TransitionZero

The Spotlight Effect

Using satellite imagery to estimate the utilisation rate of steel facilities

September 3rd 2021

About TransitionZero

TransitionZero combines financial and industry expertise with technology to help power a clear and timely transition to zero carbon in the power and heavy industry sectors. Using satellite imagery, machine learning and financial modelling, we gather real-time insights into the economic vulnerability of fossil fuel assets. We give key decision makers the solutions they need to reach their zero carbon targets.

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- Peter Levi, International Energy Agency
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The experts above that contributed to this whitepaper are not responsible for any opinions or judgments it contains. All errors and omissions are solely the responsibility of TransitionZero.

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01 Summary

The purpose of this whitepaper is threefold:

1. Detail our methodology to estimate steel production and emissions at the facility level in near real time;
2. Present the provisional results of this methodology at country and facility level; and
3. Illustrate how this data can be used to align the steel sector with a zero carbon outcome.

Based on our understanding, this is the first time an organisation has used satellite imagery to monitor steel production and emissions globally at facility level and made this data publicly available.[1] In doing so, we hope to improve information flows to support the development of practical use cases for steel sector decarbonisation. While the use cases in this whitepaper are strictly illustrative in nature, our production and emissions estimates will form the basis of our first use case: facility level production cost curves for economic and financial scenario analysis. These cost curves will be made publicly available in advance of COP26 in Glasgow.

Facility level production data is a zero carbon enabler

Considerable efforts have been made by the World Steel Association (Worldsteel), Global Energy Monitor (GEM) and others to improve data transparency in the steel sector. Despite this, the industry is currently unwilling to provide facility level production and emissions data on a consistent basis, due to steel being a global and competitive commodity. Steel production and emissions data is currently made available via company reports or voluntary initiatives. These reports and initiatives often fail to reduce information asymmetries, with data availability and quality being dependent on the size, type and motivations of the company or government. This contrasts with electricity generation – which is produced and consumed locally – where several regulators mandate production and emissions data to be made available on a sub-hourly basis. If information precedes action, then steel facility production and emissions data needs to be made public as soon as possible. Without this data, investors, governments and civil society risk being undermined by incomplete information. While third party data should never be seen as a silver bullet, we believe – and intend to prove why – it is a useful tool to help align the steel sector with the temperature goals of the Paris Agreement.

Independent facility production estimates

To improve data transparency, we developed a methodology to monitor steel production from blast furnaces (BF) and basic oxygenation furnaces (BOF), using a combination of satellite imagery, publicly available data and statistical techniques. In doing so, we convert signals from satellite images to tons of crude steel and carbon emissions. BF/BOF production routes represent 72% of global crude steel production.[2] Based on a first iteration of the countries modelled, our satellite-derived estimates currently cover 65% of operating BF/BOF capacity, which corresponds to 35% of installed global steel capacity. Our next iteration in Q4 2021, will expand coverage to the remaining BF/BOF facilities. At the time of writing, when compared to monthly national statistics from Worldsteel, our models achieved a mean average error (MAE) of 18%, with the MAE ranging from 9% to 28% depending on the country.[3]

We can scale these satellite-derived predictions and apply statistical techniques to estimate total steel production at country level. As we are getting satellite signals in near real time, we have the ability to get an indication of steel production in advance of national statistics. For electric arc furnace (EAF) routes, the other main form of steel production, where hotspots are not captured by satellite imagery, we use time series analysis based on our BF/BOF estimates and Worldsteel data. Based on this methodology, we estimate China's steel production could be 88.0Mt in August 2021, up 6% year on year. Our ability to scrutinise model accuracy at facility level is constrained by the lack of publicly available data. However, our predictions are reassuring for facilities where public information is available. Based on annual reported production data from 12 facilities, we achieve a MAE of 29% which is comparable to the MAE we achieve at country level.

1. Emissions estimates are not the focus of this publication and shall form the basis of future publications. We acknowledge efforts from other data providers, but our understanding is these offerings are either paywalled or regional coverage.
2. Worldsteel (2021).
3. MAE is the average of all the errors in a set. An error in this context is the difference between the measured value and Woodsteel value. See the notes of Table 1 for more information.

Table 01. Crude steel production estimates in countries modelled in 2021

	BF/BOF estimate for August (Mt)	BF/BOF monitored with satellites (%)	Total steel estimate for August (Mt)	Total steel monitored with satellites (%)	Historical mean average error (%)	January – August 2021 (Mt)	January – August yoy change (%)
China	73.22	30%	88.01	27%	22%	734.99	6%
US	1.76	75%	7.20	23%	9%	56.74	19%
Germany	1.35	90%	2.79	63%	16%	26.43	16%
Italy	0.50	100%	1.50	22%	19%	16.49	29%
France	0.44	59%	0.91	41%	12%	9.54	31%
Spain	0.12	100%	1.35	33%	12%	9.93	45%
Poland	0.42	89%	0.70	49%	21%	5.88	12%
UK	0.51	70%	0.58	55%	17%	5.02	8%
Austria	0.68	77%	0.71	69%	20%	5.30	22%
Belgium	0.43	100%	0.69	75%	16%	4.59	4%
Netherlands	0.57	100%	0.57	100%	9%	4.46	12%
Sweden	0.12	100%	0.17	67%	16%	2.95	6%
Slovakia	0.40	98%	0.41	91%	21%	3.08	20%
Finland	0.18	54%	0.26	36%	28%	2.47	14%
Romania	0.32	100%	0.35	92%	22%	2.30	17%

Source: Worldsteel (2021), TransitionZero analysis
Notes: The MAE is based on a comparison between TransitionZero estimates and Worldsteel data. Worldsteel data is provided by national associations as well as a variety of other sources. See Worldsteel (2021) for more information. Worldsteel provides monthly total crude steel production, whereas our satellite estimates quantify crude steel produced through the BF/BOF processing route. To make the two datasets comparable, we apply a scaling factor to total crude steel production using the share of monitored BF/BOF capacity in a given country.

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We developed a methodology which combines of satellite imagery and publicly available data to monitor steel production at facility level. Based on this whitepaper, we monitor 88 of the 150 facilities in the countries modelled. This will be expanded to 90% of glonal BF/BOF capacity by Q4 2021.

18%

At the time of writing, when compared to monthly national statistics from Worldsteel, our models achieved a MAE of 18%, with the MAE ranging from 9% to 28% depending on the country.

158 $MtCO_2$

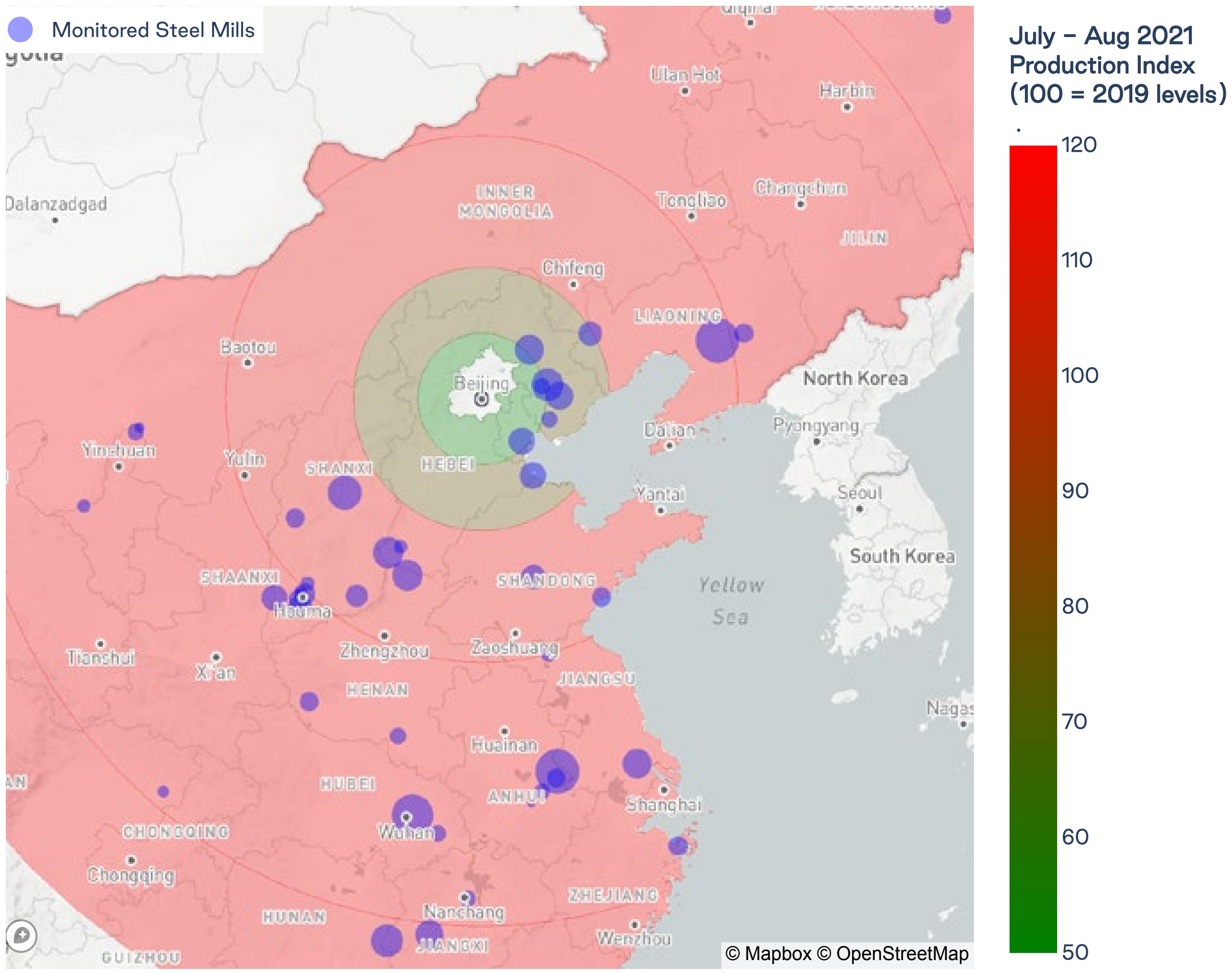
The year on year growth in China's steel production without a further crackdown would result in an additional 158Mt of CO2, the equivalent of the Netherlands total emissions.

Out of sight, out of mind? China to miss 2021 production target without crackdown

In December 2020, the Ministry of Industry and Information Technology (MIIT) stated China must limit 2021 steel production to 2020 levels.[4] This commitment was reaffirmed in April this year, with a joint statement from the National Development and Reform Commission (NDRC) and MIIT stating they will investigate excess steel construction and production.[5] Based on our model results, these efforts appear to be taking effect. In July this year, production declined to 86.8Mt (-8% month on month) and, based on our estimates, August output is up slightly at 88.0Mt (1% month on month). While the outputs of the last months are a step in the right direction, our analysis reveals production cuts depend on the location of the facility.

As detailed in Figure 1, the output of facilities closer to Beijing dropped throughout July and August, while those facilities further away maintained output. To reduce production in line with 2020 levels, more needs to be done in Central and Western provinces. Without further action, China's steel output could be up 4% to 7% in 2021. Around 90% of China's still production is from carbon intensive BF/BOF production routes. As such, this possible policy miss has climate implications.[6] The year on year growth in China's steel production without a further crackdown would result in an additional 158Mt of CO_2 – the equivalent of Netherlands' total emissions in 2019.[7] Whether the central government has the political capital and will to intervene this year across all provinces remains to be seen. In the future, however, we believe a top-down crackdown appears to be the only way for China to systematically resolve these issues to meet its carbon neutrality goals. If replicated by the Chinese government, our modelling approach could be a useful tool for monitoring and regulating steel production and emissions.

Figure 01. Production index for July and August 2021, showing lower production for steel mills close to Beijing (up to a radius of 400 km)



Source: Worldsteel (2021), TransitionZero analysis

4. Argus (2020). Per China Daily (2021), these statements differ from the China Metallurgical Industry Planning and Research Institute, which expects steel production to reach 1,070Mt in 2021.
5. Reuters (2021).
6. Industrial Info Resources (2021).
7. Assumes 7% year on year growth rate and an average crude steel emission intensity in China of 2.26 tons of CO_2 per ton of steel. The latter is based on Hasanbeigi and Springer (2019).

Use cases

This methodology was developed specifically to help decision makers with steel sector decarbonisation. In this whitepaper, we discuss three potential use cases areas we intend to explore and possibly develop in the future.

Next Steps

The facility level production estimates will be made available via an application programming interface (API) and an updated comma-separated values (CSV) file in early 2022. Our initial focus is to use our technology to help develop crude steel production cost curves to support economic and financial scenario analysis. We are in the process of establishing data agreements and partnerships with those organisations and initiatives who are interested in tracking the energy transition. We have also developed a similar methodology for other heavy industry subsectors, such as cement, and will publish the findings of these results in 2022.

Table 02. Summary of possible use cases and the role of facility level production data

	Description	Why does facility level production data help?	Examples
Transition risks and opportunities	A facility by facility assessment of production and abatement costs as well as profitability.	Utilisation rates vary from month to month and year to year. Assuming a country average or technical nameplate utilisation rate will likely lead to inaccurate economic and financial modelling at the facility level.	• Retrofit costs and financing to be zero carbon aligned. • Shutdown costs and subsidies due to the interaction between carbon prices, abatement costs and industry profitability.
Nowcasting production and emissions	Tracking production and emissions in regions with production targets and emissions trading systems.	Help resource constrained regulators establish an anomaly detection system to detect possible non compliance events at facility level.	• China steel production targets. • China ETS monitoring, reporting and verification.
Supply chain emissions	Estimating the embodied carbon associated with steel production.	Facility carbon emissions vary depending on several variables, including the coking coal quality, production route and carbon intensity of electricity, for example. While production is only one piece of the puzzle, when combined with other data sources, it makes measuring carbon emissions possible.	• EU's carbon border adjustment mechanism (CBAM). • Scope 3 corporate targets.

Source: TransitionZero analysis
Notes: These use cases are for illustrative purposes only.

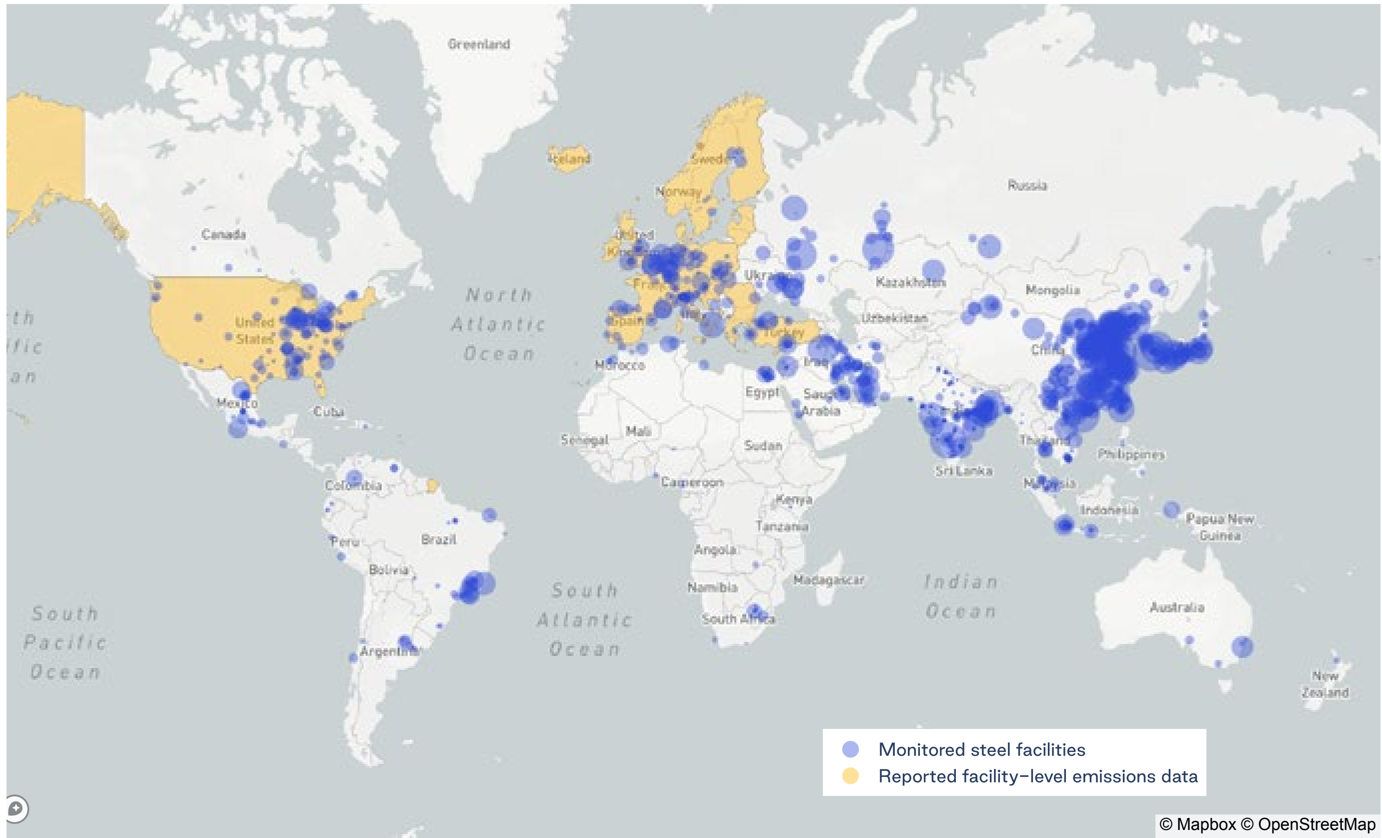
> In the future, however, we believe a top-down crackdown appears to be the only way for China to systematically resolve these issues to meet its carbon neutrality goals. If replicated by the Chinese government, our modelling approach could be a useful tool for monitoring and regulating steel production and emissions.

02 Introduction

Steel production is both energy and emissions intensive, representing about 8% of total energy demand and 7% of global energy sector carbon emissions.[8] The emissions intensity of steel production is due to its reliance on coal, the most carbon intensive fossil fuel. At the same time, steel is vitally important to the global economy, being used for buildings, infrastructure, weapons, vehicles and furniture, for example. Due to its importance to modern society, steel demand is expected to grow for the foreseeable future.[9] Steel is a globally traded commodity characteristised by fierce competition amongst producers. Steel production is relatively fragmented, with China accounting for over half of global production, followed by the EU and UK making up 9%, India 6%, Japan 5%, the US 5%, Russia 4% and South Korea 4%.[10] Production and customer price sensitivities are considered the main reasons why facility level data is not made publicly available. As detialed in Figure 2, the EU and the US are the only major regions where facility level emissions data is publicly available.

We believe publicly available facility production and emissions data is essential to help decarbonise the steel industry. For this reason, we have developed a methodology to estimate the production of crude steel at facility level. In doing so, we explore the extent to which publicly available satellite data can be used to predict production when facility data is unavailable. We also explore how this data can inform practical use cases that will prove crucial for decision makers to make informed decisions about steel sector decarbonisation.

Figure 02. Crude steel facilities and regions where facility level data is publicly available at any time sensitivity

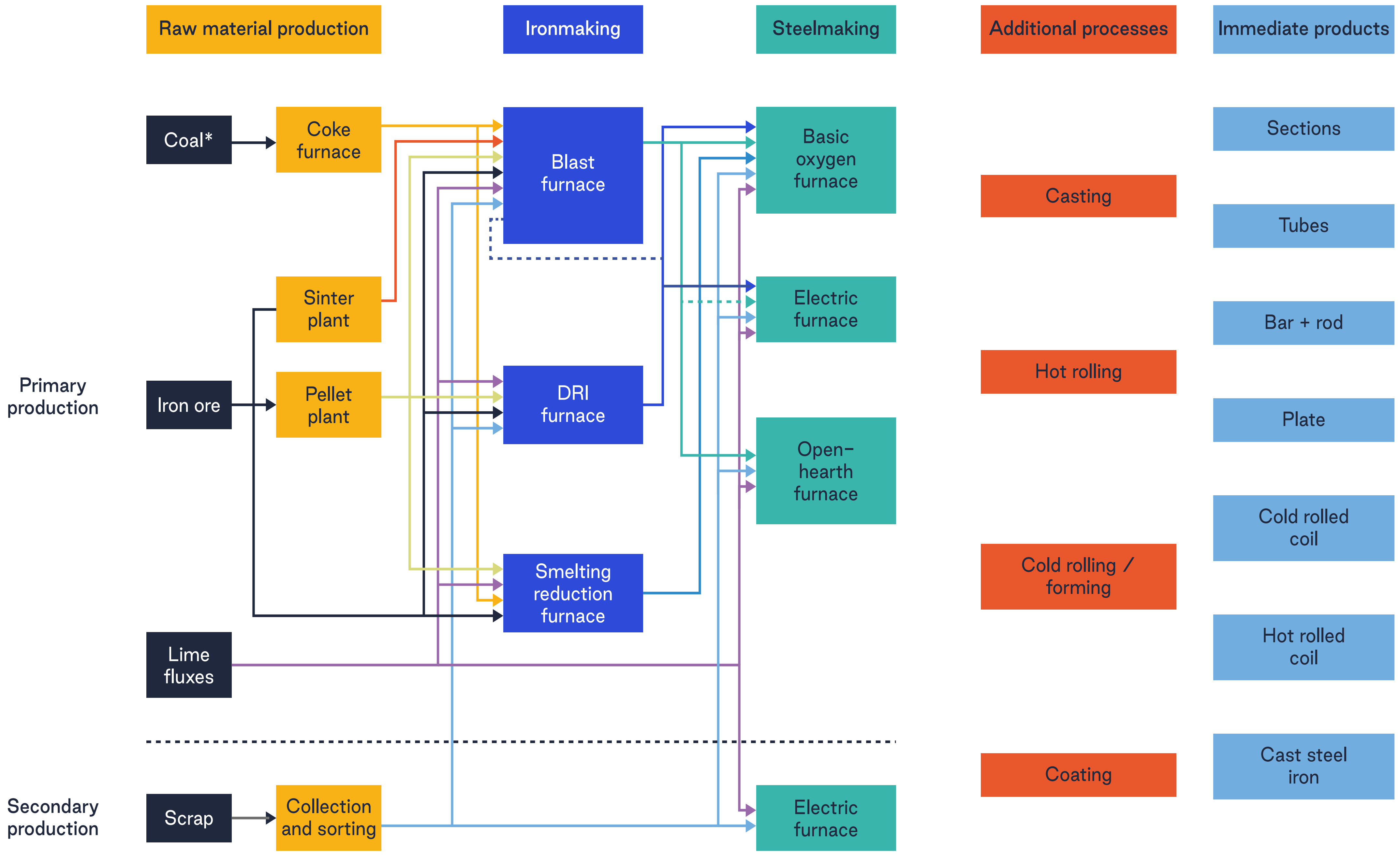


Source: Industrial Info Resources (2021), TransitionZero analysis

8. IEA (2020).
9. In the Stated Policies Scenario global end-use demand for steel reaches 2.1Gt by 2050. IEA (2020).
10. See footnote 8.

03 Steelmaking overview

Figure 03. Crude steel production value chain from raw materials, steel making and final products



Source: Adapted from Cullen, et al (2021) and IEA (2020).

The principal inputs to steelmaking today are iron ore, energy, limestone and scrap.[11] Iron ore and scrap are used to provide the metallic charge, with scrap having a much higher metallic concentration than iron ore. Energy inputs are used to provide heat to melt the metallic input, and in the case of iron ore, to chemically remove oxygen. Limestone is used at various stages of the steelmaking process to help remove impurities. Indirect carbon emissions vary widely based on the production route.[12]

Steel is produced via two main routes: BF/BOF and EAF.[13] The BF/BOF route uses raw materials such as iron ore, coal, limestone and steel scrap. Iron ores are reduced to iron, also called hot metal or pig iron. The iron is then converted to steel in the BF/BOF. BF/BOF accounts for 70% of global steel production. The EAF route uses electricity to melt scrap steel. Depending on facility configuration and availability of steel scrap, other sources of metallic iron such as direct reduced iron (DRI) or hot metal can also be used.[14] Alloying materials are used to adjust the steel to the desired chemical composition. Electrical energy can be supplemented with oxygen injected into the EAF. Downstream process stages, such as casting, reheating and rolling, are similar to those found in the BF/BOF route. EAF accounts for 30% of global steel production. It is widely understood there is not enough recycled steel to meet growing demand. Demand is currently being met through a combined use of the BF/BOF and EAF production routes. Both these production routes use recovered steel scrap as an input. Consequently, all new steel contains some recycled steel.

There are several immediate products from steel, including: sections, tubes, bars and rods, plate, cold rolled coil, hot rolled coil and cast steel iron. An illustration of the crude steel production value chain from raw materials, steel making and final products is detailed in Figure 3 below.[15]

11. A detailed overview of the steel production processes is outside the scope of this whitepaper. See the references for recommended research on steel production and decarbonisation.

12. See the methodology section for more information.

13. This is a simplified categorisation of steel making. There are other routes such as DRI-EAF and open-hearth route, which represent around 7% and 0.4% of primary global production, respectively. Moreover, scrap is often used in BF/BOF. Iron is also commonly used in EAFs. For this reason, it is common to quote the share of scrap in inputs alongside the shares of BF/BOF and EAF production.

14. China, for example, uses a large share of pig iron to feed EAFs.

15. Also see Worldsteel (2019) for more information.

04 Methodology

We developed a methodology to independently monitor steel production and emissions from BF/BOF routes, using a combination of satellite imagery and publicly available data. Our methodology is briefly outlined below.[16] Our methodology involves three steps:

1. Estimating production at the facility level from the BF/BOF routes, using a combination of satellite imagery and publicly available data;
2. Assigning an emission factor based on facility size, production process, fuel type, age and location; and
3. Multiply production with emission factors to calculate the facility's emissions.

The facility level model outputs in this analysis are based on several assumptions. These data sources and assumptions are detailed in Table 3.

Table 03. Overview of the data sources, key assumptions and methodological approaches used

Parameter	Source	Description
Inventory data	Industrial Info Resources (2021)	Data points include GPS coordinates, owner, capacity, age, product type and technology type. Data coverage includes: 323 BF/BOF facilities (1,810 Mt/year of installed capacity) and 1,362 EAF facilities (1,095 Mt/year of installed capacity) across 112 countries.
Mapping	Google Maps (2021), OpenStreetMaps (2021), TransitionZero analysis.	Since we use remote sensing data, we need facility geolocation data accurate to within a few tens of meters. While some of the listed geolocation from the IRR dataset provides geolocation information, it is incomplete and, in some cases, inaccurate. We supplement the source geolocation data using the Google Maps API and OpenStreetMaps, before manually validating all geolocations.
Training production data	Worldsteel (2021)	Monthly country level crude steel production of 64 countries, used to derive the facility level contribution in each country.
Production estimates from BF/BOF facilities	Band 11, Band 12 of Landsat 8 (NASA, 2021), Band 6, Band 7 of Sentinel 2 (Copernicus, 2021), TransitionZero analysis	We use satellite-based production estimates whenever a facility releases enough heat to be captured by satellite imagery. This is the case for BF/BOF facilities. BF/BOF facilities have several units that function at temperatures higher than 1,200oC degrees Celsius. These hotspots include signals from coke plants, sinter plants, BFs, slag pits, and BOFs. We use Sentinel-2 and Landsat-8 multispectral satellite images, with historical data dating back to 2015. For each image, we compute the normalized band ratio between the two short wave infrared bands of each satellite, called the Normalised Heat Index. Partial images (coverage of the facility's boundaries less than 80%) and cloudy images (more than 20% clouds) are excluded.
Production estimates from other facilities	TransitionZero analysis	For EAF and all other process routes, we use a basic disaggregation method: for each facility, we compute its share of national capacity, before multiplying this number by the country's production to derive the facility's contribution for the given timeframe.
Emissions factors	Hasanbeigi, A. and Springer, C. 2019. How Clean is the U.S. Steel Industry? An International Benchmarking of Energy and CO2 Intensities. Global Efficiency Intelligence.	Emissions factors are provided by process and country and are used to convert facility level production estimates to emissions. Countries include Canada, Spain, Mexico, United States, France, Russia, Japan, Germany, Italy, Brazil, Turkey, South Korea, China, India and Poland.

Source: TransitionZero analysis

Notes: TransitionZero intends to use GEM (2021) and McCarten, et al, (2021) datasets from Q4 2021, as they are publicly available.

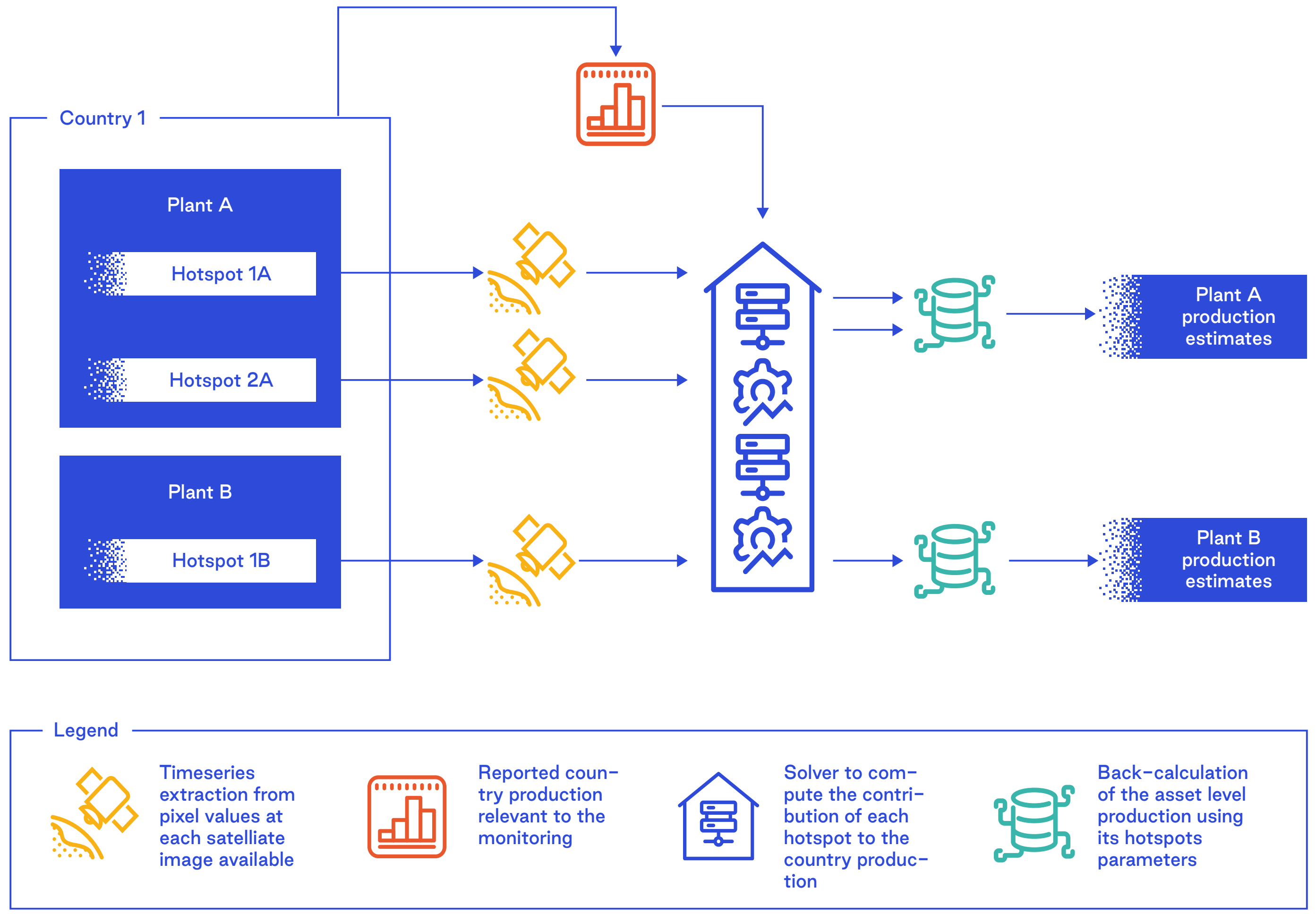
Photo by What Is Picture Perfect on Unsplash

16. A more detailed explanation of our methodology will be provided. with publication of the Climate TRACE tool in September 2021.

Regarding satellite derived estimates – i.e. production estimates from BF/BOF facilities – each normalised hotspot time series is then fed into an optimizer that computes the weights of each hotspot contribution to best match the country's reported production. The facility production estimates are then backcalculated using the facility's hotspot signals and their corresponding weight. We then estimate tons of carbon per ton of manufactured product by applying emissions factors.[17] Figure 4 provides an overview of the modelling approach for a hypothetical country.

Regarding satellite derived estimates, each normalised hotspot time series is then fed into an optimizer that computes the weights of each hotspot contribution to best match the country's reported production.

Figure 04. Schematic model approach for satellite-based estimates of facility level production



Source: TransitionZero analysis

17. Hasanbeigi and Springer (2019).

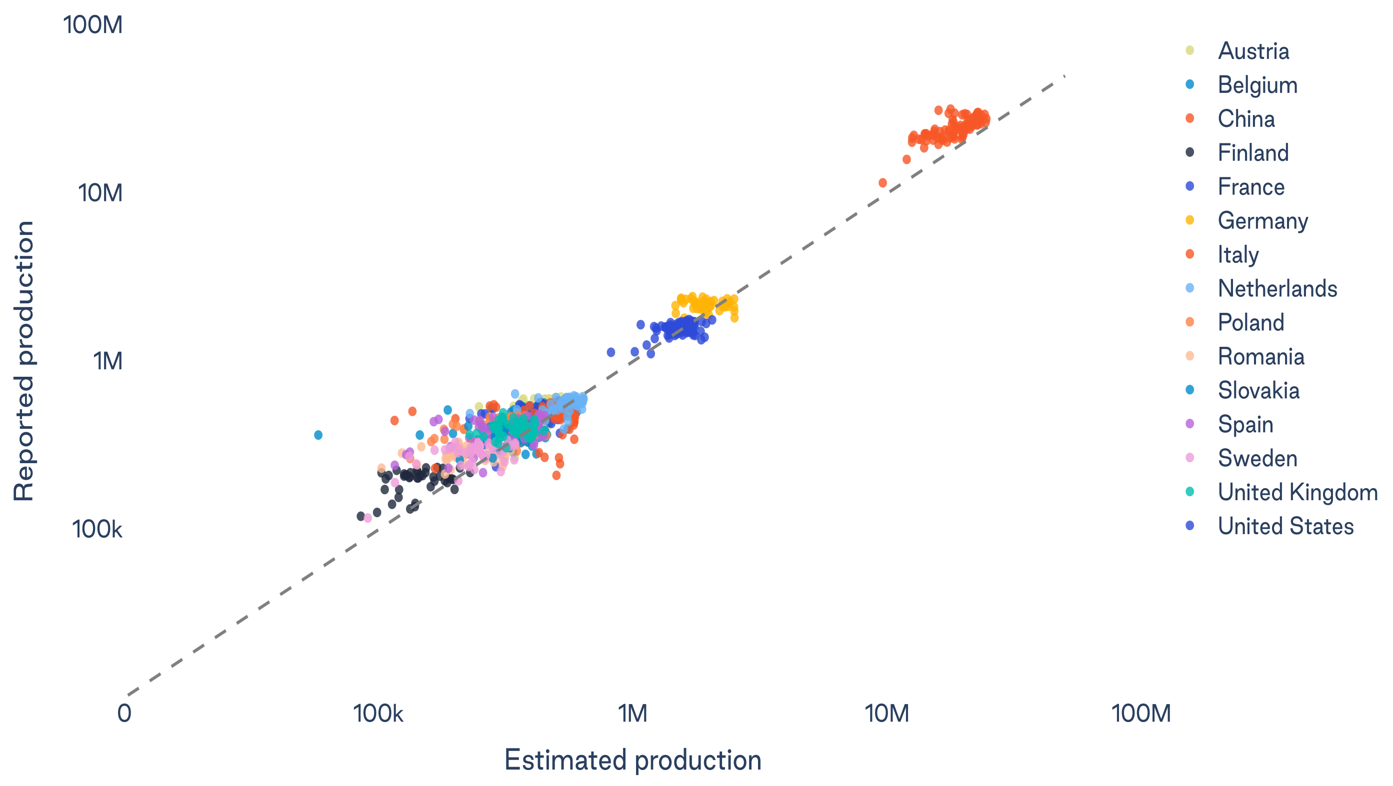
05 Independent facility production estimates

We assess the accuracy of our estimates using data available in the public arena. To do this, we use monthly country production data from Worldsteel, as well as information from company reports.

Country level

The MAE for all countries modelled is 18%. We modelled countries representing 70% of global crude production capacity.[18] As detailed in Figure 5 below, these countries include Austria, Belgium, China, Czechia, Finland, France, Germany, Italy, Netherlands, Poland, Romania, Slovakia, Spain, Sweden, UK and US, with the MAE ranging from 28% in Finland and Czechia to 9% in the US.

Figure 05. Worldsteel production data versus TransitionZero estimated production and MAE for modelled countries



Source: Worldsteel data, TransitionZero analysis

18. Model outputs for other countries are currently undergoing internal quality assurance.

Table 04. Crude steel production estimates in countries modelled from 2020 and 2021

	BF/BOF estimate for August (Mt)	BF/BOF monitored with satel-lites (%)	Total steel estimate for August (Mt)	Total steel monitored with satel-lites (%)	Historical mean average error (%)	January - August 2021 (Mt)	January - August yoy change (%)
China	73.22	30%	88.01	27%	22%	734.99	6%
US	1.76	75%	7.20	23%	9%	56.74	19%
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Italy	0.50	100%	1.50	22%	19%	16.49	29%
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Spain	0.12	100%	1.35	33%	12%	9.93	45%
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Netherlands	0.57	100%	0.57	100%	9%	4.46	12%
Sweden	0.12	100%	0.17	67%	16%	2.95	6%
Slovakia	0.40	98%	0.41	91%	21%	3.08	20%
Finland	0.18	54%	0.26	36%	28%	2.47	14%
Romania	0.32	100%	0.35	92%	22%	2.30	17%

Source: Worldsteel data, TransitionZero analysis

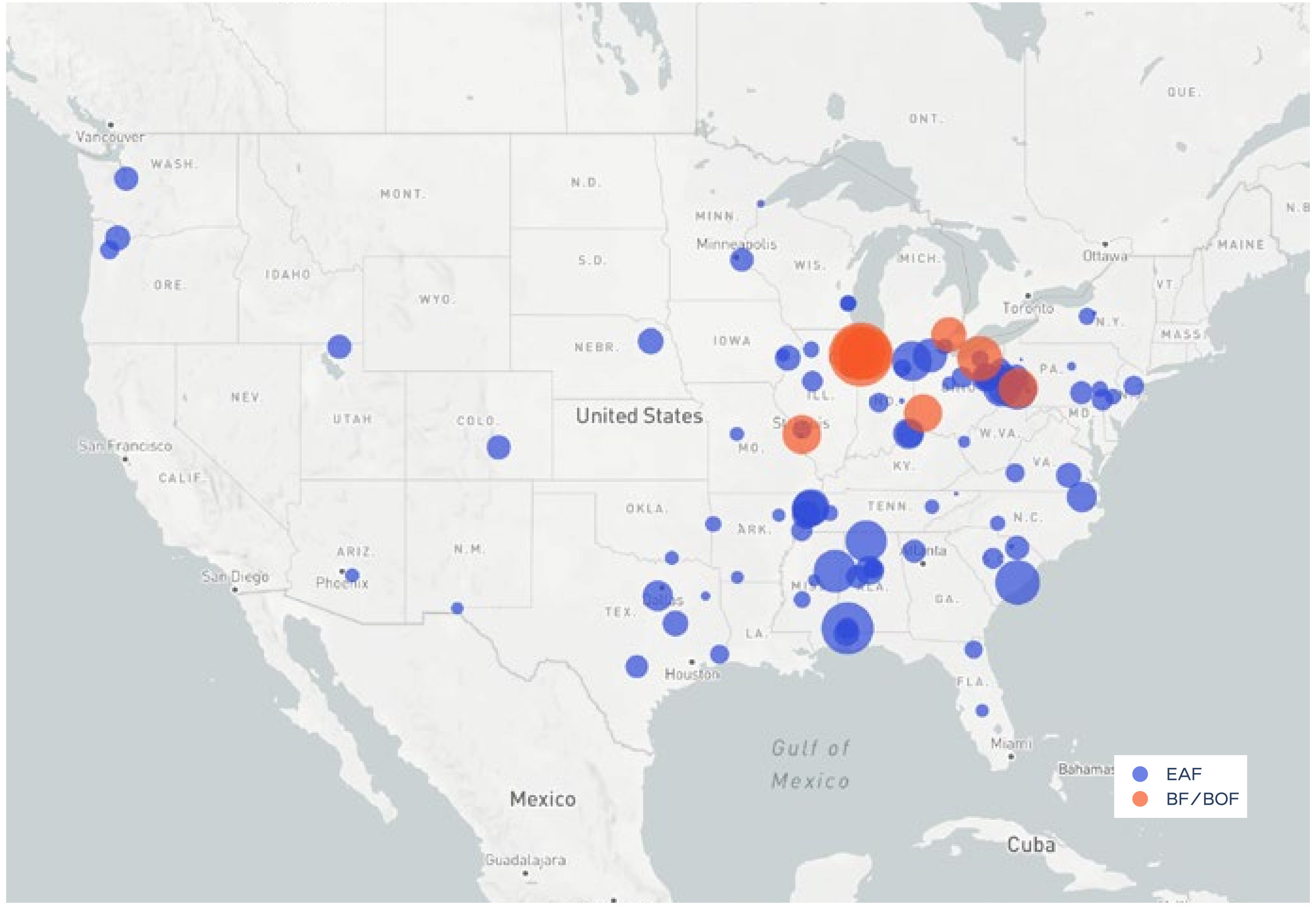
Notes: The MAE is based on a comparison between TransitionZero estimates and Worldsteel data. Worldsteel data is provided by national associations as well as a variety of other sources. See Worldsteel (2021) for more information. Worldsteel provides monthly total crude steel production, whereas our satellite estimates quantify crude steel produced through the BF/BOF processing route. To make the two datasets comparable, we apply a scaling factor to total crude steel production using the share of monitored BF/BOF capacity in a given country.

US production estimates

The US has an estimated 127Mtpa of installed crude steel capacity from 107 facilities.[19] Of the 127Mtpa, around 30% is produced through the BF/BOF route. We monitor 8 of the 10 BF/BOF facilities in the US. Figure 6 details iron and steel facilities in the US split by processing route, with the bubble size proportional to the installed capacity of each facility. BF/BOF capacity is concentrated in the northeast, while EF capacity is dispersed throughout the nation.

As detailed in Figure 7, Our estimates are consistent with Worldsteel derived data. In particular, the COVID recovery in the second half of 2020 shows our production estimates reaching 1.7 Mt in January 2021 versus 1.6 Mt from Worldsteel derived data. The first half of 2021 shows divergence from our estimates and Worldsteel derived data, possibly implying production growth over this period was driven principally by EAF facilities.

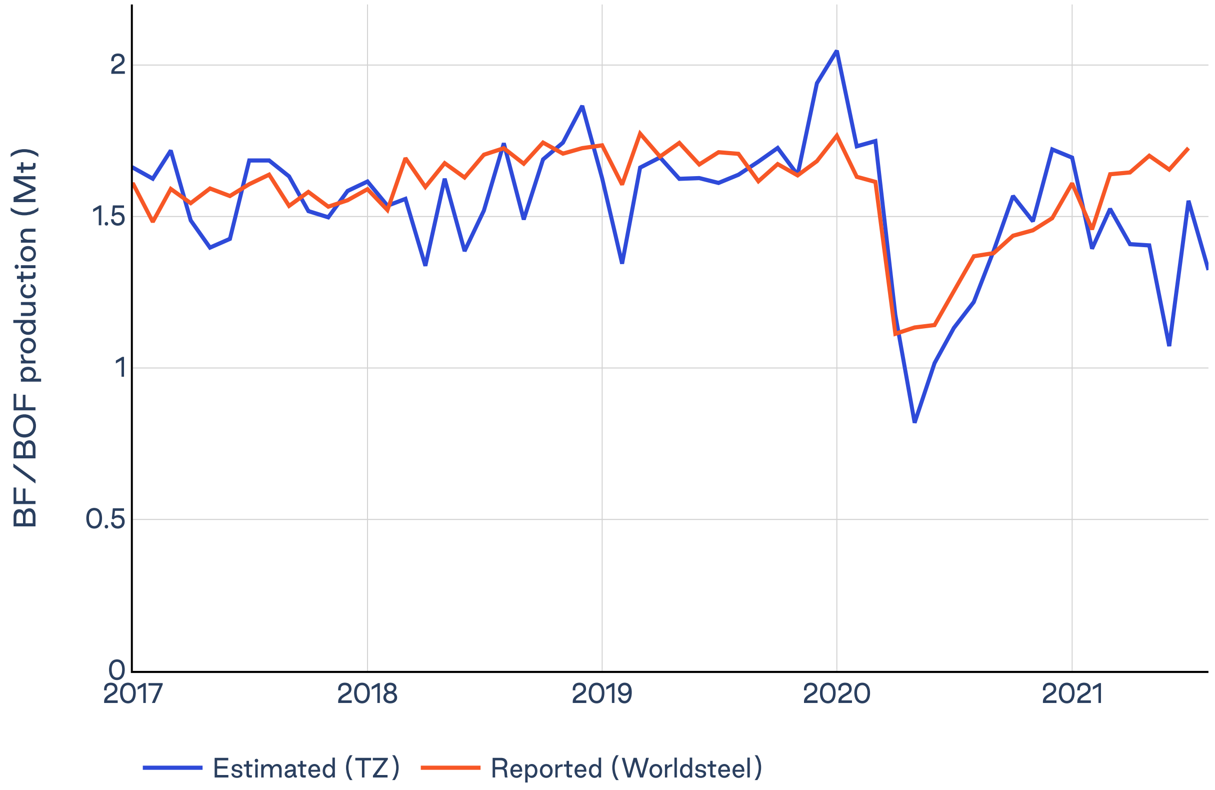
Figure 06. Iron and steel facilities in the US split by crude steel processing route



Sources: Industrial Info Resources (2021), TransitionZero analysis

19. Industrial Info Resources (2021).

Figure 07. Monthly BF/ BOF crude steel production in the US between January 2017 and May 2021



Sources: Worldsteel data, TransitionZero analysis

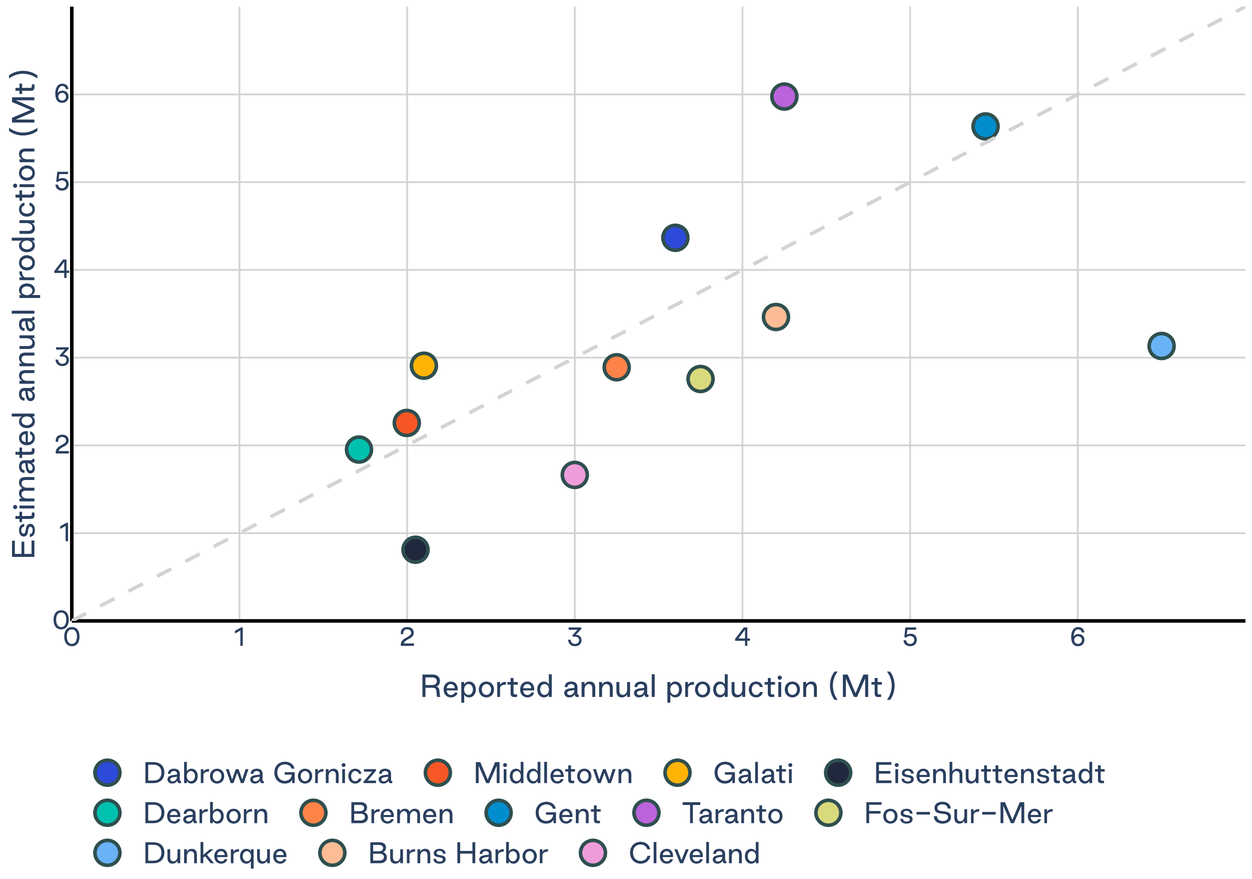
Facility data comparison

Our ability to scrutinise model accuracy at facility level is constrained by the lack of publicly available ground truth data. However, our predictions are reassuring for facilities where public information is available. Based on annual reported production data from 12 facilities, we achieve a MAE of 29% which is comparable to the MAE we achieve at country level. A generic caveat to the facility level results explained below is that they are based on disaggregating national statistics (country level reported production) to facility level using satellite signals. This limits accuracy in a number of ways, of which we have outlined the two most significant.

Firstly, to the extent that production at different facilities within a country are correlated, the approach loses accuracy. This is because it is not always possible to learn appropriate scales for the signals of each facility when each facility's signals tend to follow each other. This problem is somewhat ameliorated by having more observations, but such observations are limited by both the availability of historical country level data as well as the frequency of satellite images without cloud cover.

Secondly, we assume country level BF/ BOF production is equal to country production scaled by the percentage of capacity represented by BFs/ BOFs. The scale of our BF/ BOF facility models will be inaccurate to the extent that this assumption fails. Notwithstanding these difficulties, our models perform reasonably well. In future, a theory driven approach (inferring production from the physics of heat signals) rather than the current data driven approach could be used to tackle these sources of uncertainty. This is a more ambitious approach and is currently being researched.

Figure 08. Estimated annual production at selected facilities versus annual reported data



Source: GEM (2021), TransitionZero analysis
Notes: see the Appendix for possible explanations of the discrepancies.

Gary Works

Gary Works is a large steel mill in Indiana owned by the United States Steel Corporation (USSC). Gary Works has an installed capacity of 7.5Mt per year via BF/BOF processing. Figure 9 labels the major heat releasing areas of Gary Works. These areas include: the hot strip mill, sinter plant, coke plant and BF/BOF processes.

Figure 10 shows the results of the modelled production at Gary Steel Works. Periods of estimated production align with reported events of blast furnaces either being idled or restarted. For example, on 10 April 2020 S&P Global reported BF number 8 at Gary Works had been idled amid lower market demand and steel prices.[20] USSC reported during its Q2 2020 company results that it restarted a number of blast furnaces.[21] Both events were captured by our model estimates.

Model risks and limitations

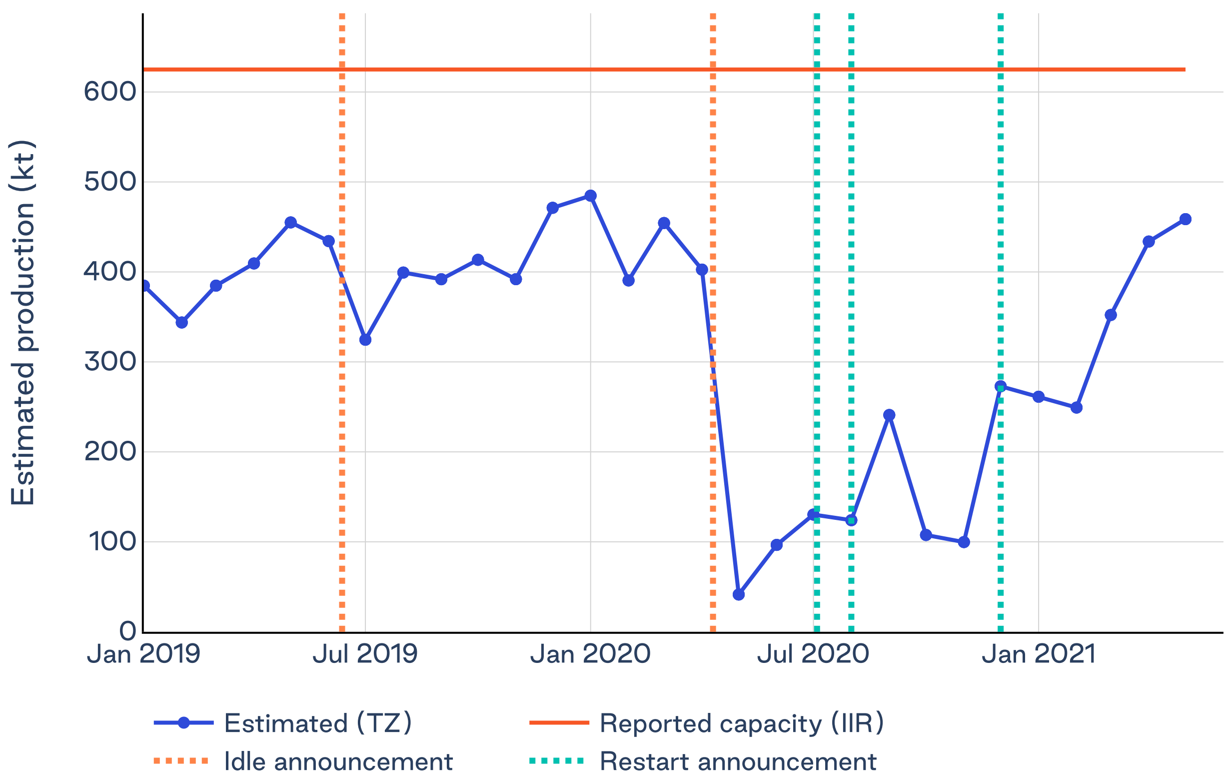
Country level results are sensitive to initial configuration parameters. In practice, this means the country level models sometimes have a slight scale offset (generally underpredicting country production) while still accurately reflecting production trends. The bias is an artifact of a trade-off between inferring country level production accurately while also ensuring predictions for any given facility do not deviate too much from its nameplate capacities. The bias is only present for the largest countries (e.g. China) because it is especially difficult to disaggregate country level data to the facility level using satellite models for these countries. Furthermore, the bias is generally small. In the future, these biases could be addressed by averaging results from models with slightly different assumptions. The idea is that the errors from different models would be somewhat uncorrelated and would therefore cancel each out. Alternatively, a bottom up approach could be used. This would involve leveraging domain knowledge to infer production at plant level directly using heat signals. The plant level results would then be aggregated. This is a potentially promising approach and is currently under investigation.

20. S&P Global (2020).
21. USSC (2020).

Figure 09. Satellite Image of Gary Steel Works in Indiana, US

Sources: OpenStreetMap (2021), TransitionZero analysis

Figure 10. Estimated monthly production at Gary Steel Works versus installed production capacity, overlaid with announced blast furnaces idling and restarts



Sources: USSC (2020), S&P Global (2020), Industrial Info Resources (2021), TransitionZero analysis

06 Potential use cases

The methodology in this whitepaper was developed specifically to help decision makers with steel sector decarbonisation. We considered these use cases principally because they all benefit from accurate and timely facility level production data.

Tracking transition risk and opportunity

The steel sector is becoming increasingly aware of the decarbonisation challenge, due to tightening environmental regulations[22], changing customer expectations[23] and growing obligations to investors.[24] For example, Baowu, ArcelorMittal, Nippon Steel, Hesteel, Posco, Tata Steel, thyssenkrupp, SSAB, Voestalpine, Salzgitter, Liberty House and Cliffs all have net zero by 2050 targets with interim targets in 2025 or 2030.[25] The transition to a zero carbon economy will create winners and losers as emission constraints force high cost and carbon intensive producers to reduce costs, decarbonise, rationalise capacity or seek bailouts. Understanding transition risk and opportunity requires a facility by facility analysis to estimate marginal costs, gross profitability and abatement opportunities. As utilisation rates vary from facility to facility, assuming a country average or technical nameplate utilisation rate will likely lead to inaccurate economic and financial modelling at the facility level.

Owing to different processes and end products, BF/BOF and EAF routes of production face different operational costs and challenges as society transitions to a zero carbon economy. The cost profile of BF/BOF and EAF production is dependent on three key variables: materials, energy and scrap.[26] Those BOF facilities which are fully integrated across their supply chain – meaning they own the mines producing the raw materials – have a distinct cost advantage of those BOF facilities that do not, as they can avoid the cyclical nature of commodity markets. For example, coking coal and iron ore prices have increased 75%[27] and 30%[28], respectively, from January to July 2021. Those BOF facilities that are not vertically integrated are price takers and therefore are subject to this price volatility on the seaborne market. EAFs faced a higher cost per ton of finished products, due to the higher impact that the electricity prices have on the electricity intensive nature of EAF production, especially in deregulated power markets.[29]

Retrofit costs

BF/BOF capacity is young, being around 13 years old on average, relative to a useful life of 40 years.[30] Therefore, strategies to deal with existing assets are considered integral to decarbonising steel. The average refurbishment lifecycle of BF/BOF production is 15 to 20 years.[31] These lengths vary depending on unit configuration, intensity of production and previous capital additions.[32] Owing to the relatively long refurbishment cycles of BF/BOF production, decision makers will have one or two chances to retrofit capacity to make it zero carbon-aligned by 2050. Based on a non-exhaustive list from the Mission Possible Partnership, zero carbon aligned abatement options include: BF/BOF with CCS and low carbon fuels or reductants, smelting reduction route with CCS and low carbon fuels or reductants, hydrogen direct reduced iron and low carbon EAF, iron ore electrolysis with low carbon electricity, and secondary route EAF with low carbon energy and primary steel quality.[33] These options are additional to material efficiency and technology performance gains from existing technologies. If these decisions are not taken on time, then stranded assets are all but inevitable.

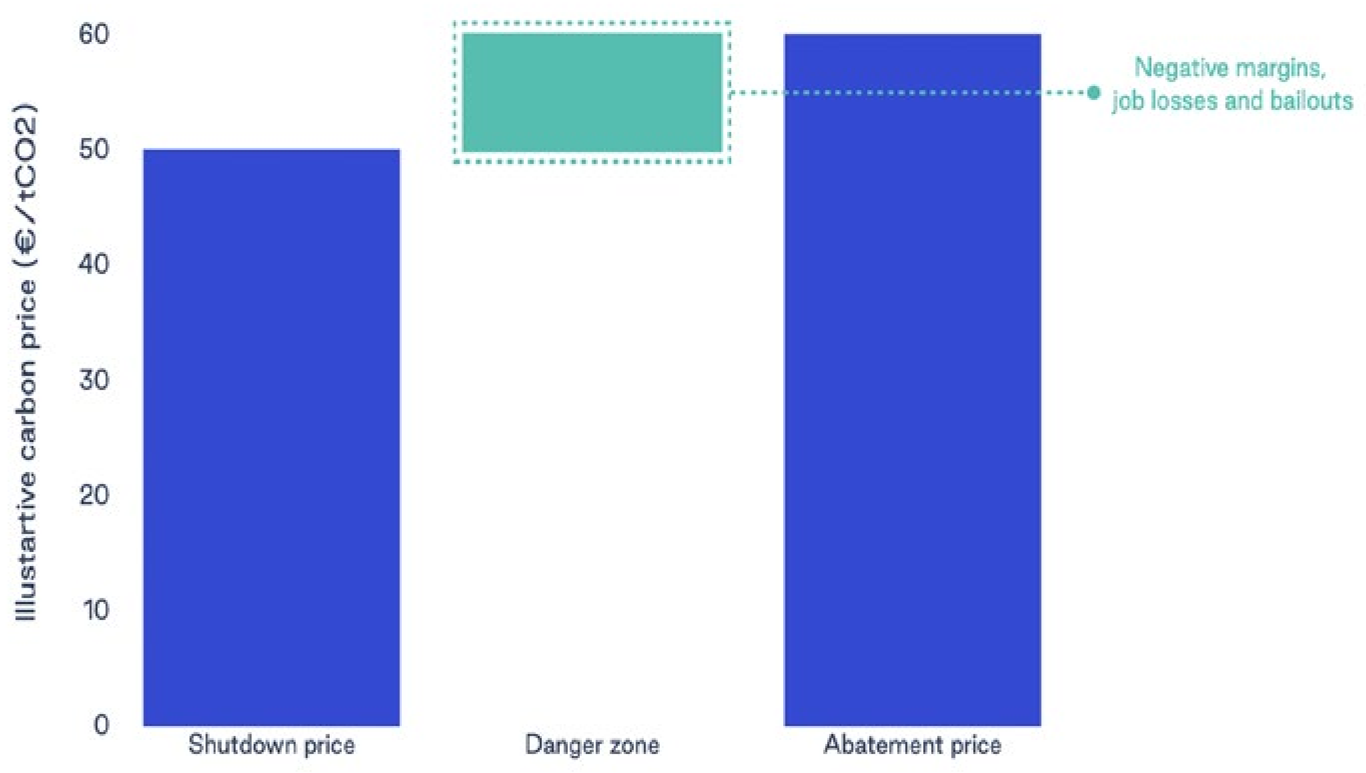
> Understanding transition risk and opportunity requires a facility by facility analysis to estimate marginal costs, profitability and abatement opportunities.

Shutdown costs

Interaction between carbon prices, abatement costs and capacity rationalisation or facility mothballing is going to be an important variable for policymakers to manage in the future. In regions such as the EU, which has a strong carbon price, there is limited transparency about the shutdown price in heavy industry and the price required to incentivise abatement at facility level. The shutdown price can be defined as the carbon price – net of free allocations and other subsidies – at which a facility will shut down or rationalise capacity. The difference between the shutdown and abatement price is what we consider the 'danger zone' as the owner can either mothball capacity or request subsidies to remain cash positive. The danger zone is where politicisation occurs, as there will either be job losses or government bailouts. The market price of EU carbon is around €50/tCO_2, but the effective carbon price for steel producers is substantially less due to free allocations. Nonetheless, as free allocations are phased-out due to the introduction of the EU carbon border adjustment mechanism (CBAM), closing the gap between the shutdown and abatement price will be essential to an orderly, timely and cost-effective transition in heavy industry.

> The difference between the shutdown and abatement price is what we consider the 'danger zone' as the owner can either mothball capacity or request subsidies to remain cash positive. The danger zone is where politicisation occurs, as there will either be job losses or government bailouts.

Figure 11. Interaction between carbon prices, abatement and shutdown costs



Sources: TransitionZero analysis
Notes: For illustrative purposes only. In this hypothetical scenario, the shutdown price assumes the net carbon price paid.

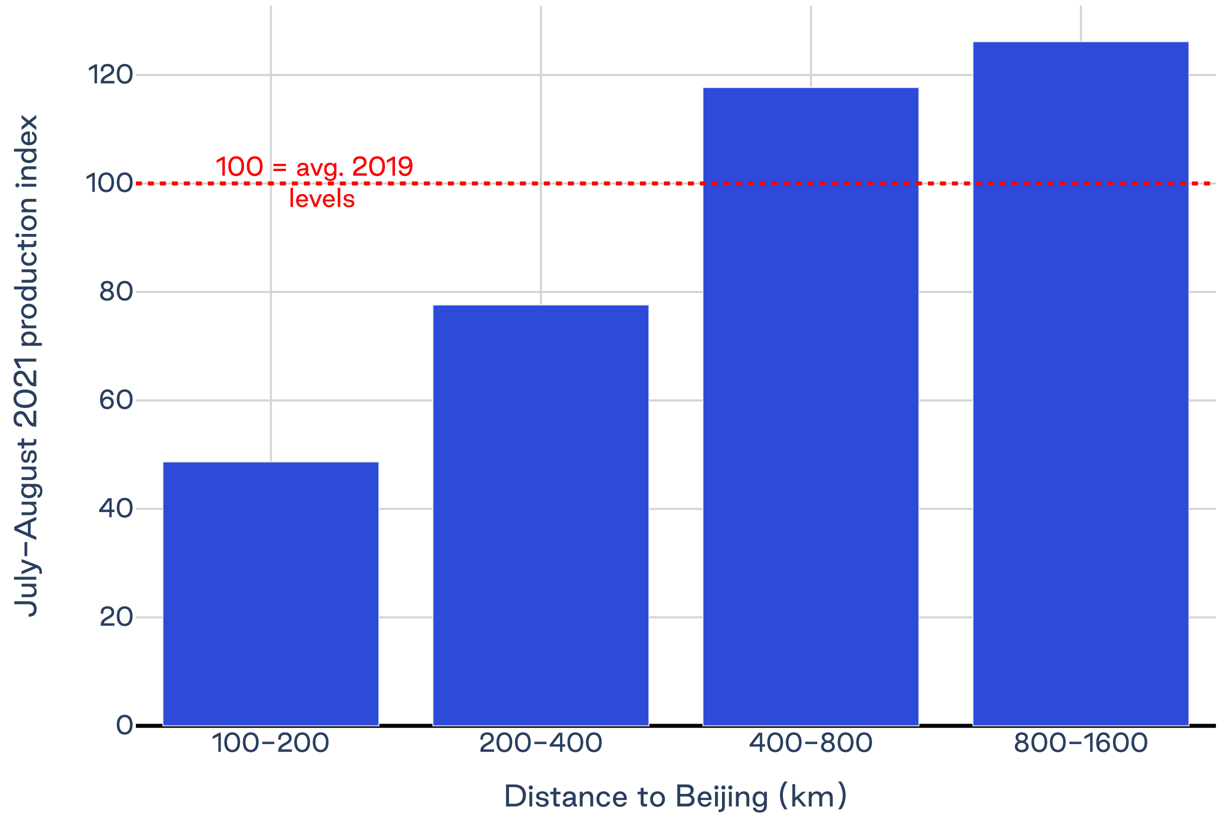
22. The EU carbon border adjustment mechanism, for example.
23. Audi has a goal of achieving carbon neutrality across its entire supply chain by 2050, for example. Audi (2020).
24. For example, the Institutional Investors Group on Climate Change recently published a sector strategy for steel as part of Climate Action 100+ initiative, outlining priority actions for steel producers and other value chain participants to align industry with the goals of the Paris Agreement. CA100+ (2021).
25. Mission Possible Partnership (2021).
26. This is a simplification as scrap is also a raw material.
27. Based on Australian Coking Coal prices from January 2021 to July 2021.
28. Based on Iron Ore 62% FE CME-NYMEX from January 4, 2021 to July 30, 2021.
29. Indirect ETS costs, transmission tariffs and renewable energy support, have on electro-intensive EAF producers, and the latter did not benefit from ETS free allocations as much as BF/BOF.
30. IEA (2020) and GEM (2021).
31. IEA (2020) and GEM (2021).
32. IEA (2020) and GEM (2021).
33. Mission Possible Partnership (2021).

Nowcasting production and emissions

Oversupply is a significant problem in the steel industry, with capacity exceeding production in China, US, Japan, South Korea, and Germany.[34] In China overcapacity has been a persistent problem. Steel capacity and production targets were part of a package of wider reforms in 2016, which aimed to wean China's economy off its reliance on construction sector stimulus for growth.[35] The State Council announced plans in February 2016 to reduce the production capacity of crude steel by 150Mt during the 13th Five Year Plan period from 2016 to 2020.[36] To promote industry consolidation, the central government has made considerable progress in closing old and inefficient BF/BOF facilities.[37]

However, this progress has been muted by government stimulus in response to COVID-19, which saw steel production increasing 10% year on year in both Q3 and Q4 of 2020.[38] In December 2020, the MIIT stated China must limit 2021 steel outputs to 2020 levels.[39] This commitment was reaffirmed in April this year, with a joint statement from the NDRC and MIIT to investigate excess steel construction and production.[40] These efforts appear to be taking effect. In July this year, production declined to 86.8Mt (-8% month on month) and, based on our estimates, August output is relatively flat, up slightly at 88.0Mt (1% month on month). While the outputs of the last months are a step in the right direction, our analysis reveals production cuts depend on the location of the facility. The output of facilities closer to Beijing dropped throughout July and August, while those further away from the capital maintained output over the same period. As illustrated in Figure 12, the big production hubs in Hebei and Shandong provinces that neighbour Beijing are driving the curb in output observed in the recent months.[41]

Figure 12. Production index for Chinese steel mills between July and August 2021, compared to their distance to Beijing

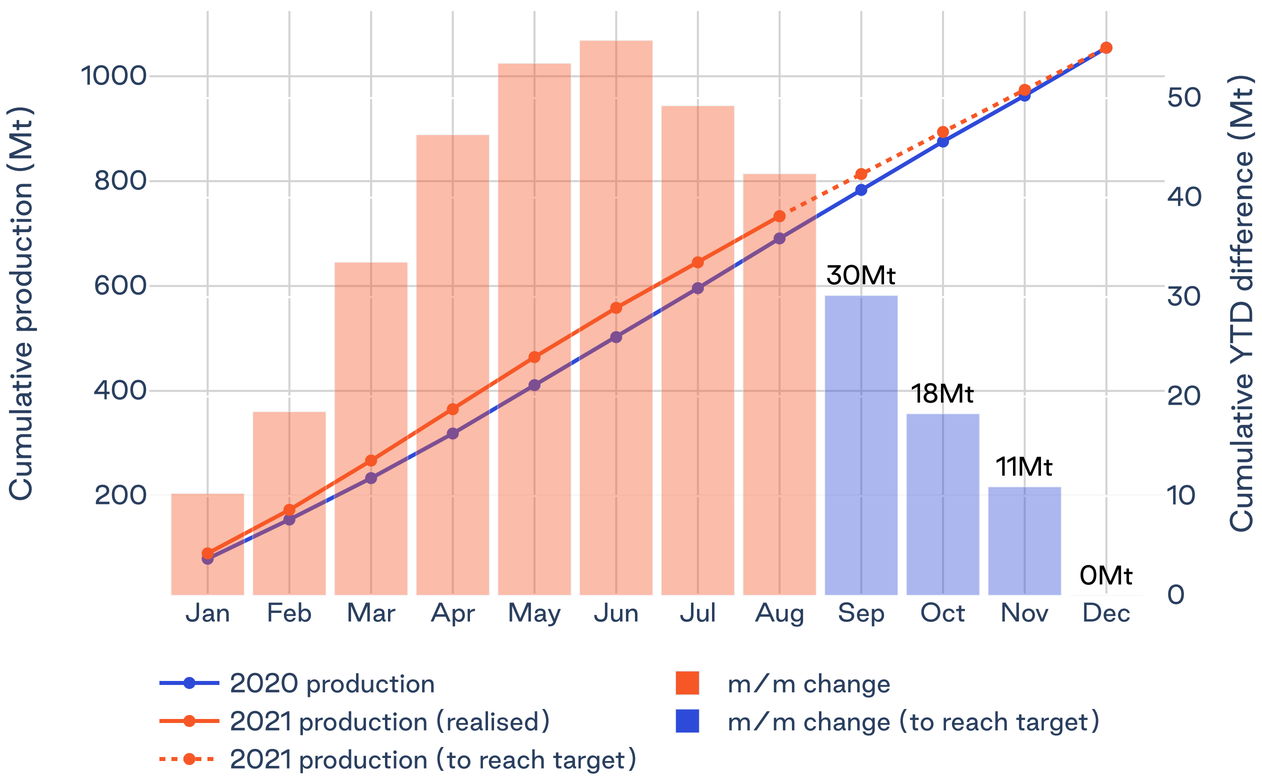


Sources: Industral Info Resources (2021), TransitionZero analysis

Our analysis shows China will need to take further action in Central and Western provinces.to reduce production below 2020 levels. Without further intervention, China's steel output could be up 4% to 7% in 2021. Given carbon intensive BF/BOF routes make up nearly 90% of China's production, this possible policy miss has significant climate implications: the year on year growth in China's steel production without a further crackdown would result in an additional 155.5Mt of CO2 - the equivalent of the Netherlands total emissions. A top-down crackdown appears to be the only way for the nation to systematically resolve these issues to meet its carbon neutrality goals. Whether the central government has the political capital to intervene this year across all provinces remains to be seen. In the future, as detailed in Turning the Supertanker, we recommend the central government establish an anomaly detection system to detect possible non compliance events at facility level.

34. GEM (2021).
35. NDRC (2016).
36. Economist Intelligence Unit (2016).
37. McKinsey & Company (2018).
38. Carbon Brief (2020).
39. Argus (2020). Per China Daily (2021), these statements differ from the China Metallurgical Industry Planning and Research Institute, which expects steel production to reach 1,070Mt in 2021.
40. Reuters (2021).
41. Hebei and Shandong represent 25% and 9% of China crude steel capacity, respectively, according to Industrial Info Resources (2021).

Figure 13. Cumulative and YTD difference for steel production in 2020 and 2021



Sources: TransitionZero analysis

Tracking carbon intensity of supply chains

The fundamental lack of data is becoming a particularly important issue for policymakers who are interested in measuring carbon intensity of heavy industry products and investors who want to finance abatement options.

EU carbon border adjustment mechanism

As part of the "Fit for 55" proposal the EU introduced CBAM.[41] If the proposal is adopted without change, EU importers will have to report emissions embedded in iron, steel, cement, fertilizer, aluminum, and electricity generation as from January 2023. EU importers will start paying a financial adjustment from January 2026. The purpose of the CBAM is to ensure importers pay the same carbon price as domestic producers under the EU ETS to avoid carbon leakage. The CBAM is based on the purchase of EU ETS allowances by importers. The price of the certificates will be calculated depending on the weekly average auction price of EU ETS allowances. Importers will have to register with national authorities and buy the equivalent certificates to comply with CBAM. The national authorities will be responsible for reviewing importer registrations, declaring the quantity of goods and buying the relevant number of certificates.

If information on the carbon intensity is not available, importers will be assigned default values on carbon emissions for each product to determine the number of certificates they need. The default values are still to be determined but will likely be conservative. Therefore, importers should be incentivised to demonstrate their own emissions to reduce CBAM compliance costs, especially if EU ETS prices keep increasing. Indeed, encouraging importers to demonstrate carbon efficiency would provide an economic incentive to increase their energy and carbon efficiency. Facility carbon emissions vary depending on several variables. While production is only one piece of the puzzle, when combined with other data sources, facility utilisation data makes measuring carbon emissions possible. What is clear is the quality and availability of emissions data will need to increase significantly for importers to move beyond the default values and for the EU to create incentives to improve the carbon intensity of heavy industry abroad.

42. EU Commission (2021).

07 Conclusion

In this whitepaper we present a novel methodology for estimating steel production at facility level. We argue facility production estimates are an important variable to develop practical use cases to help the steel sector align with the temperature goal in the Paris Agreement. The use cases described in this whitepaper are illustrative in nature and should be seen as examples of how production data can transform information flows to improve decision making as the steel sector transitions to become zero carbon.

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09 Appendices

As detailed in Table 5, a description of results for individual facilities as well as any additional contextual information needed for interpretation follows.

Table 5. Facility data comparision with TransitionZero model estimates

Facility	Owner	Production capacity (Mt)	Reported production (Mt)	TZ estimated production (Mt)	MAE (%)	Explanation
Dabrowa Gornicza	ArcelorMittal	4.5	3.6 (2019)	4.4	22	Error within reasonable bounds.
Middletown Steel	Cleveland-Cliffs	2.7	2 (2019)	2.3	15	Error within reasonable bounds.
Dearborn Steel	Cleveland-Cliffs	2.3	1.7 (2019)	2	18	Error within reasonable bounds.
Galati Steel	ArcelorMittal	2.1	2.1 (2018)	2.9	38	There are two things worth noting here. First, the satellite based estimates exceed annual production capacity. This is an artifact of our models being allowed to break capacity constraints to some extent. This decision was taken because our ground truth capacity data might not be up to date in all cases, and may disagree with other sources. For this reason, allowing constraint violations improved results. In this case, an alternative capacity source (GEM) quotes a capacity of 3Mt which, reassuringly, our prediction does not exceed.
Eissenhuttenstadt Steel	ArcelorMittal	1.8	2.1 (2018), 2 (2019)	0.9 (2018), 0.8 (2019)	59	This is a fairly large discrepancy and is best accounted for by the risks associated with our modelling approach, as described earlier.
Bremen Steel	ArcelorMittal	3.6	3.4 (2018) 3.1 (2019)	2.8 (2018), 3 (2019)	10	This is a reassuringly accurate average discrepancy over two years.
Gent Steel	ArcelorMittal	5.5	5.4 (2018), 5.5 (2019)	5.4 (2018), 5.8 (2019)	3	This gives a very reassuring average discrepancy of just 3%, with the trend also being captured (though the difference is small so the trend capture is probably not statistically significant). Production estimates exceed ostensible capacity slightly, though not by a concerning amount (well within the bounds of data source error).
Taranto Steel	ArcelorMittal	9.5	4.2 (2018), 4.3 (2019)	6 (2018), 5.9 (2019)	40	This gives a relatively large average discrepancy of 40.6%. This is partially explained by the fact that the facility is operating at a low utilisation rate but our models have a tendency to bias towards predicting nearer to capacity.
Fos-Sur-Mer Steel	ArcelorMittal	5.5	3.7 (2018), 3.8 (2019)	2.7 (2018), 2.8 (2019)	27	This discrepancy is within reasonable bounds given our occasionally limited ability of our approach to capture facility level variation.
Dunkerque Steel	ArcelorMittal	7	6.8 (2018), 6.2 (2019)	3.2 (2018), 3.1 (2019)	51	This gives a large average discrepancy of 51.8%. Again, this is an artifact of the occasional inability of our models to disaggregate country level production to the facility level in an appropriate way.
Burns Harbor	Cleveland-Cliffs	5	4.2 (2019)	3.5	17	Discrepancy within reasonable bounds.
Cleveland Steel Works	Cleveland-Cliffs	3.8	3 (2019)	1.7 (2019)	43	This discrepancy is due to the natural error that arises in disaggregating a country-level signal that includes blast furnace and electric arc furnace production into facility-level blast furnace prediction.

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