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Optimizing scrap use to focus on reducing CO2 emissions

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06/12/2023

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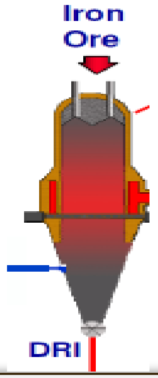
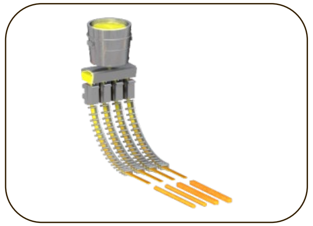
Emirates steel process route



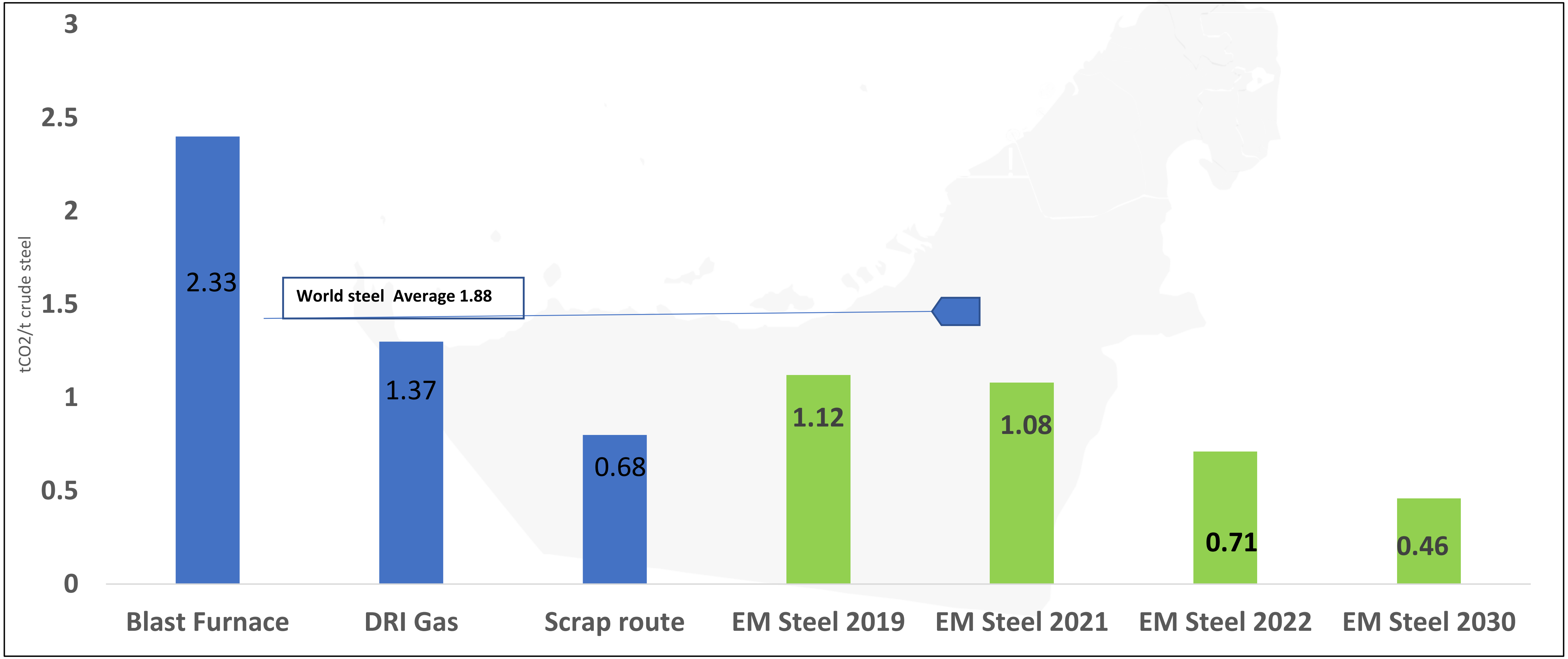


Raw Material → Direct Reduction → Steel Making (EAF) → Ladle Treatment → Billet and beam blank)

Direct Reduction Process	Steel Making	Rolling	Finished Products	
Three Direct reduction plants with a capacity of 4.2MTPA	Three Steel Making plants with a capacity of 3.6 MTPA	Three rebar mills and a Wire rod mill	Rebars, wire rod, sheet piles and heavy sections	
Iron oxide pellets > direct reduction iron > steel making	• Steel billets • Beam blanks	• Heavy section mill with a capacity of 1.0 Mt • Three rebar mills with a capacity of 2.0 Mt • Wire rod mill with a capacity of 0.5 Mt	Sheet piles	Wire rod
			Heavy sections	Rebar in coils
			Rebars	

ESA’s steel decarbonization aligned with UAE’s commitment to the Paris Agreement

Scope 1&2 CO2 intensity for steel production (tCO2/t crude steel)



Reference – world steel Sustainability Indicators report 2023 , Emirates steel Arkan sustainability report,2022

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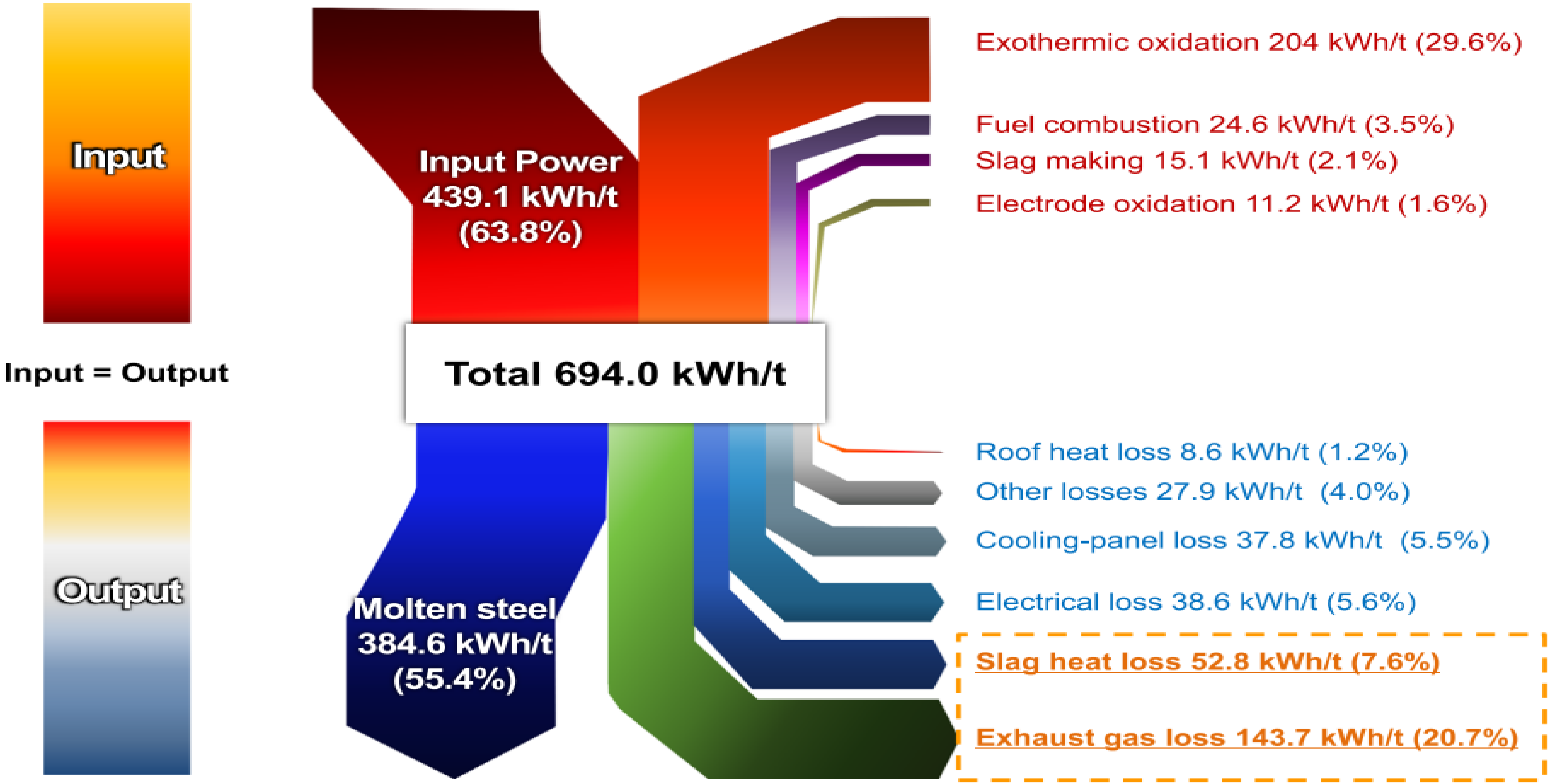
Energy balance in Electric arc furnace



Reference -Lee, B., & Sohn, I. (2014). Review of Innovative Energy Savings Technology for the Electric Arc Furnace. The Minerals, Metals & Materials Society

Technology and development

DRI

- Increase DRI Temp. by Natural gas (NG)heater
- Increase DRI Temp. by Optimizing DRI %C

EAF

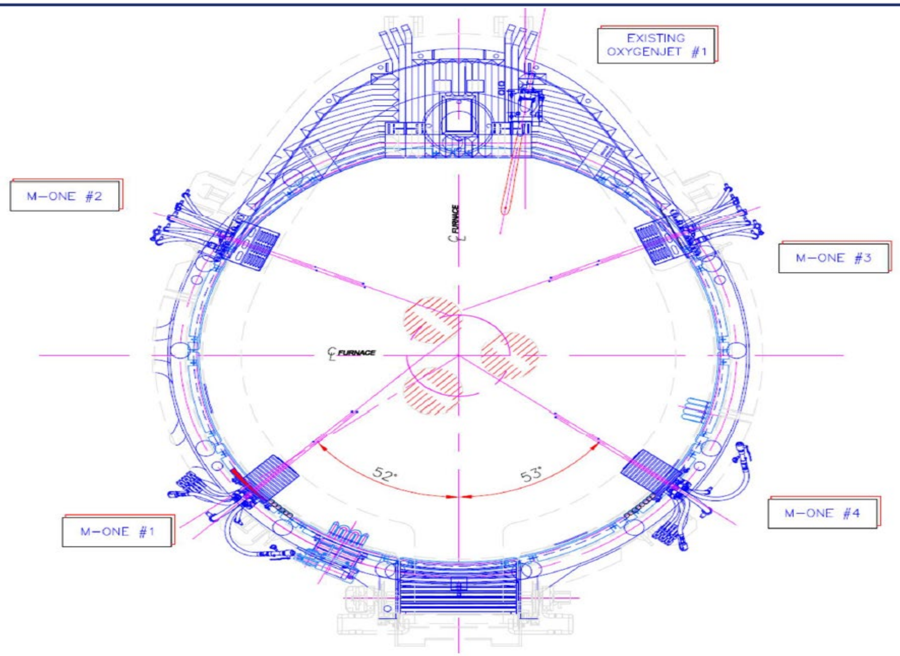
- M1 injector to increase %Scrap
- EAF off-gas analyzer to Optimize EAF Process

AI/ML model

- ML models to predict Energy, Productivity, CO2 emission
- Single and Multi-objective Optimization models .

M - One (all-in-one Injector)

- Advanced fixed wall-mounted injector- M-One
- Mixed swirled flame burner (MSF)
- High efficiency supersonic coherent oxygen lancing
- High momentum powdered solid injector



Old Oxygen Injector Specification

- ✓ Oxygen Nozzle - Laval
- ✓ Supersonic speed – Mech 2
- ✓ Oxygen Jet Length – 1.3-1.4 Meter
- ✓ Shrouding - N/A
- ✓ Burner Mode – N/A
- ✓ O2 Flow – 1500 Nm3/Hr.
- ✓ Carbon injection – Different location

New M-One Injector Specification

- ✓ Oxygen Nozzle - Laval
- ✓ Supersonic speed – Mech 2
- ✓ Oxygen Jet Length – 2.0 Meter
- ✓ Shrouding - Yes
- ✓ Burner Mode – Yes (4 MW)
- ✓ O2 Flow – 2200 Nm3/Hr.
- ✓ Carbon injection - Single unit
- ✓ Carbon injection - 25-65m/s

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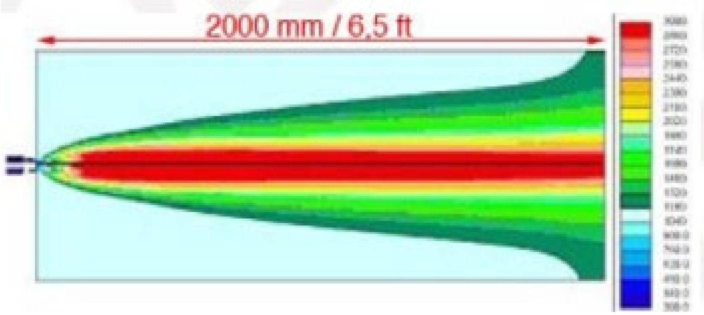
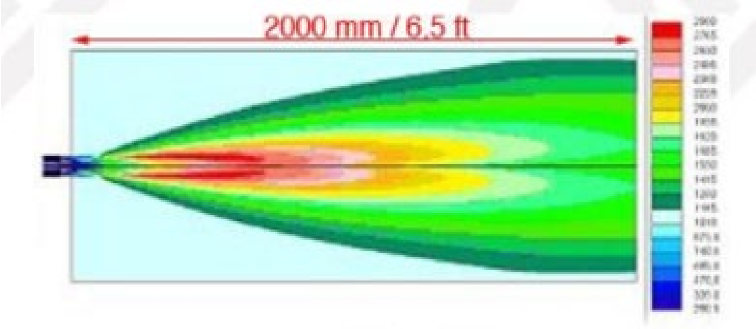
M-one Burner



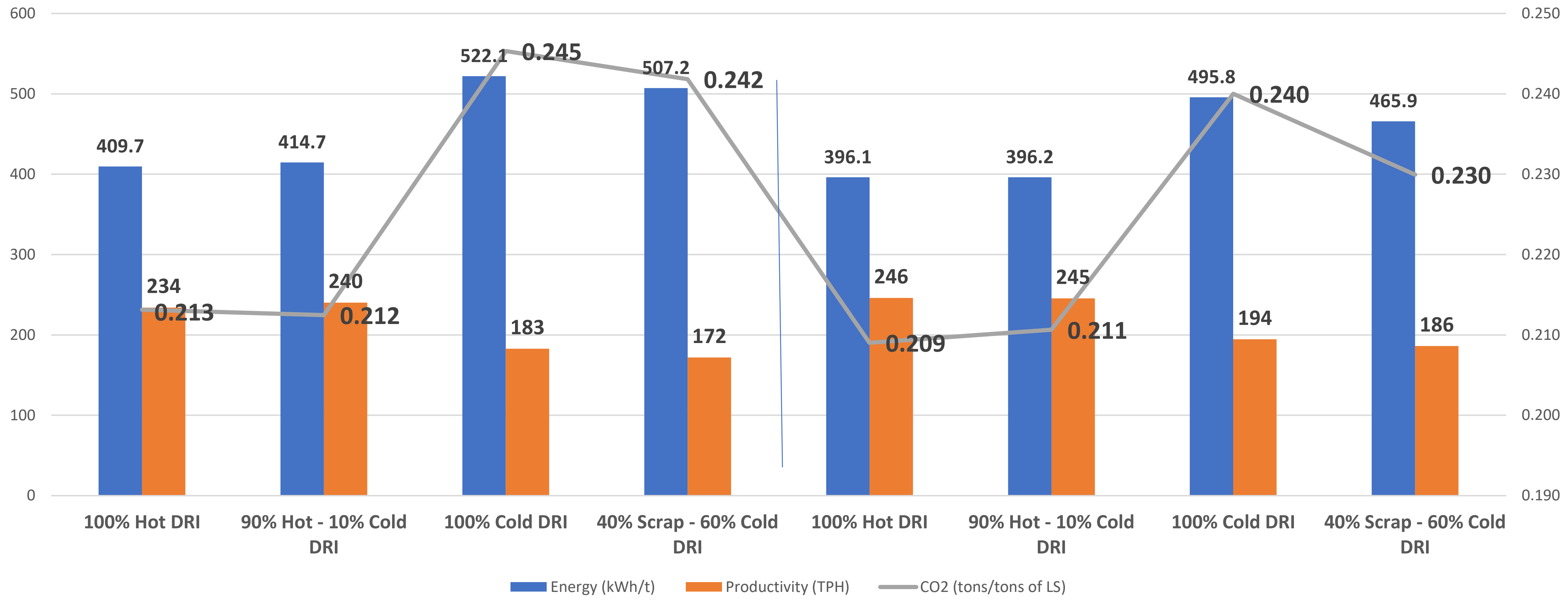


MIXED SWIRLED FLAME

CONVENTIONAL AXIAL DIFFUSION FLAME

- The burner tip was designed to improve the mixing of reactants and avoid the generation of a cold flame

M-one injector performance

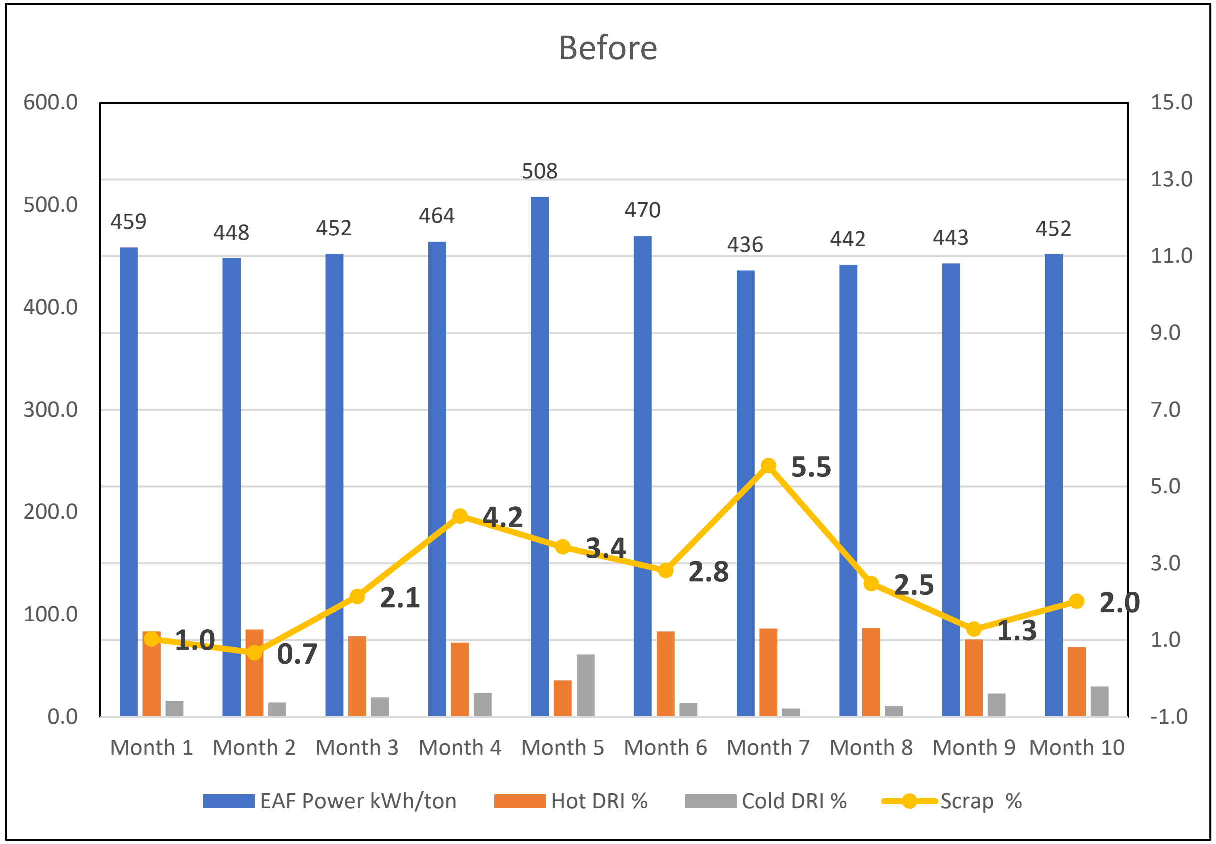


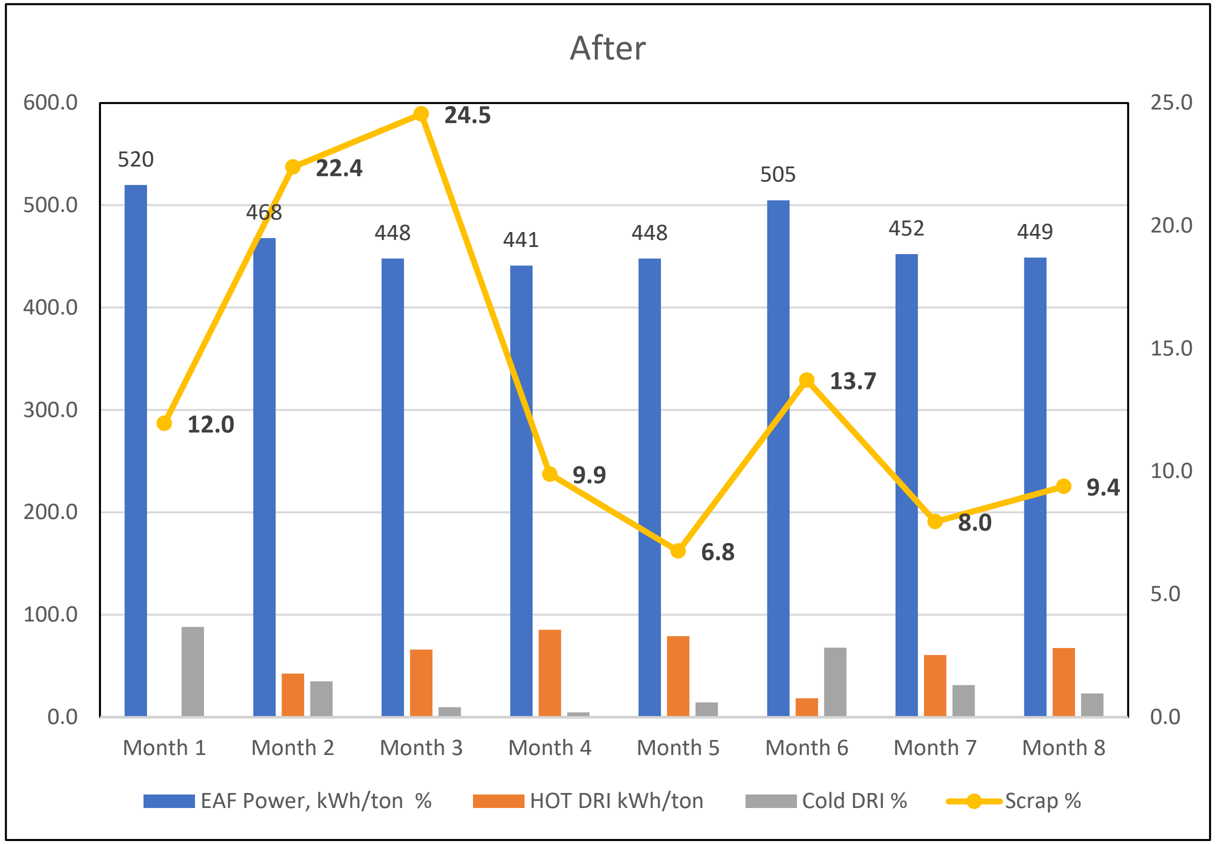
DRI Metallization 94%

DRI C% -2.3

DRI Temp- 430 Deg C.

Monthly % Scrap before and after Injector modification





Average % scrap increased from 3 to 12% after modification of M-One injector

Data Analysis and Machine learning model developed

- Operational data analysis for different charge mix (Hot DRI, Cold DRI and Scrap) for optimum energy , productivity and CO_2 emission.
- AI model was developed to Predict EAF energy.
- Coefficient of co-relation between model input parameter with Specific energy.
- Optimization model was developed for optimum energy , productivity and CO_2 emission at EAF.

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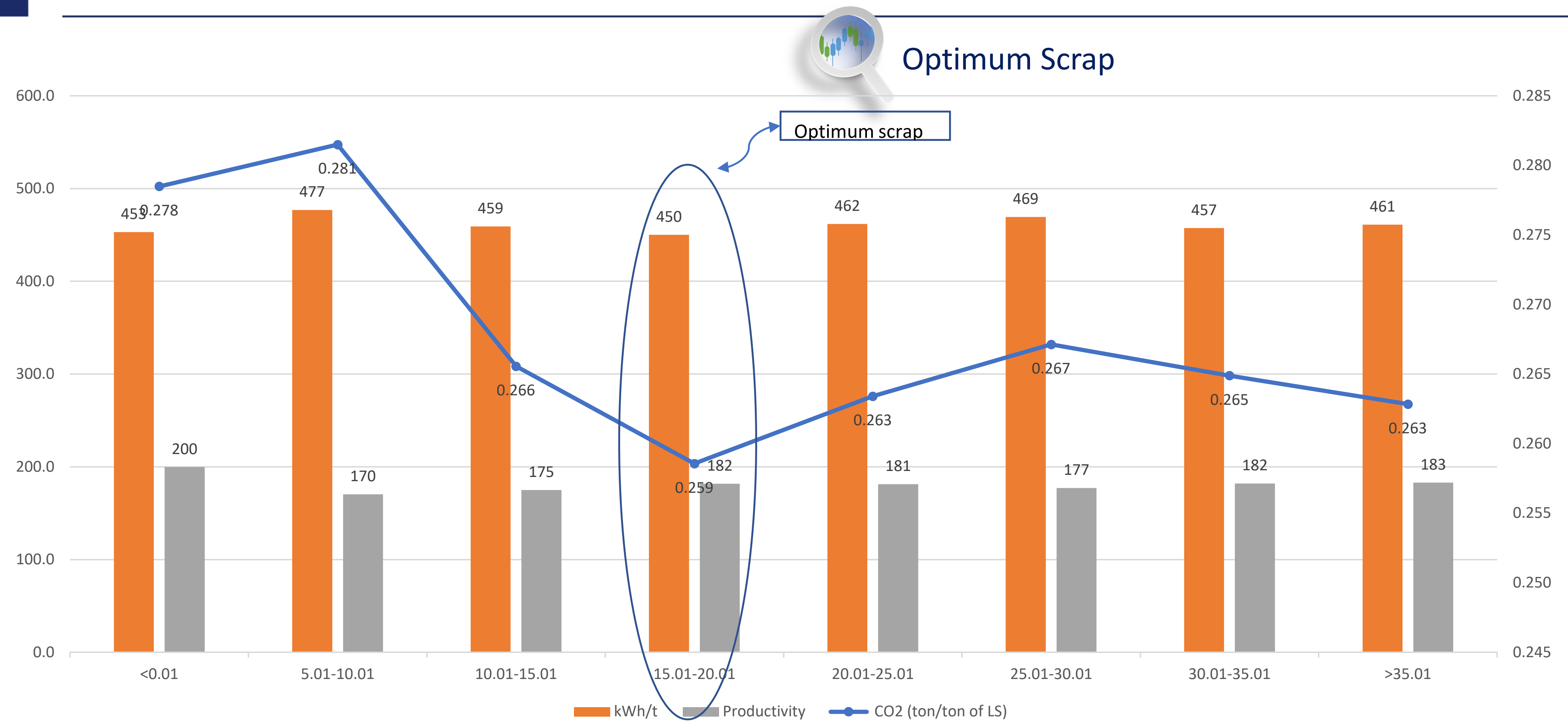
Energy, Productivity and CO2 for different %Scrap



- CO2 emission reduces with increased scrap % in the charge mix.
- Optimum scrap is 15-20% for high productivity, Low energy and CO2 emission

Steps for model development

- Step 1: Data collection and data inspection
- Step 2: Data preprocessing and data conditioning
- Step 3: Selection of relevant input output variables
- Step 4: Align data
- Step 5: Model parameter selection, training and validation
- Step 6: Model acceptance and model tuning

Modelling technique

The dataset is divided into three:

i) Training dataset
ii) Testing dataset
iii) Validation dataset

- By training dataset ANN build the model by changing weights and biases.
- The built-up model is validated by validation dataset

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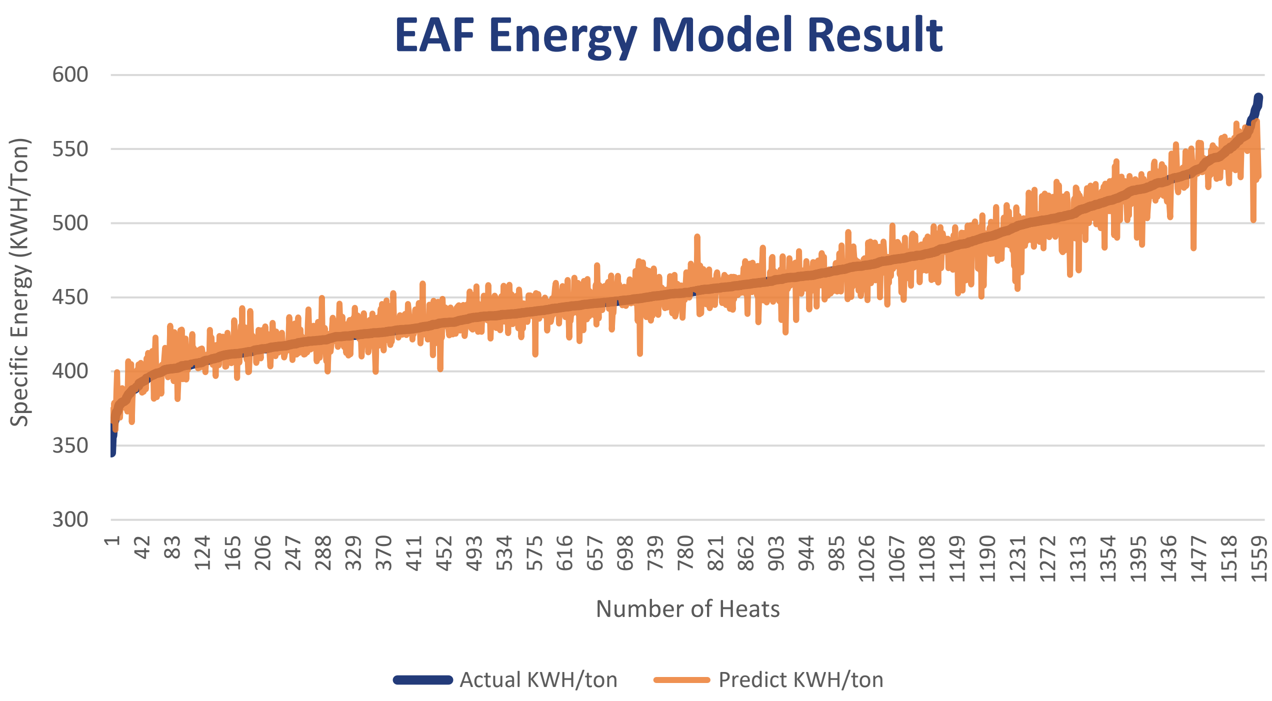
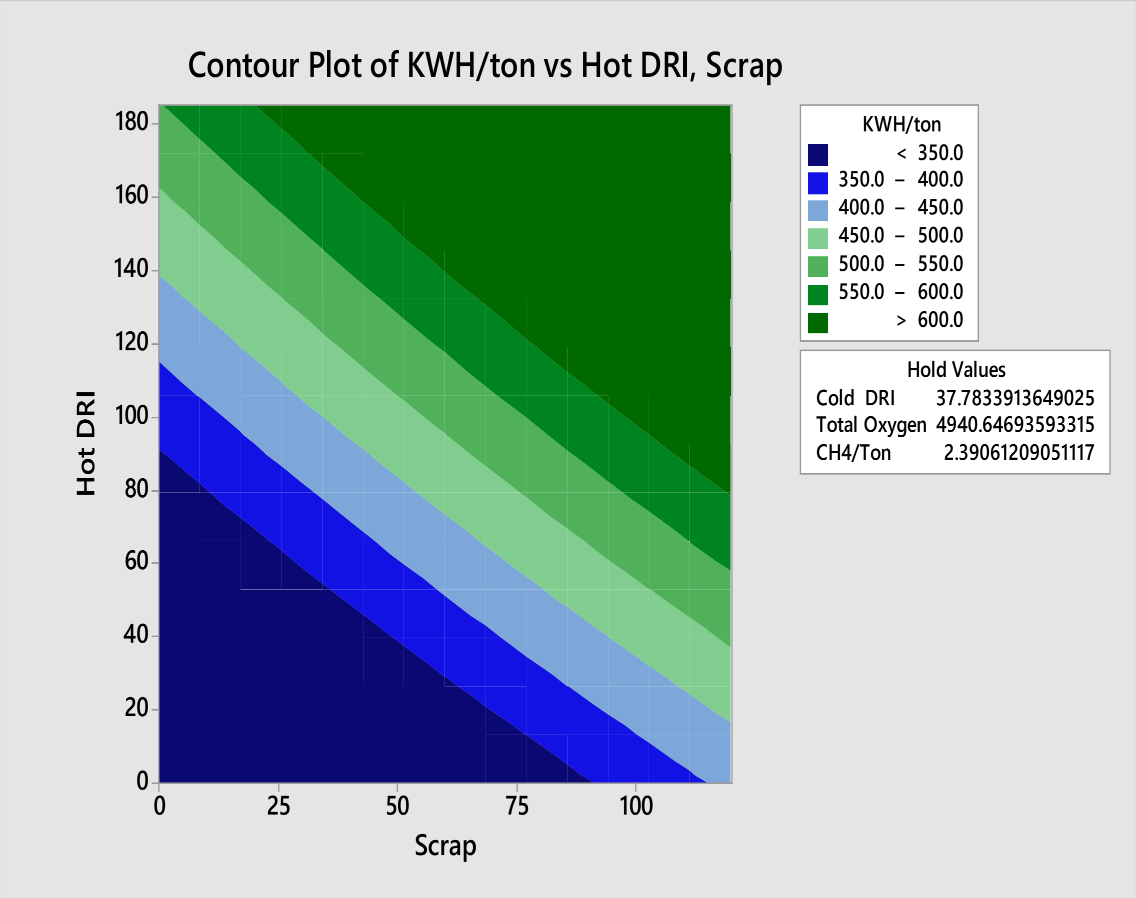
ML Model ,Artificial Neural network model (ANN)

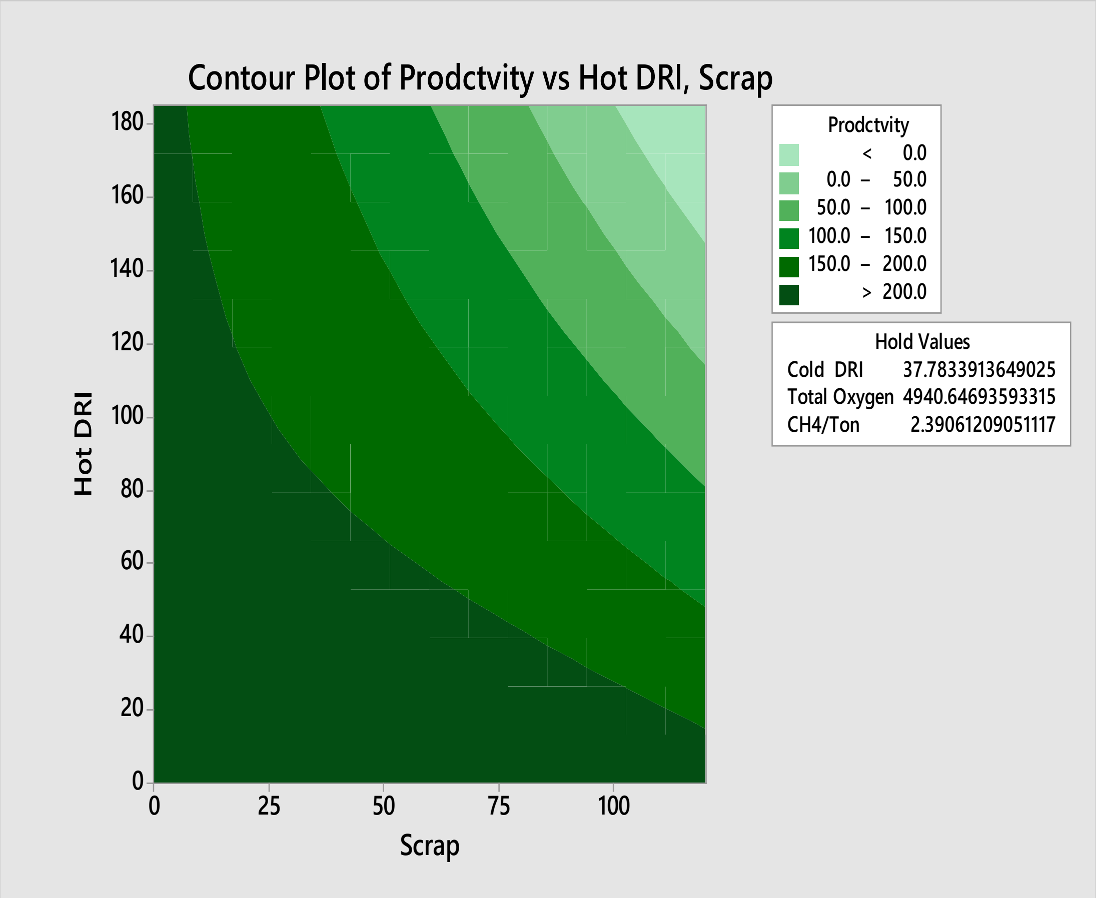


Metrics	Training Set	Test Set
R-squared (R2)	0.89	0.88
RMSE	0.51	0.50
Average error percent (%)	1.38	1.37

- The results demonstrate the model's accuracy and predictive Energy, as evidenced by high R^2 values close to 0.9 on both the training and test sets.

Optimization Plot

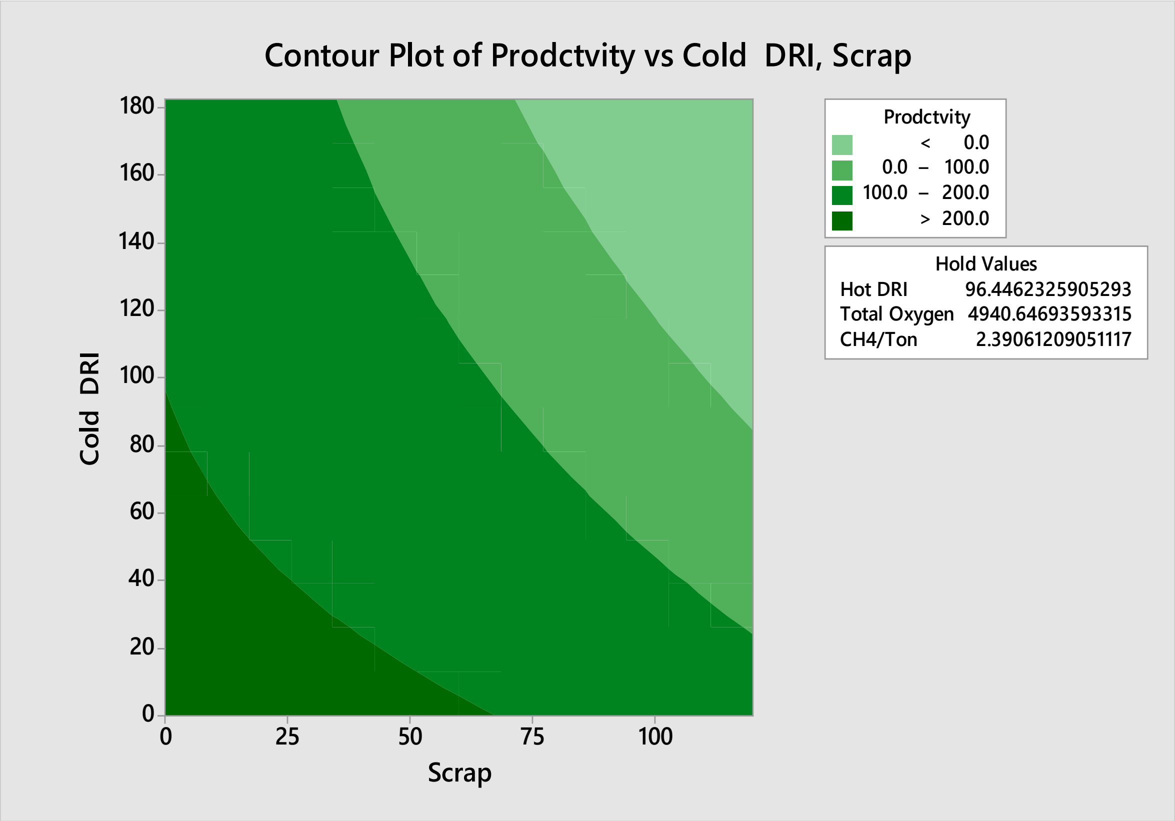


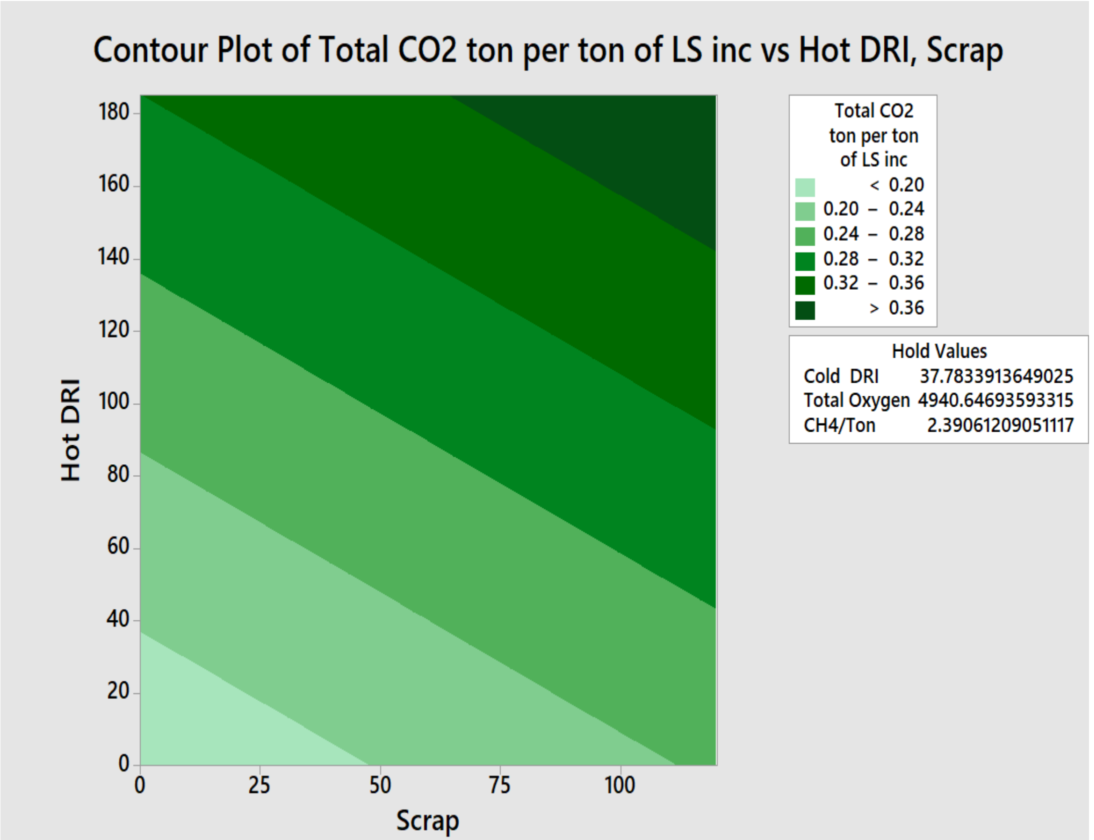


Optimization Specific energy With variation of HDRI and Scarp

Optimization of productivity With variation of HDRI and Scarp

Optimization Plot





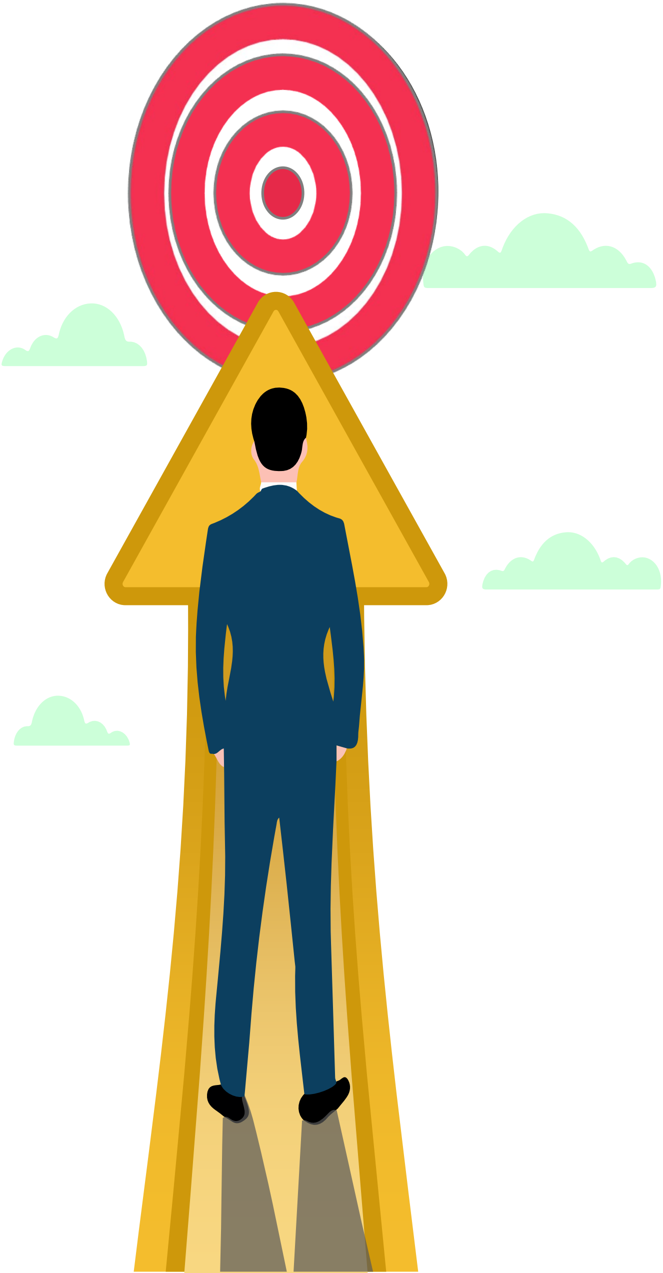
Optimization productivity with variation of CDRI and scrap

Optimization of CO2emission with variation of HDRI and scrap

Conclusion

- Scrap% Increases after implementation of M-One injector .
- With the current setup 15 -20% Scrap uses will be optimum for energy and CO2 emission.
- ANN model having higher R^2 values close to 0.9 on both the training and test sets indicates accuracy of Energy predication.
- Coefficient of corelation of model input parameters with Energy gives inside relationship of EAF process.
- Optimization model was developed to optimize energy , productivity and CO2 emission with varying charge mix at EAF process.

Future works



- Increase energy efficiency in Steel making and rolling process
- Modification of Existing EAF for more scrap use
- Partial replacement of natural gas to Hydrogen in the DRI process
- Microgrid concept
- Increase the use of Clean Energy
- Energy management to save energy
- Waste energy utilization

References

1. *world steel Sustainability Indicators report 2023*
2. *Emirates steel Arkan sustainability report,2022*

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6. *Sung, Y., Lee, S., Han, K., Koo, J., Lee, S., Jang, D., Oh, C., & Jang, B. (Year of Publication). Improvement of Energy Efficiency and Productivity in an Electric Arc Furnace through the Modification of Side-Wall Injector Systems. Processes 2020, 8, 1202; doi:10.3390/pr8101202.*

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