g. the process to another plant type. This could be hard if the process data is named differently for two plant types, which is the case for the original database. A risk of using input, process and output instead of the specific headings that are used in the original database is that it could lead to misunderstanding. Input, process and output might mean completely different things depending on plant type. Therefore, knowledge in the plant types is required to draw conclusions from the input, process and output columns. To improve the input, output and process data I would suggest that

1. information should be collected from the steel sites and added to these columns in the Plantfacts database.
2. the data would be on a form that is as standardized as possible.

When the selection is done by hand the data in the input, process and output columns might be hard to understand what it means, and some important columns that should have been named as e.g. Process might have been missed.

5.2 Site-specific Database Analysis

5.2.1 Plant types related to EAF and BF

In Table 4, the normalized columns are of biggest interest to draw conclusions about how different plant types are connected to EAF, BF or both. Whether China should be included or not is questionable, but in general the normalized result without China has bigger contrasts and there probably is an amount of hidden China statistics. Therefore, the normalization excluding China will be used for this analysis.

From Table 4 conclusions can be drawn about what plant types that appear at sites with either a BF or EAF. In upstream processes, the blast furnaces are generally connected with a Sintering plant, Coking plant, BOF shop and/or an Open hearth meltshop. Electric arc furnaces are more likely to appear with a Direct or smelting reduction plant and both EAFs and BFs are often connected to Pelletizing plants. In downstream processes, the blast furnace is followed by Vacuum Degassing plant, Continuous slab caster, Continuous billet caster, Blooming and slabbing mill, Hot strip mill, Plate mill, Pickling line, Tandem mill, Batch annealing plant, Continuous annealing, Temper /skin pass (CR) and Electrolytic metal coat. Electric arc furnaces are generally connected with a Ladle Furnace, Special converter processes, Continuous bloom caster, Heavy section mill, Medium section mill, Light section mill and bar mill and/or Reversing cold rolling mill. The rest of the downstream processes

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seam to appear for both EAFs and BFs. To be noted is that almost all down stream plant types occur with both EAF's and BF's, but the plants types that are mentioned above occur more often with either EAF's or BF's.

5.2.2 The Plantfacts database and OECD

The lack of Nominal capacity data in the Plantfacts database might explain the lower result compared to OECD. Since this occurred to 8,3 % of the plants, it is probable that it has contributed to this trend, seen in Table 5 and Table 6. To consider, is that the lack of information might mean that the Nominal capacity for the plant is negligible or zero. In my opinion, it seems unlikely because it occurs to 8,3 % of the plants which all should be operating efficiently, or they would not be profitable enough to exist at all.

Another possible reason why the Nominal capacity differs between Plantfacts and OECD, is that OECD include more plant types than Plantfacts. It is not clear if the plant types Steelmaking - not specified (STEELMKG) and Energy Optimising Furnace (OHF) exist in the Plantfacts database, see Table 1 on page 5. Since no match could be found, both STEELMKG and EOF has not contributed to the Plantfacts data. They still exist in the OECD data, where they could not be separated, because OECD only specify the Nominal capacity for all plants in Table 1.

The country with the largest difference between OECD and Plantfacts is China (45,4 %). This is because it is hard to find information about the plants of the world's biggest steel producer. It also confirms that Plantfacts database dataset covering China is incomplete.

When excluding China from the comparison of Plantfacts and OECD, the difference in the world total decreases from 29,8 % to 16,6 %. This indicates that when comparing world total with the Plantfacts database, China should be excluded. Excluding India in the comparison would also be an option, since the difference between the Plantfacts and OECD capacities is 33,6 %. This is not as urgent as for China since the steel production capacity in India is significantly smaller than in China. Other countries that have a larger difference between the databases are Russia, South Korea, Brazil, Italy, Iran, Ukraine, Egypt and Indonesia. This could be related to politics and war, for example the Krim crisis in Ukraine and war in Iran, since conflicts difficult the data collecting and probably disrupt the production in industries.

On the contrary, Germany has an almost identic result from both Plantfacts and from OECD. This implies that Plantfacts probably cover close to all production in Germany and has accessed the same data sources as OECD. Furthermore, the Plantfacts database is produced by a German organisation and I assume that the steel production in Germany is relatively transparent, which could ease the data collecting process. This indicates that the selection of 5 plant types that is made in this study is relevant and correspond to the plant types used in the OECD dataset.

The assumption that the OECD data is corresponds well to reality might not be correct and could lead to deceptive results. In the report, OECD is used as a key to Plantfacts to define Plantfacts validity. From the data used in this report, which of them that is closest to reality, and the answer might vary from country to country.

What should be noticed about Nominal capacity, is that it represents the maximal possible capacity, and not the actual amount of steel that is produced. In the OECD database, the steel production as a percentage is 81,3 %. However, it is likely that the same issue exists in the Plantfacts database. This might be one explanation why the downstream processes added together seem to have a significant lower nominal capacity than the EAF and BF in Table 4. If the BF or EAF does not run at its maximum, it is not needed for the downstream processes to

have the capacity to process as much steel as the BF or EAF max. E.g. if a BF runs on 80% of its nominal capacity, the downstream processes' nominal capacity just need to sum up to 80 % of the BF maximum. Another factor is losses in all process steps. The steel that does not attain the desired quality after one of the processes, might go back to the BF or EAF again. This results in that all steel that is produced in the BF or EAF, does not proceed to the last downstream plant.

5.3 Validity and Reliability

Because of the size of the Plantfacts database, it might be a better choice to use Microsoft Access (or another database program) than Excel to reformat the data. When handling large data sets it is usually a good choice to store them as a database to improve efficiency and keep the data consistent. The risk of losing data increases when Excel crashes because the operations are too heavy.

There is a risk that important data have been excluded when reformatting the Plantfacts database. Firstly, the columns of interest in 4.1.2 were filtered out from the complete Plantfacts data set and there might be other columns that also should have been included. Secondly, when sorting the columns on input, process and output according to Table 3, there could be additional columns of interest. Thirdly, when rearranging the data, a wrongly formatted heading could cause that a whole column was erased even though it should have been kept. A heading with wrong format could for example be an extra blank space after the desired heading.

All sites that did not include BF, EAF or both was sorted out. This might have led to that too many plants have been excluded in the Plantfacts database analysis. The site codes changed slightly depending on the plant manufacturer. Therefore, different manufacturers on the same or an adjacent site have different site code, which result in that some relevant downstream processes might have been excluded. For example, on a specific site there is an EAF and a number of downstream processes. On almost the same site is a downstream plant that probably uses the steel from the EAF site, but with another manufacturer. This downstream plant will be excluded from the sorting as it is done now. This problem mainly applies to the diagrams in 4.2.1.

Not all steel production sites and plants are covered in the Plantfacts database, which means this report does not cover all processes and flows that might exist on a steel production site. Additionally, the size of the missing steelmaking capacity in, especially, China is not known, even though the comparison of OECD and Plantfacts indicates that there probably are a considerable share of hidden statistics.

As mentioned earlier, using OECD as a key might be wrong, since there is no guarantee that OECD fully cover the world's steel production.

6 Conclusion

6.1 Answers to aim and research questions

Data regarding country, site, plant type, year of start up, supporting steel plant and nominal capacity can be used to draw conclusions about steelmaking processes.

The Plantfacts and OECD data corresponds with a difference of 16,6 % on the world production when excluding China. The accuracy in % differs for each country, but generally the Plantfacts data is lower than the OECD data. For China the difference is significant, which indicates that the Plantfacts database lack of data from steel production sites in China.

The data in the Plantfacts database are structured according to 36 plant types. All plant types have at least 17 columns that exist for all plants, and the rest are modified to each plant type.

Data including what plant types that are on one site or several sites can be extracted from the database. To this, conditions could be added, e.g. country, nominal capacity or that a particular plant type should be there. Data about how plant types are connected to each other can also be extracted.

Blast furnaces are connected to the following upstream processes: Sintering plant, Coking plant, BOF shop, Pelletizing plant and/or an Open hearth meltshop.

Furthermore, they are connected to the downstream processes: Vacuum degassing plant, Continuous slab caster, Continuous billet caster, Blooming and slabbing mill, Hot strip mill, Plate mill, Pickling line, Tandem mill, Batch annealing plant, Continuous annealing line, Temper /skin pass mill (CR) and Electrolytic metal coating line.

Electric arc furnaces are connected to the following upstream processes: Direct or smelting reduction plant and/or a Pelletizing plant.

Furthermore, they are connected to the downstream processes: Ladle furnace, Special converter processes, Continuous bloom caster, Heavy section mill, Medium section mill, Light section mill and bar mill and/or Reversing cold rolling mill.

Whether long products generally are produced by an EAF and flat products by a BF, is hard to determine. Almost all downstream plants occur together with both EAF's and BF's. Therefore, further studies on this is needed to draw a general conclusion.

6.2 Steelmaking CO2 challenge

As discussed in 1.1 Background, a great challenge for the steel industry is to reduce its large CO2 emissions. The blast furnace causes a significant part of it, so if the blast furnaces are replaced with electric arc furnaces where it is possible, it would make a large total impact. Especially downstream processes that use steel from either a BF or an EAF, the goal should be to increase the use of EAF steel, since it already is possible to use it. Another possibility is to improve the quality of secondary steel, which in most cases is the reason why BF steel is chosen. A critical factor for secondary steel is the availability of scrap. Therefore, more steel scrap need to be collected, but that would require a better system that e.g. economically profits to recycle steel for companies and people. In the downstream processes that only seem to appear with BF, raising taxes on the steel products made could be an option. This would probably result in a lower usage of the taxed products, which could lead to innovative products that replaces the BF steel products with EAF steel products.

6.3 Suggestions on further work

The following are my suggestions what this report and database analysis could lead to, and where to continue the work.

- From the plant types and their capacities, match them to steel products and analyse how the products and steelmaking are connected.
- Map the flows thoroughly for each country. This could give insight in how CO2-heavy processes could be replaced with greener processes, but still get the same products. This by comparing sites that manufacture similar products, and by that find the most effective way of producing them.
- Change the Plantfacts structure and have Input, Process and Output columns for all plant types to improve the ability to follow the processes for each plant type.
- For downstream plants that uses both primary and secondary steel, investigate if they could be converted into only using secondary steel.

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8 Appendix

8.1 Appendix A

Figure 7. Showing in detail for each plant type how different column headings has been renamed to either Input (Yellow), Process (Blue) or Output (Green). The summarized version is shown in Table 3.

8.2 Appendix B

Here follows the VBA code used to reformat the database. The methods were executed in the same order as they are presented here.

The following code deletes all irrelevant columns in the original database.

```vba
Sub DeleteColumnsInAllSheets()
    Application.ScreenUpdating = False
    For i = 1 To ThisWorkbook.Sheets.Count
        DeleteColumnsInSheet (i)
    Next i
    Application.ScreenUpdating = True
End Sub

Sub DeleteColumnsInSheet(i As Integer)
    Dim newWorkbook As Workbook: Set newWorkbook =
Workbooks.Open("C:\Users\iguto\OneDrive\Dokument\LTH\Kandidatarbete\Extract
edMarkings0105.xlsx")
    Dim ProcessColor As Long
    Dim InputColor As Long
    Dim OutputColor As Long
    ProcessColor = GetColor(newWorkbook.Sheets(1).Range("B3"))
    InputColor = GetColor(newWorkbook.Sheets(1).Range("B2"))
    OutputColor = GetColor(newWorkbook.Sheets(1).Range("B7"))
    Dim deleteList As Variant
    ReDim deleteList(60)
    Dim pos As Integer
    pos = 0
    Dim KeyWords(1 To 14) As String
    KeyWords(1) = "DB-PLANT-No."
    KeyWords(2) = "TYPE OF PLANT"
    KeyWords(3) = "COUNTRY"
    KeyWords(4) = "COMPANY"
    KeyWords(5) = "LOCATION/WORKS"
    KeyWords(6) = "PLANT No."
    KeyWords(7) = "STATUS OF THE PLANT"
    KeyWords(8) = "MANUFACTURER A)"
    KeyWords(9) = "MANUFACTURER B)"
    KeyWords(10) = "YEAR OF START UP"
    KeyWords(11) = "YEAR OF MODERNIZING"
    KeyWords(12) = "PROCESS"
    KeyWords(13) = "NOMINAL CAPACITY"
    KeyWords(14) = "SUPPORTING STEEL PLANT"

    Dim RemoveColBool As Boolean

    For col = 1 To
ThisWorkbook.Sheets(i).Cells(1,Columns.Count).End(xlToLeft).Column
        RemoveColBool = True

        Dim columnString As String
        columnString = ThisWorkbook.Sheets(i).Cells(1, col).Value
        If columnString = "YEAR OF STARTUP" Or columnString = "YEAR OF
START UP OF 1. CONVERTER" Or columnString = "YEAR OF START UP 1.FURNACE"
Then
            ThisWorkbook.Sheets(i).Cells(1, col).Value = "YEAR OF START UP"
        ElseIf columnString = "YEAR OF RELINING" Then
            ThisWorkbook.Sheets(i).Cells(1, col).Value = "YEAR OF
MODERNIZING"
        End If
```

```vb
        For Each keyword In KeyWords
            If ThisWorkbook.Sheets(i).Cells(1, col).Value = keyword Then
                RemoveColBool = False
            End If
        Next keyword

        If RemoveColBool = True And Not ThisWorkbook.Sheets(i).Cells(2,
col).Value = "Code" Then
            For j = 1 To newWorkbook.Sheets(1).Cells(i + 1,
Columns.Count).End(xlToLeft).Column
                Debug.Print (ThisWorkbook.Sheets(i).Cells(1, col).Value)
                Debug.Print (ThisWorkbook.Sheets(i).Cells(2, col).Value)
                If newWorkbook.Sheets(1).Cells(i + 1, j).Value =
ThisWorkbook.Sheets(i).Cells(1, col).Value Then
                    If newWorkbook.Sheets(1).Cells(i + 1,
j).Interior.ColorIndex = InputColor Then
                        ThisWorkbook.Sheets(i).Cells(1, col).Value =
"INPUT"
                        RemoveColBool = False
                    ElseIf newWorkbook.Sheets(1).Cells(i + 1,
j).Interior.ColorIndex = ProcessColor Then
                        ThisWorkbook.Sheets(i).Cells(1, col).Value =
"PROCESS"
                        RemoveColBool = False
                    ElseIf newWorkbook.Sheets(1).Cells(i + 1,
j).Interior.ColorIndex = OutputColor Then
                        ThisWorkbook.Sheets(i).Cells(1, col).Value =
"OUTPUT"
                        RemoveColBool = False
                    End If
                End If
            Next j
        End If

        If RemoveColBool = True Then
            pos = pos + 1
            deleteList(pos) = col
            Debug.Print (ThisWorkbook.Sheets(i).Cells(1, col))
        End If

    Next col

    DoEvents
    Dim counter As Integer
    counter = 0
    For Each col In deleteList
        If col = Empty Then
            Debug.Print ("Empty")
        Else
            Debug.Print (ThisWorkbook.Sheets(i).Cells(1, col - counter) & "
deleted")
            ThisWorkbook.Sheets(i).Columns(col -
counter).EntireColumn.Delete
            counter = counter + 1
        End If
    Next
    newWorkbook.Close
End Sub
```

```vba
Function GetColor(Mycell As Range)
    GetColor = Mycell.Interior.ColorIndex
End Function

Sub CheckIfNominalCapacityExist(i)
        Dim columnString As String
        columnString = ThisWorkbook.Sheets(i).Cells(1, 19).Value
        If columnString = "NOMINAL CAPACITY" Then
            Debug.Print (ThisWorkbook.Sheets(i).Name & " is ok! " & i)
        End If
End Sub

Sub CheckAllSheetsIfNomCapExists()
    Application.ScreenUpdating = False
    For i = 1 To ThisWorkbook.Sheets.Count
        CheckIfNominalCapacityExist (i)
    Next i
    Application.ScreenUpdating = True
End Sub
```

The code below ensures that all needed columns exist and if not, the missing ones get inserted.

```vba
Sub FindMissingColumnsInAllSheets()
    Application.ScreenUpdating = False
    For i = 1 To ThisWorkbook.Sheets.Count
        Application.Wait (Now + TimeValue("0:00:03"))
        FindMissingColumns (i)
    Next i
    Application.ScreenUpdating = True
End Sub

Sub FindMissingColumns(i As Integer)
    Dim KeyWords(1 To 34) As String
    KeyWords(1) = "DB-PLANT-No."
    KeyWords(2) = "TYPE OF PLANT"
    KeyWords(3) = "TYPE OF PLANT"
    KeyWords(4) = "COUNTRY"
    KeyWords(5) = "COUNTRY"
    KeyWords(6) = "COMPANY"
    KeyWords(7) = "COMPANY"
    KeyWords(8) = "LOCATION/WORKS"
    KeyWords(9) = "LOCATION/WORKS"
    KeyWords(10) = "PLANT No."
    KeyWords(11) = "STATUS OF THE PLANT"
    KeyWords(12) = "STATUS OF THE PLANT"
    KeyWords(13) = "MANUFACTURER A)"
    KeyWords(14) = "MANUFACTURER A)"
    KeyWords(15) = "MANUFACTURER B)"
    KeyWords(16) = "MANUFACTURER B)"
    KeyWords(17) = "YEAR OF START UP"
    KeyWords(18) = "YEAR OF MODERNIZING"
    KeyWords(19) = "NOMINAL CAPACITY"
    KeyWords(20) = "SUPPORTING STEEL PLANT"
    KeyWords(21) = "SUPPORTING STEEL PLANT"
    KeyWords(22) = "PROCESS"
    KeyWords(23) = "PROCESS"
    KeyWords(24) = "PROCESS"
    KeyWords(25) = "PROCESS"
    KeyWords(26) = "INPUT"
```

```vba
        KeyWords(27) = "INPUT"
        KeyWords(28) = "INPUT"
        KeyWords(29) = "INPUT"
        KeyWords(30) = "OUTPUT"
        KeyWords(31) = "OUTPUT"
        KeyWords(32) = "OUTPUT"
        KeyWords(33) = "OUTPUT"
        KeyWords(34) = "OUTPUT"

    For col = 1 To ThisWorkbook.Sheets(i).Cells(1,
Columns.Count).End(xlToLeft).Column
        For j = 1 To UBound(KeyWords)
            If ThisWorkbook.Sheets(i).Cells(1, col).Value = KeyWords(j)
Then
                Debug.Print (KeyWords(j))
                KeyWords(j) = "Empty"
                Exit For
            End If
        Next j
    Next col

    DoEvents
    Dim counter As Integer
    counter = 1

    For Each keyword In KeyWords
        If keyword = "Empty" Then
            Debug.Print ("Empty")
        Else
            ColumnLetter = Split(Cells(1, counter).Address, "$")(1)
            Debug.Print (ColumnLetter)
            ThisWorkbook.Sheets(i).Columns(counter).Insert
            ThisWorkbook.Sheets(i).Range(ColumnLetter & 1).Value = keyword
            ThisWorkbook.Sheets(i).Range(ColumnLetter & 1).Orientation = 90
            Debug.Print (keyword)
        End If
        counter = counter + 1
    Next

    SetColumnOrder (i)

End Sub

Sub SetColumnOrder(i As Integer)
    Dim KeyWords(1 To 34) As String
    KeyWords(1) = "DB-PLANT-No."
    KeyWords(2) = "TYPE OF PLANT"
    KeyWords(3) = "TYPE OF PLANT"
    KeyWords(4) = "COUNTRY"
    KeyWords(5) = "COUNTRY"
    KeyWords(6) = "COMPANY"
    KeyWords(7) = "COMPANY"
    KeyWords(8) = "LOCATION/WORKS"
    KeyWords(9) = "LOCATION/WORKS"
    KeyWords(10) = "PLANT No."
    KeyWords(11) = "STATUS OF THE PLANT"
    KeyWords(12) = "STATUS OF THE PLANT"
    KeyWords(13) = "MANUFACTURER A)"
    KeyWords(14) = "MANUFACTURER A)"
    KeyWords(15) = "MANUFACTURER B)"
```

```
    KeyWords(16) = "MANUFACTURER B)"
    KeyWords(17) = "YEAR OF START UP"
    KeyWords(18) = "YEAR OF MODERNIZING"
    KeyWords(19) = "NOMINAL CAPACITY"
    KeyWords(20) = "SUPPORTING STEEL PLANT"
    KeyWords(21) = "SUPPORTING STEEL PLANT"
    KeyWords(22) = "PROCESS"
    KeyWords(23) = "PROCESS"
    KeyWords(24) = "PROCESS"
    KeyWords(25) = "PROCESS"
    KeyWords(26) = "INPUT"
    KeyWords(27) = "INPUT"
    KeyWords(28) = "INPUT"
    KeyWords(29) = "INPUT"
    KeyWords(30) = "OUTPUT"
    KeyWords(31) = "OUTPUT"
    KeyWords(32) = "OUTPUT"
    KeyWords(33) = "OUTPUT"
    KeyWords(34) = "OUTPUT"

    DoEvents

    Dim sortPos As Integer
    For k = 17 To UBound(KeyWords)
        If Not ThisWorkbook.Sheets(i).Cells(1, k) = KeyWords(k) Then
            For l = k + 1 To UBound(KeyWords)
                If ThisWorkbook.Sheets(i).Cells(1, l).Value = KeyWords(k)
Then
                    sortPos = l
                    Exit For
                End If
            Next l

            ThisWorkbook.Sheets(i).Columns(k).Insert XlDirection.xlToRight
            ThisWorkbook.Sheets(i).Columns(k).Value =
ThisWorkbook.Sheets(i).Columns(sortPos + 1).Value
            ThisWorkbook.Sheets(i).Columns(sortPos + 1).EntireColumn.Delete
        End If
    Next k
End Sub
```

The code below creates the site-specific database.

```
Sub CreateNewSteelDatabase()
    Dim wbName As String
    wbName = ThisWorkbook.Path & Application.PathSeparator & "test.xlsx"
    If Not Dir(wbName) = "" Then
        Kill wbName
    End If
    Application.ScreenUpdating = False
    Workbooks.Add

    ActiveWorkbook.SaveAs wbName
    Dim newWorkbook As Workbook: Set newWorkbook = Workbooks.Open(wbName)
    Dim site As String

    For Each Sheet In ThisWorkbook.Worksheets
        For i = 4 To Sheet.Range("A1048576").End(xlUp).Row
            site = Replace(Left(Sheet.Cells(i, 8), 30), "/", ".")
            If Not sheetExists(site, newWorkbook) Then
                newWorkbook.Sheets.Add.Name = site
```

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```vba
            End If
            Sheet.Rows(i).Copy
Destination:=newWorkbook.Sheets(site).Range("A" &
Rows.Count).End(xlUp).Offset(1)
        Next i
    Next Sheet


    Application.ScreenUpdating = True
    newWorkbook.Save
    newWorkbook.Close
    Application.ScreenUpdating = False
    IngridsSortingsmetod (wbName)
    AddHeadingsToAllColumns (wbName)
    Application.ScreenUpdating = True
    ActiveWorkbook.Save
    ActiveWorkbook.Close wbName
End Sub

Function sheetExists(sheetToFind As String, newWorkbook1 As Workbook) As
Boolean
    sheetExists = False
    Debug.Print sheetToFind
    For Each Sheet In newWorkbook1.Worksheets
        If sheetToFind = Sheet.Name Then
            sheetExists = True
            Exit Function
        End If
    Next Sheet
End Function

Sub IngridsSortingsmetod(wbName As String)

    Dim newWorkbook1 As Workbook: Set newWorkbook1 = Workbooks.Open(wbName)
    Dim ShCount As Integer, i As Integer, j As Integer
    ShCount = newWorkbook1.Worksheets.Count

    For i = 1 To ShCount - 1
        For j = i + 1 To ShCount
            If UCase(newWorkbook1.Worksheets(j).Name) <
UCase(newWorkbook1.Sheets(i).Name) Then
                newWorkbook1.Worksheets(j).Move
before:=newWorkbook1.Worksheets(i)
            End If
        Next j
    Next i
End Sub

Sub AddHeadingsToAllColumns(wbName)
    Dim newWorkbook As Workbook: Set newWorkbook = Workbooks.Open(wbName)

    For i = 1 To newWorkbook.Sheets.Count
        AddColumnHeadings (i)
    Next i

End Sub

Sub AddColumnHeadings(i)
    Dim KeyWords(1 To 34) As String
    KeyWords(1) = "DB-PLANT-No."
```

```
    KeyWords(2) = "TYPE OF PLANT"
    KeyWords(3) = "TYPE OF PLANT"
    KeyWords(4) = "COUNTRY"
    KeyWords(5) = "COUNTRY"
    KeyWords(6) = "COMPANY"
    KeyWords(7) = "COMPANY"
    KeyWords(8) = "LOCATION/WORKS"
    KeyWords(9) = "LOCATION/WORKS"
    KeyWords(10) = "PLANT No."
    KeyWords(11) = "STATUS OF THE PLANT"
    KeyWords(12) = "STATUS OF THE PLANT"
    KeyWords(13) = "MANUFACTURER A)"
    KeyWords(14) = "MANUFACTURER A)"
    KeyWords(15) = "MANUFACTURER B)"
    KeyWords(16) = "MANUFACTURER B)"
    KeyWords(17) = "YEAR OF START UP"
    KeyWords(18) = "YEAR OF MODERNIZING"
    KeyWords(19) = "NOMINAL CAPACITY"
    KeyWords(20) = "SUPPORTING STEEL PLANT"
    KeyWords(21) = "SUPPORTING STEEL PLANT"
    KeyWords(22) = "PROCESS"
    KeyWords(23) = "PROCESS"
    KeyWords(24) = "PROCESS"
    KeyWords(25) = "PROCESS"
    KeyWords(26) = "INPUT"
    KeyWords(27) = "INPUT"
    KeyWords(28) = "INPUT"
    KeyWords(29) = "INPUT"
    KeyWords(30) = "OUTPUT"
    KeyWords(31) = "OUTPUT"
    KeyWords(32) = "OUTPUT"
    KeyWords(33) = "OUTPUT"
    KeyWords(34) = "OUTPUT"

    For j = 1 To 34
        Sheets(i).Cells(1, j).Value = KeyWords(j)
        Sheets(i).Cells(1, j).Orientation = 90
    Next j


End Sub


Sub AddHeadingsToAllSheetsApp()
    AddHeadingsToAllColumns (ThisWorkbook.Path & Application.PathSeparator
& "test.xlsx")
End Sub
```

The code below create site codes in the new database and sort the sheets alphabetically
according to the site codes.

```
Sub SetSiteCodesApp()
    Application.ScreenUpdating = False
    Dim wbName As String
    wbName = ThisWorkbook.Path & Application.PathSeparator & "test.xlsx"
    SetSiteCodes (wbName)
    Application.ScreenUpdating = True
End Sub

Sub SetSiteCodes(wbName As String)
```

```vba
    Dim newWorkbook As Workbook: Set newWorkbook = Workbooks.Open(wbName)
    Dim countryCodeName As String
    countryCodeName = ThisWorkbook.Path & Application.PathSeparator & _
"CountryCodes.xlsx"
    Dim codeWorkbook As Workbook: Set codeWorkbook = _
Workbooks.Open(countryCodeName)

    Dim country As String
    Dim countryCode As String
    Dim site As String

    pos = 0
    For i = 1 To newWorkbook.Sheets.Count
        If IsEmpty(newWorkbook.Sheets(i).Range("A1")) Then
            newWorkbook.Sheets(i).Delete
        Else
            country = newWorkbook.Sheets(i).Cells(2, 5).Value
            site = newWorkbook.Sheets(i).Cells(2, 8).Value
            site = Left(site, 1) & Right(site, 4)
            With codeWorkbook.Sheets(1).Range("b1").EntireColumn
                Set c = .Find(country, LookIn:=xlValues)
                If Not c Is Nothing Then
                    countryCode = c.Offset(, -1).Value
                    newWorkbook.Sheets(i).Name = countryCode & site
                End If
                If c Is Nothing Then
                    Debug.Print (country)
                End If
            End With
        End If
    Next i

End Sub

Sub SortWorksheetNames()
    Dim wbName As String
    wbName = ThisWorkbook.Path & Application.PathSeparator & "test.xlsx"
    IngridsSortingsmetod (wbName)
End Sub
```