Towards Reducing Carbon Emission Through Tuyere Injections in Blast Furnace – A RAFT-RIST Approach

International Conference on Green and Sustainable Iron Making

Dr. Viswanathan N Nurni
Sajjan Jindal Steel Chair Professor & Head

Metallurgical Engineering and Materials Science
Professor In-Charge Centre of Excellence in Steel Technology
IIT Bombay

17th Jan, 2024

CoEST Centre of Excellence in Steel Technology

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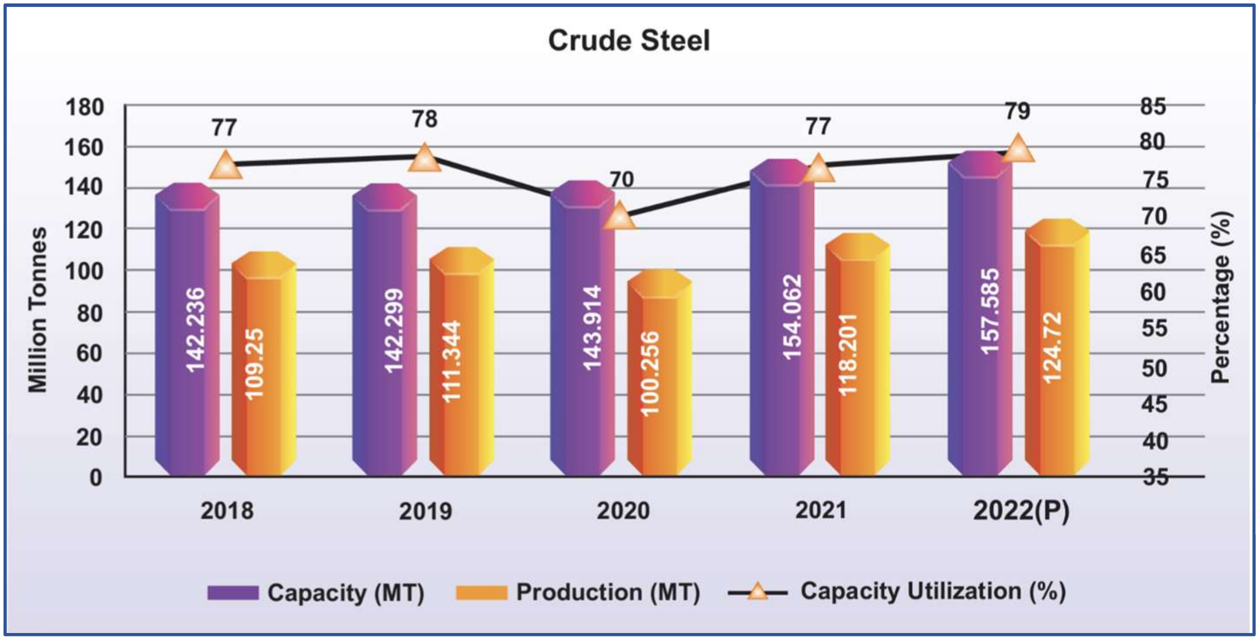
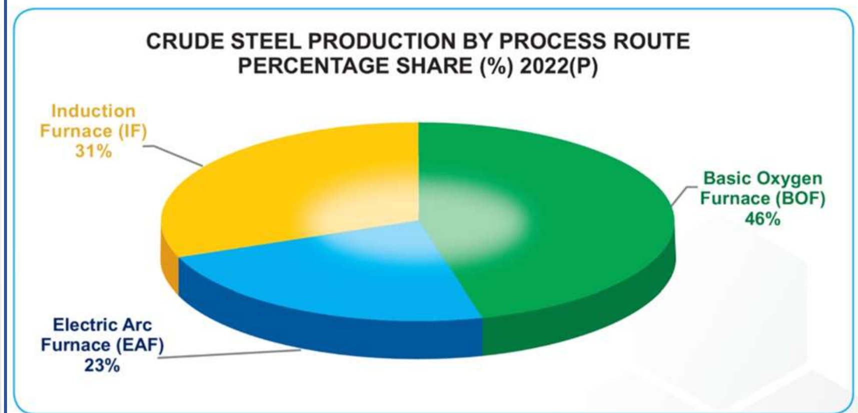
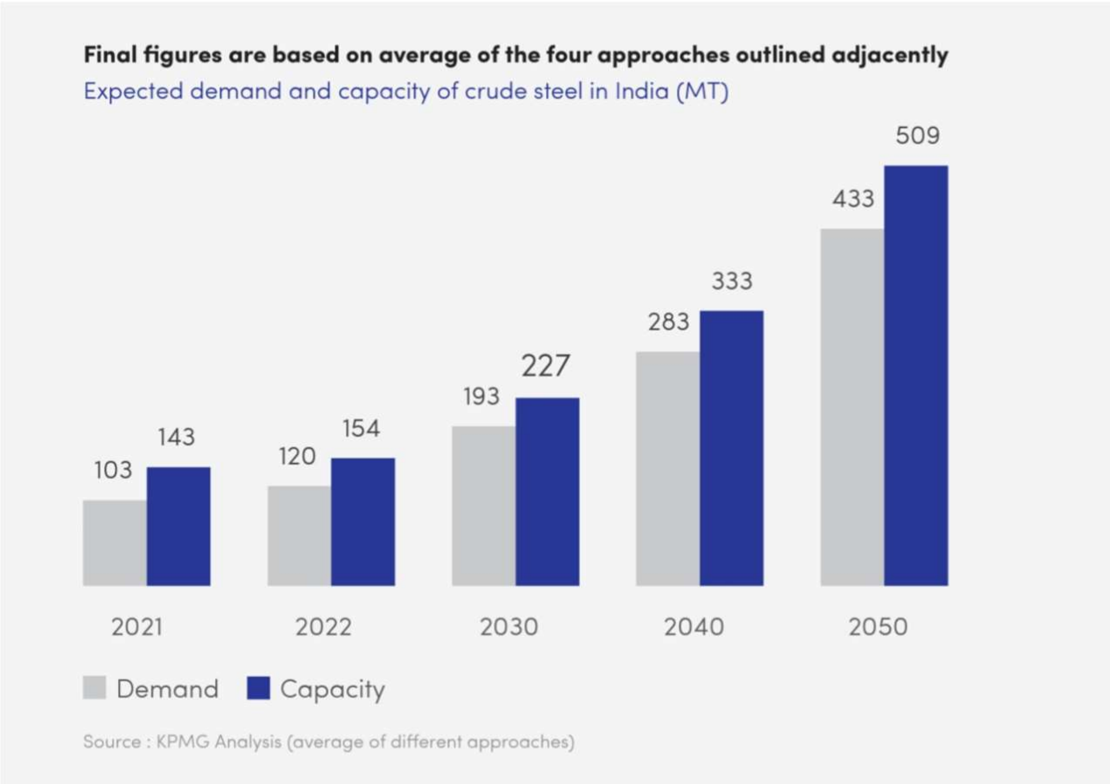
Indian Steel Sector Current Picture





Source: JPC; *Provisional, January-December, 2022

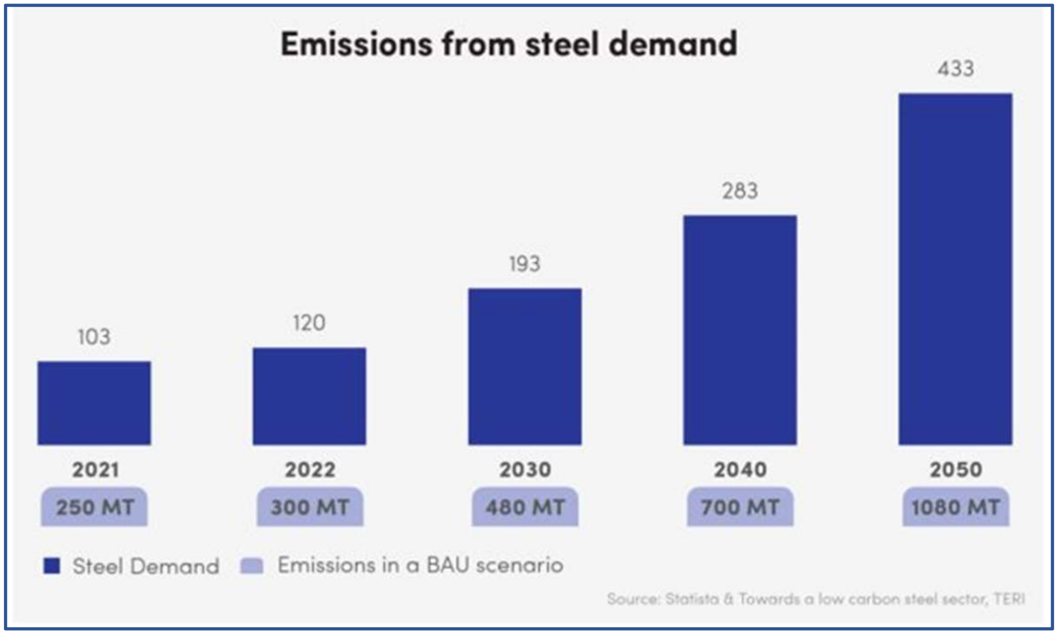
Crude steel production goal

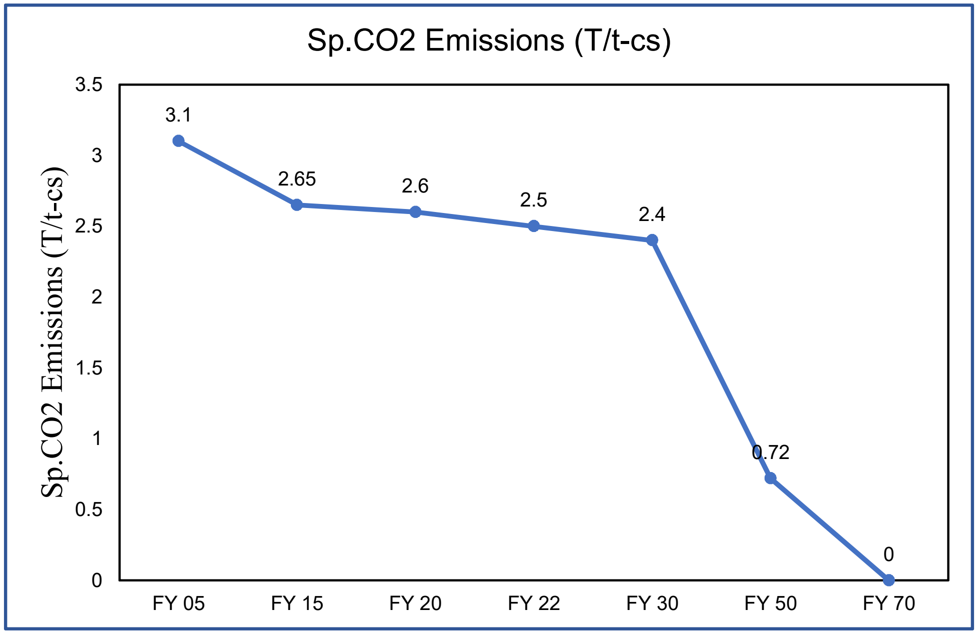


- Indian steel production is expected to grow strongly at 8.1% CAGR 2022-30.
- Steel industry contributes 2% in overall GDP of India.
- Steel industry employing more than 2 million people directly & indirectly.

Source: SteelZero: India Net Zero Steel Demand Outlook Report, https://theclimategroup.org

Emission from steel plant’s





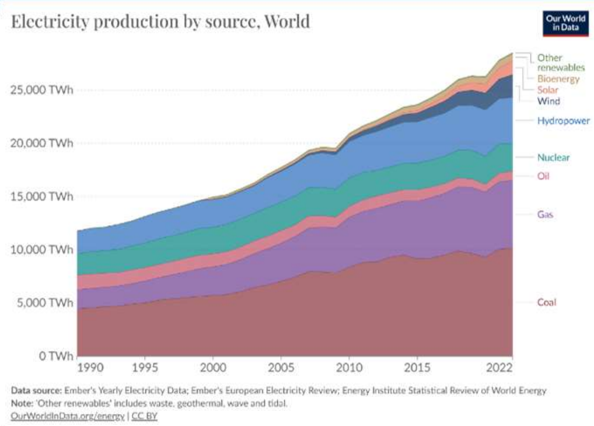
Source: SteelZero: India Net Zero Steel Demand Outlook Report, https://theclimategroup.org

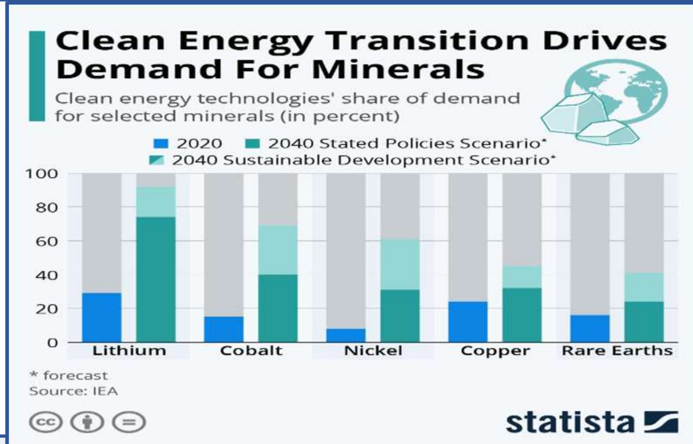
Challenges & Opportunities

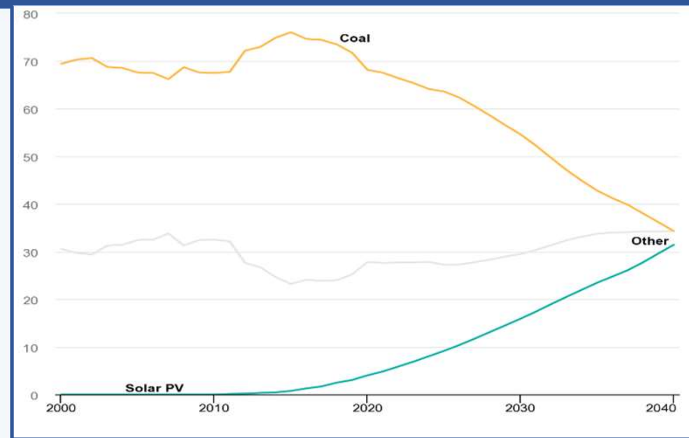
- Energy Sector
- Raw Materials – Iron Ore, Fuel/Reducing Agent
- Processes
- Engineering Expertise and Pilot Plants
- Man Power

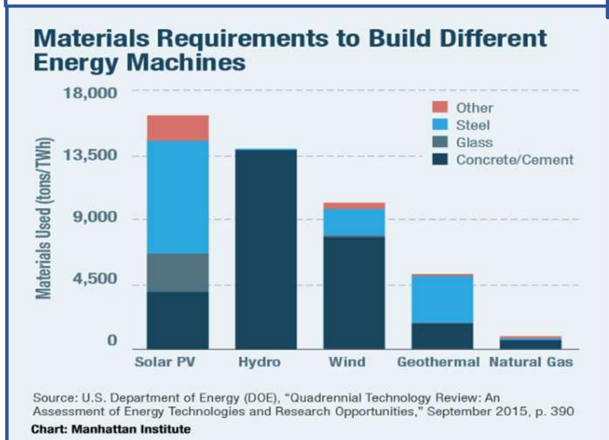
Additionally, Land and Water also Pose Huge Challenges

Energy Sector









Thermodynamics –

- Every Energy Conversion comes with a factor of Efficiency
- Mineral Resources needed for the transition is huge

Developed countries to overshoot carbon emissions goal: study

The U.S., Russia and EU will be responsible for 83% of the projected overshoot, according to a CEEW study; developed countries were able to meet their 2020 targets largely due to COVID-19 lockdowns

October 30, 2023 01:20 am | Updated 01:19 pm IST - NEW DELHI

https://ourworldindata.org/electricity-mix
https://www.iea.org/data-and-statistics/charts/changes-in-share-of-power-generation-in-india-in-the-stated-policies-scenario-2010-2040

Blast Furnace – The Most Efficient Reactor

- Operates close to Thermodynamic Efficiencies (Second Law)
- Very efficient Heat Transfer
- High productivity – Flexible as well
- Has stood tall and reinvented itself when other iron making processes challenged it
- Expected to remain tall and possibly will reinvent itself for at least another two decades

Tuyere Injection Management through RAFT

Basic Idea

Use of Cheaper Fuel/Reductant

Increase Hydrogen input to the furnace to aid Reduction in Carbon Emission

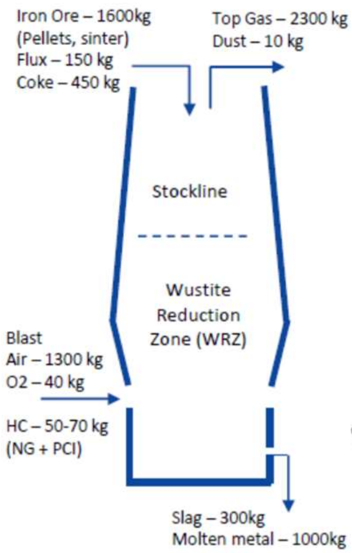
Increase Production

- Pulverized Coal
- Moisture
- Any other Hydrocarbons such as Natural Gas, Coke Oven Gas, Plastics, etc.
- Can inject H_2 as well
- Managed through Oxygen Enrichment

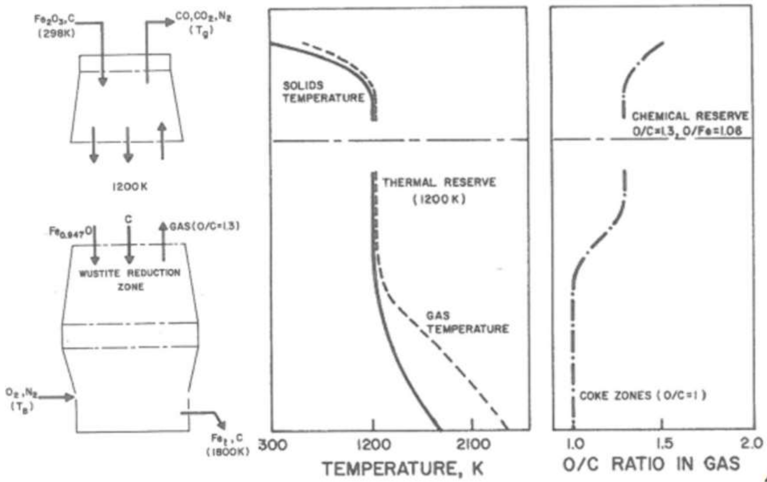
Carbon gives Energy (CO formation) – Reducing Agent (CO to CO_2)

H_2 cannot provide Energy, only Reducing Agent

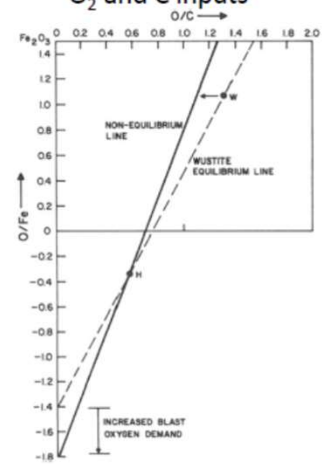
The Blast Furnace is a highly efficient thermodynamic reactor



Concept of two "reactors"



O_2 and C inputs



Adapted from Peacey and Davenport

Thermodynamics and mass balance considerations:

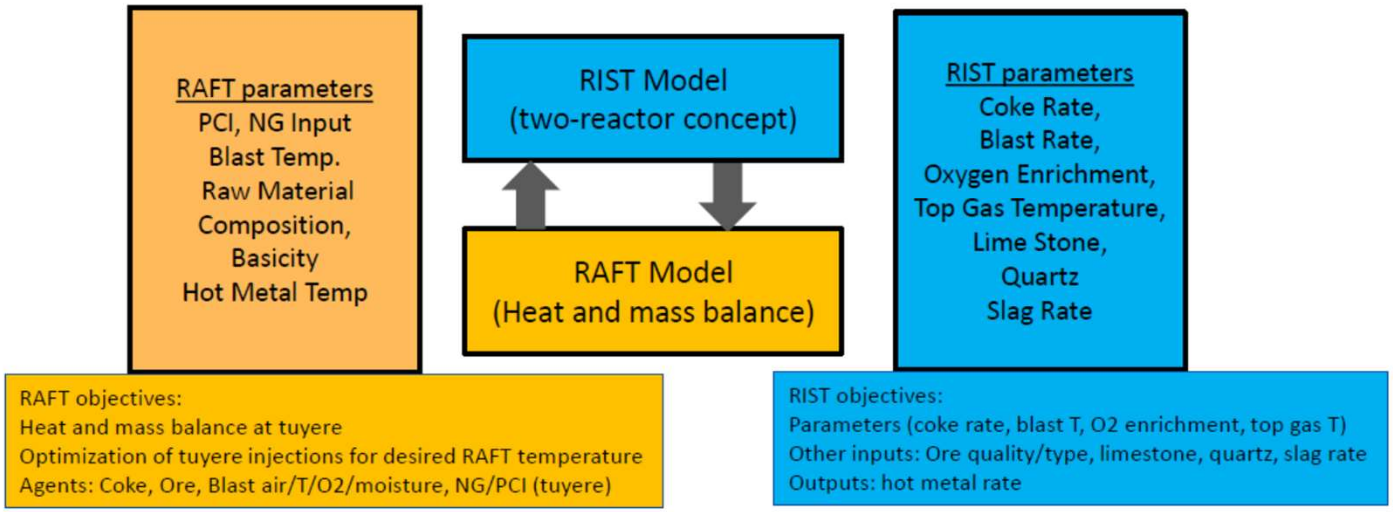
$(O/Fe) = - n_O^B + n_c^g (O/C)^g$ (Oxygen Balance)

$1.06 + n_O^B + 2(Si/Fe) + ... = n_c^g \, 1.3$ (Oxygen Balance in Bottom Zone)

Overall enthalpy balance

$319620 + (C/Fe)^m \, 44000 + 250 \times \text{slag wt.} + \text{Heat losses} = E^B n_O^B + 197600 \, n_c^g$

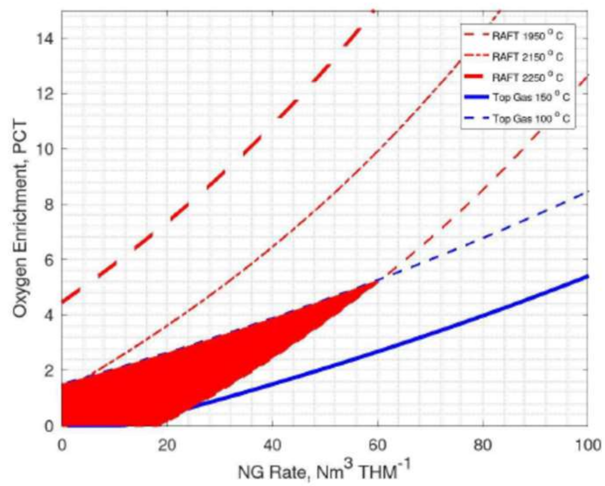
Methodology adopted for current study



- Iterative optimization between RIST and RAFT model
- Establish impact of tuyere input agents on ore reduction

Example analysis

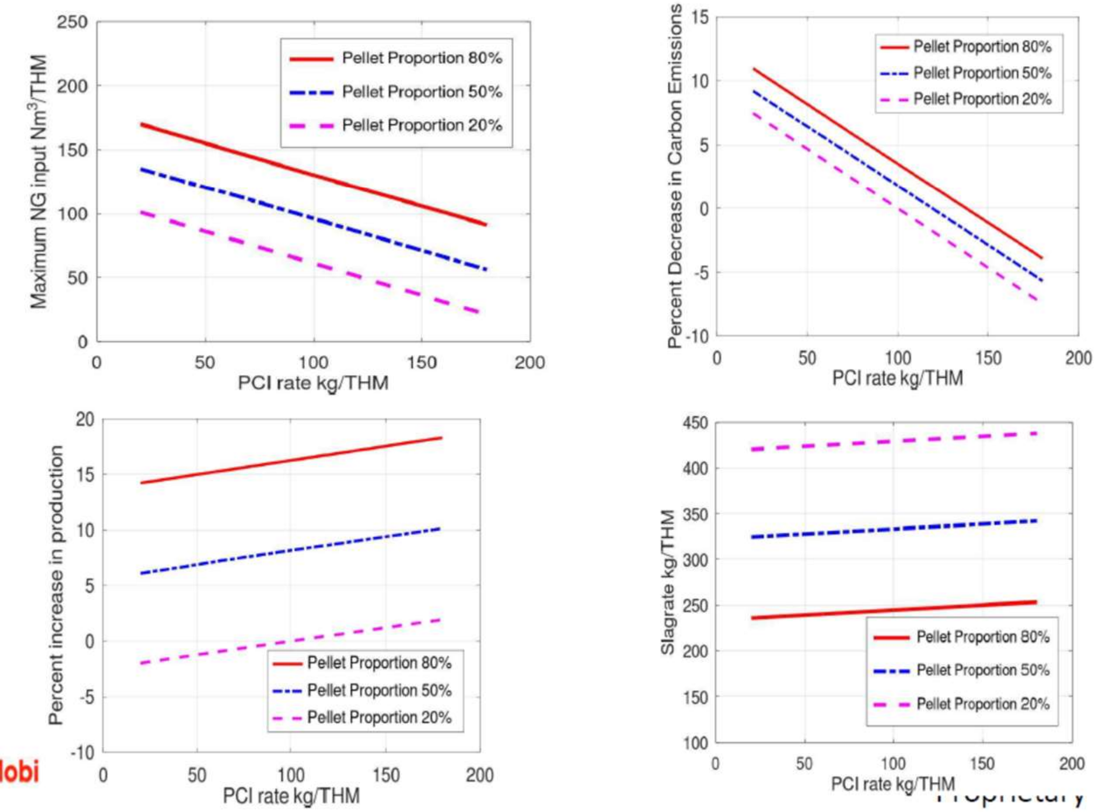
PCI – 100 kg; Blast Temp – 1200 °C; Blast Moisture – 8 kg; $Al_2O_3 : SiO_2$ – 0.7



Key points:

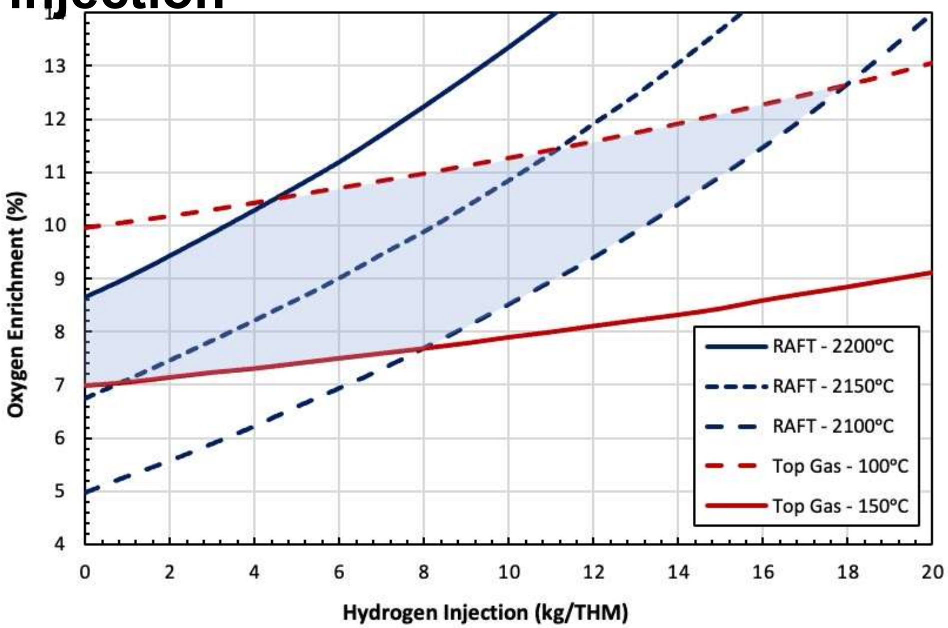
- RAFT – Need to maintained above a critical value (1950°C has been chosen for the study)
- Top Gas Temperature – Has to maintained above critical value (100 °C has been chosen for the study)
- For a given NG input, increasing Oxygen increases RAFT, but decreases top gas temperature
- Limited window of operation
- Gives the maximum NG input

Effect of Pellet Proportion on the Maximum NG input



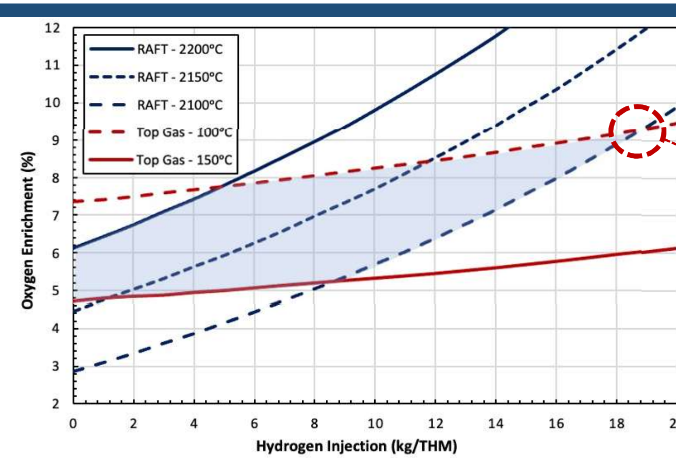
HYDROGEN INJECTION SIMULATIONS

1. Effect of PCI on extent of injection –



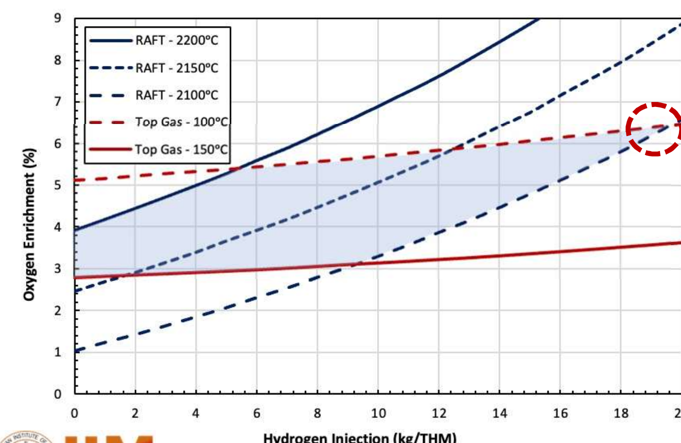
(a) PCI rate of 200 kg/THM

Maximum H_2 injection rate – *18 kg/THM (or 201 Nm³/THM)*



18.8 kg/THM or 210 Nm³/THM)

(b) PCI rate of 150 kg/THM

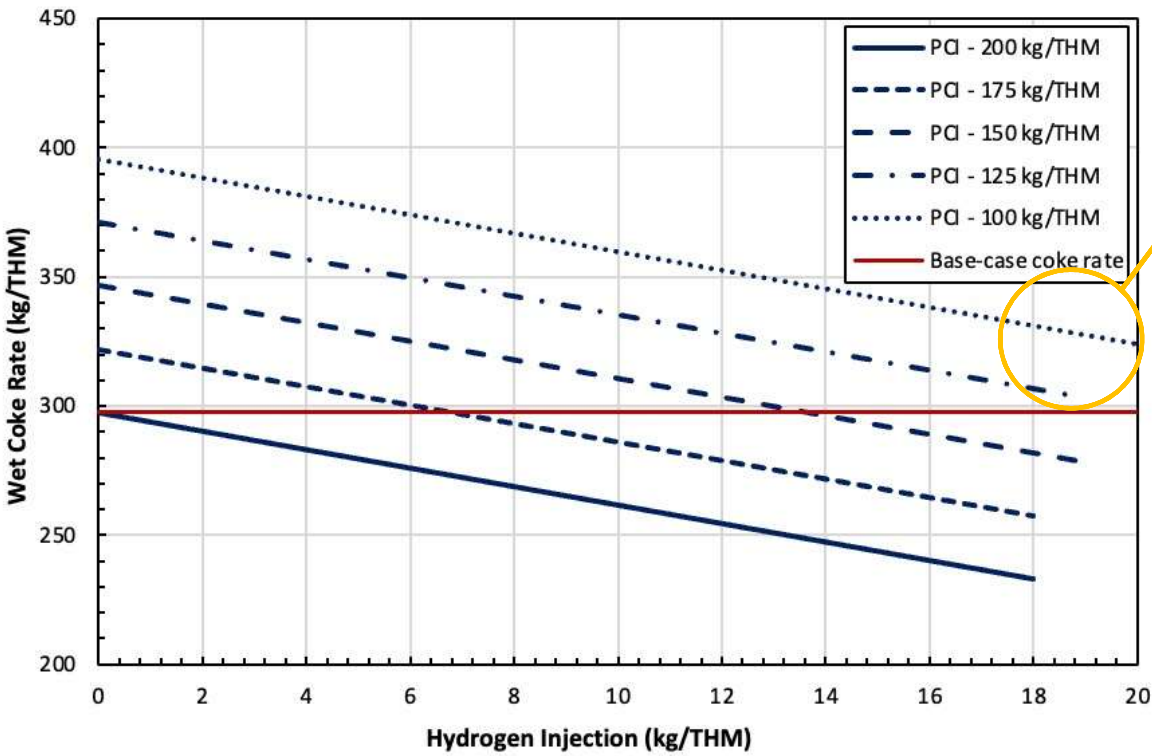


19.6 kg/THM or 220 Nm³/THM)

(c) PCI rate of 100 kg/THM

HYDROGEN INJECTION SIMULATIONS

2. Effect of H_2 injection on coke rate –

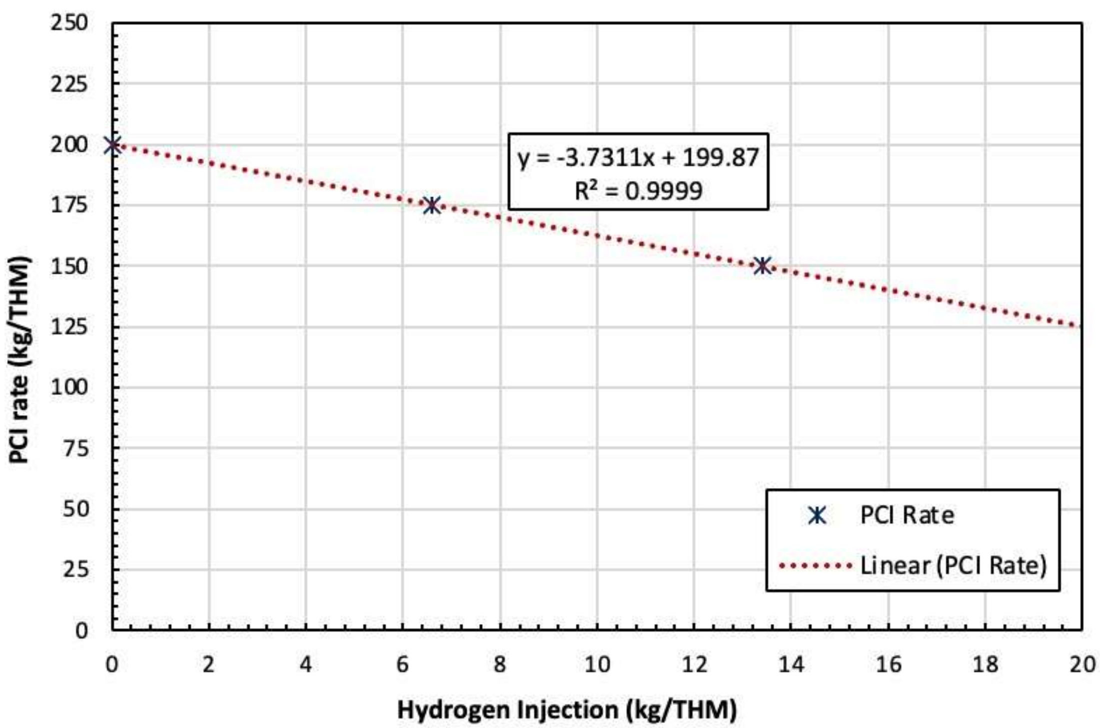


Reduction in base case coke rate not possible for PCI rates less than 125 kg/THM for a ***limiting RAFT of 2100℃ and minimum top gas temperature of 100℃.***

3.6 kg of coke can be replaced for every 1 kg of hydrogen injected to maintain any given PCI rate.

HYDROGEN INJECTION SIMULATIONS

3. PCI rate to maintain base-case coke rate –



Linear fit on model results

↓

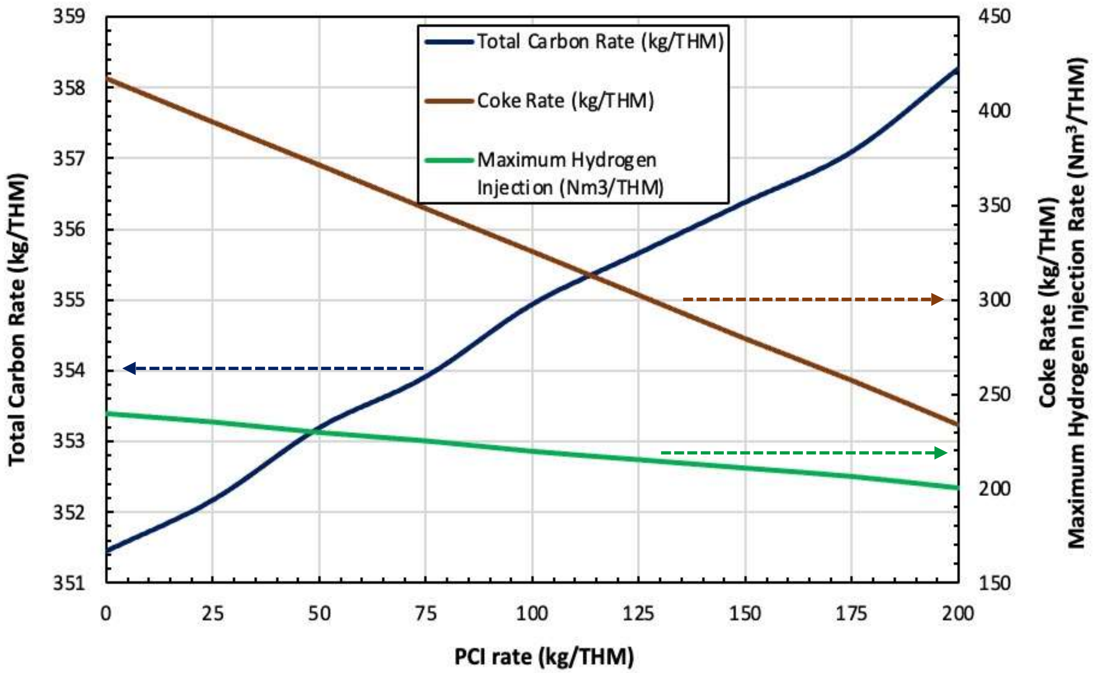
To establish relationship between PCI rate and H_2 injection rate for maintaining base-case coke rate.

↓

PC replacement of ***3.73 kg*** per kg of hydrogen injected to maintain base-case coke rate and limiting RAFT.

HYDROGEN INJECTION SIMULATIONS

Effect of PCI rate on carbon emissions at max. H_2 injection –



Base-case total carbon rate = 412.5 kg/THM

Decreasing PCI rate

↓

Extent of H_2 injection increases

↓

Coke rate increases

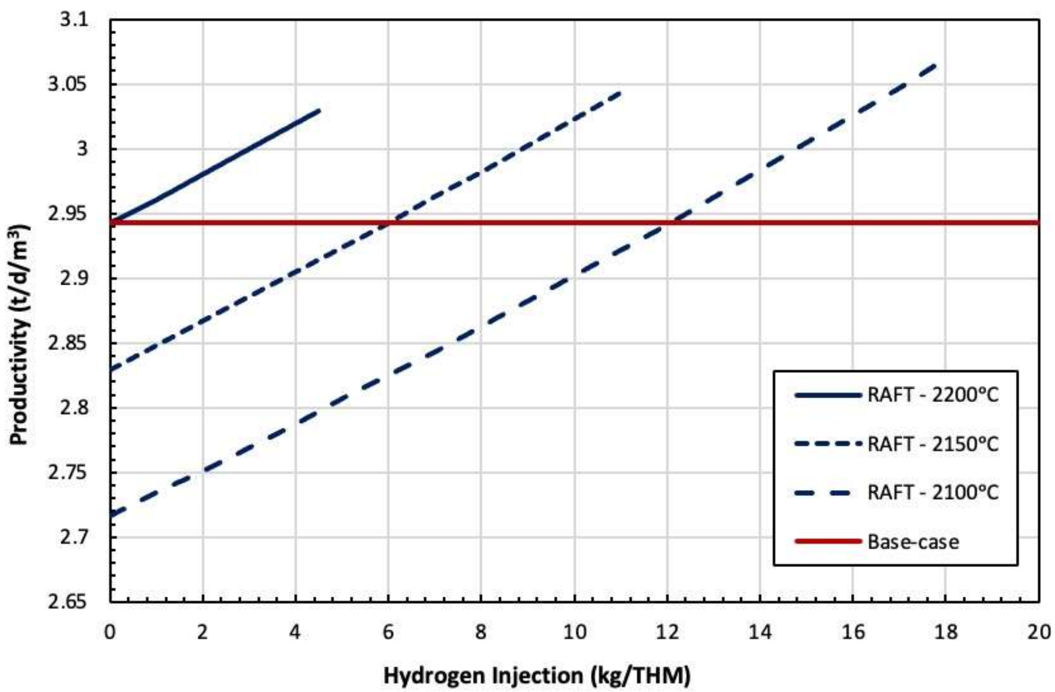
↓

Total carbon rate decreases

Potential reduction of carbon emissions by decreasing PCI rate and incorporating H_2 injection!!

HYDROGEN INJECTION SIMULATIONS

5. Effect of H_2 injection on productivity –



PCI rate fixed at 200 kg/THM

Productivity increases with increasing H_2 injection.

Decrease in RAFT brings down the productivity for a given H_2 injection rate.

Lower RAFT allows higher H_2 injection rate which further allows us to achieve higher productivity.

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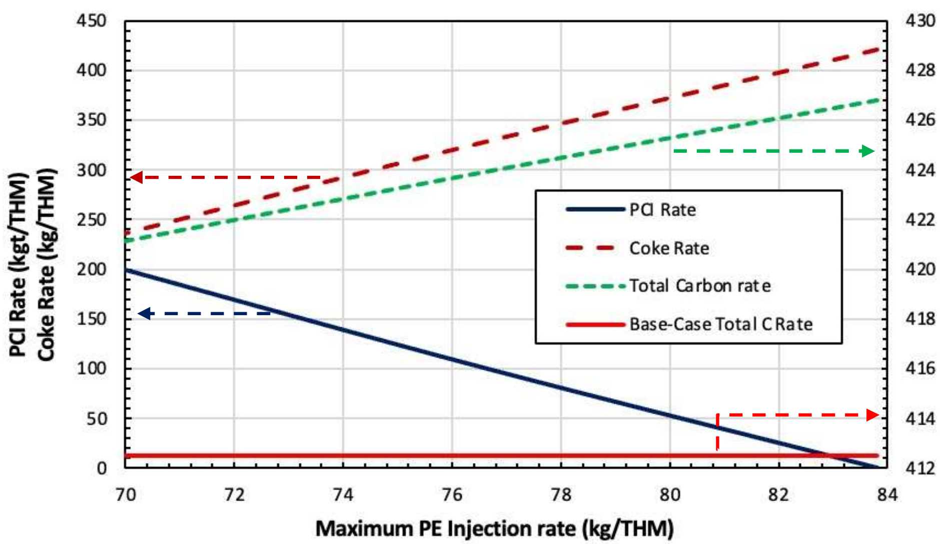
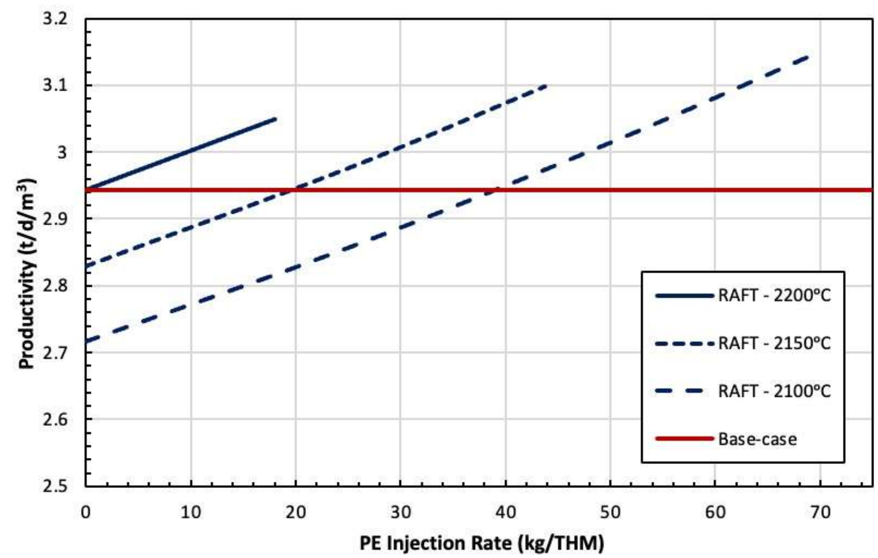
WASTE PLASTIC INJECTION SIMULATIONS

2. Effect of PE injection on carbon



Decreasing PCI rate at maximum PE injection increases the total carbon rate (and hence, carbon emissions)!!

3. Effect of PE injection on



PE injection increases productivity for a given RAFT..

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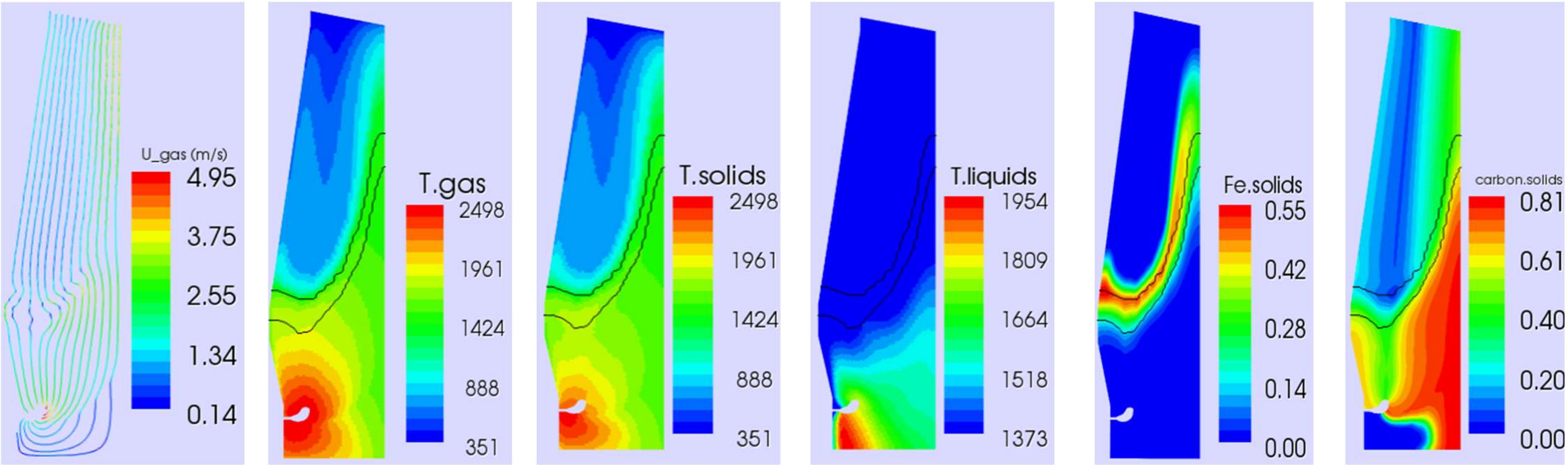
Blast furnace Simulator (BlaSim)

-A 2-D Process Model of Blast Furnace a Simulation Tool Developed using open source CFD Tool Open FOAM



- Can understand the movement of cohesive zone with varying operating parameters
- Different tuyeres injection can be studied
- Being modified to take care of shaft injections

To Summarize

- Blast Furnace shall Continue for Another 2 decades or more
- RAFT-RIST Model can be easily used to arrive at the Injection Parameters towards CO2 Reduction
- Engineering challenges can be addressed

  through a combination of

  CFD based Simulation Tools and

  Laboratory Level Experimentation

  Well Instrumented Experimental Blast Furnace

Pilot Plants

➢ Industries, academic institutions, R&D laboratories, Organizations with Design & Engineering Expertise, etc. with the support of Government needs to

- **Utilize the Existing Pilot Plant Facilities**
- **Create New Pilot Facilities**
  - Consortium mode could be the way forward
  - Having a neutral custodian of such facilities is preferable.
  - if not used, can be thought of as a production facility
  - With a sustainable business model.
  - Collaboration among competitors till the innovation comes to a particular TRL level and further individual organization(s) may take it forward.

➢ We have engineering and design expertise scattered around the country. We need to bring them together towards creation of these pilot plant facility