U.S. DEPARTMENT OF ENERGY

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AMMTO & IEDO JOINT PEER REVIEW

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Carbon-free Iron for a Sustainable future | IEDO

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Project Overview

Boston Metal is industrializing an innovative electrolytic extractive metallurgy technology called Molten Oxide Electrolysis (MOE) to produce primary steel.

IEDO mission statement

IEDO accelerates the innovation and adoption of cost-effective technologies that eliminate industrial GHG emissions

- MOE remove the GHG direct emission from steel production by using electrons as a reductant instead of carbon
- MOE has the capacity to produce steel using less energy than the traditional Blast Furnace/Basic Oxygen Furnace route
- MOE offers scalable production capacity at a smaller tonnage requirements

Challenges

- This cooperative agreement with the AMO-DOE was designed to support the scaling-up of the inert anode technology from a laboratory to an industrial scale

Impact

- Decarbonizing the primary production of steel would have a significant impact on worldwide CO_2 emission (~10%)

Project Outline

Innovation: Decarbonization of Steel Manufacturing

Project Lead: Boston Metal

Project Partners: -

Timeline: 8/1/2018 - 1/31/2023 - project completed

Budget:

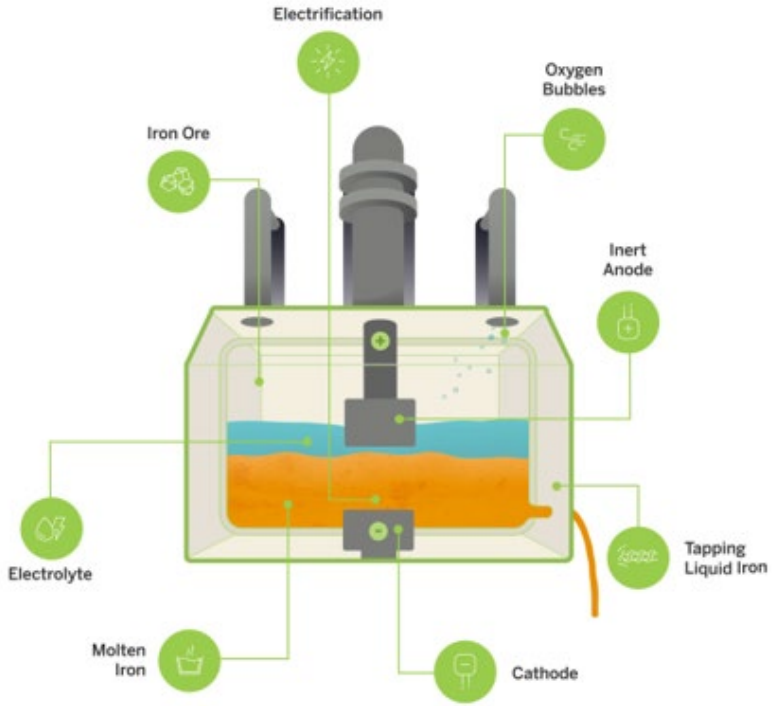
	BP1	BP2	BP3	Total Actual Funding
DOE Funded	$ 734,453	$ 558,129	$ 432,450	$ 1,750,032
Project Cost Share	$ 183,613	$ 1,906,401	$ 205,738	$ 2,295,752

End Project Goal: Demonstrating at pilot-scale the stable production of iron and oxygen as a by-product with Boston Metal's inert anode technology

Background & Strategic Approach

With an inert anode Molten Oxide Electrolysis (MOE is a zero CO_2 emission steel production process:

- Electrolytic primary production of steel from commercial iron ore feedstock
  - Fe_2O_3 becomes Fe^{3+} and O^{2-}
    - Cathode: $2\ Fe^{3+} + 6\ e^- = 2\ \mathbf{Fe}$
    - Anode: $3\ O^{2-} = 1.5\ \mathbf{O_2} + 6\ e^-$
- Single-step process to transform iron into high-purity liquid iron
- Continuous process with recurrent metal tapping
- Process modularity with MOE cell size and number of cells in MOE plant



Molten **O**xide **E**lectrolysis

Background & Strategic Approach

Budget Period 1

- Develop knowledge of operational window for inert anode for Steel MOE
  - Extensive use of laboratory-scale testing
- Derive design requirements necessary for scaling activity
  - Test knowledgebase through preliminary scaling tests

Budget Period 2

- Scaling to MOE pilot cell and testing of inert anode
  - Extensive multi-physics modeling, design for manufacturing
  - MOE testing at pilot-scale

Budget Period 3

- Long duration testing at pilot-scale
  - Final design/optimization
  - Base-line performance of MOE iron/steel production

Laboratory-scale MOE cell

Pilot-scale MOE cell

Results and Achievements

During Budget Period 1, Boston Metal conducted a series of laboratory-scale experiments to achieve the targeted Go/No-Go milestone:

- Measured oxygen evolution at the anode
- Validated iron production at the cathode
- Demonstrated inert anode stability

By achieving this milestone, Boston Metal also characterized the process operating window for scaling-up MOE

Iron deposited during laboratory-scale MOE experiment

Results and Achievements

To perform Budget Period 2 activities, Boston Metal modified its existing pilot-scale MOE cell to operate with an inert anode for the production of iron.

With the second pilot-scale campaign in BP2, Boston Metal achieved the milestone of :

- Producing 10 kg of Fe
- Measuring the production of oxygen during pilot-scale operations

Pilot-scale MOE cell

Results and Achievements

With the results obtained from the two campaigns from BP2, Boston Metal conducted a design review and analysis to implement improvements to its pilot-scale cell and inert anode design.

Two endurance campaigns were conducted with the project final milestone, 100 kg of iron produced during a week-long MOE campaign, as a target.

Operational challenges were encountered during the first campaign and process modifications implemented for the second one.

The second campaign demonstrated improvements, the iron produced and campaign duration were lower than the BP3 milestone targets.

Liquid metal tapping

Future Work, Technology Transfer, & Impact

Future Work

- Boston Metal further optimized its inert anode design and pilot-scale reactor anode.
- On-going validation of MOE operations at semi-industrial scale.

Technology Transfer

- Boston Metal has created a subsidiary to produce high-value ferroalloys from mining waste and commercially deploy MOE.
- Boston Metal has started activities related to a demonstration plant.

Impact

- About 2 billion tons of steel are produced every year, accounting for ~10% of global carbon emissions. Boston Metal is electrifying the primary steel industry with a simple, efficient, and modular solution to decarbonize the most important engineering material in the world.

Questions?

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https://www.bostonmetal.com/contact-us/