BOSTON UNIVERSITY

# Aluminum Powder Combustion

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- Why does this matter?
- Problem Statement

**M**

**1. Motivation**

**S**

**2. Solution**

- Aluminum Powder
- Comparative Metrics

- Source to Flight Processes
- Inert Anode Hall–Héroult
- Alumina Recyclibility

**S**

**3. Supply Chain**

**E**

**4. Engine**

- Gas Turbine Engine Overview
- Modified Components
- Particle Size Effects

- Non-recurring Costs
- Recurring Costs
- Cost Comparison to Jet A

**C**

**5. Cost Analysis**

**T**

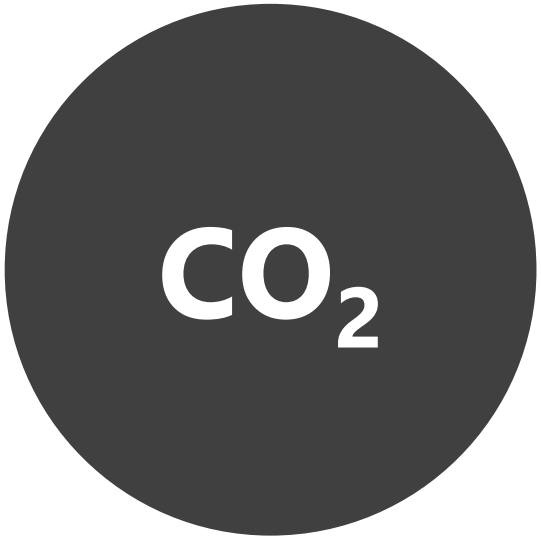
**6. Timeline**

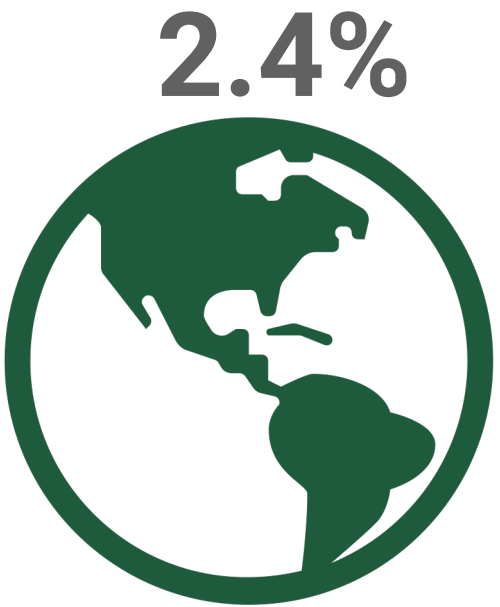
- Technological Advances
- Aluminum Production Growth
- Certifications

# 1. Motivation

# Motivation

# Motivation

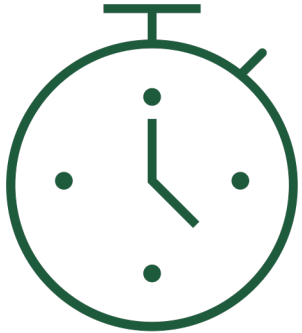


# Motivation

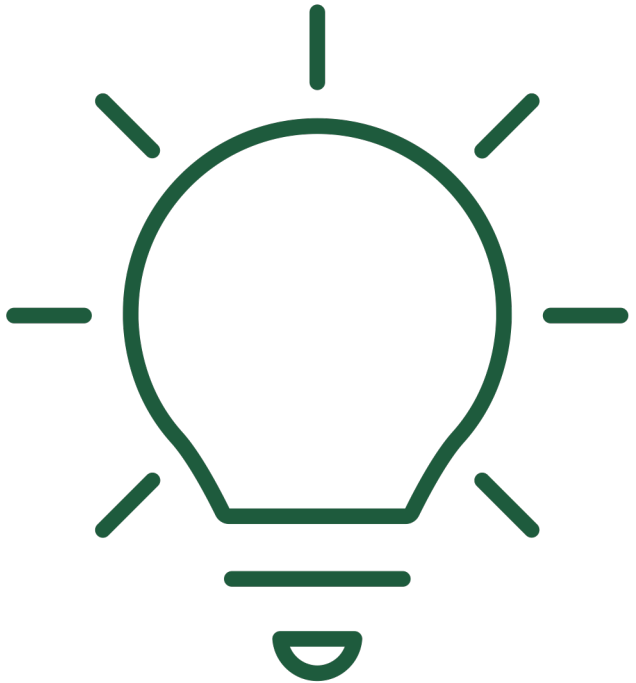
**Environmentally Friendly**

**Alternative Fuel Source**

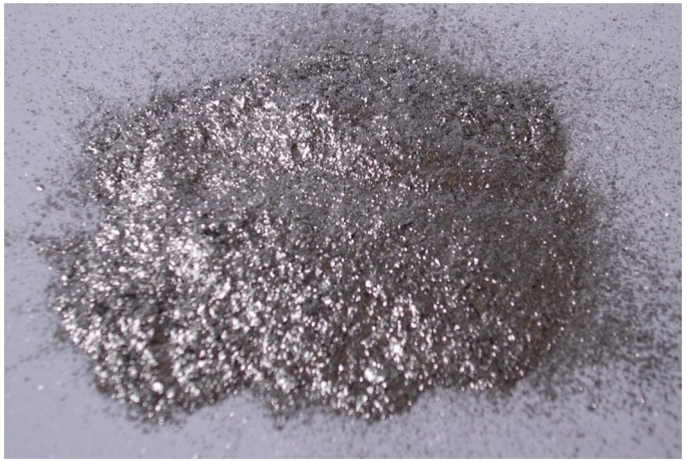


**Sustain 2hr Flights**

# 2. Solution

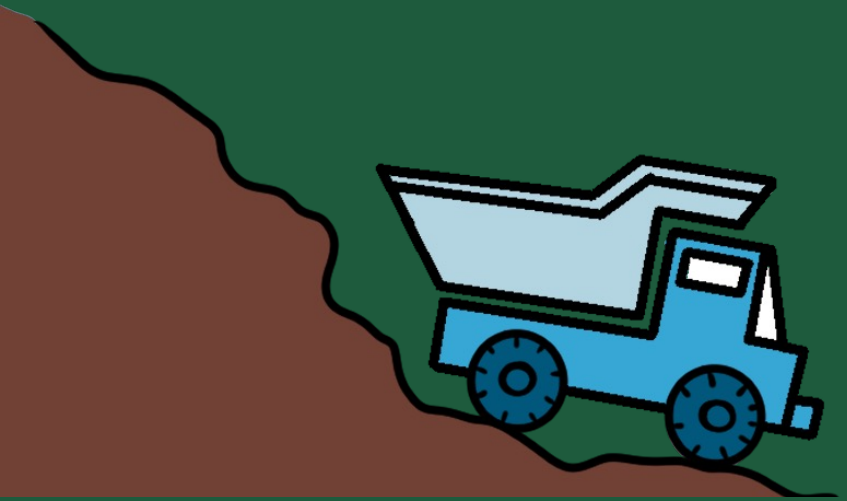


# Aluminum Powder

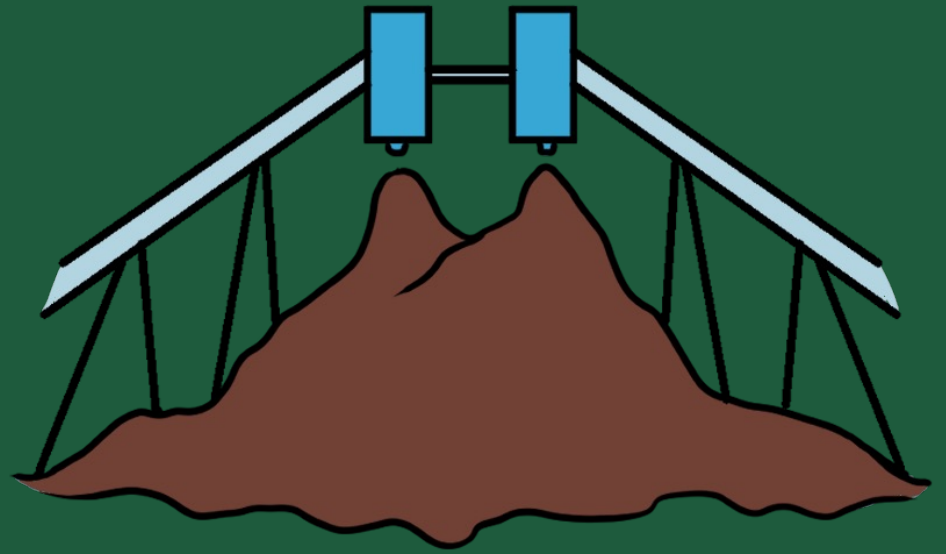


| | Jet A | Aluminum Powder | % Difference |
|---|---|---|---|
| Effective Energy per Volume | 13 MJ/L | 38 MJ/L | +198% |
| Effective Energy per Mass | 16 MJ/kg | 14 MJ/kg | −11% |
| Mass of Fuel Consumed per Flight | 24 MT | 27 MT | +11% |
| Total Yearly Emissions | 920 MMT $CO_2$ | 42 MMT $CO_2$ | −96% |

# 3. Supply Chain



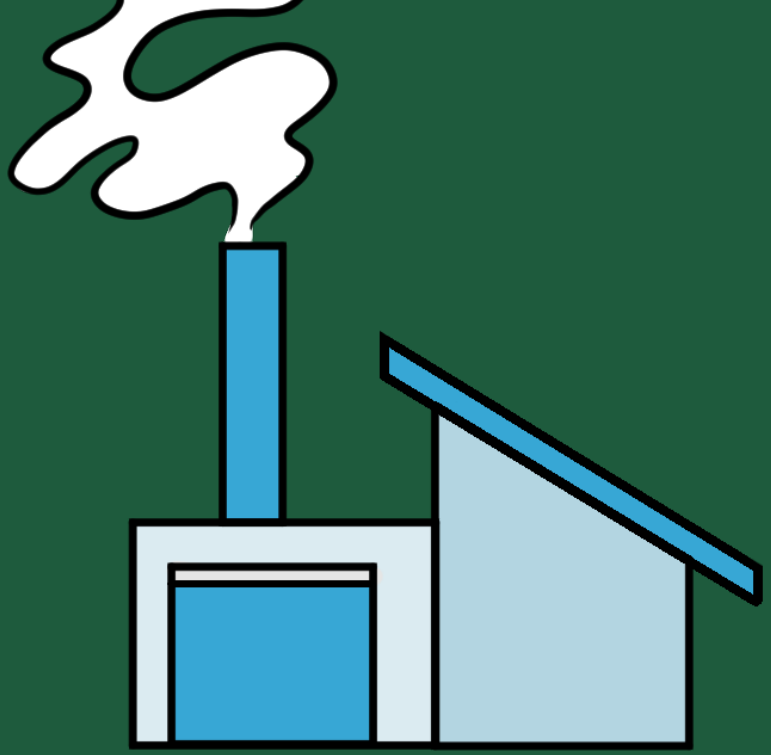
# Bauxite Mining



# Processing

Alumina Refining

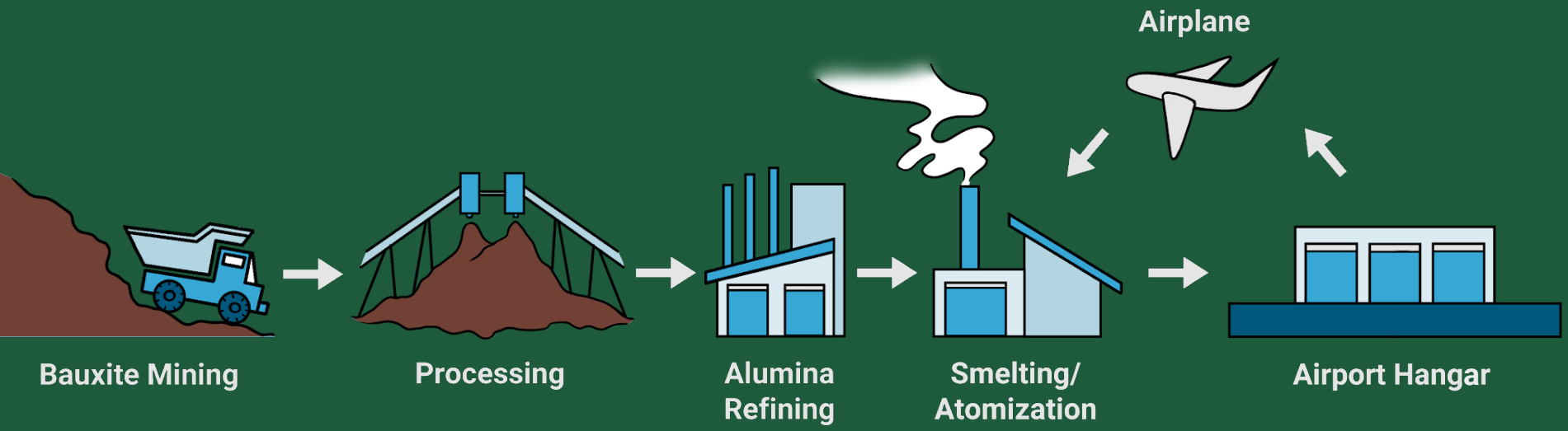
Smelting/ Atomization



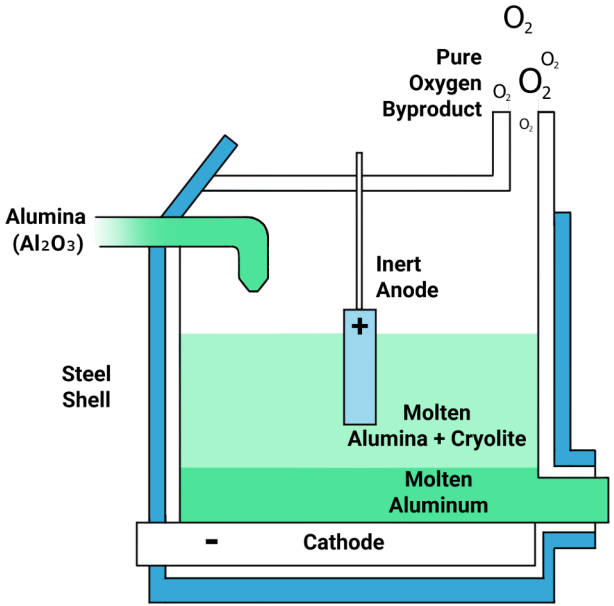
# Smelting/ Atomization

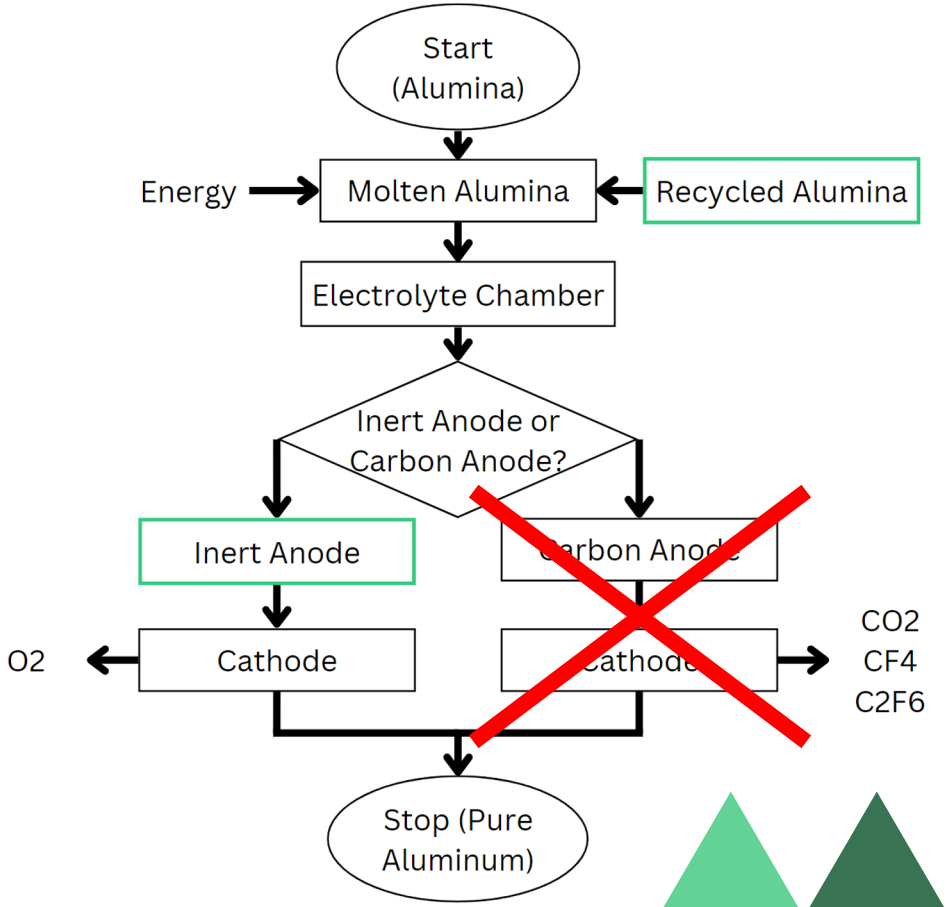
# Airport Hangar

# Alumina Refining

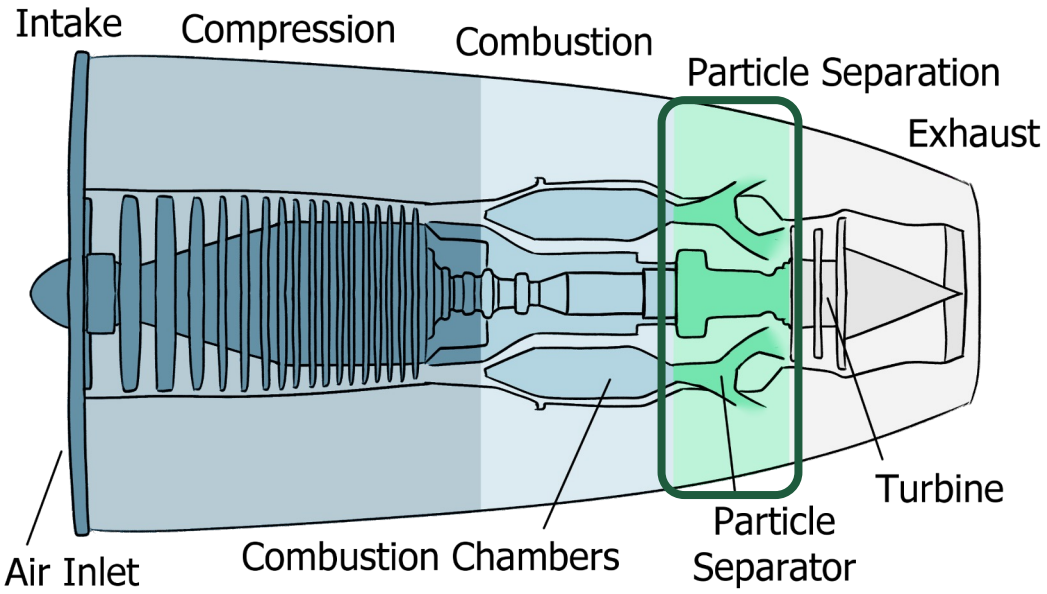

Airplane
Bauxite Mining
Processing
Alumina Refining
Smelting/ Atomization
Airport Hangar

# Supply Chain – Inert Anode



# 4. Engine




$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

# Engine - Modified Components

Fuel Injection

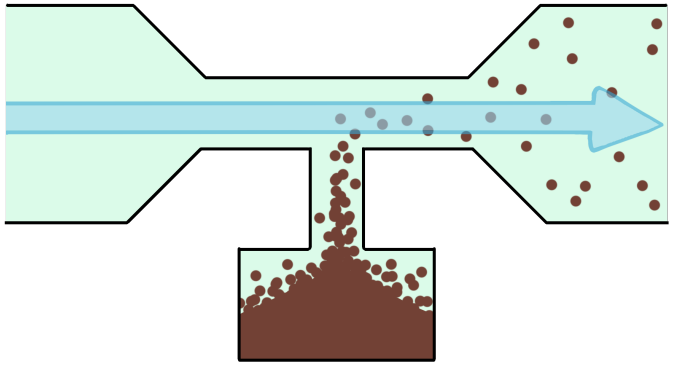
Combustion Chamber

Fuel Ignition

Particle Separator

# Engine - Modified Components

## Fuel Injection



Shift to Solid Fuel

Powder Dispersers | Venturi Channel

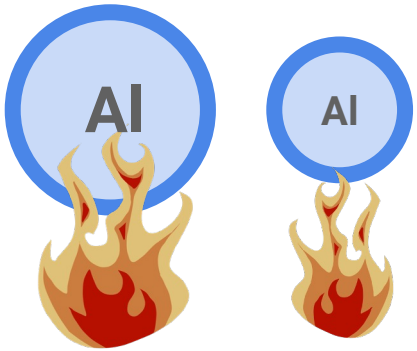
Aluminum Aerosol

High Speed Air Required

TRL: 4
‘Validation in Lab’

# Engine - Modified Components

## Fuel Ignition




High Ignition Temps

Smaller Particle Size

High Energy Igniter

Retain Ordinary Igniters

New Combustor Components

TRL: 4

TRL: 5
‘Ground Model’

# Engine - Modified Components

## Combustion Chamber

3500K

2600K

High Burn Temps

Smaller Particle Size | Combustion Chamber Design

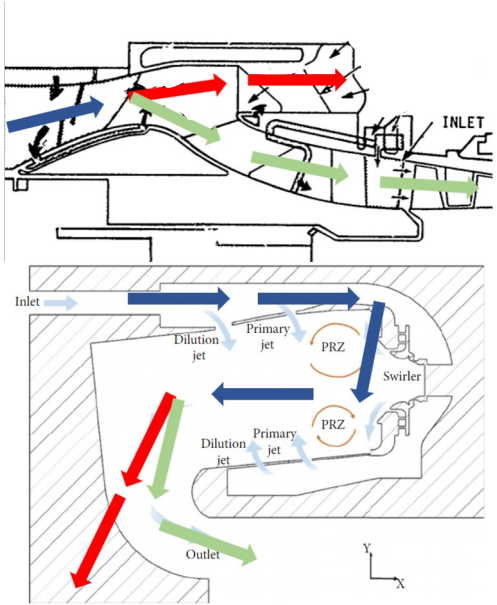
Mimic Jet A Burn Temperatures

Optimal Particle Size Research

TRL: 4

# Engine - New Component

## Particle Separator




Exhaust Byproduct Capture

Subsonic Flow Turn

Reverse Flow Combustor

Extra Space Required

Further Testing

TRL: 6 ‘System Model’

TRL: 2 ‘Concept’

# Engine - Other Emissions

**$NO_x$**

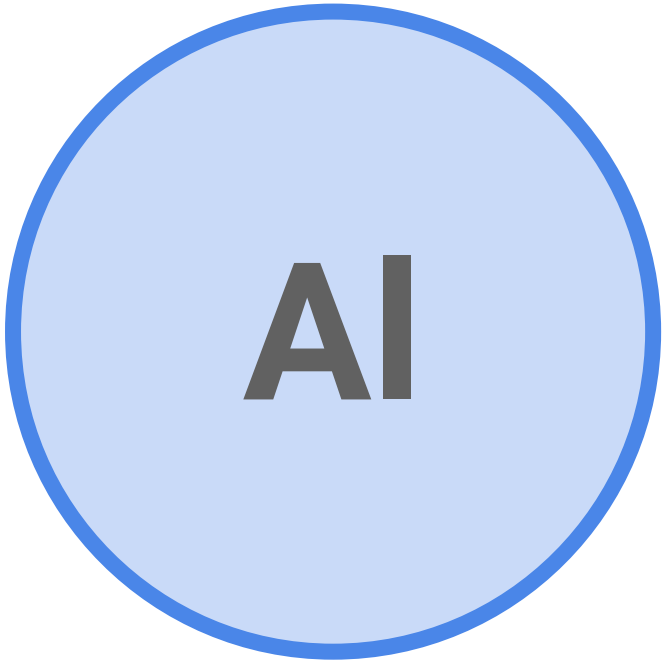
Emissions Reduction

| | |
|---|---|
| Decrease Burn Temps | Particle Filtering |
| Engine Performance | Reuse Existing Components |
| TRL: 4 | TRL: 2 |

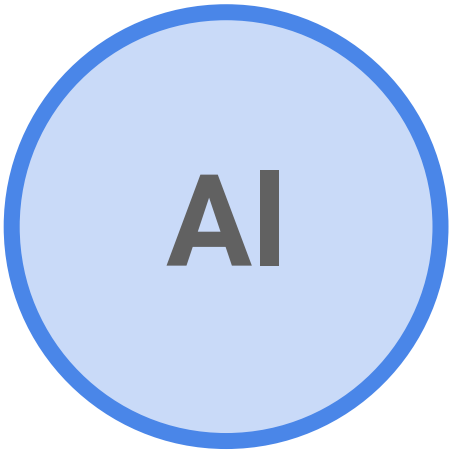
# Engine – Particle Size

# Engine – Particle Size

Large ~100μm




Small ~10nm



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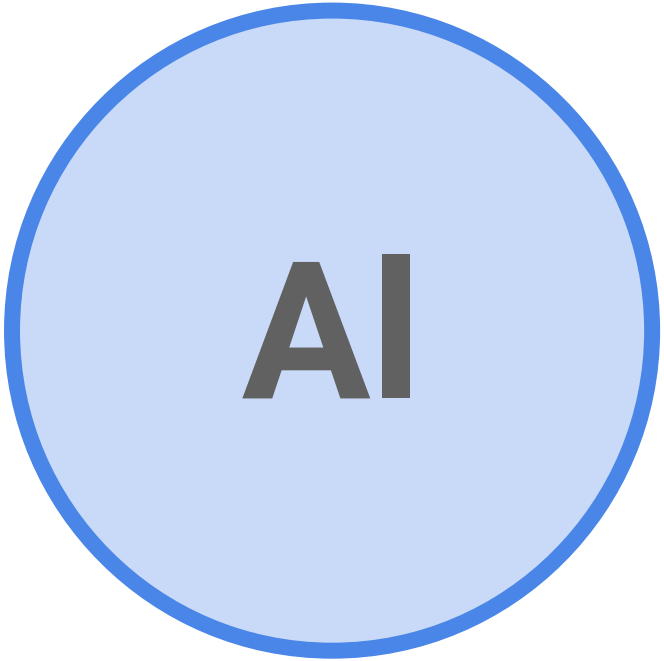
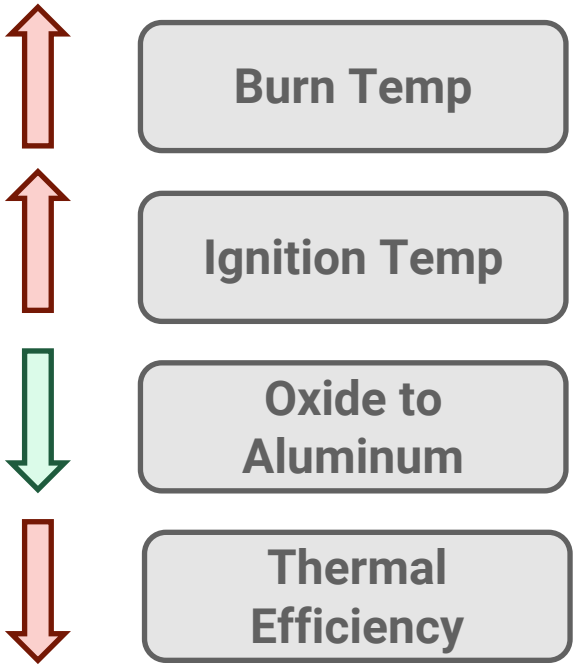
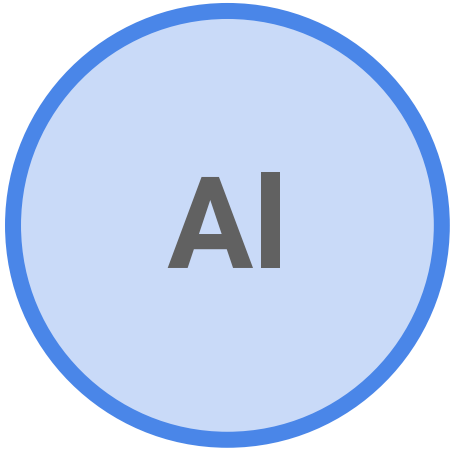
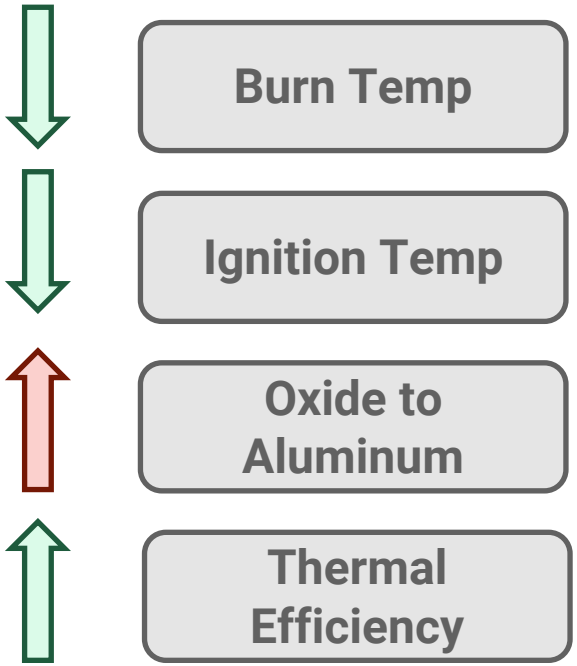


# Engine – Particle Size

Small ~10nm



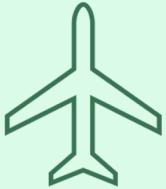
# 5. Cost Analysis

# Non-recurring

**$785B**

**Construction of new smelter facilities**

**29%**



**Retrofit commercial aircraft**

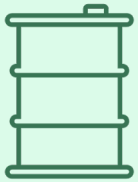
**41%**

**Buying new aluminum**

**30%**

# Recurring

**Jet A**
**$87.5B per year**

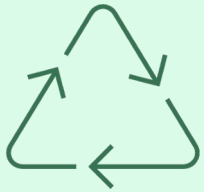


Cost of fuel — 34%

Engine maintenance — 46%

Labor & transportation — 20%

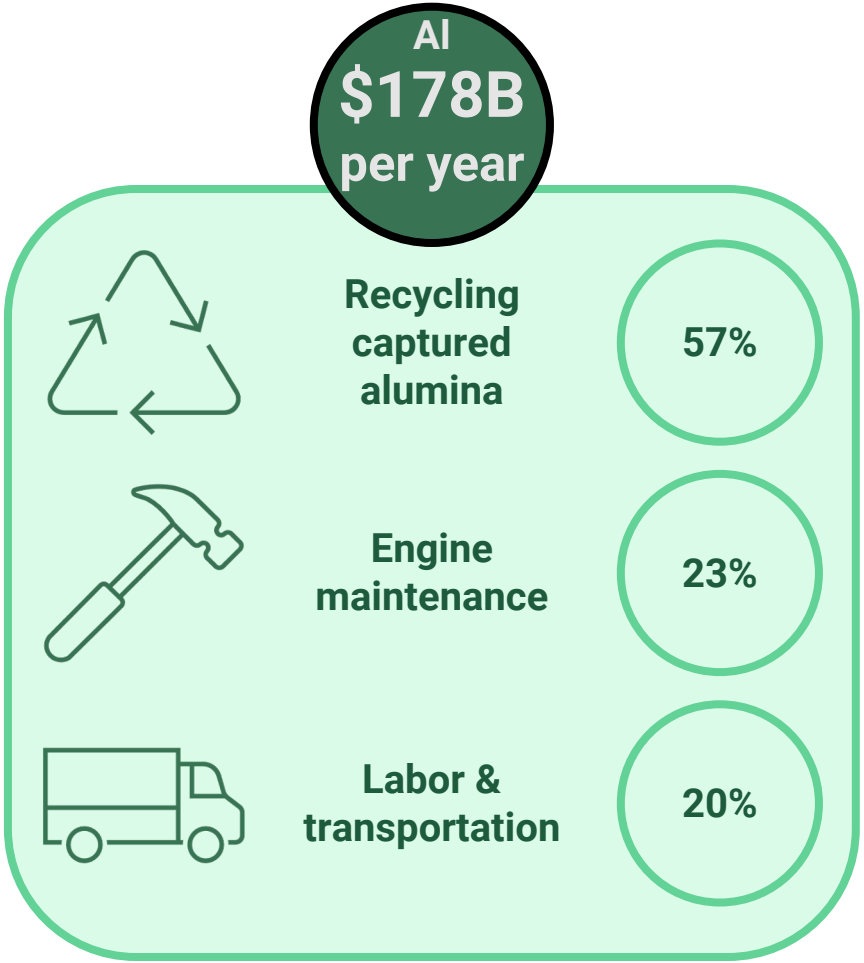
**Al**
**$178B per year**



Recycling captured alumina — 57%

Engine maintenance — 23%

Labor & transportation — 20%




**103% Increase (2x as much)**

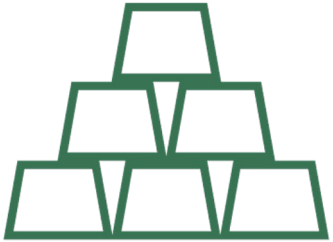
# Cost Reduction Methods

1

Commercial Energy Contracts

2

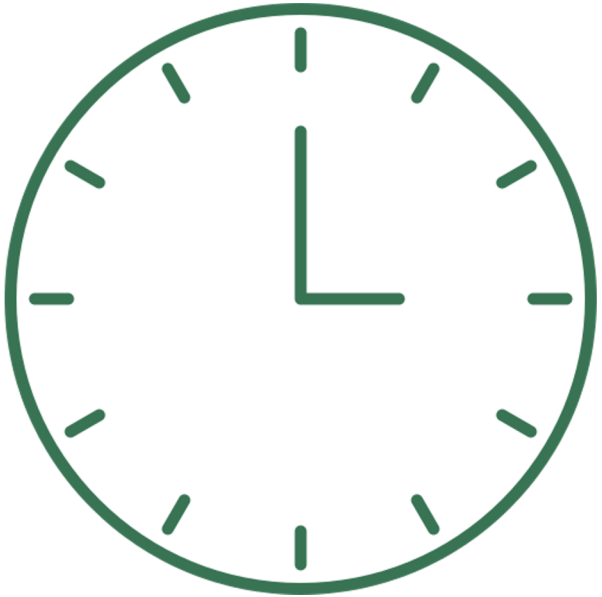
Smelter Raw Material Price Decrease

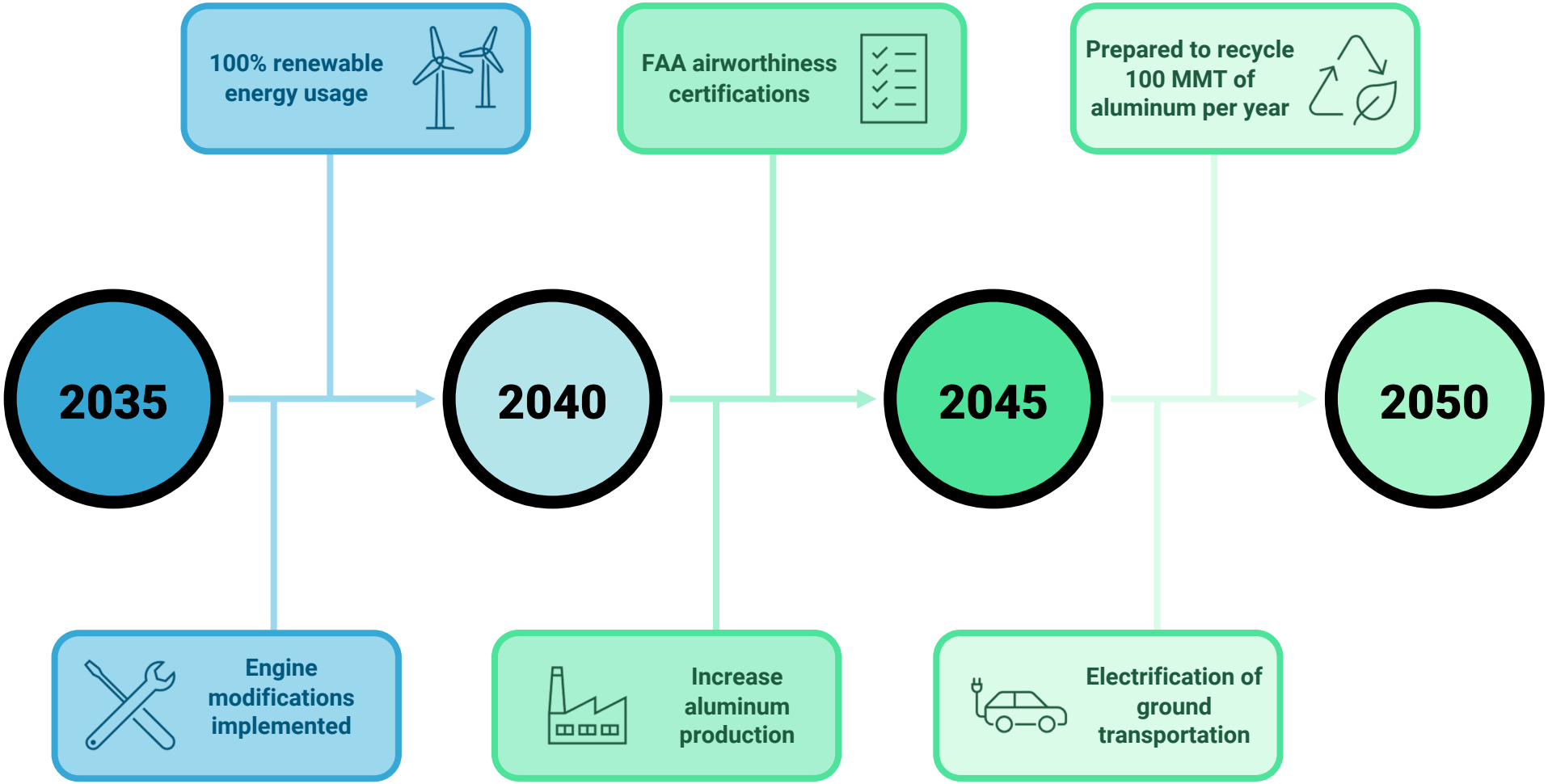


3

Increased Engine Efficiency

# 6. Timeline




100% renewable energy usage
FAA airworthiness certifications
Prepared to recycle 100 MMT of aluminum per year
2035
2040
2045
2050
Engine modifications implemented
Increase aluminum production
Electrification of ground transportation

# Conclusions

1. Aluminum powder will reduce carbon emissions by up to 96%.
2. Minimal changes to current aluminum processing technology.
3. Recycling 100 million MT of aluminum per year.
4. Gas turbine engines will require modifications.
5. Total non-recurring cost of $785B, recurring cost doubles.
6. Transition by 2050 with zero harmful emissions.

# THANK YOU!

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