AAF QUEENSLAND

RESEARCH & DATA — 02

SUSTAINABILITY & ENVIRONMENTAL PERFORMANCE

Low-Carbon Aluminium Is Only the Beginning

Reducing the emissions associated with aluminium manufacture is an important first step. Selecting an architectural finish that supports long service life can extend the environmental benefits of that aluminium for generations.

Introduction — The Next Stage of Aluminium Sustainability

The aluminium industry is making significant progress towards reducing greenhouse gas emissions through renewable energy, more efficient manufacturing technologies and increased use of recycled aluminium.

These developments represent important advances for sustainable architecture.

However, the environmental performance of aluminium cannot be assessed solely by the carbon emissions associated with its initial manufacture.

Once aluminium becomes part of a building, its useful service life becomes an important consideration.

A building component that can remain functional and retain its intended appearance for many decades may avoid the environmental impacts associated with premature refurbishment, replacement and additional manufacturing.

The finishing process selected for architectural aluminium can play an important role in achieving this outcome.

Research undertaken in Australia and internationally provides valuable evidence regarding the environmental characteristics of different finishing technologies and the relationship between finish durability and whole-of-life sustainability.

This paper examines that research and its implications for architectural specification.

2.1 Low-Carbon Aluminium Is Only the Beginning

Extending Aluminium's Sustainability Journey

Aluminium is an increasingly important material in sustainable building design.

Its combination of light weight, strength, versatility, corrosion resistance and recyclability makes it particularly suitable for architectural and infrastructure applications.

However, primary aluminium production has traditionally required substantial amounts of electricity.

The source of this electricity has a major influence on the greenhouse gas emissions associated with producing the metal.

Manufacturers are now making important progress through renewable energy, improved production processes and increased use of recycled aluminium.

In Australia, lower-carbon aluminium products are becoming more widely available, allowing architects and specifiers to consider embodied carbon when selecting building materials.

These developments are welcome.

But the sustainability journey should not end when the aluminium leaves the smelter or extrusion plant.

What Happens After Manufacture?

Once aluminium is extruded, fabricated and incorporated into a building, it may remain in service for many decades.

During that time, the building's appearance, functionality and maintenance requirements can be influenced by the performance of the aluminium finish.

Although finishing accounts for only part of a completed aluminium product's environmental footprint, its performance may help determine whether the component remains suitable for continued use.

A durable finish can therefore contribute to extending the useful life of aluminium and reducing the need for additional materials and manufacturing.

The 2025 Australasian Aluminium Extrusion Conference Research

This principle was examined in the paper presented by Bill Wyllie at the 7th Australasian Aluminium Extrusion Conference, held in Brisbane on 15–16 July 2025.

Low-carbon Aluminium is a Great Start — Next, Aluminium's Journey to Further Optimise Sustainability

The paper reviewed research into aluminium finishing, durability and life cycle environmental performance.

It brought together evidence from international durability studies, North American Environmental Product Declarations and Australian research comparing architectural finishing systems.

A central proposition was that the sustainability benefits of reducing aluminium's initial carbon footprint can be extended by keeping finished aluminium products in service for longer.

This introduces an important consideration for architectural design:

Sustainability depends not only on how aluminium is manufactured, but also on how long the completed product remains useful.

2.2 Environmental Product Declarations — Aluminium Finishing

Understanding the Carbon Footprint of Finished Aluminium

Environmental Product Declarations, commonly known as EPDs, provide independently verified information about the environmental impacts of products using established life cycle assessment methodologies.

An EPD may report several environmental indicators, including global warming potential, resource use and other impacts associated with production and relevant life cycle stages.

EPDs can help designers and specifiers understand the environmental implications of different materials and manufacturing processes.

However, meaningful comparisons require consistent assessment boundaries, declared or functional units, product characteristics and performance requirements.

North American Aluminum Extruders Council Research

In November 2022, the Aluminum Extruders Council published an industry-wide Environmental Product Declaration covering three categories of aluminium extrusion products:

1. Mill-finished aluminium.
2. Anodised aluminium.
3. Painted aluminium, including liquid and powder-coated products.

The study was based on manufacturing data collected from participating facilities in the United States and Canada.

The declaration was independently verified through the UL Environment EPD programme.

It provides an important source of information about the environmental impacts associated with finishing aluminium extrusions.

The Carbon Emissions Findings

The 2022 research reported the following global warming potential values for the product categories discussed in AAF's 2025 conference paper.

Aluminium finish	Reported emissions	Increase over mill finish
Mill-finished aluminium	2.44 kg CO_2e/kg	Baseline
Anodised aluminium	2.87 kg CO_2e/kg	Approximately 18%
Painted/powder-coated aluminium	3.48 kg CO_2e/kg	Approximately 43%

Source: Aluminum Extruders Council, 2022 Environmental Product Declaration, as presented in Wyllie (2025). Figures apply to the specific product categories and assessment basis used in the study.

These results indicate that finishing can make a measurable contribution to the initial embodied carbon of aluminium extrusion products.

In this particular assessment, anodised aluminium recorded a lower global warming potential than the combined painted/powder-coated product category.

Understanding the Findings

The study provides useful environmental evidence, but the results need to be interpreted carefully.

They are industry-average results based on specified North American production data, rather than universal figures applicable to every manufacturing operation.

The painted category includes liquid and powder painting and does not provide a separate result for every architectural coating formulation.

Likewise, results for anodising can vary according to production efficiency, process chemistry, electricity sources and finishing requirements.

The reported figures should therefore not be interpreted as proving that all anodising operations produce lower emissions than all powder coating operations.

Nevertheless, the research reinforces an important consideration:

The environmental impact of architectural aluminium does not end with the manufacture of the metal. The finishing process also matters.

The 2022 EPD primarily provides product environmental information under defined assessment boundaries. It does not, by itself, establish which finished product will provide the lowest environmental impact over a particular building's complete service life.

That requires further consideration of durability, maintenance and replacement.

2.3 Australian Life Cycle Research — KMH Environmental Study

Comparing Architectural Finishes Over 100 Years

An important Australian study was undertaken by KMH Sustainable Infrastructure in November 2010.

The report, titled:

Environmental Impact Comparison of Fluoropolymer Powder Coating, Polyester Powder Coating and Anodising Processes

was prepared for the Australian Anodising Association.

The study compared the energy requirements and greenhouse gas emissions associated with three established aluminium finishing technologies.

Unlike a comparison limited to initial finishing emissions, KMH examined the consequences of assumed finish service lives over a 100-year assessment period.

This approach recognised that the need to replace finished aluminium components can significantly influence whole-of-life environmental outcomes.

The Three Finishing Systems

The study examined:

Anodising

An electrochemical process that converts the aluminium surface into a protective oxide layer.

Polyester Powder Coating

An organic polymer coating applied and cured onto the aluminium surface.

Fluoropolymer Powder Coating

A high-performance organic coating technology developed for extended durability and resistance to environmental exposure.

These processes have different energy requirements, raw materials and expected durability characteristics.

Assumed Service Lives

For the purpose of its 100-year comparison, the KMH study adopted the following service-life assumptions.

Finishing system	Service life assumed in study
Anodising	50 years
Fluoropolymer powder coating	40 years
Polyester powder coating	25 years

These were modelling assumptions based on the information available at the time, rather than guaranteed or universally applicable finish lifespans.

The study then considered the manufacturing, finishing and recycling consequences associated with providing finished aluminium over a 100-year period.

Greenhouse Gas Emissions — Study Results

The KMH report presented the following estimated greenhouse gas emissions for the modelled 100-year period.

Finishing system	Emissions excluding original primary aluminium production
Anodising	6.5 tonnes CO_2e
Fluoropolymer powder coating	7.9 tonnes CO_2e
Polyester powder coating	10.3 tonnes CO_2e

Values are tonnes of CO_2-equivalent per tonne of aluminium product over the modelled 100-year period. Source: KMH Sustainable Infrastructure, 2010, Table 5. Values include the study's assumed finishing and recycling activities but exclude the common initial primary-production contribution.

Under these assumptions, anodising produced the lowest estimated greenhouse gas emissions of the three systems.

The results illustrate how finish life and the frequency of replacement can influence cumulative emissions.

Important Qualifications

The KMH study is a valuable historical contribution to Australian finishing research, but its limitations must be recognised.

It used manufacturing data and electricity emissions factors available in 2010.

Its calculations also depended on assumed finish lifespans, coating thicknesses, recycling processes and the replacement of aluminium components at the end of each assumed finish life.

Current coating technologies, manufacturing systems, electricity generation and refurbishment practices may differ substantially.

In particular, a deteriorated finish does not necessarily require an entire aluminium component to be replaced. Refurbishment, recoating or component retention may be possible.

The research should therefore be regarded as evidence of how finishing choices can affect long-term environmental outcomes under defined conditions, not as a universal prediction of future emissions.

What Can We Learn?

The significant contribution of the KMH study is its recognition that environmental comparisons should extend beyond the initial finishing operation.

Its findings demonstrate that the durability and expected life of a finish can materially influence its overall environmental impact.

This principle remains relevant to modern sustainable architectural design.

2.4 Service Life and Whole-of-Life Carbon

Why Durability Matters in Environmental Assessment

Life cycle assessment considers the environmental effects associated with a product over defined stages of its existence.

For architectural aluminium, these stages may include raw material production, extrusion, fabrication, finishing, transport, construction, maintenance, refurbishment and eventual disposal or recycling.

The useful life of the completed aluminium component can influence the cumulative environmental impact.

If a finish deteriorates prematurely, the building owner may need to repair, refinish or replace the affected component.

Each intervention can involve additional materials, energy, labour, transport and associated emissions.

Conversely, a durable finish may assist in preserving the original aluminium and avoiding unnecessary replacement.

Initial Embodied Carbon Is Only Part of the Assessment

A comparison of two finishing systems should therefore consider more than the emissions measured at the factory gate.

It should also examine:

- Expected service life in the intended environment.
- Cleaning and routine maintenance.
- Resistance to weathering and loss of appearance.
- Opportunities for repair or refurbishment.
- Likelihood and extent of component replacement.
- Environmental impacts associated with those activities.
- Eventual recovery, reuse or recycling of materials.

A Hypothetical Building Example

Consider a building designed for a service life of 80 years.

One aluminium finishing system may remain suitable for the full period with routine maintenance.

Another may require significant refurbishment after several decades.

The second system may involve additional materials, processing and emissions that are not captured by comparing only the initial finishing operations.

However, the final result depends on the specific products and circumstances. Refurbishing an existing coated component may have less environmental impact than replacing it, and different finishing systems may perform differently in different environments.

The appropriate question is therefore:

Which finishing system is most likely to meet the building's architectural and performance requirements over its intended life, with the lowest reasonable whole-of-life environmental impact?

Real-World Durability Evidence

Published research by Professor Michael Stacey for the International Aluminium Institute provides useful examples of aluminium remaining in architectural service for many decades.

The New Bodleian Library at the University of Oxford, now the Weston Library, is a particularly informative example.

Its original anodised aluminium windows, installed around 1940, were assessed during major refurbishment many decades later.

The frames were found suitable for retention and reuse with upgraded glazing.

This demonstrates the potential environmental value of preserving existing aluminium components rather than replacing them unnecessarily.

The Oxford example is evidence from one particular installation, not a guarantee of equivalent performance for all anodised aluminium.

Nevertheless, it illustrates why documented service life deserves consideration alongside laboratory testing, manufacturers' warranties and environmental declarations.

Beyond the Warranty

A manufacturer's warranty provides important assurance regarding specified product performance and contractual obligations.

However, the warranty period should not be confused with the maximum useful life of a finishing system.

A finish may remain suitable for continued service long after its original warranty period has ended.

Equally, failure to meet maintenance or exposure requirements may reduce its performance.

Real-world evidence, appropriate standards and project-specific specification should therefore be considered together.

2.5 Aluminium Recycling, Retention and Reuse

Preserving the Value of Aluminium

Aluminium is widely recognised as a valuable recyclable material.

Recycling aluminium generally requires substantially less energy than producing primary aluminium from ore.

The ability to recover and recycle aluminium makes an important contribution to resource efficiency and the circular economy.

However, recycling is not the only way to preserve the environmental value of aluminium.

Retaining an existing aluminium component in service can avoid the need to manufacture its replacement.

This distinction is particularly important in architecture, where building components may remain structurally sound long after other parts of the building require refurbishment.

Retention Before Replacement

Building refurbishments frequently involve replacing glazing, seals, hardware, insulation and other components.

Where aluminium framing remains suitable, it may be possible to retain these components while upgrading other elements.

This can preserve the original material and reduce the need for additional aluminium production, processing and installation.

Successful retention depends on structural condition, building compliance, appearance, corrosion, compatibility with new components and the practical requirements of the refurbishment.

The Role of Anodised Finishes

Anodising's integral aluminium oxide surface and demonstrated architectural durability make it particularly relevant to this discussion.

Where anodised components retain their protective and decorative properties, the original aluminium may be capable of continued use through successive building refurbishments.

The Oxford Weston Library provides a documented example.

AAF Queensland is also interested in identifying and recording Australian building and marine refurbishment examples where anodised aluminium has remained serviceable while other materials have required replacement.

Such examples can contribute useful real-world evidence, provided their original specifications, age, exposure conditions and present condition are adequately documented.

Design for a Circular Economy

The principles of material retention and reuse can be incorporated into architectural design from the beginning.

These include:

- Specifying aluminium and finishes suited to the intended environment.
- Designing components for appropriate maintenance and inspection.
- Allowing for replacement of glazing, seals and other shorter-life elements.
- Considering the future refurbishment of facade systems.
- Retaining sound aluminium components wherever practical.
- Recovering and recycling aluminium when it can no longer remain in service.

The objective is to preserve the value of the original material and the resources invested in its manufacture for as long as reasonably possible.

The most sustainable outcome may be to retain suitable aluminium in service, rather than recycle it prematurely.

Conclusion — Extending the Benefits of Low-Carbon Aluminium

The transition towards lower-carbon aluminium manufacturing is an important achievement for the aluminium industry and the built environment.

However, the environmental opportunities do not end when the metal is manufactured.

Independent research demonstrates that finishing processes contribute to embodied carbon and that the durability of a finish can influence long-term environmental outcomes.

The North American Aluminum Extruders Council Environmental Product Declaration provides evidence of differences in the initial environmental footprints of finished aluminium products.

The Australian KMH study illustrates how service-life assumptions, maintenance and replacement can influence emissions over an extended period.

Research into the performance of existing buildings further demonstrates the potential value of retaining aluminium components through major refurbishments.

Together, these findings reinforce an important principle for sustainable architecture:

The environmental value of low-carbon aluminium can be extended by selecting finishes that help preserve its useful life, appearance and performance for generations.

AAF Queensland believes that high-grade architectural anodising deserves consideration as part of this process.

Our objective is to make the relevant research and real-world evidence available to assist architects, designers, fabricators and building owners in making informed decisions.

Research References and Further Reading

1. Wyllie, B. (2025)
Low-carbon Aluminium is a Great Start — Next, Aluminium's Journey to Further Optimise Sustainability.
7th Australasian Aluminium Extrusion Conference, Brisbane, 15–16 July 2025.

Full conference paper:
https://aafonline.com.au/wp-content/uploads/2025/08/AAEC25_Low-carbon-finishes.pdf

2. Aluminum Extruders Council (2022)
Environmental Product Declaration — Aluminum Extrusions: Mill Finished, Painted, and Anodized.
Industry-average, independently verified Environmental Product Declaration.

Research and original report:
https://aec.org/extrusion-epdslca

3. KMH Sustainable Infrastructure (2010)
Environmental Impact Comparison of Fluoropolymer Powder Coating, Polyester Powder Coating and Anodising Processes.
Report prepared for the Australian Anodising Association, 23 November 2010.

Original research report:
https://sapphirealuminium.com.au/wp-content/uploads/KMH-Environmental-Report-Anodising-Vs-PowderCoating.pdf

4. Stacey, M. (2014)
Aluminium and Durability — Towards Sustainable Cities.
International Aluminium Institute.

Research publication:
https://international-aluminium.org/resources/aluminium-durability-towards-sustainable-cities/

5. Stacey, M. and Bayliss, C. (2015)
Aluminium and Durability: Reviewed by Inspection and Testing.
Materials Today: Proceedings, Volume 2, Issue 10, pp. 5088–5095.

6. Standards Australia
AS 1231 — Anodic Oxidation Coatings.
AS 3715:2025 — Thermoset Powder Coatings for Architectural Applications.
AS 4312:2019 — Atmospheric Corrosivity Zones in Australia.

Research results should be interpreted within the scope, methodology, assumptions and publication dates of the original studies. Historic research findings are not substitutes for current, project-specific environmental or performance assessments.

Explore Further

Research-01 — Anodising: The Technology
Understanding the electrochemical process, architectural finishing systems, quality requirements and metallic finishes.

Research-03 — Durability and Real-World Evidence
Examining long-term architectural performance through historic buildings and documented research.

Research-04 — Technical Performance and Australian Standards
Understanding film thickness, corrosion resistance, exposure conditions and applicable specifications.

Research-05 — Specification, Certification and Maintenance
Practical assistance for architects and fabricators specifying high-grade architectural anodising.

Discuss Your Project with AAF Queensland
Our team can assist with finish selection, technical requirements and architectural specification.

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