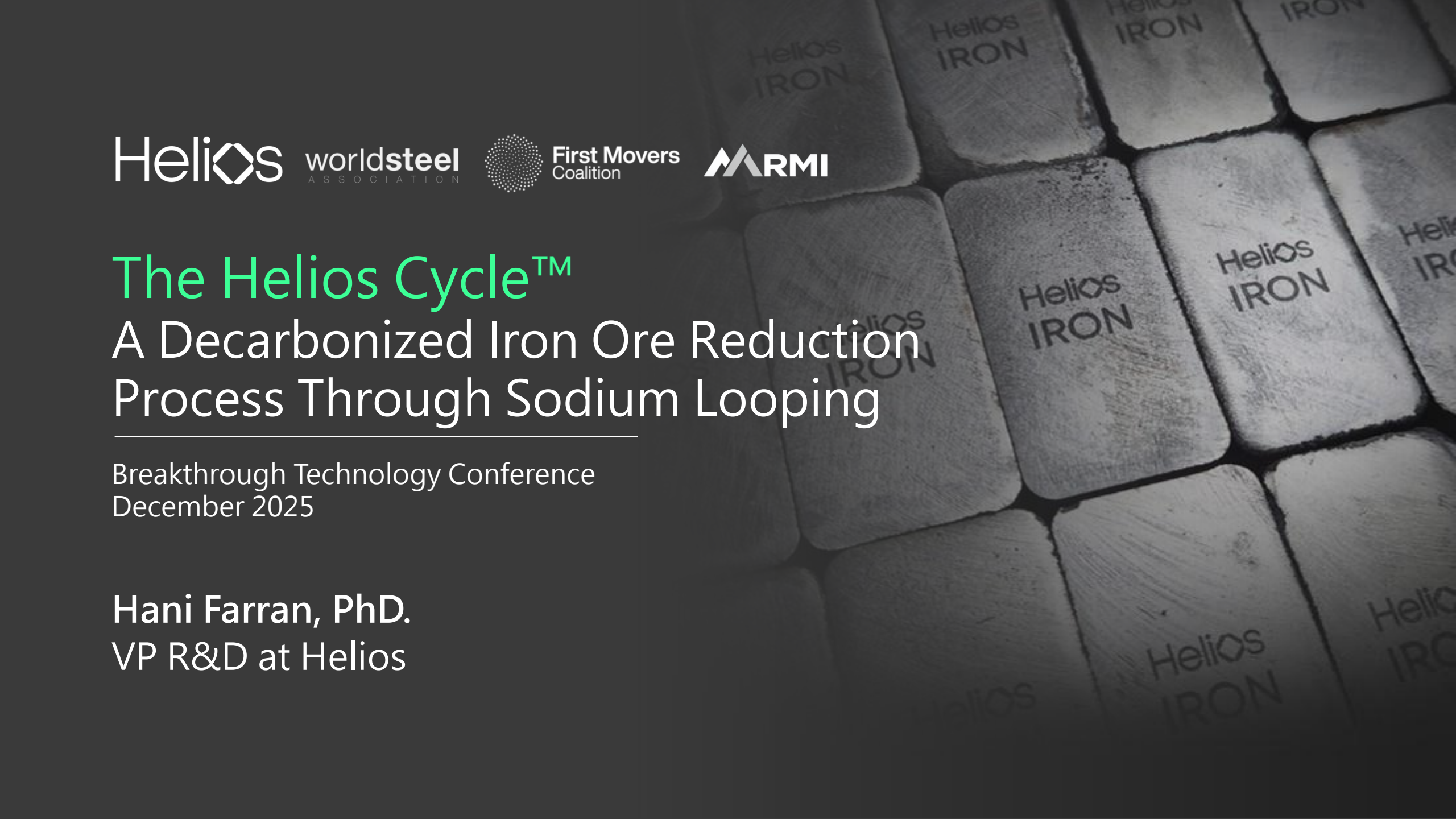



# The Helios Cycle™

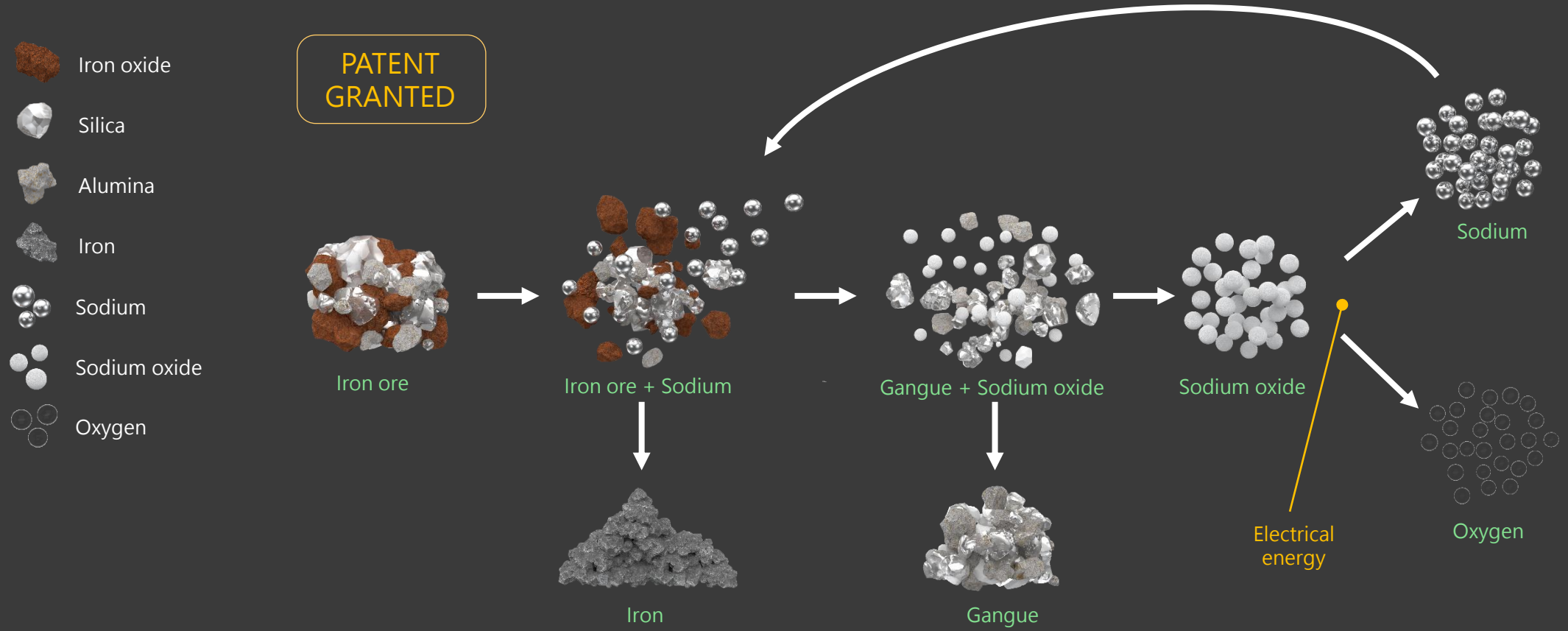
## A Decarbonized Iron Ore Reduction Process Through Sodium Looping

Breakthrough Technology Conference
December 2025

**Hani Farran, PhD.**
VP R&D at Helios

# The Helios Cycle™

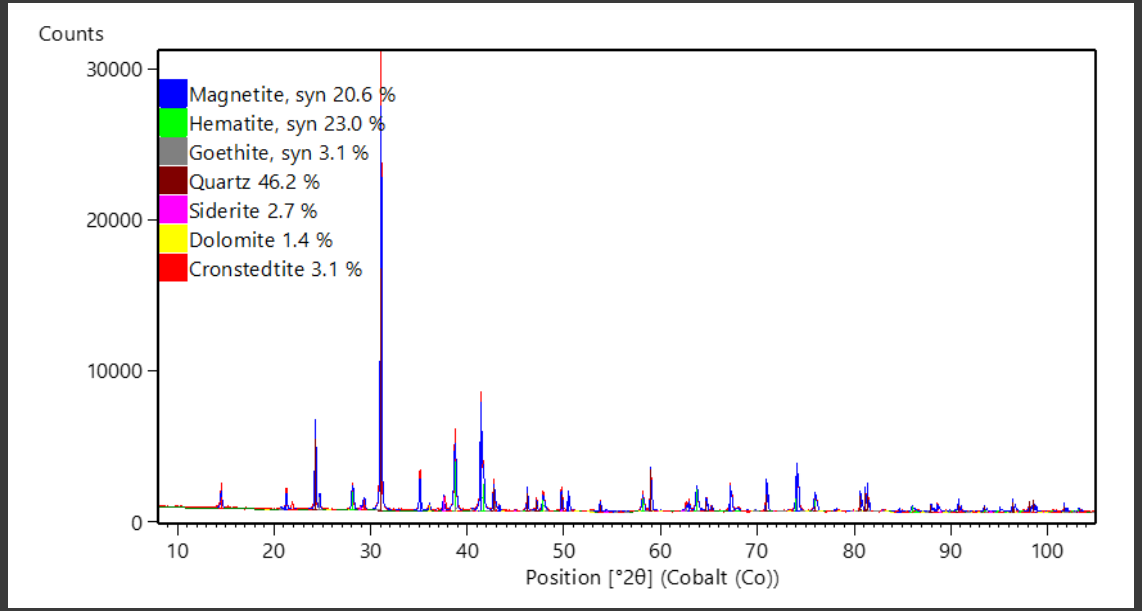
- Using sodium, replacing coal or hydrogen
- Indifferent to feedstock grade
- 3.0MWh-4.0MWh per ton (at 250°C to 350°C)



# Reduction Results For Various Ores

## Hematite & Magnetite (USA – Run of mine) Low grade ore, Fe total 37.3%wt

| Compound Name | Formula | %wt |
|---|---|---|
| Hematite | $Fe_2O_3$ | 23 |
| Magnetite | $Fe_3O_4$ | 20.6 |
| Goethite | FeO(OH) | 3.1 |
| Silicon Oxide | $SiO_2$ | 46.2 |
| Cronstedtite | $Fe_4SiO_5(OH)_4$ | 3.1 |
| Dolomite | $Fe_4SiO_5(OH)_4$ | 1.4 |
| Siderite | $FeCO_3$ | 2.7 |




Calculated results after reduction, before separation:

| Experiment ID | Fe | $Na_2O$ | $SiO_2$ | $Na_4(SiO_4)$ | Sodium |
|---|---|---|---|---|---|
| B02-40 | 19.5 | 52.2 | 25.2 | 2.4 | 0.7 |

# Calculating Iron Metallization

$$\textbf{\% Metallization} = \frac{n(Fe)_{metal}}{n(Fe)_{total}} \text{x}100$$

$$n(Fe)_{total} = \sum \frac{wt(Compound_i)}{Mw(Compound_i)} \times stoichiometric\ ratio\ of\ Fe\ in\ Compound_i$$

$$\%\text{Metallization} = \frac{0.349}{0.349} \text{ X } 100$$

$$n(Fe)_{total} = \sum \frac{19.5}{55.845} \text{ X } 1$$

**Iron metallization > 99%**

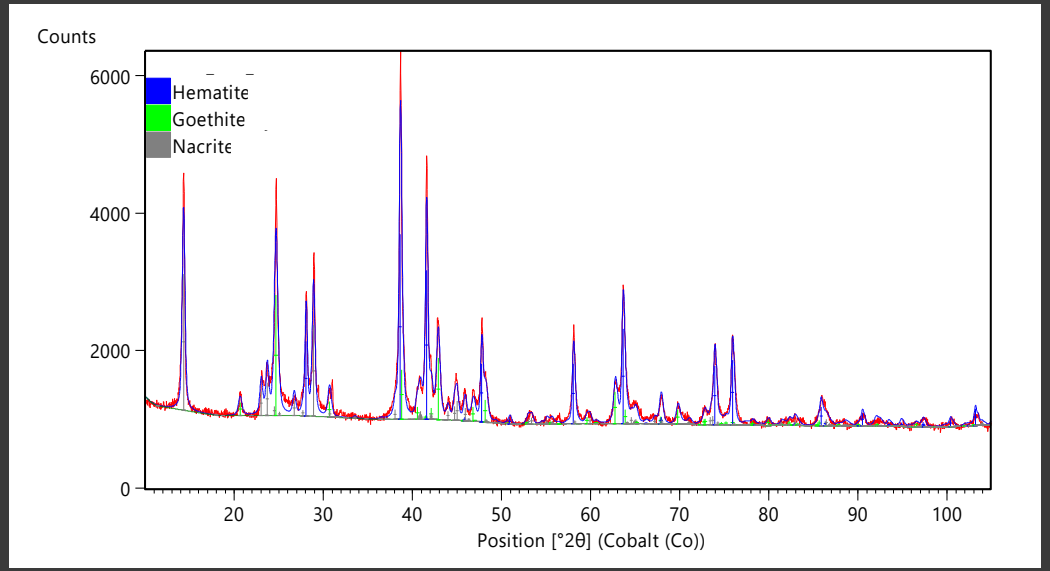
| Experiment ID | Fe | $Na_2O$ | $SiO_2$ | $Na_4(SiO_4)$ | Sodium |
|---|---|---|---|---|---|
| B02-40 | 19.5 | 52.2 | 25.2 | 2.4 | 0.7 |

# Reduction Results for Various Ores

## Tailings (Australia) - Fe total 41%wt

XRD

| Compound Name | Formula | %wt |
|---|---|---|
| Hematite | $Fe_2O_3$ | 37.5 |
| Goethite | FeOOH | 23.3 |
| Nacrite | $Al_2Si_2O_5(OH)_4$ | 39.1 |




XRF

| Sample ID | Fe | SiO2 | Al2O3 | P | S | Mn | CaO | MgO | TiO2 | K2O |
|---|---|---|---|---|---|---|---|---|---|---|
| Tailings | 39.0 | 18.95 | 14.6 | 0.072 | 0.018 | 0.411 | 0.14 | 0.28 | 0.8 | 0.068 |

# Reduction Results for Various Ores

## Tailings (Australia) - Fe total 41%wt

Calculated results after reduction, before separation:

| Experiment ID | Fe | $Na_2O$ | $Na_4(SiO_4)$ |
|---|---|---|---|
| B01-120 | 34.9 | 15.8 | 49.4 |

ICP

| Sample ID | Fe | SiO2 | Al2O3 | P | S | Mn | CaO | MgO | TiO2 | K2O |
|---|---|---|---|---|---|---|---|---|---|---|
| Tailings | 52.54 | 4.14 | 24.19 | 0.0011 | 0.01 | 0.65 | 0.28 | 0.40 | 0.90 | 0.08 |

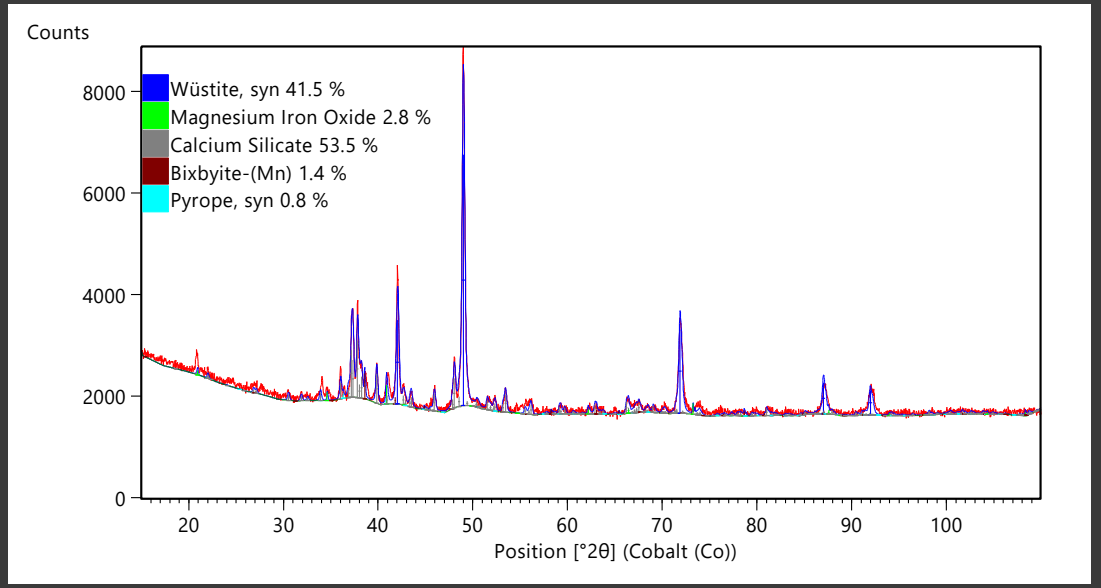
## Iron metallization > 99%

# Yes,
# we can extract iron from slag

# Reduction Results for Various Ores

## EAF Slag (U.S.A) - Fe total 22.8%wt

| Compound Name | Formula | %wt |
|---|---|---|
| Wustite | FeO | 41.5 |
| Magnesioferrite | $MgFe_2O_4$ | 2.8 |
| Calcium Silicate | $Ca_2(SiO_4)$ | 53.5 |
| Bixbyite | $MnFeO_3$ | 1.4 |
| Pyrope | $Mg_3Al_2(SiO_4)_3$ | 0.8 |




Calculated results before separation:

| Experiment ID | Fe | $Na_2O$ | FeO | $Ca_2(SiO_4)$ | CaO | Sodium |
|---|---|---|---|---|---|---|
| %wt | 14.3 | 68.8 | 0.6 | 2.9 | 2.9 | 14.5 |

## Iron metallization = 96.9%

# Byproduct Management

$Fe + Na_2O + SiO_2 + impurities$

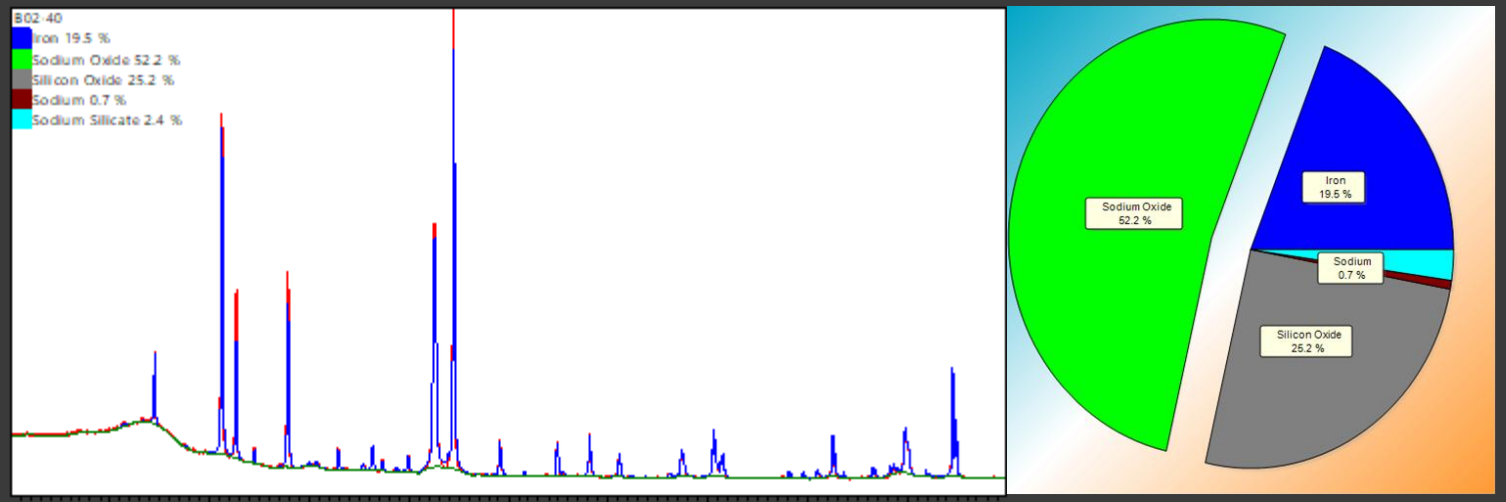
Low grade Ore

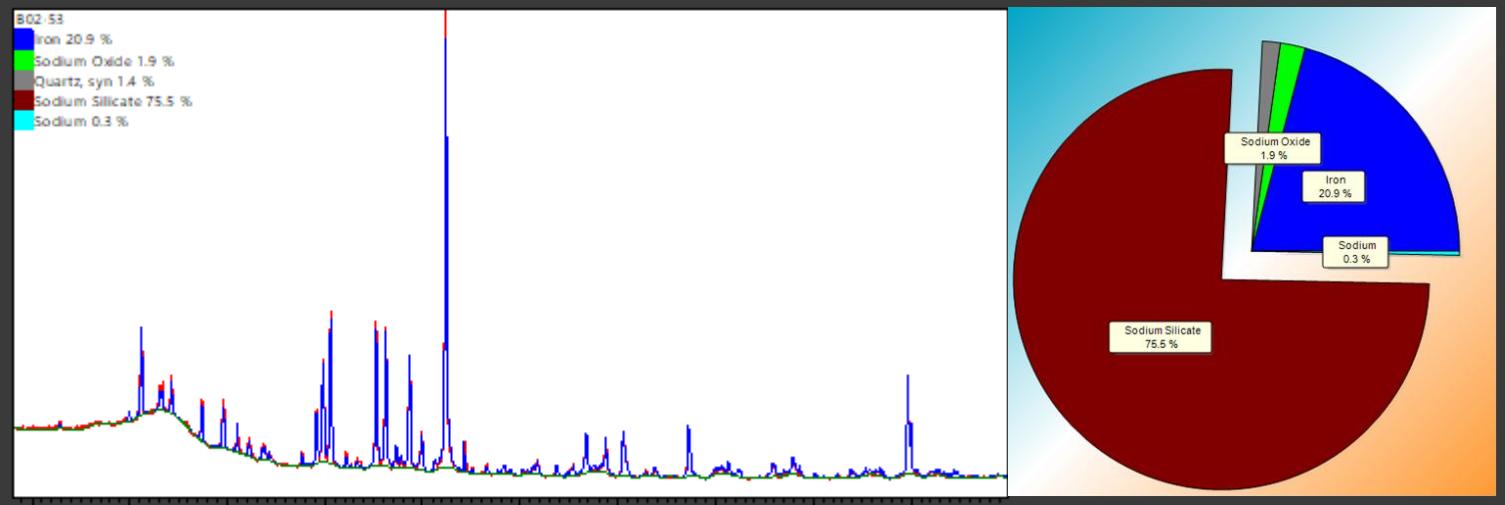
\+

Metallic Na

Via combination of mixing parameters, process sequence, ratio and temperature

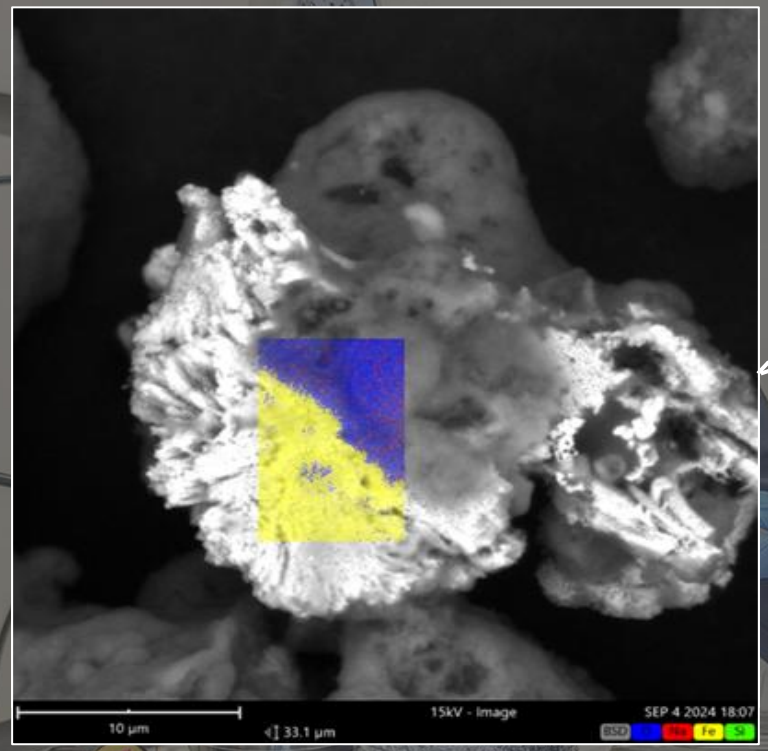
$Fe + Na_2SiO_4 + impurities$



# Separation Flow

## From iron ore to pure iron




Fe $Na_2O$ $SiO_2$

Magnetic Separation

Fe $Na_2O$ $SiO_2$

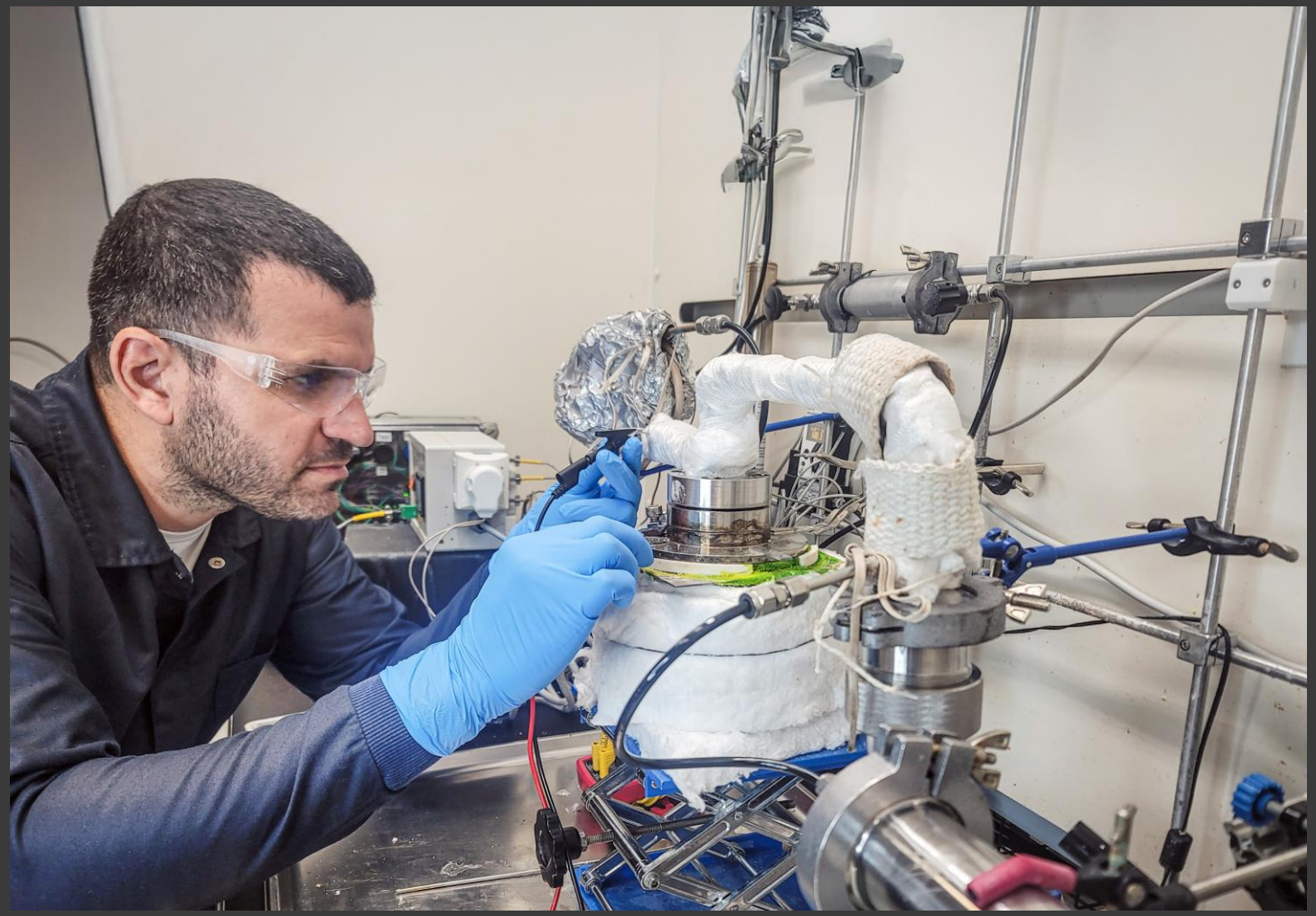
Chemical Separation

Fe $Na_2O$

Electrochemical Dissociation

Na $O_2$

# Sodium Looping



# Sodium looping

## Concept of Operation

The Helios concept of operation is relying on the Castner process of manufacturing sodium metal by electrolysis of molten sodium hydroxide at approximately 330 °C

Molten hydroxide bath

$NaOH_{(aq)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

Anode

Humidity Presence

$4OH^{-} \rightarrow O_2 + 2H_2O + 4e^{-}$

$Na_2O_{(s)} + H_2O_{(l)} \rightarrow 2NaOH_{(aq)}$

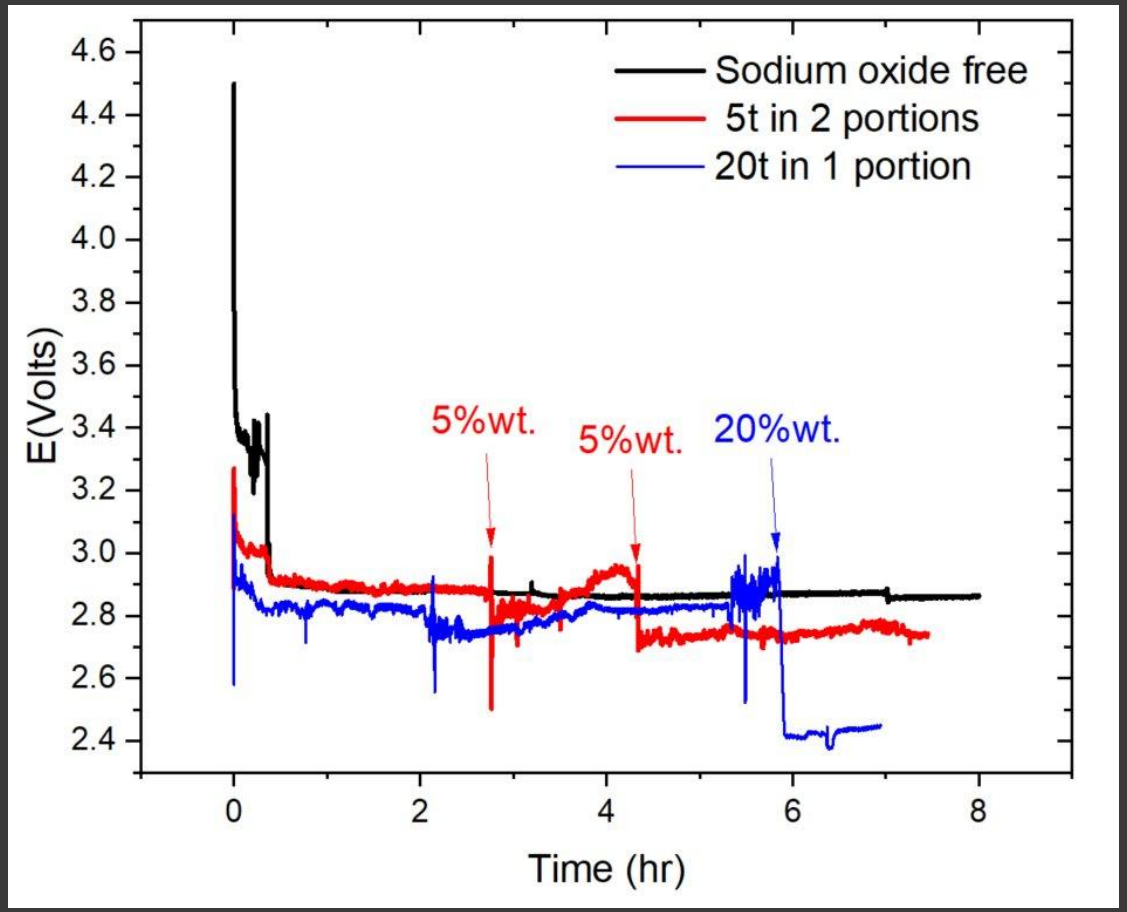
"Dry" Condition

$Na_2O \rightarrow 2Na + O^{-2}$

$2O^{-2} \rightarrow O_2 + 4e^{-}$

Cathode

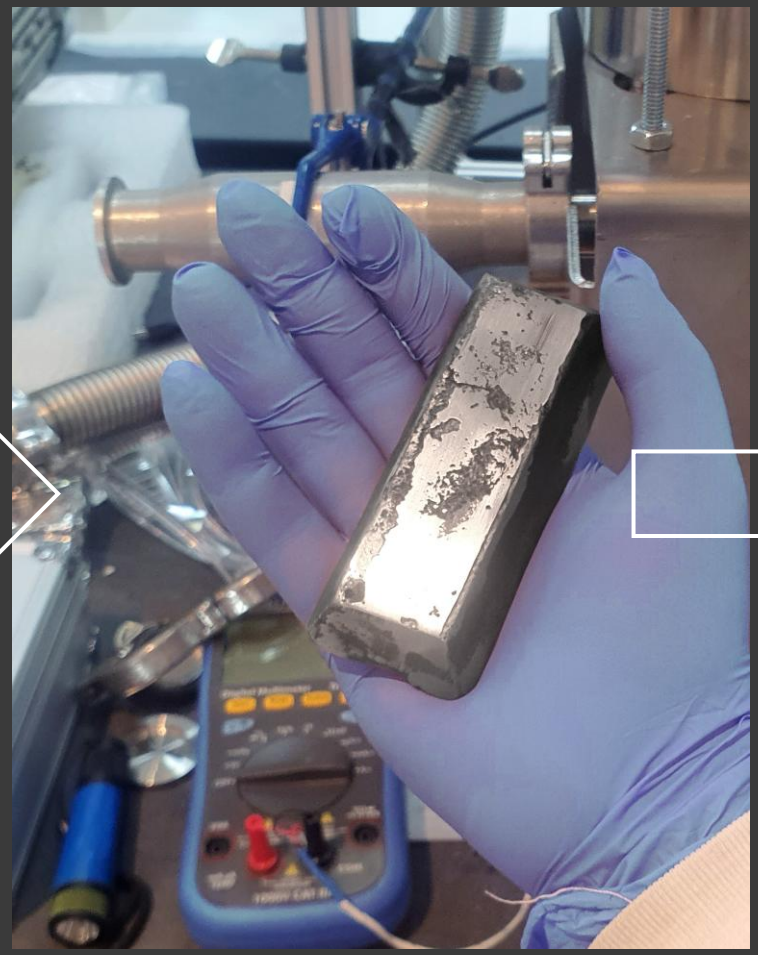
$2Na^{+} + 2e^{-} \rightarrow 2Na$

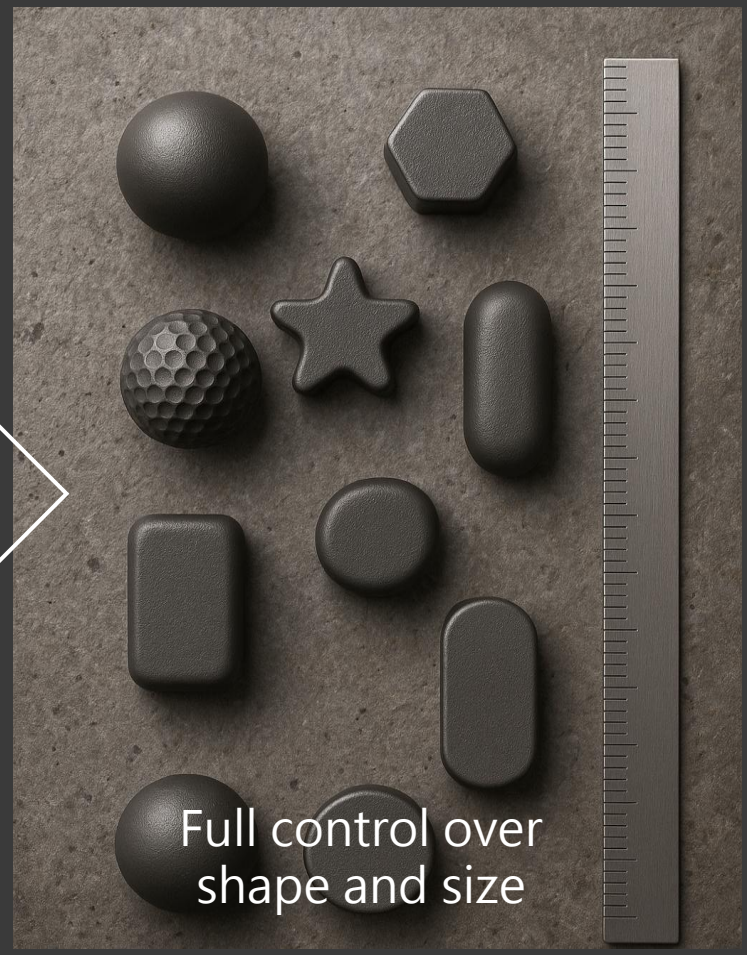


# The Final Product

## HGI™ – Helios Green Iron

From iron powder to a uniform briquetted iron





# Cost Advantage

No Market Value

Helios Furnace

Competitive Green Steel

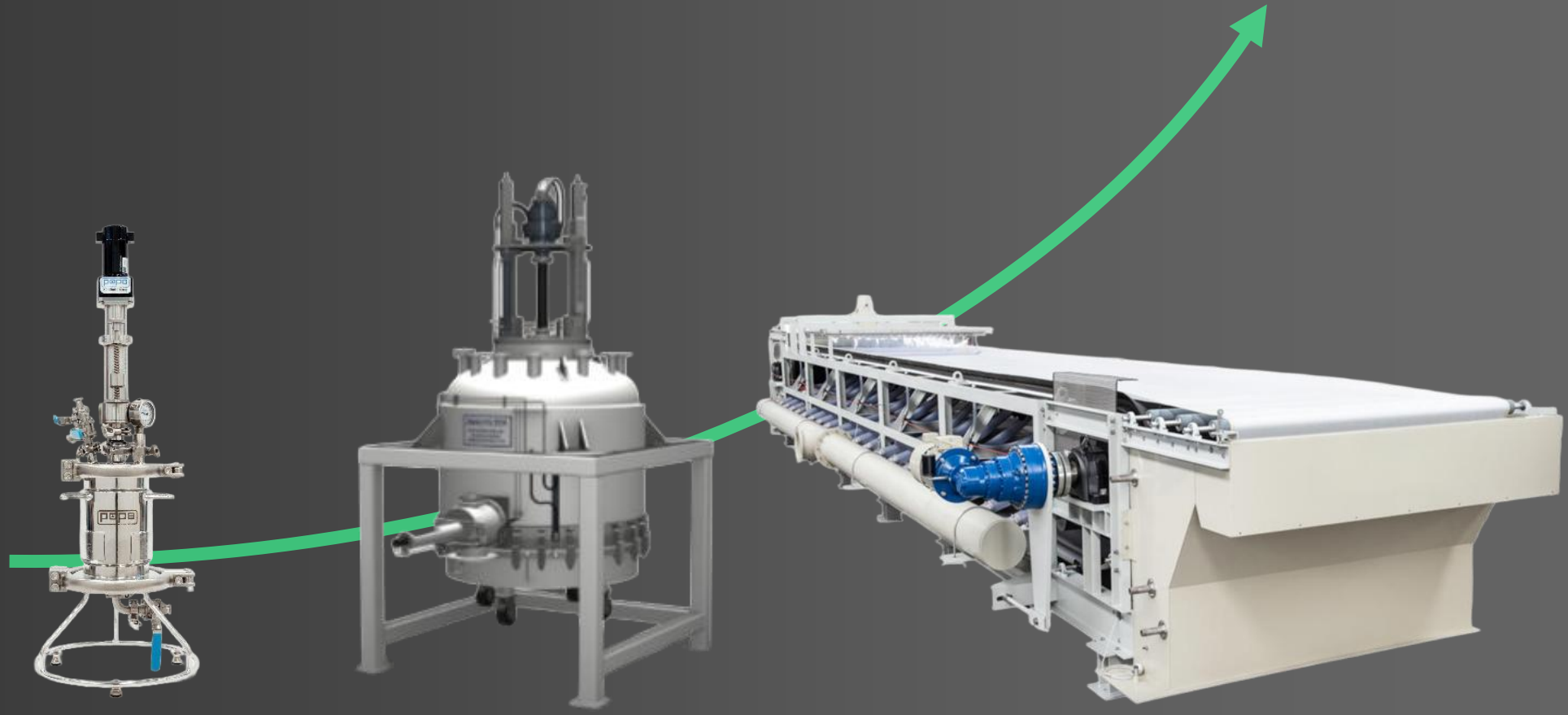
# Scale-Up

Helios is using scalable, readily available "off the shelf" equipment

**Chemical reactors**

# Scale-Up

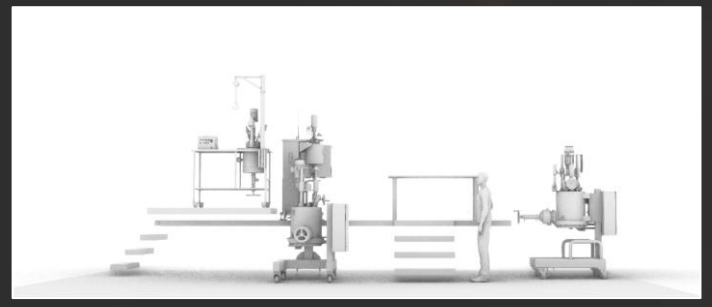
Helios is using scalable, readily available "off the shelf" equipment



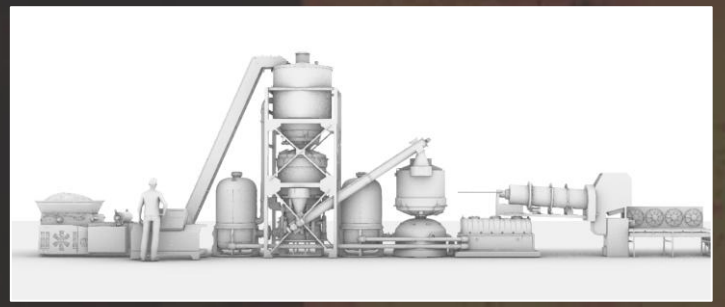
**Nutsche filters**

# Roadmap

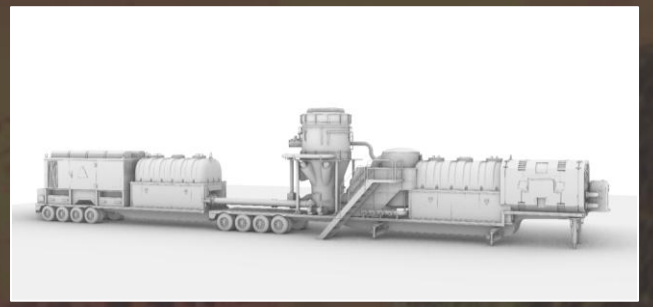
| Nov 2025 | 2026 | 2027 | 2029 | 2030 | 2035 |
|---|---|---|---|---|---|
| Kg/day | Mini-Pilot scale<br>Hundreds of Kg/month | Pilot scale<br>tons/day | FOAK<br>50K tons/year | Five units<br>250K tons/year | Fabrication factory |



Mini Pilot →



Pilot →



Modular Furnace → $

# 2029
## FOAK 50K t/year


2031
5 units - 250K t/year

# 2035

Fabrication factory - 400 units/year

20,000,000 tonne/year[2]

# Key Takeaways:

- Indifferent to feedstock
- Ready for scaleup
- Lower cost

# Q&A

Thank you, please connect with us for more information

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**Chen Shnitman Balili**
Product Lead

LinkedIn

Helios