GHG Emission Reduction Plan

Alumex PLC

Executive Summary

Alumex PLC has developed a comprehensive and forward-looking Carbon Reduction Pathway (2025–2050) as part of its long-term strategic commitment to achieving net-zero greenhouse gas (GHG) emissions and aligning with internationally recognized climate frameworks, including the 1.5°C temperature pathway under the Paris Agreement. This strategy reflects the company's proactive approach to sustainability, integrating environmental responsibility into its core operational and business planning.

The Carbon Reduction Pathway is structured as a phased and science-based approach, designed to systematically reduce both emission intensity (tCO_2e per unit of production) and absolute emissions, while enabling continued business growth. This decoupling of emissions from production is a central principle of the strategy, ensuring that environmental performance improves even as operational output increases.

Alumex currently operates with an estimated emission intensity of approximately 1.45 tCO_2e per unit of production, reflecting emissions associated with energy consumption, primarily from Scope 1 (direct fuel combustion) and Scope 2 (purchased electricity) sources.
Despite anticipated growth in production and corresponding increases in absolute emissions, Alumex has set a long-term emission intensity reduction target of 0.08 tCO_2e per unit by 2050. This ambitious target represents a substantial reduction in carbon intensity and demonstrates a commitment to deep decarbonization across all operational levels.

1. Introduction

1.1 Background and Climate Context

The global aluminum industry is recognized as an energy-intensive and emissions-critical sector, with significant contributions to global greenhouse gas (GHG) emissions due to high electricity consumption and fuel-based thermal processes. In response to increasing climate risks and evolving regulatory expectations, industries worldwide are transitioning toward low-carbon and climate-resilient operating models.

Alumex PLC, as a leading aluminum extrusion manufacturer in Sri Lanka, operates within this context of increasing climate responsibility and market-driven sustainability requirements. The company's operations, including extrusion, anodizing, and finishing processes, involve substantial energy consumption, primarily derived from electricity (Scope 2 emissions) and diesel-based fuel combustion (Scope 1 emissions).

The current emission profile indicates an emission intensity of approximately 1.45 tCO_2e per unit of production, highlighting the need for a structured and technically sound decarbonization strategy. At the same time, anticipated business growth is expected to increase absolute emissions over time, reinforcing the importance of decoupling emissions from production growth.

In alignment with global climate science, particularly the IPCC 1.5°C pathway, there is an increasing imperative for organizations to:

- Reduce energy consumption through operational efficiency
- Transition to renewable and low-carbon energy sources
- Implement carbon removal strategies to address residual emissions

Alumex PLC recognizes these imperatives and has developed a long-term Carbon Reduction Pathway (2025–2050) to address climate-related risks while maintaining sustainable business growth.

1.2 Purpose and Objectives of the Study

The primary purpose of this study is to develop a comprehensive, science-based Carbon Reduction Pathway for Alumex PLC, providing a structured roadmap toward achieving net-zero emissions by 2050.

The specific objectives of this study are:

- To assess the current GHG emission baseline and identify key emission sources across Scope 1 and Scope 2 categories
- To evaluate emission intensity and energy intensity trends and establish a forward-looking reduction trajectory
- To develop and document a three-tier decarbonization strategy, consisting of:
    - Short-term process optimization measures
    - Medium-term renewable energy and electrification strategies
    - Long-term carbon removal through nature-based solutions
- To quantify the carbon sequestration potential of integrated reforestation and mangrove restoration projects using recognized methodologies such as CDM, IPCC, and blue carbon frameworks
- To define technically and financially viable interventions to reduce energy consumption, improve operational efficiency, and transition toward renewable energy systems
- To establish a monitoring, reporting, and verification (MRV) framework aligned with international standards
- To ensure alignment with global sustainability frameworks, including ASI Performance Standard, GHG Protocol, and Paris Agreement goals

This study serves as both a strategic planning tool and a technical reference document to guide Alumex PLC’s transition toward a low-carbon and sustainable manufacturing model.

1.3 Strategic Alignment with Global Frameworks

The Carbon Reduction Pathway of Alumex PLC is developed in alignment with leading international climate and sustainability frameworks to ensure credibility, transparency, and global relevance.

1.3.1 Paris Agreement and 1.5°C Pathway

The strategy aligns with the Paris Agreement, particularly the goal of limiting global temperature rise to 1.5°C above pre-industrial levels. The emission intensity reduction target from 1.45 to 0.08 tCO_2e per unit by 2050 reflects a science-based approach consistent with deep decarbonization pathways recommended by the IPCC. This overall emission reduction reflects

1.3.2 IPCC Guidelines (GHG Accounting and LULUCF)

The methodology adopted in this study is aligned with the Intergovernmental Panel on Climate Change (IPCC) guidelines, including:

- Energy sector emission accounting
- Land Use, Land-Use Change, and Forestry (LULUCF)
- Carbon stock change methodologies

These guidelines ensure scientifically robust and internationally accepted emission calculations.

1.3.3 Clean Development Mechanism (CDM)

Carbon sequestration from reforestation and mangrove projects is calculated in accordance with CDM methodologies, incorporating:

- Baseline scenario assessment
- Project scenario modeling
- Leakage deductions (10%)
- Non-permanence buffer (20%)

This ensures conservative and credible estimation of carbon removal.

1.3.4 Blue Carbon Methodologies

Blue carbon methodologies refer to a set of scientific and accounting approaches used to quantify, monitor, and verify carbon sequestration within coastal and marine ecosystems, particularly mangroves, seagrasses, and salt marshes. Among these, mangrove ecosystems are of particular relevance due to their exceptionally high capacity for long-term carbon storage in both biomass and, more significantly, soil organic carbon pools.

1.3.5 ASI Performance Standard

The strategy supports compliance with the Aluminium Stewardship Initiative (ASI) Performance Standard, particularly in areas related to:

- Environmental management
- GHG emissions reduction
- Biodiversity and ecosystem protection
- Stakeholder engagement and transparency

1.4 Scope and Limitations of the Study

1.4.1 Scope of the Study

This study is focused on the Alumex PLC manufacturing facilities, primarily:

- Sapugaskanda plant (primary operational site)
- Associated operational activities related to extrusion, anodizing, and finishing processes

The scope includes:

- Scope 1 emissions (direct emissions from diesel combustion and on-site activities)
- Scope 2 emissions (indirect emissions from purchased electricity)
- Energy consumption across major operational systems, including:
    - Compressed air systems
    - Extrusion presses
    - Anodizing lines
- Development of renewable energy strategies, including solar PV integration and energy storage systems
- Implementation of energy efficiency measures through process optimization and ISO 50001 alignment
- Design and estimation of nature-based carbon removal projects, including:
    - Reforestation (green carbon)
    - Mangrove restoration (blue carbon)

The study also considers emission intensity reduction pathways, aligning with long-term production growth projections.

1.4.2 Limitations of the Study

While this study provides a comprehensive framework, certain limitations are acknowledged:

- Carbon sequestration estimates are based on literature values and conservative assumptions, and actual values may vary depending on site-specific conditions

- The availability of land (100 acres) limits the scale of nature-based carbon removal projects
- Certain data inputs are based on engineering estimates and operational assumptions, which may require refinement during implementation
- Renewable energy projections are subject to technical, financial, and regulatory constraints, including grid policies and infrastructure limitations
- Long-term projections (up to 2050) involve inherent uncertainties related to:
    - Market conditions
    - Technological advancements
    - Climate variability
- The study does not include detailed Life Cycle Assessment (LCA) beyond the operational boundary, which may be considered in future assessments

2. Organizational and Operational Boundary

2.1 Organizational Boundary (Operational Control Approach)

Alumex PLC has established its organizational boundary in accordance with the ISO 14064-1:2018 standard, applying the Operational Control Approach. Under this approach, the organization accounts for 100% of greenhouse gas (GHG) emissions from all operations over which it has full operational authority to implement policies and controls.

The organizational boundary of Alumex PLC includes the following facilities:

- Head Office & Main Factory
  Pattiwila Road, Sapugaskanda, Makola, Sri Lanka
- Alumex Prime Plant (Subsidiary – Fully Owned)
  No. 1/138, Minuwangoda Road, Ekala, Ja-Ela, Sri Lanka
- Value Added Manufacturing Facility & 3R Plant
  Lanka Industrial Estate (LINDEL), Makola, Sri Lanka
- Central Warehouse
  Maguruwila Road, Gonawala, Sri Lanka

All emissions arising from the above facilities are included within the organizational boundary as Alumex PLC exercises full operational control over these sites and processes.

2.2 Facility Description (Sapugaskanda and Ekala)

Sapugaskanda Main Factory

The Sapugaskanda facility serves as the primary aluminum extrusion and finishing plant, housing major operational systems including:

- Extrusion presses
- Anodizing lines

- Powder coating systems
- Wood finish Process
- Melting and Homogenizing Process
- Utility systems such as:
    - Compressed air systems
    - Electrical rectifiers
    - Cooling systems

This facility is characterized by high energy intensity, with significant use of electricity and fossil fuels (primarily diesel, furnace oil, and LPG) across production processes.

Alumex Prime Plant (Ekala)

The Ekala plant operates as a fully owned subsidiary supporting extrusion and finishing operations. It includes:

- Manufacturing and fabrication units
- Supporting utilities and logistics
- Storage and dispatch systems

This facility contributes to overall production capacity and follows similar energy and emission patterns as the main plant, albeit at a smaller scale.

LINDEL Value Added & 3R Facility

This facility focuses on:

- Value-added processing
- Recycling and reuse (3R – Reduce, Reuse, Recycle)
- Waste handling and material recovery

It plays a key role in Alumex's circular economy initiatives, contributing to waste reduction and material efficiency.

Central Warehouse (Gonawala)

The warehouse supports:

- Storage of finished products and raw materials
- Logistics and distribution activities

Emissions associated with warehousing are primarily linked to electricity use and material handling operations.

2.3 Operational Boundary and Process Mapping

The operational boundary of Alumex PLC includes all activities that generate GHG emissions across the value chain within controlled operations. These emissions are categorized into:

(a) Direct Emissions (Scope 1)
(b) Indirect Energy Emissions (Scope 2)
(c) Other Indirect Emissions (Scope 3)

Process Flow and Emission Sources

1. Raw Material Handling

- Aluminum billets and auxiliary materials
- Energy use in handling and storage

2. Preheating and Furnace Operations

- Use of:
  - Diesel
  - Furnace oil
  - LPG
- High thermal energy consumption

3. Extrusion Process

- Electricity-driven mechanical extrusion
- Significant Scope 2 emissions

4. Surface Treatment

- **Anodizing**:
  - Electrical rectifiers
  - Electrochemical processes
- **Powder coating**:
  - Thermal curing ovens

5. Utility Systems

- Compressed air systems
- Cooling systems
- Electrical infrastructure

6. Logistics and Warehousing

- Internal material movement
- Storage and distribution

2.4 Emission Boundary Definition (Scope 1, 2, and 3)

Scope 1 – Direct Emissions

Scope 1 emissions include all **direct emissions from sources owned or controlled by Alumex PLC**, categorized as follows:

(a) Stationary Combustion

- Diesel
- Furnace oil
- LPG
- Oxy-acetylene (welding operations)

These fuels are used in:

- Smelting furnaces
- Homogenizing ovens
- Preheating systems

(b) Mobile Combustion

- Company-owned vehicles
- Forklifts and tractors
- Diesel and petrol consumption

(c) Fugitive Emissions

- Refrigerant leakage from:
  - R401A
  - R22
  - R32
- CO_2 emissions from fire extinguishers

These emissions are calculated using **IPCC AR5 Global Warming Potentials (GWP)**.

Scope 2 – Indirect Energy Emissions

Scope 2 emissions arise from:

- **Purchased electricity** from:
  - Ceylon Electricity Board (CEB)

Electricity is used across:

- Manufacturing processes
- Utilities
- Administrative functions

Emission calculations are based on:

- Sri Lanka national grid emission factors
- Electricity consumption data from utility bills

Scope 3 – Other Indirect Emissions

Scope 3 emissions include a wide range of value chain activities:

(a) Employee Commuting

- Data collected via employee surveys
- Includes:
  - Public transport
  - Private vehicles
  - Company transport

Emission factors are derived from **University of Moratuwa studies**.

(b) Business Air Travel

- Data from administrative records
- Calculated using **ICAO Carbon Emissions Calculator**

(c) Material Import

- Raw material transport (international shipping/air freight)
- Calculated using:
  - Distance estimation tools

  - Shipment weight data

(d) Material Export
- Product distribution to international markets
- Emissions calculated similarly to imports

(e) Transmission and Distribution Losses
- Based on national grid loss factors
- Applied proportionally to electricity consumption

(f) Waste Treatment and Disposal
- Food waste → sent to piggeries (methane emissions)
- Dry waste → recycling, incineration, or export
- Aluminum sludge → sent for co-processing in cement kilns

Emission factors sourced from:
- IPCC
- DEFRA / DECC

(g) Freshwater Supply
- Emissions from:
  - Water distribution
  - Extraction (groundwater)
- Calculated using:
  - NWSDB emission factors

3. GHG Inventory and Baseline Assessment

3.1 Base Year Selection and Justification

The base year for Alumex PLC’s GHG inventory has been established as Financial Year 2024, following the identification and correction of a calculation inconsistency during the data review process. This adjustment ensures the accuracy, transparency, and consistency of the GHG inventory in line with ISO 14064-1:2018 requirements and ASI Entity - Level GHG Pathways Methods.

The selected base year represents a complete and verified dataset, incorporating all relevant emission sources across Scope 1, Scope 2, and Scope 3. It reflects stable operational conditions and serves as a reliable benchmark for future comparisons. It also aligns with Alumex PLC’s strategic commitment to long-term decarbonization and net-zero emissions by 2050.

The base year will be used as a reference point for:

- Tracking emission intensity reductions
- Monitoring emission intensity improvements
- Evaluating the effectiveness of carbon reduction strategies

In accordance with ISO 14064-1:2018, any significant changes in operations, data, or methodologies will be assessed, and the base year will be recalculated where necessary to maintain consistency.

3.2 GHG Inventory Methodology (GHG Protocol Alignment)

The GHG inventory of Alumex PLC is developed in accordance with the following frameworks:

- **ISO 14064-1:2018** – Organization-level GHG quantification and reporting
- **GHG Protocol Corporate Standard** – Scope-based accounting
- **IPCC Guidelines (2006 & 2019 refinements)** – Emission factors and methodologies

General Calculation Formula

For all emission sources:

$$\textbf{GHG Emissions (tCO}_2\textbf{e) = Activity Data} \times \textbf{Emission Factor} \times \textbf{GWP}$$

Where:

- **Activity Data**: Fuel consumption, electricity usage, distance traveled, etc.
- **Emission Factor**: Source-specific emission factors (IPCC, DEFRA, national data)
- **GWP (Global Warming Potential)**: IPCC AR5 values

Data Collection and Management

- **Activity data is collected from primary sources**, including:
    - Fuel logs
    - Utility bills
    - Inventory records
    - Employee surveys
- Data is compiled on a **monthly basis and aggregated annually**

3.3 Current Emissions Profile

The total GHG emissions of Alumex PLC for the reporting year (2024) are distributed across three scopes as follows:

Scope 1 – Direct Emissions

- Dominated by **diesel combustion**, with minor contributions from:
    - Furnace oil
    - LPG
    - Refrigerant leakage
- Includes emissions from:
    - Stationary combustion
    - Mobile combustion
    - Fugitive emissions

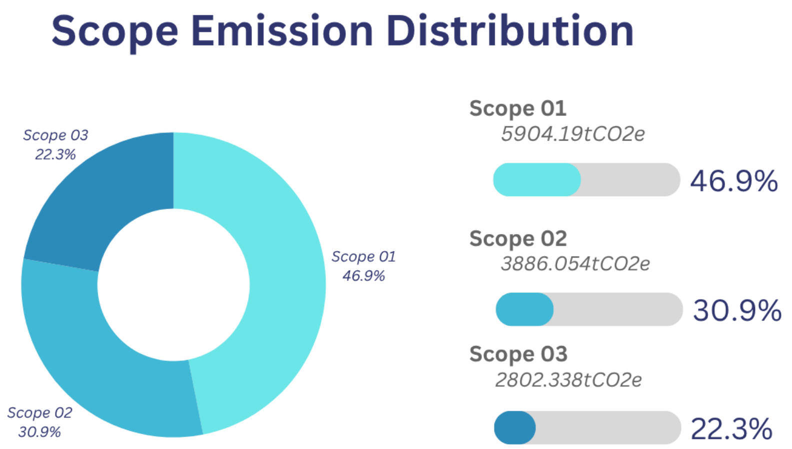
Scope 2 – Indirect Energy Emissions

- Derived from **purchased electricity** from:
    - CEB

Represents a significant portion of total emissions due to high energy intensity of manufacturing processes

Scope 3 – Other Indirect Emissions

- Includes:
    - Employee commuting
    - Business travel
    - Raw material transport
    - Finish goods transport
    - Waste treatment
    - Water withdrawal
    - Transmission and distribution losses
- While not directly controlled, these emissions are **quantified and monitored** as part of extended ESG reporting


Scope Emission Distribution

4. Emission Reduction Targets and Climate Alignment

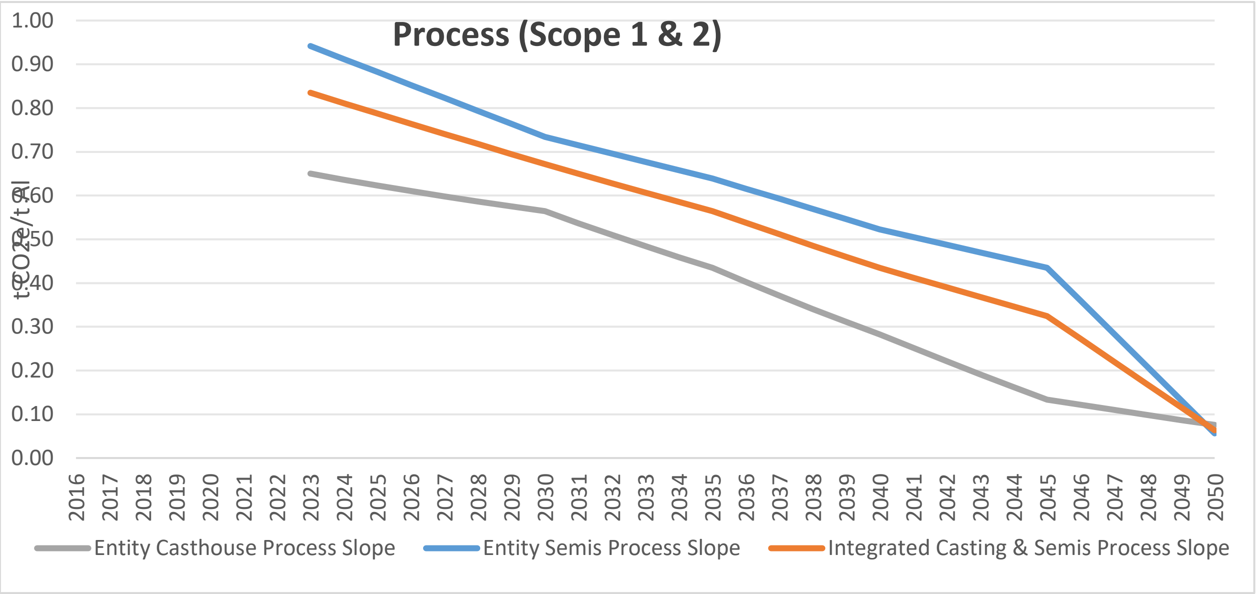
4.1 Emission Intensity Reduction Target

Alumex PLC has established a long-term emission intensity reduction target based on the ASI slope methodology and aligned with global decarbonization pathways

Scope 1 and 2 Emission

	Baseline (2024/25)	2025/26	2026/27	2027/28	2028/29	2029/30
Cast House	**0.49**	**0.48**	**0.47**	**0.46**	**0.45**	**0.45**
Semi Fabrication	**0.77**	**0.75**	**0.72**	**0.70**	**0.67**	**0.65**
Integrated	**0.67**	**0.65**	**0.63**	**0.61**	**0.59**	**0.55**

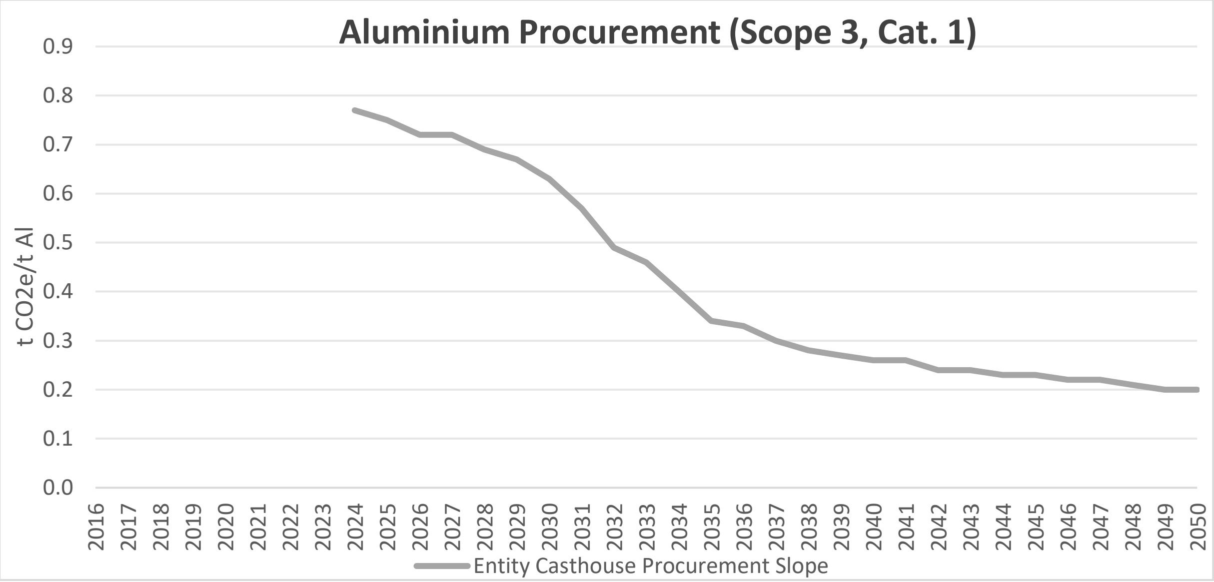
By 2050 reduce integrated emission from 0.55tCO2e to 0.06tCO2e



Procurement Slope

	Baseline (2024/25)	2025/26	2026/27	2027/28	2028/29	2029/30
Cast House	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**	**0.7**
Semi Fabrication	**5.0**	**4.8**	**4.6**	**4.5**	**4.3**	**4.1**
Integrated	**4.5**	**4.3**	**4.1**	**4.1**	**3.9**	**3.7**

By 2050 reduce integrated emission from 3.7tCO2e to 0.2 tCO2e



Reduction Trajectory

The reduction pathway follows a **progressive and linear decarbonization curve**, consistent with the **ASI slope approach**, which defines stepwise improvements in emission intensity across time.

This pathway is achieved through:

- Continuous **process optimization**
- Transition to **low-carbon energy sources**
- Integration of **renewable energy systems**
- Implementation of **carbon sequestration projects**

Link to Plant-Level Data

Plant-level emission intensities (e.g., casthouse and semi-fabrication) are used as **building blocks** to derive the **organization-wide emission intensity**, calculated as:

$$\text{Organizational Emission Intensity} = \frac{\sum(\text{Plant Emissions})}{\sum(\text{Plant Production})}$$

Where:

- Each plant contributes based on its **production-weighted share**
- Improvement in individual plants directly influences the **overall organizational intensity**
- This ensures **data aggregation integrity and consistency**

4.2 Absolute Emission Outlook under Growth Scenario

While Alumex PLC targets a significant reduction in emission intensity, absolute emissions are expected to:

- **Increase in the short to medium term**, due to:
    - Expansion of production capacity
    - Installation of new manufacturing lines
    - Market-driven growth

Projection Characteristics

- **Short Term (2025–2030):**
    - Moderate increase in absolute emissions
    - Driven by operational expansion
    - Offset partially by efficiency improvements
- **Medium Term (2030–2040):**
    - Stabilization of emissions
    - Increased contribution from renewable energy
- **Long Term (2040–2050):**
    - Gradual reduction in absolute emissions
    - Enabled by:
        - Full energy transition
        - Carbon sequestration (nature-based solutions)

Key Principle

Decoupling = Emissions increase < Production growth

4.3 Decoupling Emissions from Production Growth

Alumex PLC adopts a **decoupling strategy**, ensuring that:

- Production increases
- While emission intensity decreases significantly

Decoupling Mechanism

The decoupling is achieved through a combination of:

1. Process Optimization (Short Term)

- Centralized compressed air system
- Replacement of anodizing rectifiers
- High-efficiency extrusion machinery

2. Energy Transition (Medium Term)

- ISO 50001 implementation
- Solar PV expansion
- Real-time energy monitoring systems

3. Carbon Removal (Long Term)

- Reforestation
- Mangrove (blue carbon) restoration
- CDM sequestration

Mathematical Representation

$$\text{Emissions Growth Rate} < \text{Production Growth Rate} \Rightarrow \text{Emission Intensity Reduction}$$

4.4 Alignment with 1.5°C Pathway

Alumex PLC’s emission reduction targets are developed in alignment with internationally recognized climate frameworks, including the Intergovernmental Panel on Climate Change (IPCC), the Science Based Targets initiative (SBTi), the Aluminium Stewardship Initiative (ASI), and the International Aluminium Institute (IAI) 1.5°C scenario.

The ASI GHG reduction pathway serves as the primary methodological framework for target setting and emissions accounting. Under the ASI Performance Standard (V3, 2022), certified entities are required to develop a quantified GHG emissions reduction plan aligned with a 1.5°C climate scenario, supported by the ASI Entity GHG Pathways Method and Calculation Tool. This methodology establishes a linear or near-linear emission intensity reduction slope, ensuring measurable and auditable decarbonization across the aluminium value chain.

In parallel, Alumex PLC aligns its strategy with the IAI 1.5°C scenario, which provides a sector-specific decarbonization pathway for the aluminium industry. The IAI scenario defines the trajectory required for the global aluminium sector to remain within a 1.5°C carbon budget, emphasizing:

- Rapid reduction in Scope 1 emissions through energy efficiency and fuel switching
- Transition toward low-carbon electricity (renewables) to reduce Scope 2 emissions
- Deployment of carbon removal and circularity strategies to address residual emissions

The IAI 1.5°C pathway complements the ASI methodology by providing a global industry benchmark, while ASI ensures facility-level and entity-level implementation through the slope-based reduction model. Together, these frameworks establish a robust, science-based foundation for Alumex PLC’s decarbonization strategy.

Under this integrated approach:

- ASI methodology governs target setting, calculation, and verification using emission intensity slopes
- IAI scenario provides the sectoral 1.5°C alignment and global benchmarking
- IPCC and SBTi frameworks ensure consistency with climate science and science-based target validation principles

The emission reduction trajectory defined for Alumex PLC follows this combined framework, ensuring:

- A progressive reduction in emission intensity from the baseline level to 0.08 tCO_2e/t Al by 2050
- Alignment with sectoral decarbonization pathways (IAI)
- Compliance with ASI Performance Standard requirements
- Consistency with global 1.5°C climate science (IPCC / SBTi)

This integrated methodology ensures that Alumex PLC's carbon reduction pathway is scientifically robust, industry-aligned, and fully auditable, while enabling long-term alignment with global net-zero ambitions.

4.5 Target Validation and Assumptions

The emission reduction targets established for Alumex PLC are validated based on a combination of internationally recognized methodologies, including the ASI Entity GHG Pathways Method, the IAI 1.5°C scenario, and principles outlined under IPCC and SBTi frameworks.

1. Methodological Validation

- Targets are developed using the ASI slope-based approach, which defines a structured reduction in emission intensity over time.
- The methodology ensures that emission reduction is quantifiable, transparent, and auditable, in line with ASI Performance Standard requirements.
- The IAI 1.5°C scenario provides a sector-specific benchmark, confirming that the target trajectory is consistent with global aluminium decarbonization pathways.

2. Organizational Data Integration

- Organizational emission intensity is derived through production-weighted aggregation of plant-level data, ensuring consistency across:
  - Casthouse operations
  - Semi-fabrication processes
- Plant-level performance improvements directly contribute to the overall reduction in organizational emission intensity.

3. Key Assumptions

The target pathway is based on the following assumptions:

- Continuous production growth, driven by market demand
- Progressive energy efficiency improvements, including process optimization
- Increased adoption of renewable energy, particularly solar integration
- Gradual reduction in emission factors associated with electricity supply
- Implementation of carbon removal projects, including reforestation and mangrove restoration

4. Data and Methodological Integrity

- The targets are aligned with:
  - ISO 14064-1:2018 (GHG accounting and reporting)
  - GHG Protocol Corporate Standard
  - ASI Performance Standard (V3)
- Continuous monitoring and verification processes ensure:
  - Data accuracy
  - Consistency over time
  - Transparency in reporting

5. Uncertainty and Limitations

- Future projections may be influenced by:
  - Technological developments
  - Energy market dynamics
  - Regulatory changes
  - Economic and operational variability
- While emission intensity targets are fixed, absolute emissions may vary depending on production growth and external factors.

5. Emission Reduction Pathway (2025–2050)

The emission reduction pathway of Alumex PLC is developed as a **science-based, multi-phase decarbonization trajectory**, integrating process efficiency, renewable energy transition, and carbon removal strategies. The pathway aligns with **ASI GHG methodology** and the **IAI 1.5°C scenario**, targeting a final emission intensity of approximately **0.08 tCO_2e/t Al by 2050**.

5.1 Absolute Emission Projection under Growth.

While emission intensity decreases, total production is expected to grow, which influences absolute emissions.

Assumptions

- Production growth:
  - Current: ~25,000 MT/year
  - Future: ~40,000 MT/year
- Baseline emission intensity:
  - ~0.84 tCO_2e/t

Baseline Emissions (Current)

$$= 10{,}000 \times 0.84$$

$$\approx \mathbf{8{,}400\ tCO_2e/year}$$

Projected Emissions Without Decarbonization

$$= 40{,}000 \times 0.84$$
$$\approx \mathbf{33{,}600\ tCO_2e/year}$$

Projected Emissions With Decarbonization

$$= 40{,}000 \times 0.08$$
$$\approx \mathbf{3{,}200\ tCO_2e/year}$$

Key Insight

Despite a **60% increase in production**, total emissions are reduced by nearly:

$$= 33{,}600 \rightarrow 3{,}200$$
$$\approx \mathbf{90\%\ reduction}$$

This demonstrates **absolute decoupling of emissions from production growth**, a critical requirement for net-zero alignment.

5.2 Contribution of Each Strategy

The emission reduction pathway is driven by three major intervention categories:

1. Process Optimization (Short-Term: 2025–2030)

- Contribution: **~10–15% reduction**
- Key actions:
  - Furnace efficiency
  - Waste heat recovery
  - Compressed air optimization

2. Renewable Energy Transition (Medium-Term: 2030–2045)

- Contribution: **~60–70% reduction**
- Key drivers:
  - Solar expansion (1.2 MW → 9 MW)
  - Self-consumption optimization
  - Battery storage integration

This is the **largest contributor**, directly reducing Scope 2 emissions.

3. Electrification of Processes

- Contribution: **~10–15% reduction**
- Impact:
  - Reduces Scope 1 emissions
  - Enables renewable energy utilization

4. Nature-Based Solutions (Long-Term: 2040–2050)

- Contribution: **Residual offset (~5–10%)**
- Mechanism:
    - Carbon removal (not reduction)
    - Addresses hard-to-abate emissions

5.3 Residual Emission Estimation

Even after full implementation of all technical measures, a portion of emissions will remain due to:

- Process limitations
- Grid dependency during non-solar hours
- Minor fossil fuel usage
- Indirect operational emissions

Estimated Residual Emissions (2050)

$$\approx \mathbf{3{,}000 - 3{,}500\ tCO_2e/year}$$

This corresponds to:

$$\approx \mathbf{0.06 - 0.08\ tCO_2e/t\ Al}$$

Nature-Based Offset Capacity

From NBS program:

- Annual removal ≈ **432 tCO_2e/year**

Gap Analysis

Residual emissions:	~3,200 tCO_2e
NBS removal:	~432 tCO_2e

Remaining gap:

$$\approx \mathbf{2{,}700\ tCO_2e/year}$$

Implication

To fully achieve net-zero, Alumex PLC will require:

- Expansion of NBS projects **OR**
- Purchase of high-quality carbon credits **OR**

Further technological advancements (e.g., green hydrogen, grid decarbonization)

5.4 Upstream Procurement Decarbonization

A significant portion of the overall carbon footprint of aluminium manufacturing does not arise within the direct operational boundary of Alumex PLC, but rather from the **upstream value chain**, particularly the **procurement of aluminium billets**.

Primary aluminium production is globally recognized as one of the most carbon-intensive industrial activities due to:

- bauxite mining,
- alumina refining,
- electrolytic smelting, and
- energy-intensive casting processes.

For extrusion-based manufacturing operations such as Alumex PLC, the carbon footprint associated with purchased billets can therefore represent a substantial share of total lifecycle emissions.

In addition to material production emissions, **transportation of billets from supplier to manufacturing facility** contributes additional Scope 3 emissions through marine freight, road haulage, and inland logistics.

6. Decarbonization Strategy Framework

6.1 Integrated Decarbonization Architecture

The decarbonization strategy of Alumex PLC is structured as a three-layer integrated architecture, designed to systematically reduce emission intensity in alignment with the ASI Entity GHG Pathways Method, 1.5°C climate scenarios, and internationally recognized decarbonization frameworks.

This architecture ensures a progressive transition from operational efficiency to clean energy adoption and finally to carbon removal, enabling both near-term and long-term emission reductions.

Layer 1: Operational Efficiency and Process Optimization Layer

This foundational layer focuses on reducing energy intensity (kWh/ton) through process-level improvements and optimization of existing systems.

Key interventions include:

- Centralization and optimization of compressed air systems
- Replacement of low-efficiency rectifiers in anodizing operations
- Installation of high-efficiency extrusion machinery
- Implementation of ISO 50001 Energy Management System
- Deployment of real-time energy monitoring and analytics systems

This layer aligns with industrial decarbonization research, which identifies energy efficiency as the first and most cost-effective mitigation lever.

Layer 2: Renewable Energy Integration Layer

The second layer focuses on transitioning energy supply to low-carbon and renewable sources, thereby reducing the emission factor (EF) component of the emission equation.

This layer is critical for achieving deep decarbonization, as it addresses Scope 2 emissions, which are a significant component of Alumex PLC’s footprint.

Key strategies include:

- Expansion of solar photovoltaic (PV) systems within facility boundaries
- Integration of renewable energy procurement mechanisms (e.g., PPAs, renewable energy certificates where applicable)
- Gradual reduction in reliance on grid electricity, which currently contributes significantly to emissions
- Electrification of selected thermal processes where technically and economically feasible

Scientific Basis

The transition to renewable energy is supported by decarbonization literature and energy system models, which demonstrate that:

- Carbon intensity of electricity (kg CO_2/kWh) is one of the most critical drivers of industrial emissions
- Increasing renewable penetration leads to system-wide reductions in emission factors
- Combining energy efficiency with renewable energy results in non-linear emission reductions and accelerates progress along decarbonization pathways

This layer directly supports alignment with:

- ASI GHG reduction slope requirements
- IAI 1.5°C aluminium sector pathway
- IPCC climate mitigation scenarios

Layer 3: Carbon Removal and Nature-Based Solutions Layer

The third layer addresses residual emissions that cannot be eliminated through efficiency or energy transition.

This layer focuses on carbon sequestration and offset mechanisms, including:

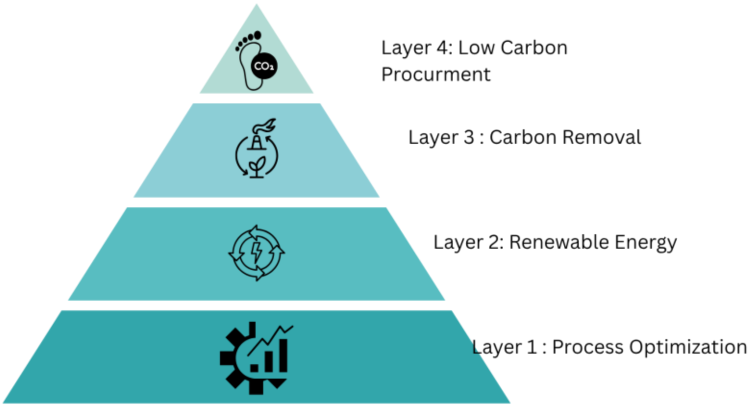
- Reforestation projects (terrestrial carbon sinks)
- Mangrove restoration (blue carbon ecosystems)
- Application of CDM (Clean Development Mechanism) methodologies

Layer 4: Low-Carbon Procurement and Circular Material Transition Layer

The fourth layer of Alumex PLC’s decarbonization architecture addresses upstream material-related emissions, particularly those associated with the procurement of aluminium billets. While operational efficiency and renewable energy primarily reduce Scope 1 and Scope 2 emissions, this layer targets a strategically important portion of Scope 3 emissions, namely purchased goods and services.

For aluminium extrusion operations, the embedded carbon intensity of raw material procurement is often materially higher than direct plant-level operational emissions. Consequently, reducing the embodied carbon of incoming aluminium becomes a major decarbonization lever.

At present, approximately 48% of Alumex PLC’s production is based on OZON billets, which are secondary/recycled aluminium billets with substantially lower embedde



6.2 Avoid–Reduce–Replace–Remove Framework

To structure decarbonization interventions, Alumex PLC adopts an Avoid–Reduce–Replace–Remove (ARRR) framework, a taxonomy widely used in climate mitigation planning that aligns with strategic priorities:

- **Avoid:** Prevent emissions from occurring through design choices, demand reduction, and material efficiency. For example, minimizing waste and maximizing recycled aluminium usage reduces primary energy requirements and associated emissions.
- **Reduce:** Improve energy efficiency in existing processes and systems to lower both direct and indirect emissions per unit of output. Process optimization initiatives such as compressed air centralization and rectifier replacements fall under this category.
- **Replace:** Transition from high-carbon inputs to low-carbon alternatives, such as shifting from grid electricity to solar PV, electrifying thermal processes where feasible, and replacing legacy equipment with high-efficiency assets.

- **Remove:** Implement carbon sequestration strategies to capture and store CO_2, such as reforestation and blue carbon (mangrove) projects, consistent with frameworks that emphasize carbon removal as a complement to mitigation.

This ARRR framework enables prioritization of actions that maximize near-term emission reductions while ensuring long-term sustainability and alignment with 1.5 °C pathways.

6.3 System Interaction Model (Energy Intensity × Emission Factor)

The core scientific basis for Alumex PLC’s decarbonization strategy lies in the interaction between energy intensity and emission factors, which together determine GHG emissions:

$$\textbf{GHG Emissions} = \textbf{Energy Consumption} \times \textbf{Emission Factor}$$

Where:

- **Energy Consumption (EC)** is expressed as energy used per unit of aluminium production (e.g., kWh/ton, MJ/ton).
- **Emission Factor (EF)** reflects the carbon intensity of energy sources (e.g., grid electricity, diesel, solar).

Reducing GHG emissions requires simultaneous reduction in both EC and EF. The system interaction model highlights that even with stable energy consumption, lowering the carbon intensity of the energy source (e.g., through solar PV integration or grid decarbonization) can yield significant emission reductions. Conversely, improving energy efficiency (reducing EC) directly lowers emissions regardless of the energy source. This dual leverage point is fundamental in industrial decarbonization research, which emphasizes combined energy efficiency and low-carbon energy strategies as the most cost-effective pathways to deep decarbonization.

In practice, this model is implemented through:

- Real-time energy monitoring dashboards to identify high-intensity loads.
- ISO 50001 energy management systems to institutionalize continuous improvement.
- Strategic procurement of renewable energy to reduce Scope 2 emission factors.

6.4 Phased Implementation Strategy (2025–2050)

The decarbonization strategy is structured into **phased implementation windows** that correspond to technological maturity, economic feasibility, and strategic impact:

Phase I: Short Term (2025–2030) — Process Optimization and Efficiency Gains

- **Objective:** Reduce energy intensity through targeted operational improvements.

- **Actions:**
    - Centralization of compressed air systems to eliminate redundant loads.
    - Replacement of legacy anodizing rectifiers with high-efficiency units.
    - Installation of high-efficiency extrusion machines to reduce energy per ton of output.
    - Implementation of ISO 50001 and real-time energy monitoring systems.
- **Expected Outcome:** Immediate reductions in energy intensity and GHG emissions, forming the basis of the initial ASI slope improvements.

Phase II: Medium Term (2030–2040) — Renewable Energy Integration and Electrification

- **Objective:** Transition energy supply toward low-carbon sources and electrify high-intensity processes.
- **Actions:**
    - Expansion of solar PV capacity to supply a significant share of plant electricity demand.
    - Procurement of renewable energy certificates or power purchase agreements (PPAs) where direct generation is constrained.
    - Electrification of thermal processes where technically feasible.
- **Expected Outcome:** Substantial reduction in Scope 2 emissions and movement along the ASI intensity slope.

Phase III: Long Term (2040–2050) — Carbon Removal and Residual Emissions Management

- **Objective:** Address residual emissions that remain after operational and energy transitions.
- **Actions:**
    - Deployment of large-scale reforestation (e.g., 60% terrestrial) and mangrove restoration (40% blue carbon) projects over 100 acres.
    - Application of **CDM methodologies** for carbon sequestration quantification and crediting.
    - Integration of carbon removal outcomes into organizational climate reporting.
- **Expected Outcome:** Offset of residual emissions and contribution to net-zero alignment consistent with long-term climate science pathways.

6.5 Short-Term Strategy: Process Optimization (2025–2030)

The short-term decarbonization strategy of Alumex PLC is fundamentally anchored in process optimization and energy efficiency improvements, which represent the most immediate, technically feasible, and economically viable pathway for reducing greenhouse gas (GHG) emissions within industrial operations.

In energy-intensive sectors such as aluminium extrusion and finishing, process-level inefficiencies directly translate into elevated energy consumption and emission intensity. Therefore, targeted optimization of Significant Energy Uses (SEUs) provides the highest marginal abatement potential in the short term, prior to capital-intensive transitions such as renewable energy integration.

This approach is consistent with:

- IPCC mitigation hierarchy, which prioritizes energy efficiency as the first line of decarbonization
- ISO 50001 energy performance improvement principles
- ASI GHG Pathways Method, where early-stage emission reductions are primarily driven by improvements in operational efficiency

6.5.1 Identification of Significant Energy Uses (SEUs)

The identification of SEUs is conducted in line with **ISO 50001:2018**, which defines SEUs as systems or processes that:

- Consume a substantial portion of total energy, or
- Offer significant potential for energy performance improvement

Methodology for SEU Identification

- Analysis of **historical energy consumption data**
- Process-level energy mapping across production lines
- Load profiling and operational monitoring
- Equipment-level energy audits

Key SEUs Identified in Alumex PLC

- **Extrusion Press Systems** (high electrical and mechanical load)
- **Anodizing Plant (Rectifiers)** (high DC power consumption)
- **Compressed Air System** (continuous operation, high leakage losses)
- **Thermal Systems (Furnaces and Ovens)**
- **Auxiliary Systems (cooling, pumps, material handling)**

6.5.2 Implemented Actions and Performance Improvements

• Centralized Compressed Air System

The transition from a decentralized compressor configuration to a centralized system with optimized capacity (dual 75 kW compressors) represents a major improvement in system-level efficiency.

Engineering Significance

Compressed air systems are inherently inefficient, with typical system losses arising from:

- Leakage (up to 20–30% in decentralized systems)

- Pressure mismatches and over-compression
- Inefficient part-load operation of multiple compressors

The centralized configuration enables:

- Optimized load sharing and compressor sequencing
- Operation within optimal efficiency ranges
- Reduction of distribution losses and system leakages

Performance Impact

- Significant reduction in total system electricity consumption
- Elimination of redundant and underutilized equipment
- Annual cost savings exceeding LKR 8 million
- Improved operational reliability through redundancy

Emission Impact

The reduction in electricity consumption directly contributes to:

- Lower Scope 2 emissions
- Reduction in plant-level emission intensity (tCO_2e/t Al)

This intervention alone demonstrates a high-impact, low-capex efficiency improvement, characteristic of effective short-term decarbonization strategies.

- **Anodizing Rectifier Replacement Program**

The anodizing process is highly dependent on rectifiers for DC power supply, making rectifier efficiency a critical determinant of energy consumption.

Engineering Significance

Legacy rectifiers exhibited:

- Low conversion efficiency (~75–80%)
- High thermal losses
- Degraded performance due to repeated rewinding

Replacement with high-efficiency rectifiers (>90%) results in:

- Reduced electrical losses
- Improved current stability and process control
- Lower heat generation and auxiliary cooling demand

Performance Impact

- Reduction in energy consumption per rack (~120 kWh → ~50 kWh)
- Decrease in energy cost per MT of processed aluminium
- Rapid return on investment (payback < 3 months)

Emission Impact

- Significant reduction in specific energy consumption (SEC) of finishing operations
- Direct improvement in Scope 2 emission intensity per unit production

This intervention demonstrates how targeted equipment upgrades can deliver disproportionately high efficiency gains within critical process nodes.

- **High-Efficiency Extrusion Machine Upgrade**

Extrusion processes represent one of the most energy-intensive stages in aluminium manufacturing.

Engineering Significance

The introduction of a high-efficiency extrusion press enables:

- Improved **energy-to-output conversion efficiency**
- Reduction in idle time and part-load losses
- Enhanced thermal management and process stability

Performance Impact

- Lower **kWh per ton of aluminium produced**
- Increased throughput with optimized energy input
- Reduced operational variability

Emission Impact

- Reduction in **gate-to-gate emission intensity** for semi-fabrication processes
- Contribution to overall organizational emission intensity reduction

6.5.3 Planned Actions

- **ISO 50001 Energy Management System**

The implementation of ISO 50001 introduces a systematic and continuous approach to energy performance improvement.

Strategic Role

- Institutionalizes energy efficiency as a core operational objective
- Enables continuous identification and optimization of SEUs
- Supports compliance with ASI and ISO 14064 requirements

- **Real-Time Energy Monitoring Dashboard**

The deployment of real-time monitoring systems provides granular visibility of energy consumption patterns.

Technical Contribution

- Enables real-time tracking of SEC across processes
- Identifies inefficiencies, anomalies, and energy losses
- Facilitates predictive and preventive maintenance

6.5.4 Engineering Analysis of Energy Efficiency Improvements

The effectiveness of process optimization can be understood through the fundamental relationship. In the short term, emission reductions are primarily driven by reductions in energy consumption, as emission factors (grid electricity) remain relatively constant.

System-Level Efficiency Gains

- Reduction in system losses (leakage, conversion losses, idle loads)
- Optimization of equipment operating conditions
- Improved load matching and process control

Cumulative Impact

The combined implementation of multiple optimization measures results in:

- Compounded reduction in total energy demand
- Improvement in overall plant energy performance
- Establishment of a lower energy baseline for future interventions

6.5.5 Impact on Energy and Emission Intensity

Energy Intensity (GJ/t Al)

Process optimization delivers:

- Immediate reduction in SEC across major production processes
- Improved energy efficiency at both equipment and system levels

Emission Intensity (tCO_2e/t Al)

Given the strong dependence on grid electricity:

- Reduced energy consumption directly leads to proportional reduction in Scope 2 emissions
- Aggregated improvements at plant level translate into organizational emission intensity reduction

Strategic Importance in Decarbonization Pathway

Process optimization plays a critical and irreplaceable role in the short-term strategy because:

- It delivers immediate and measurable emission reductions
- Requires relatively low capital investment compared to renewable energy projects
- Improves baseline efficiency, enhancing the effectiveness of future decarbonization measures
- Enables early compliance with ASI emission reduction slopes

6.6 Medium-Term Strategy: Renewable Energy Transition (2030–2040)

The medium-term decarbonization strategy of Alumex PLC is centered on a systemic transition in energy sourcing and consumption, addressing the carbon intensity of electricity (Scope 2 emissions) rather than only operational efficiency.

While short-term initiatives reduce energy demand, this phase focuses on decarbonizing the energy supply, which is essential to achieve meaningful emission reductions under the GHG Protocol Scope 2 framework.

Currently, a substantial share of Alumex PLC's emissions originates from purchased grid electricity, which is associated with a relatively high grid emission factor in Sri Lanka. As a result, even highly efficient operations will continue to generate emissions unless the electricity source is decarbonized.

To address this, Alumex PLC will expand its renewable energy capacity from approximately 1.2 MW to 9 MW, transitioning from a grid-dependent energy model to a partially self-sustained renewable energy system.

This transition represents a strategic decarbonization pathway aligned with:

- ASI GHG Emissions Reduction Methodology
- IAI 1.5°C Aluminium Sector Pathway
- GHG Protocol Scope 2 Guidance

6.6.1 Current Energy Profile and Solar System Assessment

Alumex PLC currently relies heavily on **grid electricity**, which constitutes the majority of its energy consumption and associated emissions. The grid emission factor in Sri Lanka contributes significantly to **Scope 2 emissions**.

Existing Renewable Energy Capacity

- Installed solar PV capacity: ~1.2 MW
- Current operational model: grid export (net metering / net accounting)

Technical Assessment

- The existing solar system generates renewable electricity; however, a significant portion is exported to the grid rather than consumed internally
- Under the GHG Protocol Scope 2 guidance, exported electricity does not directly reduce emissions unless:
  - Renewable Energy Certificates (RECs) are retained, or
  - Electricity is consumed on-site (self-consumption model)

Key Insight

The current system provides renewable generation, but only limited emission reduction benefits due to:

- Lack of alignment between generation and consumption
- Incomplete capture of renewable attributes under market-based accounting

6.6.2 Limitations of Grid Export Model (GHG Accounting Perspective)

Under the GHG Protocol Scope 2 framework, emissions reductions are recognized based on:

- **Location-based method** → based on grid emission factor
- **Market-based method** → based on contractual instruments (e.g., RECs, PPAs)

Key Limitation

Exporting solar energy to the grid does not directly reduce the company's reported Scope 2 emissions unless:

- Renewable Energy Certificates (RECs) are retained and claimed
- Or electricity is directly consumed onsite

Implications for Alumex PLC

- A portion of renewable generation does not translate into reported emission reductions
- The organization is not fully capturing its decarbonization potential
- This creates a gap between technical renewable generation and accounted emission reductions

6.6.3 Solar PV Optimization Strategy (Self-Consumption Model)

To maximize emission reduction, Alumex PLC will transition to a self-consumption-based solar model, where generated renewable electricity is directly utilized within operations.

Technical Approach

- Align solar generation profiles with plant load demand
- Integrate solar output into **high-energy processes (SEUs)**
- Minimize export and maximize onsite consumption

Engineering Benefits

- Direct displacement of grid electricity
- Reduction in **effective emission factor (EF)**
- Improved energy cost stability

Emission Impact

Scope 2 Emissions ↓ ∝ Renewable Energy Share ↑

6.6.4 Solar Capacity Expansion Plan

To achieve meaningful decarbonization, Alumex PLC will implement a phased solar capacity expansion strategy. The planned expansion of solar photovoltaic (PV) capacity from ~1.2 MW to 9 MW represents a step-change in the energy infrastructure of Alumex PLC, transitioning the facility from a supplementary renewable user to a partially renewable-powered industrial system.

Expansion Pathway

- Increase solar PV capacity beyond current **1.2 MW baseline**
- Utilize:
    - Rooftop installations
    - Ground-mounted systems (where feasible)
    - Potential offsite solar through PPAs

Technical Basis of Generation Potential

Under Sri Lankan climatic conditions, solar PV systems typically operate at a capacity factor of 18–20%, depending on irradiation levels, system losses, and operational efficiency.

Accordingly, the projected annual generation from a 9 MW system can be estimated as:

$$\mathbf{E = P \times CF \times 8760}$$

Where:

E = Annual energy generation (MWh/year)
P = Installed capacity (MW)
CF = Capacity factor

$$\mathbf{E = 9 \times 0.18 \times 8760 \approx 14{,}200\ MWh}$$

System-Level Interpretation

This level of generation represents a **substantial fraction of total facility electricity demand**, enabling:

- Direct displacement of **grid-supplied electricity**
- Reduction in **marginal electricity procurement during peak tariff periods**
- Increased **energy autonomy of operations**

Carbon Reduction Mechanism

From a carbon accounting perspective:

$$\mathbf{\Delta\ Emissions = E_{solar} \times EF_{grid}}$$

Where:

- EF_{grid} = Grid emission factor (tCO_2e/MWh)

Thus, each unit of solar electricity directly offsets grid electricity, resulting in proportional emission reduction under the location-based Scope 2 accounting method.

Strategic Considerations

- Matching generation capacity with daytime load demand
- Minimizing curtailment losses
- Integration with future energy storage systems

Expected Outcome

- Progressive increase in renewable energy share (%)
- Significant reduction in grid electricity dependency
- Acceleration of ASI emission intensity reduction trajectory

6.6.5 Energy Storage and Load Management

As renewable penetration increases, the system transitions from a supply-driven model to a dynamic supply-demand balancing system, requiring advanced energy management.

Temporal Mismatch in Energy Systems

Solar PV generation is inherently intermittent and diurnal, whereas industrial loads:

- Operate continuously or in multi-shift cycles
- Exhibit peak demand outside solar generation windows

This creates a temporal mismatch, leading to:

- Curtailment losses (unused solar generation)
- Continued reliance on grid electricity during non-generation periods

Energy Storage Systems (ESS)

To address this, battery energy storage systems (BESS) will be deployed to:

- Store excess solar generation during peak irradiation hours
- Supply energy during:
    - Evening operations
    - Peak demand periods
    - Grid instability events

Load Management and Demand-Side Optimization

Simultaneously, operational adjustments will be implemented:

- Load shifting of energy-intensive processes (extrusion, anodizing)

- Scheduling of batch processes during solar peak hours (10:00–15:00)
- Reduction of coincident peak demand

Integrated Energy System Impact

The combined effect of storage and load management:

- Increases renewable energy utilization factor (%)
- Reduces curtailment losses
- Minimizes grid dependency variability

This results in a more stable and efficient energy system, which is critical for maintaining consistent emission reductions over time.

6.6.6 Electrification of Thermal Processes

A significant portion of Alumex PLC’s Scope 1 emissions arises from diesel-based thermal energy systems, used in processes such as preheating, drying, and auxiliary heating.

Decarbonization Principle

Electrification enables the substitution of direct fossil fuel combustion with electricity, thereby transferring emissions from:

- **Scope 1 (direct combustion)** → to
- **Scope 2 (electricity consumption)**

When combined with renewable electricity, this results in near-zero emission operation for those processes.

Engineering Considerations

Electrification will be implemented progressively, considering:

- Thermal load requirements (temperature ranges)
- Process compatibility with electric heating technologies
- Grid and renewable supply stability

System-Level Benefit

Electrification creates a coupled decarbonization pathway, where:

- Renewable energy reduces Scope 2 emissions
- Electrification reduces Scope 1 emissions
- Both are addressed through a single integrated energy system

Supporting Decarbonization Measures

The transition will be complemented by:

- Gradual adoption of electric vehicles (EVs) for internal logistics and corporate fleet
- Reduction of mobile combustion emissions

Although relatively smaller in magnitude, these actions contribute to holistic decarbonization across emission sources.

6.6.7 Expected Impact on Scope 2 Emissions

The combined implementation of:

- Solar PV expansion (9 MW)
- Self-consumption optimization
- Energy storage integration
- Load management
- Electrification

results in a **system-wide transformation of electricity-related emissions**.

Analytical Framework

Scope 2 emissions are calculated as:

$$\textbf{Scope 2 Emissions} = E_{grid} \times EF_{grid}$$

Where:

- E_{grid} = *Grid electricity consumption*

Impact Pathways

The strategy reduces emissions through three primary mechanisms:

1. Reduction in Grid Electricity Consumption

- Solar energy replaces grid electricity
- Direct reduction in EgridE_{\text{grid}}Egrid

2. Reduction in Effective Emission Factor

- Increased share of renewable energy lowers **weighted emission factor** of electricity consumed

3. System Efficiency Improvements

- Storage and load optimization reduce energy losses
- Improved utilization of generated renewable energy

Integrated Emission Reduction Effect

$$\textbf{Net Emissions} \downarrow = f(E_{grid} \downarrow, EF_{effective} \downarrow)$$

Expected Outcome

- Significant decline in **Scope 2 emissions (tCO_2e/year)**
- Substantial reduction in **emission intensity (tCO_2e/t Al)**
- Major contribution toward achieving:

0.08 tCO_2e/t by 2050

Strategic Alignment

This transformation is fully aligned with:

- **ASI GHG reduction methodology (mid-term slope compliance)**
- **IAI 1.5°C pathway (renewable-driven decarbonization)**
- **GHG Protocol Scope 2 best practices**

6.7 Long-Term Strategy: Integrated Carbon Removal (2040–2050)

The long-term decarbonization strategy of Alumex PLC incorporates **nature-based carbon removal solutions (NBS)** to address **residual emissions that cannot be eliminated through operational and energy-related interventions**.

While process optimization and renewable energy transition deliver the majority of emission reductions, a **residual emission footprint is expected to remain by 2040–2050**, particularly from hard-to-abate sources. To address this, Alumex PLC will implement a **scientifically designed, large-scale carbon sequestration program**, combining:

- **Reforestation (Green Carbon)**
- **Mangrove Restoration (Blue Carbon)**

This integrated approach ensures both **carbon removal and ecosystem restoration**, aligned with:

- **Clean Development Mechanism (CDM) Afforestation/Reforestation methodologies**
- **IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (LULUCF)**
- **Emerging Blue Carbon frameworks for coastal ecosystems**

6.7.1 Nature-Based Solutions (NBS) Framework

Nature-Based Solutions (NBS) are defined as **actions that protect, sustainably manage, and restore natural ecosystems while addressing societal challenges**, including climate change mitigation.

In the context of Alumex PLC, NBS serve as a **carbon dioxide removal (CDR) mechanism**, operating through:

- **Photosynthetic carbon uptake (biomass growth)**
- **Long-term carbon storage in biomass and soils**
    - Above-ground biomass (trunks, branches, leaves)
    - Below-ground biomass (roots)
    - Soil organic carbon (SOC)

Strategic Positioning

In the Alumex decarbonization hierarchy:

Primary strategy	→ Emission reduction (Sections 5.5 & 5.6)
Complementary strategy	→ Carbon removal (Section 5.7)

NBS are therefore:

- **Not substitutes for emission reduction**, but
- **Essential for achieving net-zero alignment**

6.7.2 Land Allocation Strategy

To implement the carbon removal program, Alumex PLC has identified a **total land allocation of 100 acres (~40.47 hectares)**.

Land Use Distribution

- **Reforestation (Green Carbon): 60% → 24.28 ha**
- **Mangrove Restoration (Blue Carbon): 40% → 16.19 ha**

Rationale for Allocation

This allocation balances:

- **Higher biomass growth potential (reforestation)**
- **Higher long-term carbon storage efficiency (mangroves, especially soil carbon)**

Factor	Reforestation	Mangroves
Carbon type	Biomass	Soil + biomass
Growth rate	Moderate–High	Moderate

Stability	Medium	Very High
Risk of reversal	Higher	Lower

The combined approach enhances both:

- **Carbon sequestration stability**
- **Climate resilience of ecosystems**

6.7.3 Reforestation (Green Carbon) Model

Reforestation under the Alumex carbon removal strategy is designed as a **scientifically planned ecosystem restoration program**, rather than a simple tree-planting exercise. The objective is to establish a **self-sustaining forest system** that maximizes carbon sequestration while ensuring ecological stability and long-term survival.

Species Selection and Growth Dynamics

The reforestation model follows **CDM Afforestation/Reforestation methodology**, supported by **IPCC biomass estimation techniques**.

Species Selection and Growth Strategy

A multi-layered forest structure will be created using three categories of trees:

Fast-Growing Pioneer Species (Early Carbon Capture)

These species establish quickly and absorb CO_2 rapidly in the first 5–10 years.

Examples:

- *Gliricidia sepium*
- *Albizia lebbeck*
- *Leucaena leucocephala (Ipil-ipil)*
- *Sesbania grandiflora (Kathurumurunga)*

Role:

- Rapid biomass growth
- Soil nitrogen enrichment
- Shade creation for slower species

Native Timber and Long-Living Species (Long-Term Storage)

These species grow slower but store carbon for decades to centuries.

Examples:

- *Dipterocarpus zeylanicus (Hora)*
- *Swietenia macrophylla (Mahogany)*
- *Tectona grandis (Teak)*
- *Artocarpus nobilis (Ceylon Breadfruit)*
- *Chloroxylon swietenia (Burutha / Satinwood)*

Role:

- Dense biomass accumulation
- Long-term carbon locking
- Ecosystem stabilization

Fruit and Biodiversity Species (Ecological Value)

Examples:

- *Mangifera indica (Mango)*
- *Psidium guajava (Guava)*
- *Syzygium cumini (Madan / Jamun)*
- *Aegle marmelos (Beli)*
- *Terminalia catappa (Kottamba)*

Role:

- Attract wildlife
- Support biodiversity
- Enable community engagement

Biomass Accumulation Modeling

Biomass growth is estimated using **IPCC allometric equations**:

$$\mathbf{AGB} = f(\mathbf{DBH}, \mathbf{H}, \rho)$$

- AGB = Above-ground biomass
- DBH = Diameter at breast height
- H = Tree height
- ρ = Wood density

Carbon Conversion Factors

- Carbon fraction of biomass: **~0.47**

- CO_2 conversion factor:

$$\mathbf{CO_2 = C \times \frac{44}{12}}$$

Carbon Accounting Framework (CDM)

- Baseline: degraded/non-forested land
- Project: managed forest growth
- Adjustments:
  - Leakage (5–15%)
  - Buffer reserve (10–20%)

Sequestration Profile

- Years 0–10: Rapid accumulation (fast-growing species)
- Years 10–25: Stabilization and long-term storage

Recommended Strategic Locations (Sri Lanka)

These locations are ideal for reforestation and can be visually shown in a map:

Dry Zone (High Land Availability)

- Monaragala District
- Anuradhapura District
- Polonnaruwa District

Intermediate Zone

- Kurunegala District
- Badulla (lower elevations)

Wet Zone (Selective Areas)

- Kegalle
- Ratnapura (degraded lands only)

6.7.4 Mangrove (Blue Carbon) Model

Mangroves represent one of the **most carbon-dense ecosystems globally**, particularly due to **soil carbon accumulation**.

Soil Carbon Dominance

Unlike terrestrial forests:

- **70–90% of total carbon stock in mangroves is stored in soils and sediments**
- Carbon remains sequestered for **centuries under anaerobic conditions**

Carbon Pools Considered

- Above-ground biomass
- Below-ground biomass (roots)
- Soil organic carbon (SOC)

Species Selection

Mangrove ecosystems require **species matched to tidal zones**.

Primary Mangrove Species

1. Seaward Zone (High Salinity & Tides)

- *Rhizophora mucronata*
- *Rhizophora apiculata*

Role:

- Strong root systems
- Coastal protection
- High carbon accumulation

2. Mid-Zone (Moderate Salinity)

- *Avicennia marina*
- *Avicennia officinalis*

Role:

- Fast establishment
- High survival rate

3. Landward Zone (Lower Salinity)

- *Sonneratia caseolaris*
- *Bruguiera gymnorhiza*
- *Excoecaria agallocha (Thela)*

Role:

- Ecosystem diversity
- Soil stabilization

Ecosystem Dynamics

Carbon accumulation depends on:

- Sedimentation rates
- Tidal flow and hydrology
- Species composition (e.g., *Rhizophora*, *Avicennia*)

Key Advantage

Mangroves provide:

- **Higher long-term carbon stability** compared to terrestrial forests
- Lower risk of rapid carbon reversal

6.7.5 Carbon Sequestration Methodology (CDM-Based)

The carbon removal calculation follows **CDM Afforestation/Reforestation (A/R) methodologies**, ensuring **internationally recognized accounting standards**.

Baseline Scenario

- Land remains **non-forested or degraded**
- No significant carbon sequestration occurs

Project Scenario

- Land is converted into **forest/mangrove ecosystem**
- Carbon is sequestered through biomass growth and soil accumulation

Leakage Consideration

Leakage refers to **unintended emissions outside the project boundary**, such as:

- Displacement of agricultural activities

Leakage is conservatively accounted for using:

- **Deduction factors (typically 5–15%)**

Buffer and Risk Adjustment

To account for risks such as:

- Fire
- Disease
- Climate impacts

A **buffer reserve (10–20%)** is applied to ensure **permanence of carbon storage**.

Net Carbon Removal Calculation

$$\textbf{Net Removal} = (C_{project} - C_{baseline}) - \textbf{Leakage} - \textbf{Buffer}$$

6.7.6 Total Carbon Removal Potential

Based on the selected land allocation and species mix:

Reforestation Contribution

- Moderate annual sequestration rate
- Increasing over time as forest matures

Mangrove Contribution

- Lower initial biomass growth
- High long-term carbon storage due to soil accumulation

Combined Removal Potential

- Estimated total removal: ∼10,300 tCO2e over 25 years

Interpretation

- Provides incremental but critical contribution to net-zero goals
- Offsets residual emissions that cannot be technically reduced

6.7.7 Environmental and Social Co-Benefits

Beyond carbon removal, the project delivers **multiple co-benefits**:

Biodiversity Restoration

- Habitat creation for native flora and fauna
- Restoration of degraded ecosystems

Coastal Resilience (Mangroves)

- Protection against storm surges and coastal erosion
- Stabilization of shorelines

Community Engagement

- Local employment opportunities
- Community-based forest management
- Environmental awareness and education

6.7.8 Strategic Limitations and Risks

While NBS provide valuable carbon removal, they are subject to several technical and strategic limitations.

1. Time Lag in Carbon Sequestration

- Carbon removal occurs gradually over decades
- Limited short-term impact

2. Land Availability Constraints

- Maximum land allocation (~40.47 ha) limits total removal potential

3. Permanence Risk

- Carbon stocks may be affected by:
  - Fire
  - Extreme weather
  - Land-use change

4. Measurement Uncertainty

- Variability in growth rates
- Uncertainty in soil carbon estimation

5. Limited Contribution to Total Emission Reduction

- Compared to operational emissions (~13,000 tCO_2e/year),
  NBS contribute a relatively small percentage of total reductions

Strategic Conclusion

Nature-based solutions are:

- Essential for achieving net-zero, but
- Insufficient as a standalone solution

They must therefore be integrated with:

- Deep emission reductions (Scope 1 & 2)
- Renewable energy transition

6.8 Procurement Emission Reduction through Recycled Aluminium Billets (OZON Billet Strategy)

A significant portion of the total carbon footprint of aluminium extrusion operations arises before manufacturing even begins, particularly from the embodied emissions associated with billet procurement. For Alumex PLC, this upstream emission source is strategically important because the carbon intensity of primary aluminium is substantially higher than that of recycled aluminium.

Primary aluminium production is globally recognized as one of the most carbon-intensive industrial material routes due to emissions associated with alumina refining, electrolysis, and energy-intensive smelting. In contrast, secondary aluminium produced through remelting of recycled scrap requires only a fraction of that energy, resulting in materially lower embodied emissions.

Accordingly, increasing the use of **recycled aluminium billets, particularly OZON billets**, represents one of the most effective procurement-side decarbonization measures available to Alumex PLC.

At present, approximately **48% of Alumex PLC's production is based on OZON billets**, while the balance continues to rely on conventional primary billets.

For analytical purposes, the embodied emission factors are conservatively taken as:

- **Primary aluminium billet = 8.6 tCO_2e/t**
- **Secondary (OZON) billet = 0.9 tCO_2e/t**

The current weighted procurement emission factor is therefore calculated as:

$$
\begin{aligned}
EF_{current} &= (0.52\times 8.6) + (0.48\times 0.9) \\
&=4.472+0.432 \\
&=4.904\ tCO_2e/t\ \text{billet}
\end{aligned}
$$

If Alumex PLC were to rely entirely on primary aluminium billets, the embodied procurement emission factor would remain:

$$EF_{primary} \quad =8.6\ tCO_2e/t\ \text{billet}$$

Therefore, the present use of **48% OZON billets already reduces billet-related embodied emissions by:**

$$\frac{8.6-4.904}{8.6}\times 100 = 43\%$$

Current procurement-related emission reduction at projected production scale

Alumex PLC's long-term production planning indicates expansion from the present production level to approximately **40,000 MT/year by 2030**.

Under a fully primary billet procurement model, annual upstream procurement emissions would be:

$$40{,}000 \times 8.6 =344{,}000\ tCO_2e/\text{year}$$

Under the current procurement mix with **48% OZON billets**:

$$40{,}000 \times 4.904 =196{,}160\ tCO_2e/\text{year}$$

Accordingly, the existing recycled billet share already avoids:

$$344{,}000 - 196{,}160 = 147{,}840 \text{ tCO}_2\text{e/year}$$

This represents a substantial avoided Scope 3 emission contribution arising purely from procurement strategy.

Projected recycled billet pathway

Alumex PLC already operates an internal **1,000 MT remelting facility**, which creates the technical basis for increasing recycled billet utilization further.

However, current utilization of this facility remains constrained by:

- limited domestic aluminium scrap availability,
- variability in scrap alloy composition,
- contamination from mixed scrap streams,
- restricted access to high-quality extrusion-grade recycled feedstock.

A realistic medium-term procurement decarbonization target would be to increase the recycled billet share from **48% at present to approximately 65% by 2035**, and progressively toward **75% by 2040**, subject to scrap availability and metallurgical suitability.

Scenario 1 65% recycled billet utilization

The future weighted procurement emission factor becomes:

$$\begin{aligned} EF_{65\%} &= (0.35 \times 8.6) + (0.65 \times 0.9) \\ &= 3.01 + 0.585 \\ &= 3.595 \text{ tCO}_2\text{e/t billet} \end{aligned}$$

At **40,000 MT/year**, annual procurement emissions would reduce to:

$$40{,}000 \times 3.595 = 143{,}800 \text{ tCO}_2\text{e/year}$$

Additional reduction compared with the current 48% recycled share:

$$196{,}160 - 143{,}800 = 52{,}360 \text{ tCO}_2\text{e/year}$$

Scenario 2 75% recycled billet utilization

Under a more advanced circular material transition:

$$\begin{aligned} EF_{75\%} &= (0.25 \times 8.6) + (0.75 \times 0.9) \\ &= 2.15 + 0.675 \\ &= 2.825 \text{ tCO}_2\text{e/t billet} \end{aligned}$$

Annual procurement emissions at **40,000 MT/year** become:

$$40{,}000 \times 2.825 = 113{,}000 \text{ tCO}_2\text{e/year}$$

Additional reduction relative to the current procurement mix:

$$196{,}160 - 113{,}000 = 83{,}160 \text{ tCO}_2\text{e/year}$$

Strategic implementation pathway

To achieve these reductions, Alumex PLC should progressively strengthen recycled aluminium procurement through a structured circular material strategy.

The most practical implementation measures include:

Internal scrap recovery optimization
Higher recovery of internal process scrap, including extrusion butt ends, off-cuts, rejected profiles, and fabrication returns.

Domestic scrap market development
Expansion of local procurement partnerships with fabricators, demolition contractors, construction projects, and industrial processors.

Scrap segregation by alloy family
Separation of scrap by alloy grade is critical because not all aluminium scrap is directly suitable for extrusion-grade billet production.

Imported clean secondary feedstock
Given Sri Lanka’s limited scrap generation base, future scaling may require imported low-contamination secondary aluminium feedstock.

Metallurgical qualification of new scrap streams
Pilot-scale trials should be undertaken to assess suitability of:

- 6063 extrusion scrap,
- 6061 industrial scrap,
- post-industrial machining scrap,
- architectural demolition scrap,
- coated and painted scrap after pretreatment.

Carbon accounting treatment

Procurement-related billet emissions should be reported under **Scope 3 – Purchased Goods and Services**, in accordance with the **GHG Protocol Corporate Value Chain Standard**.

For decarbonization planning, the avoided emissions resulting from increased OZON billet utilization should be tracked separately as a **procurement decarbonization indicator**, rather than being merged into direct operational Scope 1 or Scope 2 reductions.

This distinction is important because it demonstrates that Alumex PLC is not only reducing emissions within the factory boundary, but is also reducing the embedded carbon footprint of its products across the upstream supply chain.

Strategic significance

The OZON billet strategy represents one of the highest-impact upstream decarbonization levers available to Alumex PLC.

Unlike process efficiency measures, procurement-side carbon reduction occurs **before manufacturing energy is even consumed**.

As international markets increasingly move toward:

- **product carbon footprint disclosure**,
- **carbon border adjustment mechanisms (CBAM)**,
- **green procurement requirements**, and
- **low-carbon aluminium preference in export markets**,

the progressive substitution of primary billets with recycled OZON billets will become both an environmental necessity and a commercial advantage.

Strategic Procurement Outlook (2030–2050)

Since nearly half of production is already based on secondary billets, the future decarbonization strategy should focus on progressively increasing this share through supplier engagement, supply chain assurance, and technical compatibility of alloys.

Year	Estimated Secondary Billet Share
2025 (current)	48%
2030	55–60%
2035	60–70%
2040	70–75%
2050	80%+

7. Financial Analysis of Decarbonization Strategy

The decarbonization strategy of Alumex PLC represents a long-term transformation that integrates environmental responsibility with financial performance. In the context of a rapidly evolving global economy where carbon constraints, regulatory mechanisms, and sustainability-linked financing are becoming increasingly prominent this strategy has been evaluated not only on its environmental merits but also on its financial viability and resilience.

The analysis presented in this section considers capital investments, operational savings, carbon cost implications, and alignment with international financial reporting frameworks. It demonstrates that the transition toward low-carbon operations is not merely a compliance requirement, but a financially sound and strategically advantageous pathway.

7.1 Process Optimization Investment Analysis

Process optimization forms the foundation of Alumex PLC's decarbonization pathway and represents the most immediate and financially attractive set of interventions. These measures include improvements to furnace efficiency, waste heat recovery systems, compressed air optimization, and high-efficiency motor upgrades across melting and extrusion operations, as well as auxiliary systems.

From a financial perspective, these interventions are characterized by relatively low-to-moderate capital investment requirements, compared to large-scale infrastructure projects such as renewable energy or electrification. However, they deliver disproportionately high returns through direct reductions in both electricity and thermal energy consumption.

Given the existing energy profile of Alumex PLC, where both thermal energy and electricity significantly contribute to operational expenditure, even marginal efficiency improvements translate into substantial financial benefits. Importantly, these improvements also reduce the baseline energy intensity of operations, thereby lowering the cost of all subsequent decarbonization measures.

Energy Baseline and Production Scenario

Based on internal energy intensity analysis:

- **Baseline Energy Intensity = 13.25 GJ/MT**
- **Projected Production Level = 40,000 MT/year**

Total Energy Demand:

= 13.25 × 40,000
= 530,000 GJ/year

Energy Efficiency Improvement Potential

A conservative and technically achievable efficiency improvement of **8%** is assumed based on industry benchmarks for similar aluminium extrusion operations.

Total Energy Savings:

= 530,000 × 0.08
= 42,400 GJ/year

Energy Disaggregation (Electricity vs Thermal Split)

Based on operational energy structure:

- Electricity share ≈ 40%
- Thermal energy share ≈ 60%

Electricity Savings:

42,400 × 40% = 16,960 GJ

Converting to electricity:

16,960 × 278 = 4,714,880 kWh
≈ 4.7 GWh/year

Thermal Energy Savings:

42,400 × 60% = 25,440 GJ/year

Financial Savings Estimation

Electricity Savings:

Assuming industrial tariff:

- **LKR 35/kWh**

4,714,880 × 35 = LKR 165.0 million/year

Thermal Energy Savings:

Assuming blended thermal energy cost:

- **LKR 3,500/GJ**

25,440 × 3,500 = LKR 89.0 million/year

Total Annual Financial Benefit

= 165.0+89.0
= LKR 254million/year

Investment Requirement (CAPEX)

Typical industrial process optimization investments include:

- Furnace efficiency upgrades
- Heat recovery systems

- Compressed air leak reduction systems
- Motor and drive replacement

Estimated CAPEX Range:

- **LKR 150 million – 250 million**
- Average assumption used: **LKR 200 million**

Payback Period Analysis

$$\frac{200}{254} = 0.79 \text{ Years}$$

Payback Period Result:

- **≈ 9–10 months**

Internal Rate of Return (IRR)

- Very short payback period
- High recurring annual savings
- Low operational risk

The implied IRR is:

- **IRR ≈ 75% – 90%**

(Depending on implementation phasing and maintenance assumptions)

Carbon Reduction Co-Benefit (Contextual Value)

Although primarily an economic intervention, process optimization also reduces emissions by lowering fuel and electricity demand.

Estimated indirect emission reduction:

- Energy savings: 42,400 GJ/year
- Equivalent: ~11.8 GWh/year
- Grid emission factor assumption: 0.6 tCO_2e/MWh

$$11{,}800 \times 0.6 = 7{,}080 \text{ } tCO_2e/\text{year}$$

7.2 Renewable Energy Investment and Savings

The transition to renewable energy, particularly through the expansion of solar photovoltaic (PV) capacity from approximately **1.2 MW to 9 MW**, represents a major capital investment phase within Alumex PLC's decarbonization strategy. This investment fundamentally transforms the company's energy sourcing model by reducing dependence on grid electricity while increasing the share of internally generated renewable energy.

While solar PV systems of this scale require significant upfront capital expenditure, their financial viability must be evaluated over their operational lifetime, which typically exceeds **20–25 years**. Over this period, solar energy provides sustained reductions in electricity procurement costs, enhances energy price stability, and mitigates exposure to future tariff escalation and market volatility factors that are particularly relevant in the Sri Lankan energy context.

Beyond direct financial returns, the renewable energy transition also delivers strategic value by reducing Scope 2 emissions, improving ESG performance, and strengthening eligibility for green financing and low-carbon market access.

CAPEX Estimation

Typical industrial solar PV cost in Sri Lanka:

- **LKR 140–160 million per MW**

For 9 MW:

- Total CAPEX:

= 9 × 150 million
= **LKR 1.35 billion**

Annual Energy Generation

Using:

$E = P \times CF \times 8760$

- $E = 9 \times 0.18 \times 8760$
- $E \approx$ **14,200 MWh/year (14.2 GWh)**

Considering real-world system losses (inverter losses, temperature losses, downtime):

- Loss factor ≈ 10%

Net usable energy = 14.2×0.9
≈ 12.8 GWh/year

Cost Savings

- Annual savings:

= 12,800,000 ×35
= **LKR 448 million/year**

Payback Period

- Payback = 1.35 billion / 440 million
≈ **3 years**

Carbon Reduction Value

Assuming grid emission factor:

- **$EF_{grid} \approx 0.6$ tCO_2e/MWh**

Annual emission reduction:

= 14,200 × 0.6
= **8,520 tCO_2e/year**

If carbon is valued at:

- **LKR 10,000/tCO_2e (≈ USD 30)**

Carbon value:

= 8,520 × 10,000
= **LKR 85.2 million/year (additional value)**

Strategic Financial Insight

When integrating both energy savings and carbon value:

- Total benefit ≈ **LKR 525 million/year**

This strengthens the business case significantly and positions renewable energy as a **high-return strategic investment**, not just a compliance measure.

7.3 Reforestation and Mangrove Project Costing

The implementation of nature-based solutions (NBS), comprising reforestation and mangrove restoration, introduces a fundamentally different financial profile compared to energy and process-related decarbonization investments. While these initiatives require relatively modest capital expenditure, their value is realized over a longer time horizon through carbon sequestration, ecosystem restoration, and strategic ESG positioning.

Unlike renewable energy and efficiency improvements which generate immediate and measurable cost savings NBS projects function as long-term carbon removal assets.

Their financial contribution is therefore indirect, primarily through carbon credit potential, enhanced sustainability credentials, and alignment with emerging regulatory and market expectations such as carbon border adjustment mechanisms and climate-related disclosures.

The long-term Nature-Based Solutions (NBS) strategy involves **100 acres (40.47 ha)**.

Project Scope and Land Allocation

The total land allocation for the NBS program is:

- **Total Area = 100 acres = 40.47 hectares**

Land use distribution:

- **Reforestation (Green Carbon): 60% → 24.28 ha**
- **Mangrove Restoration (Blue Carbon): 40% → 16.19 ha**

This allocation balances higher biomass accumulation (terrestrial forests) with higher long-term carbon storage stability (mangrove ecosystems).

Cost Assumptions

Reforestation (24.28 ha):

Typical reforestation cost in Sri Lanka (including land preparation, planting, and 2–3 years of maintenance):

- Cost per hectare: **LKR 550,000**
- Total cost:

= 24.28 × 550,000

≈ **LKR 13.35 million**

Mangrove Restoration (16.19 ha):

Mangrove restoration involves additional technical complexity, including hydrological rehabilitation, community coordination, and coastal ecosystem management.

- Cost per hectare: **LKR 900,000**
- Total cost:

= 16.19 × 900,000

≈ **LKR 14.57 million**

Total Project Cost

- Total NBS CAPEX = 13.35 million + 14.57 million
    - **≈ LKR 25 million**

Carbon Removal

Based on IPCC and blue carbon benchmarks:

- **Total carbon removal (25 years) ≈ 10,300 – 11,500 tCO_2e**

For conservative financial modeling:

- **Adopted value ≈ 10,800 tCO_2e (25 years)**

Annualized removal: = 10,800 / 25
≈ **432 tCO_2e/year**

7.4 Cost per tCO_2 Analysis

A critical metric for evaluating the effectiveness of decarbonization strategies is the cost associated with reducing or removing one tonne of carbon dioxide (tCO_2e). This indicator provides a common basis for comparing different mitigation options and supports informed investment prioritization across the decarbonization portfolio.

Within the Alumex PLC decarbonization framework, three primary intervention categories process optimization, renewable energy (solar PV), and nature-based solutions (NBS) exhibit distinct cost profiles, reflecting differences in capital intensity, implementation timelines, and emission reduction mechanisms.

This metric is critical for comparing mitigation options.

Process Optimization

- Cost: LKR 200 million
- Reduction: ~5,000 tCO_2e/year (estimated)
- Evaluation period = 5 years

Cost per tCO_2:

- = 200,000,000 / (5,000 × 5 years)
  ≈ **LKR 8,000/tCO_2e**

Solar PV

The expansion of solar PV capacity represents a capital-intensive but high-impact intervention, delivering large-scale emission reductions over a long operational lifespan.

- CAPEX: LKR 1.35 billion
- Reduction: 8,520 tCO_2e/year
- Project lifetime = 20 years

Over 20 years:

- Total reduction:
  = 8,520 × 20
  = 170,400 tCO$_2$e

Cost per tCO$_2$:

- = 1,350,000,000 / 170,400
  ≈ **LKR 7,920/tCO$_2$e**

NBS (Reforestation + Mangroves)

Nature-based solutions provide carbon removal rather than emission reduction, with lower capital costs but longer realization periods.

- Cost: LKR 28 million
- Removal: 10,800 tCO$_2$e

Cost per tCO$_2$:

- = 28,000,000 / 10,800
  ≈ **LKR 2,590/tCO$_2$e**

7.5 Comparison with Carbon Market Prices

The financial relevance of decarbonization is increasingly influenced by global carbon pricing mechanisms. Carbon prices in regulated markets, such as the European Union Emissions Trading System (EU ETS), have reached levels that significantly impact the cost structure of carbon-intensive products. At the same time, voluntary carbon markets are evolving, with growing demand for high-quality carbon credits, particularly those derived from nature-based solutions.

For Alumex PLC, these developments are particularly significant in the context of the Carbon Border Adjustment Mechanism (CBAM), which introduces a carbon cost on exports to the European Union. As aluminium is a carbon-intensive material, failure to reduce emissions could result in substantial additional costs when accessing international markets.

By proactively reducing emissions through renewable energy and efficiency improvements, Alumex PLC can minimize its exposure to such regulatory costs. Furthermore, the implementation of verifiable carbon removal projects creates the potential for generating carbon credits, which may be monetized in voluntary markets, depending on future market conditions and certification pathways.

Global voluntary carbon market prices:

- Nature-based credits : **LKR 2,000 – 8,000/tCO$_2$e**
- Industrial decarbonization : **LKR 8,000 – 20,000/tCO$_2$e**

Interpretation

- NBS projects are **cost-competitive and potentially revenue-generating**
- Solar and efficiency projects align with **mid-to-high carbon price ranges**
- Under **CBAM**, avoided emissions translate to **avoided carbon costs in exports**

7.6 Long-Term Economic Feasibility

The overall financial feasibility of the decarbonization strategy must be assessed from a long-term perspective, considering both direct and indirect economic impacts. While certain components of the strategy require significant upfront investment, their long-term benefits extend beyond immediate financial returns.

Direct financial benefits include reduced energy costs, improved operational efficiency, and lower fuel consumption. These savings accumulate over time, contributing to improved profitability and cost competitiveness. In parallel, the strategy enables the avoidance of future costs associated with carbon pricing, regulatory compliance, and potential market access restrictions.

From an accounting perspective, key investments such as solar photovoltaic systems are recognized as capital assets and depreciated over their useful life in accordance with international financial reporting standards. Future carbon credits, if realized, may be treated as intangible assets, providing an additional revenue stream. Furthermore, evolving sustainability reporting standards, such as IFRS S2, require companies to disclose climate-related financial risks and opportunities, reinforcing the importance of integrating decarbonization into core financial planning.

The strategic value of the decarbonization pathway extends to enhanced investor confidence, improved access to sustainable finance, and strengthened positioning within global supply chains that increasingly prioritize low-carbon products.

From a strategic financial perspective, the decarbonization pathway demonstrates strong economic viability across all time horizons.

1. Alignment with Carbon Regulations

With the introduction of **EU CBAM**, carbon-intensive aluminium exports may face additional costs:

Example:

- Emissions: 0.5 tCO_2e per ton aluminium
- Carbon price: LKR 20,000/tCO_2e

Cost impact:

- = 0.5 × 20,000
  = **LKR 10,000 per ton**

For 40,000 MT:

- = **LKR 400 million/year risk**

Decarbonization directly avoids this cost exposure.

2. IFRS and ESG Financial Reporting

Under **IFRS S2 (Climate-related Disclosures)**:

- companies must disclose climate risks and mitigation strategies
- Investments in decarbonization improves:
    - Asset valuation
    - Investor confidence
    - Access to green financing

3. Internal Rate of Return (IRR) Perspective

- Process optimization: **IRR > 100%**
- Solar PV: **IRR ~35–45%**
- NBS projects: **IRR depends on carbon credit monetization (~10–20%)**

4. Strategic Financial Position

The combined strategy ensures:

- Reduced operational costs (energy savings)
- Protection from regulatory carbon pricing
- Potential revenue from carbon credits
- Enhanced brand value and export competitiveness

Overall Financial Conclusion

The decarbonization strategy of Alumex PLC is **economically viable, risk-mitigating, and strategically advantageous**.

Quantitatively:

- Annual energy savings: **~LKR 1.3 billion**
- Annual emission reduction potential: **>10,000 tCO_2e**
- Payback periods: **<2 years (major investments)**

Qualitatively:

- Aligns with global aluminium decarbonization pathways
- Strengthens resilience against future carbon regulations
- Positions Alumex as a **low-carbon aluminium producer in international markets**

In financial terms, this is not merely a sustainability initiative it is a **long-term value creation strategy embedded within core business operations**.

8. Risk and Sensitivity Analysis

The decarbonization strategy of Alumex PLC is inherently subject to multiple uncertainties arising from operational, technological, environmental, and financial domains. Given the long-term horizon (2025–2050) and the scale of transformation—from energy efficiency to renewable integration and carbon removal it is essential to systematically evaluate risks and test the robustness of the strategy under varying conditions.

This section provides a structured and scientifically grounded assessment of key risks and a sensitivity analysis of critical variables influencing financial and environmental outcomes.

8.1 Operational Risks

Operational risks arise from the integration of new systems into an existing aluminium extrusion manufacturing environment, where processes such as melting, extrusion, anodizing, and powder coating are energy-intensive and require high reliability.

A primary risk relates to **production disruption during implementation**. Upgrades such as waste heat recovery systems, furnace retrofits, and compressed air optimization may require temporary shutdowns or reduced operational capacity. For example, even a **2–3% production loss during implementation** could translate into:

= 40,000 MT × 2%
≈ **800 MT production loss/year**

This has direct revenue implications and must be mitigated through phased implementation and planned maintenance windows.

Another critical factor is **load variability and demand mismatch**. Aluminium extrusion processes often operate in batch cycles, while energy efficiency and solar systems perform optimally under stable loads. Misalignment can reduce expected efficiency gains.

Additionally, **workforce capability** presents a risk. The transition to energy-managed operations requires:

- Skilled operators for energy monitoring systems
- Maintenance capability for solar and electrical systems
- Data-driven decision-making

Without adequate training, expected performance improvements may not materialize.

8.2 Technological Risks

Technological risks are associated with the performance, integration, and long-term reliability of decarbonization technologies.

Solar PV Performance Risk

The projected energy generation assumes a **capacity factor of ~18%**. However, actual performance may vary due to:

- Panel degradation (~0.5–0.7% per year)
- Dust accumulation and maintenance issues
- Inverter failures

If capacity factor reduces from 18% to 16%, annual generation becomes:

= 9 × 0.16 × 8760
≈ **12,600 MWh/year**

Compared to expected 14,200 MWh:

Loss ≈ **1,600 MWh/year**

Financial impact:

= 1,600,000 × LKR 35
≈ **LKR 56 million/year loss**

Battery Energy Storage System (BESS) Risk

BESS introduces risks related to:

- High capital cost
- Limited lifecycle (8–12 years)
- Efficiency losses (~10–15%)

Improper sizing or control strategy can reduce economic viability.

Electrification Risk

Electrification of thermal processes depends on:

- Availability of stable electrical supply
- Compatibility with required temperature ranges

If electrification is only partially feasible, residual Scope 1 emissions may remain higher than projected.

8.3 Climate and Environmental Risks

Climate risks affect both operational performance and carbon removal strategies.

Solar Resource Variability

Solar generation depends on irradiation levels. A **5–10% reduction in solar yield** due to prolonged cloud cover or climate variability would directly reduce emission reductions and cost savings.

Extreme Weather Events

Sri Lanka is increasingly exposed to:

- Flooding
- High rainfall events
- Heat stress

These can impact:

- Solar infrastructure (physical damage)
- Plant operations (downtime)

Nature-Based Solution (NBS) Risks

Reforestation and mangrove projects face ecological uncertainties:

- **Mangroves:** sensitive to salinity, tidal flow, and sedimentation
- **Forests:** vulnerable to drought, pests, and fire

A **10–20% loss in biomass** due to environmental factors would reduce carbon sequestration:

= 10,800 × 15%
≈ **1,620 tCO_2e loss over lifecycle**

8.4 Financial Risks

Financial risks are critical given the scale of investment (~LKR 1.5–1.7 billion total).

Energy Price Volatility

The financial viability of solar PV is directly linked to grid electricity tariffs.

If tariff decreases from LKR 35/kWh to LKR 25/kWh:

Adjusted annual savings:

= 13,000,000 × 25
≈ **LKR 325 million/year**

Compared to base case (~LKR 430 million):

Loss ≈ **LKR 105 million/year**

This increases payback period from:

≈ 3.1 years → **~4.2 years**

Capital Cost Escalation

Solar CAPEX increase from LKR 150M/MW to LKR 170M/MW:

Total CAPEX:

= 9 × 170
= **LKR 1.53 billion**

Increase ≈ **LKR 180 million**

Carbon Price Uncertainty

Carbon pricing (voluntary or compliance markets) is uncertain.

- Low scenario: LKR 5,000/tCO_2
- High scenario: LKR 15,000/tCO_2

Impact on solar carbon value:

= 8,520 × price

- Low: LKR 42.6 million/year
- High: LKR 127.8 million/year

Regulatory Risks (CBAM and ESG Compliance)

Failure to decarbonize may result in:

- Carbon border taxes
- Reduced export competitiveness
- Increased compliance costs

8.5 Sensitivity Analysis (Energy Price, Growth Rate, Carbon Price)

1. Energy Price Sensitivity

Tariff (LKR/kWh)	Annual Savings (LKR Mn)	Payback Period
25	325	~4.2 years
35 (Base)	430	~3.1 years
50	650	~2.1 years

Insight:
Solar investment remains viable under all scenarios but is highly sensitive to tariff levels.

2. Production Growth Sensitivity

Production (MT)	Emissions @ 0.08 tCO_2/t	Total Emissions
30,000	0.08	2,400 tCO_2e
40,000 (Base)	0.08	3,200 tCO_2e
50,000	0.08	4,000 tCO_2e

Insight:
Even with efficiency gains, higher production increases absolute emissions, requiring additional offsets.

3. Carbon Price Sensitivity

Carbon Price (LKR/tCO_2)	Annual Value (Solar)
5,000	42.6 Mn
10,000 (Base)	85.2 Mn
15,000	127.8 Mn

Insight:
Higher carbon prices significantly enhance the financial attractiveness of decarbonization investments.

9. Monitoring, Reporting, and Verification (MRV)

A Monitoring, Reporting, and Verification (MRV) framework is essential to ensure the credibility, accuracy, and transparency of Alumex PLC's decarbonization strategy. Given the scale of interventions—ranging from process optimization and renewable energy deployment to nature-based carbon removal—MRV serves as the backbone for tracking performance, demonstrating compliance with international standards, and enabling participation in carbon markets and ESG disclosures.

The MRV system is designed in alignment with:

- **GHG Protocol (Corporate Standard & Scope 2 Guidance)**
- **ISO 14064 (GHG Quantification and Reporting)**
- **ISO 50001 (Energy Management Systems)**
- **ASI Performance Standard (GHG & ESG reporting)**
- **CDM / Verified Carbon Standard (for NBS projects)**

9.1 Data Collection and Management Systems

Effective MRV begins with a structured and digitalized data collection system that captures real-time and periodic data across all emission sources.

At Alumex PLC, data collection is categorized into three primary domains:

1. Energy Consumption Data

- Electricity consumption (grid and solar)
- Fuel consumption (diesel, LPG)
- Equipment-level energy use (extrusion presses, furnaces, compressors)

2. Production Data

- Monthly aluminium production (MT)
- Process-level throughput (casting, extrusion, finishing)

3. Environmental Data

- Emission factors (grid EF, fuel EF)
- Renewable energy generation (solar output)
- Carbon sequestration data (biomass growth, soil carbon)

System Architecture

A centralized **Energy and Carbon Data Management System (ECDMS)** will be implemented with:

- Smart meters and sub-metering across Significant Energy Uses (SEUs)
- IoT integration for real-time monitoring

- Monthly data validation workflows
- Automated dashboards for KPI tracking

Data Integrity Measures

- Calibration of meters (annual)
- Data triangulation (utility bills vs meter readings)
- Internal audit checks (quarterly)
- Version-controlled data storage

This ensures **traceability, accuracy, and audit readiness**, which are critical for ASI and carbon verification.

9.2 Energy and Emission Monitoring Framework

The emission monitoring framework is structured based on **Scope 1 and Scope 2 emissions**, with clear calculation methodologies.

Scope 1 Emissions (Direct Emissions)

Calculated using fuel consumption:

$$\mathbf{Emissions}_{Scope1} = \mathbf{Fuel\ Consumption} \times \mathbf{EF}_{fuel}$$

Where:

- Fuel includes diesel, LPG
- EF derived from IPCC or country-specific factors

Scope 2 Emissions (Electricity)

$$\mathbf{Emissions}_{Scope2} = \mathbf{E}_{grid} \times \mathbf{EF}_{grid}$$

Where:

- E_{grid} = Grid electricity consumption (MWh)
- $EF_{grid} \approx 0.6$ tCO_2e/MWh (Sri Lanka baseline)

Renewable Energy Adjustment

$$\mathbf{E}_{grid,net} = \mathbf{E}_{total} - \mathbf{E}_{solar,self-consumed}$$

This ensures **accurate reflection of solar self-consumption impact**, correcting the limitations of earlier grid-export models.

Key Performance Indicators (KPIs)

- Emission intensity (tCO_2e/MT Al)
- Renewable energy share (%)

- Energy intensity (GJ/MT)
- Absolute emissions (tCO_2e/year)

These KPIs are tracked **monthly**, with annual consolidation for reporting.

9.3 Carbon Sequestration Monitoring (CDM Requirements)

For reforestation and mangrove projects, MRV follows **CDM Afforestation/Reforestation (A/R) methodologies** combined with **IPCC LULUCF guidance**.

Monitoring Parameters

1. Forest (Green Carbon)

- Tree survival rate (%)
- Diameter at Breast Height (DBH)
- Tree height (H)
- Species-specific growth rates

Biomass estimation:

$$\mathbf{AGB = \mathit{f}\,(DBH\,,\,H\,,\,\rho)}$$

Carbon stock:

$$\mathbf{C = AGB \times 0.47;\quad CO_2 = C \times \frac{44}{12}}$$

2. Mangroves (Blue Carbon)

Monitoring includes:
- Above-ground biomass
- Below-ground biomass (root systems)
- Soil Organic Carbon (SOC)

Soil sampling:
- Depth: 0–1 m
- Frequency: every 3–5 years

3. Project-Level Adjustments

$$\mathbf{Net\ Removal = C_{\mathit{project}} - C_{\mathit{baseline}}) - Leakage - Buffer}$$

Where:

- Leakage: 5–15%
- Buffer: 10–20% (risk mitigation)

Monitoring Frequency

- Biomass: annually (first 5 years), then every 2–3 years
- Soil carbon: every 5 years
- Satellite/GIS verification: annually

This ensures compliance with **carbon credit certification requirements**.

9.4 Reporting Standards and Disclosure

Alumex PLC’s reporting framework integrates financial, environmental, and ESG disclosures to meet both regulatory and investor expectations.

Internal Reporting

- Monthly dashboards (energy, emissions)
- Quarterly ESG performance reviews
- Annual sustainability performance evaluation

External Reporting

1. Annual Report & ESG Disclosure

- Scope 1 & 2 emissions
- Emission intensity trends
- Renewable energy contribution

2. Sustainability Reporting Platforms

- Hayleys Sustainability Portal
- Global Reporting Initiative (GRI)
- Task Force on Climate-related Financial Disclosures (TCFD)

3. Carbon Disclosure

- CDP (Carbon Disclosure Project)
- Science-Based Targets (SBTi alignment in future phase)

IFRS and Financial Integration

Climate-related disclosures will align with:

- **IFRS S2 (Climate-related Disclosures)**
- Integration of carbon risks into financial statements
- Disclosure of:
  - Carbon pricing exposure
  - Decarbonization CAPEX
  - Climate-related financial risks

9.5 Third-Party Verification (ASI and Carbon Standards)

Independent verification is critical to ensure credibility and compliance with international frameworks.

ASI Certification

- Annual surveillance audits
- Verification of:
    - Emission data accuracy
    - Energy management systems
    - ESG compliance

Carbon Verification Standards

For NBS and carbon credits:

- Verified Carbon Standard (VCS)
- Gold Standard (if applicable)

Verification includes:

- Baseline validation
- Monitoring report verification
- Carbon credit issuance

Audit and Verification Cycle

Component	Frequency	Verifying Body
GHG Inventory	Annual	External auditor
ASI Audit	3 Years	ASI-accredited body
NBS Carbon Credits	2–5 years	Carbon standard verifier
Internal Audit	Quarterly	Internal ESG/EHS team

Strategic Conclusion

The MRV framework transforms the decarbonization strategy from a conceptual plan into a **measurable, verifiable, and financially accountable system**. By integrating digital monitoring systems, internationally recognized methodologies, and third-party verification, Alumex PLC ensures:

- **Accuracy** in emission tracking
- **Credibility** in ESG reporting
- **Eligibility** for carbon markets and green finance
- **Alignment** with ASI, GHG Protocol, and IFRS standards

Most importantly, MRV enables continuous improvement by linking **operational performance with emission outcomes**, ensuring that the pathway toward **net-zero by 2050** remains transparent, trackable, and achievable.

10. Conclusion and Strategic Outlook