Definitions of stainless/ high alloy steels…

Stainless Steels
> 10.5% chromium

High-Alloy Steels
> 8% alloys by weight

Alloy Steels
> 4 % alloys by weight

Proposal for discussion

- The more complex approach for defining high alloy/ stainless steel thresholds *must* be used when the total amount of alloy elements is >= 8% by weight, and *may* be used when the total amount of alloy elements is >=4% by weight.

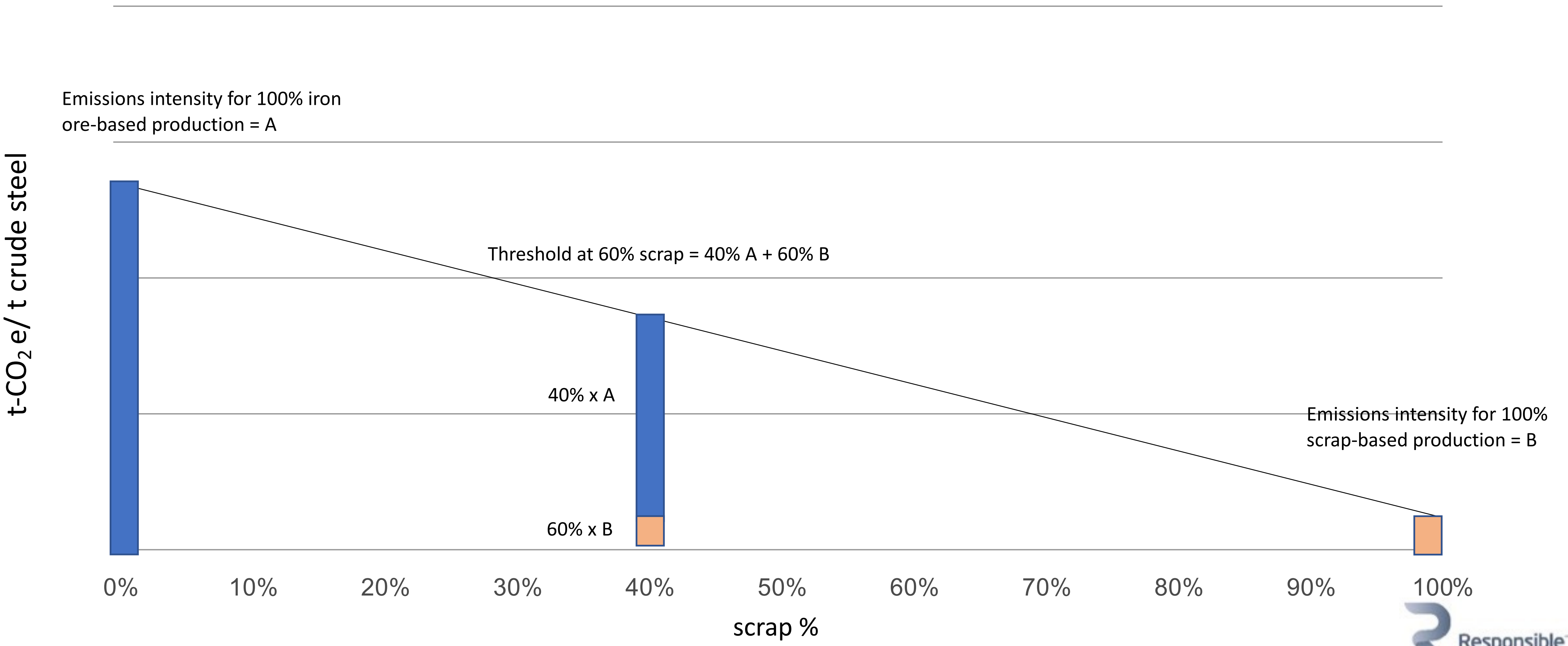
Application of GHG threshold levels to stainless/high alloy steels

- Which alloying metals make a significant contribution to the GHG emissions intensity of high alloy/ stainless steels:
  - Al, B, Co, Cr, Mo, Mg, Mn, Nb, Ni, P, Si, Ti, V, W
  - Ferro alloys
  - Nickel Pig Iron (NPI)
  - Scrap

- Could any of these be excluded from consideration?
- Would we need to consider e.g. Nickel Pig Iron vs Nickel metal as two completely different materials?

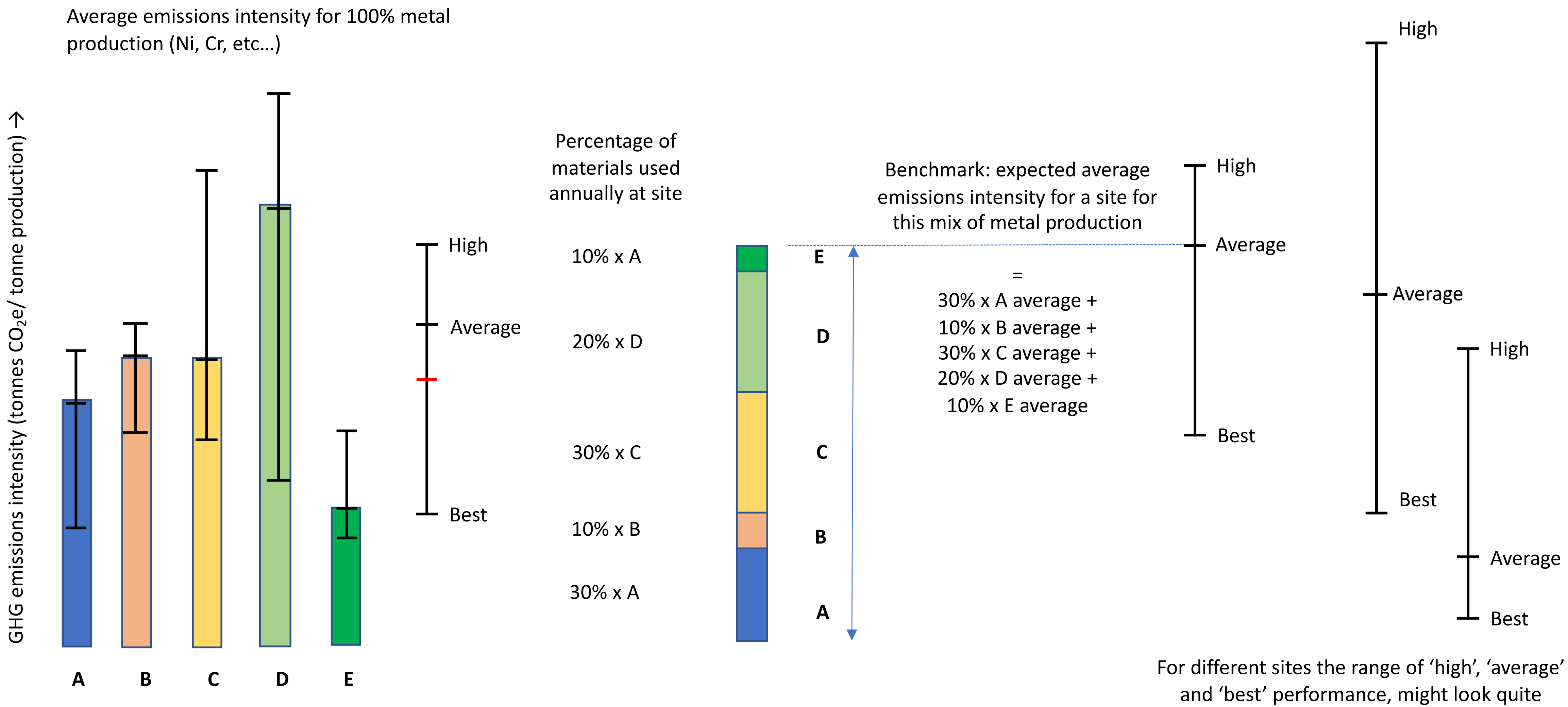
For carbon steels, we consider the range of GHG emissions for just two input materials: iron ore and scrap, and can calculate the threshold for any particular percentage of scrap taking account of the emissions intensity for 100% iron ore based steelmaking and for 100% scrap based steelmaking:

Threshold (for given percentage of scrap) = *((emissions intensity of 100% iron ore-based production, A) x (percentage of iron ore) + (emissions intensity of 100% scrap-based production, B) x (100 - percentage of scrap).*



Responsible Steel

In principle, we can generalise the same approach to include any number of materials. Could this be a basis for determining thresholds for sites producing stainless and high alloy steels?



For different sites the range of 'high', 'average' and 'best' performance, might look quite different, depending on the particular mix of metals used

Developing and testing the model benchmarking approach

- Key 'output' metals to consider to develop and test the model: Cr, Ni, Mo, Fe, Mn
- Other key inputs to consider: Lime, oxygen, nitrogen, energy (scope 2)
- Scrap
- Direct emissions

Considerations

- Requires an 'average' and a 'near zero target' emissions intensity factor for the production of a tonne of each of the key output metals (for the purpose of the initial model, Cr, Ni, Mo, Fe, Mn)
- Need to know that steelmaker can calculate the quantity of key output metals produced over a 12 month period. This requires:
  - The site has accessible data on the proportion of key output metals in each grade
  - The site has accessible data on the annual production of each metal grade at the site;
- Need basis for considering direct emissions
- Need basis and data for considering consumable input materials (lime, O_2, N_2)
- Need basis and data for considering emissions associated with electricity generation
- Need specifications for basis for suppliers to determine and submit their own emissions for input materials

Average emissions data : preliminary estimates for purpose of model development: output side

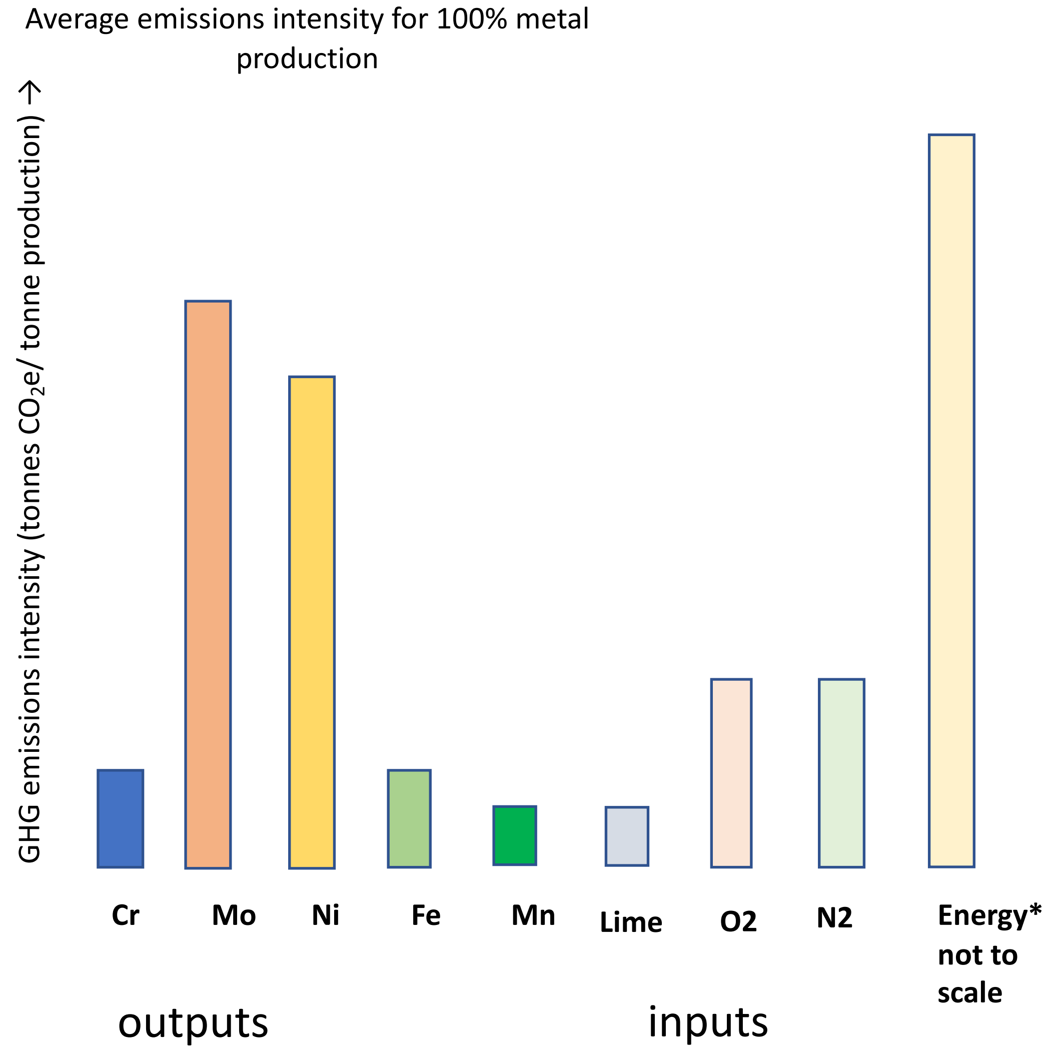
	Average tCO2-eq/t	Nuss (2014)	Figure to test model	References and notes
Cr*		2.4	2.4	
Mo* (FeMo, 60%Mo)	5.3 to 24.7 (3.16 to 14.79)	5.7	15.0	Wei et al (2020b) – very wide range, not clear what would be the global average The total energy required for producing 1 tonne of FeMo can vary between 29.1 GJ/t FeMo and 188.6 GJ/t FeMo. Furthermore, the corresponding GHG emissions differ from 3.16 tCO_2-eq/t FeMo to 14.79 tCO_2-eq/t FeMo. Wei (2021, page 31). NB allocation is critical, with co-production with Cu.
Ni*	14 13	6.5	13.0	Upstream scope 3 excluded from Ni metal value? Wei et al (2020a) Nickel Institute LCA (ISO14040), excluding China. Other LCA figures given: FerroNi: 45kg/kg; $NISO_4$:5.4kg/kg; NPI(not included)
Fe*	2.5	1.5	?	This would be 100% iron ore. 100% scrap would be more like 0.5 tCO2-eq/t
Mn*		1.0	1.0	

Average emissions data : preliminary estimates for purpose of model development: input side

	Average tCO2-eq/t	Nuss (2014)	Figure to test model	References and notes
Lime	0.75 0.9		0.8	IPCC database EF-ID 213928 for lime production (1996)m Table 3, Wei et al (2020a) Table C1, EN19694-2:2016 gives emissions factor of 0.44 for limestone, 0.0238 burnt lime and 0.471 for dolomite, but this is focused on direct emissions not upstream. Indirect emissions are given as 0.95 for burnt lime and 1.1 for dolime – not given for limestone or crude dolomite
Oxygen	5		5	Table 3, Wei et al (2020a) Table C2, EN19694-2:2016 gives emissions factors ofr Nitrogen and low/high pressure Oxygen in terms of upstream energy, which needs to be converted using an energy emissions factor..
Nitrogen			?	Table C2, EN19694-2:2016 gives emissions factors of Nitrogen and low/high pressure Oxygen in terms of upstream energy, which needs to be converted using an energy emissions factor. I haven't tried to convert into emissions for stainless
Energy (scope 2)	0.565 t /MWh]		0.565 t /MWh]	Table C1, EN19694-6:2016, 2010 data. IEA has more up to date information, but not publicly accessible without subscription
Scrap	-	-	0	Defined as zero emissions, plus transportation
Direct emissions			0	Process CO2 emissions in Wei(2021) case studies vary from 0.07 to 0.084 tonnes/tonne SS, vs 2.5 to 3.4 t/t for indirect – propose to ignore

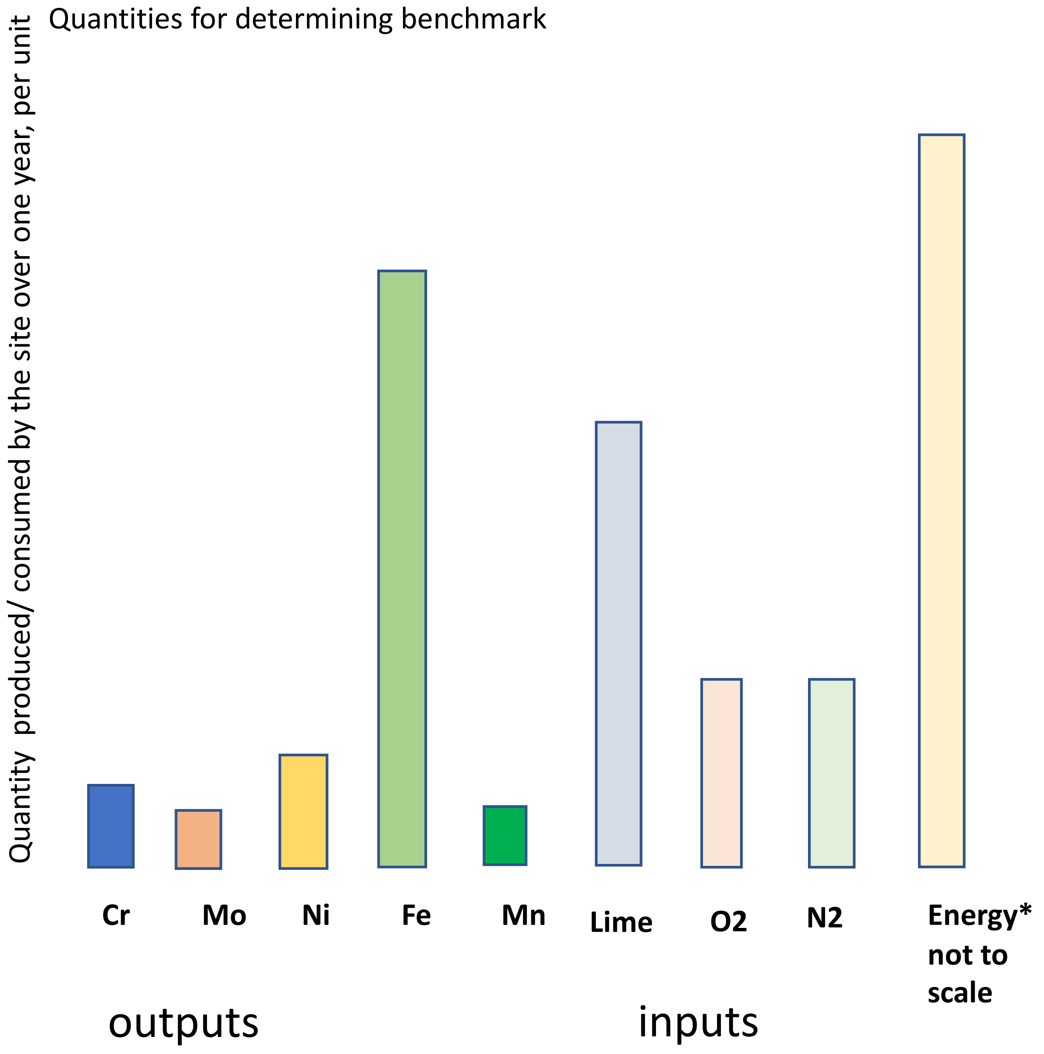
Average emissions data: preliminary estimates for purpose of model development

	Model test data	Units
Cr	2.4	tCO2-eq/t output metal
Mo	15.0	tCO2-eq/t output metal
Ni	13.0	tCO2-eq/t output metal
Fe	?	tCO2-eq/t output metal
Mn	1.0	tCO2-eq/t output metal
Lime	0.8	tCO2-eq/t input material
Oxygen	5	tCO2-eq/t input material
Nitrogen	(5?)	tCO2-eq/t input material
Energy (scope 2)	0.565 t /MWh]	tCO2-eq/MWh
Scrap	0	NA
Direct emissions	0	NA



Annual input/output data for a theoretical site

	Model test data	Units
Cr	180,000	Tonnes/yr
Mo	20,000	Tonnes/yr
Ni	80,000	Tonnes/yr
Fe	700,000	Tonnes/yr
Mn	20,000	Tonnes/yr
Lime	1,000,000?	Tonnes/yr
Oxygen	?	Tonnes/yr
Nitrogen	?	Tonnes/yr
Energy (scope 2)	2,000,000?	MWh
Scrap	?	NA
Direct emissions	?	NA



Overall emissions of stainless steel (ISSF, 2016)

- Ni: 23.8%
- Cr: 34.9%
- Mo: 0.5%
- Others: 8.6%
- Electricity: 17.0%, 0.49 tonnes/ tonne SS
- Direct emissions: 15.2%, 0.44 tonnes/tonne SS