

SUBSTITUTION OPPORTUNITIES FOR
ALUMINIUM
IN THE CONSTRUCTION AND INFRASTRUCTURE MARKET

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1. Summary

Aluminium is a key material in the construction and infrastructure markets based on its light weight, relative strength, longevity, low maintenance and conductivity.

In the construction and infrastructure markets, architects and engineers have a wide range of materials to evaluate and choose from, where aluminium is often one of the higher-priced alternatives. Choosing aluminium is only justified if the advantages delivered by aluminium are either:

- necessary for the application based on the specifications of aluminium (performance advantage), or
- offer a lower-cost-overall solution (cost advantage).

In such applications, aluminium has a strong position and will gain market share with limited marketing support. Conversely, it is predestined to lose market share in applications where aluminium cannot offer a performance or cost advantage. Marketing can slow this process, but to improve the process, innovations are needed to create a new performance or cost advantage for aluminium.

Marketing aluminium in these markets requires a combination of cost analysis, reaching out to material decision-makers to increase their knowledge about aluminium applications, and R&D work to create performance and cost advantages for aluminium-based systems.

A significant opportunity for aluminium exists to become a key material in the building envelope for modern, organic, light, and air-filled structures. Aluminium is the only material that can deliver the combination of light weight and stability required for the panelling and frames of these designs. The future growth of aluminium's market share here results from supporting such designs via case studies and cost analysis.

The largest threat for aluminium is in the window frame market, where aluminium positioned at the top of the market (e.g. ThermoBlok, Slim Frame) as well as at the bottom, and is losing market share to uPVC frames from the middle segment of the market. In the window frame market, innovation to improve performance and to lower costs could re-establish aluminium as a better alternative for the mid-top segments of the market.

In formwork, a smaller market, aluminium can significantly increase market share. Aluminium is a better system for intricate concrete work, which will likely further increase in the future. Technical and cost comparisons of aluminium and steel formwork could be used in marketing and analysis. Increasing the strength of aluminium formwork pieces while maintaining their lightweight characteristics could place aluminium formwork in direct competition with steel formwork for larger concrete works.

In the roofing and cladding market aluminium has the advantage of being lightweight. For roofing architects are often unaware of the potential overall cost savings from using a lighter roofing material and tradition drives material choice. Thus, the potential to grow aluminium's market share here is relevant; however, aluminium's advantage might be insufficient to strongly increase aluminium's market share in these markets.

In markets of heat exchangers, winding wires in transformers, aluminium has a substantial cost advantage while delivering on-par performance with alternative materials. Here substitution by aluminium is automatic, and any promotion can only speed up the process.

Building wires is a large market, but aluminium's growth potential is limited by regulations and industry recommendations. Nevertheless, based on the market size, it makes sense to explore marketing opportunities, although the progress of substitution might be slow.

Aluminium applications in the construction and transport infrastructure markets have different substitution drivers and require a differentiated approach combining the following factors:

- Working on regulations, codes, and recommendations to include aluminium where possible.
- Supporting technological development innovations to create performance or cost advantages for aluminium.
- Sharing experience and knowledge with aluminium-based solutions, especially those from China, with material decision-makers around the globe.

2. Objectives and methodology of the study

According to research, the construction sector will lead the aluminium market by 2027. In particular, this is driven by the increasing construction activities in the Asia-Pacific region. This region has an accelerated demand for hotels, shopping malls, high-rise buildings, arenas, and stadiums (both outdoor and indoor), boosting the construction industry and driving the demand for aluminium in the region. China also remains in the midst of a construction mega-boom. As a result, the country has the largest building market in the world, making up 20% of all construction investments globally.¹

Post-Covid economic packages often focused on investments in construction and infrastructure projects. At the same time, new regulations, technologies, price landscapes, and procurement policies led to structural changes in these markets. The International Aluminium Institute (IAI) is the foremost organisation for supplying intelligence on aluminium markets and promoting aluminium products. It is expanding its market intelligence and exploring how to strengthen aluminium's competitive position in the construction and selected infrastructure markets (railway, expressway, subway).

The results of this study will be used for the industry strategy of IAI and its members, external communication, and the strategic directions of work priorities.

Objectives of the study

The main objective of the study is to understand aluminium's role in the construction and transport infrastructure markets, and to evaluate how it could best increase and defend its market share against competing materials in the medium and long-term future.

The objectives of the proposed study include the following:

- **Market-specific substitution trends:** Provide a narrative and detailed explanation of past and expected future markets, substitution developments, and trends in the construction and specific transport infrastructure markets.
- **Material decision-making process:** Explain the material decision-making process in these markets focusing on:
 - Material specifications, including alternative materials,
 - Value-engineering processes to select the final material.
- **Quantification of substitution opportunities:**
 - Quantify, compare, and prioritise substitution opportunities to suit aluminium's expected market share change by 2035.
 - Develop market scenarios for aluminium's role and indicate market share change by 2050.
- **Evaluation and substitution drivers:**
 - Evaluate current and future aluminium use, substitution drivers and inhibitors, and their comparative importance in the view of the material decision-makers.
 - Identify, flag and explain general and socioeconomic market trends impacting the material decision, including decarbonisation, green buildings, and recycling trends.
- **Innovations:** Identify and investigate existing innovations (for aluminium or competing materials), innovative production processes, and the apparent need to provide new solutions for existing problems to foresee potential innovations in the future.

¹ https://www.reportlinker.com/p06134965/Aluminum-Market-Growth-Trends-COVID-19-Impact-and-Forecasts.html?utm_source=GNW

- **Action plan:** Provide narrative and detailed recommendations on the market opportunities and the positive influence of substitution drivers and aluminium's market share, with a timeline and market participants to be targeted.
- **Prompting discussions:** Collect thought-provoking market feedback and indicate unorthodox marketing ideas to the IAI management and members, prompting discussions and the development of leading-edge solutions.

Methodology of the study

The investigation combined secondary research, online surveys, and in-depth interviews, which entailed the following:

- Three weeks of secondary research of Internet resources in English and Chinese Mandarin,
- Development of a standardised questionnaire for the online surveys and an interview guide for telephonic interviews, and collation of feedback from the IAI and its members,
- Launching the online survey using SurveyMonkey, an online survey tool,
- Structured an interview sample of 700 material decision-makers at design teams, operating companies, public and private project owners, pre-contract surveyors, subcontractors, aluminium fabricators, cable makers, and policymakers, among others. Of these, approximately 500 were approached for interviews,
- Conducted 76 telephonic interviews; the details of the companies interviewed are shown in Annex 1,
- Worked closely with the IAI management at each step, shared working hypotheses to be tested in the study, and reported back on a regular basis.

3. General material and substitution trends in the construction and transport infrastructure markets

Construction and transport infrastructure industries have long been strategic industries and have also been the focus of fiscal expansion policies. As populations expand, more and more buildings and transport networks are required. The growth of the construction industry closely correlates with GDP and population growth.

Aluminium is a relatively new material in the construction industry and competes against a wide variety of available materials, both traditional and newly-invented. Aluminium is often a higher-priced material, and its use is justified only when the advantages delivered by aluminium are either

- necessary for the application based on the specification of aluminium (performance advantage) or
- offer a lower-cost overall solution (cost advantage).

The majority of the material selection decisions are made based on the following:

1. material specifications,
2. aesthetics/design and
3. material/project costs.

Regulations, codes, and industry recommendations cover parts of the application's required material specifications but are often limited to minimal and not best practice requirements of the application. These regulations are continuously changing and are inconsistent across geographic regions.

If the specifications of the applications are met by alternative materials and the general aesthetics are aligned with the design, cost becomes the key decision-making factor.

Carbon footprint appears to be a minor factor influencing the material selection decisions, except when it is a public and commercial project based in the EU. Interviewees in all geographic regions, however, expect a stricter decarbonisation approach in the future, but until then, costs overrule carbon footprint considerations.

Non-conductive applications

In non-conductive applications, aluminium is the material of choice if lightweight solutions with adequate strength are required. Currently, only aluminium can provide this combination, but it is expected that engineered plastics will increasingly enter this arena. For example, uPVC is already taking over market share from aluminium in the window frame market.

Aluminium often competes with steel, and in scenarios where strength is more important than weight, steel will always be a lower-priced and stronger material than aluminium. For instance, in load-bearing elements in construction, bridges, frames of temporary buildings, the advantage of steel will continue to limit the growth of aluminium's market share in the future unless innovative solutions can significantly increase the aluminium's strength.

A further key advantage of aluminium over steel is that it can be cold-formed in many different shapes as extrusion is a key production process. Steel requires costly hot forming and has a limited variety of end forms. Thus, aluminium is a key material for unusual shapes and narrow elements, such as window frames or panelling of curved structures etc.

Conductive applications

In heat, electricity and sound conductivity applications, aluminium is a highly conductive material. Heat and electrical conductive applications such as power cables, winding wires, and heat exchangers require high conductivity; aluminium can offer on-par performance with the leading competitor, copper, at lower costs. Therefore, the substitution of aluminium can proceed without marketing, unless it is restricted by other factors, such as energy efficiency regulations (electrical motor winding wires) or building codes (building wires).

High sound conductivity of aluminium is not an advantage for noise barriers, but this can be addressed by combining aluminium frames with sound insulation materials.

4. Material decision-making in construction and transport infrastructure projects

Material decision-making process in the construction industry

The main material decisions are made by concept architects. They design the “look and feel” of buildings and select materials based on how these fit into their “concept” and the technical parameters required by the design. Building engineers and planners fine-tune the design and prepare the technical drawings for different contractors: structural drawings for the construction company, electrical drawings for the electrical installations, and HVAC drawings for the heating and cooling system suppliers. They also cost the technical drawings with the materials suggested by the architects or the materials commonly used for those applications.

Architects select from a wide range of materials suitable for construction. There are many ways to build structures and cover roofs – although aluminium is one of the higher-priced material options, it offers specific advantages. Therefore, aluminium is often a good choice of material when the benefits derived from the specific advantages outweigh the disadvantages.

- **Value-engineering**

If the budget required is higher than the budget available, a “value-engineering” exercise takes place where processes, materials and designs are altered to meet the available budget. The focus of value-engineering is always to cut costs, but only where:

- this cost-cutting will not significantly deteriorate performance, and
- where cost cuts can achieve a significant percentage saving on the overall project costs.

For instance, as building wires represent only a small percentage of the overall building costs, substitution of copper with aluminium building wires leads to minimal savings; therefore, this replacement would be less advantageous.

- **Use of aluminium**

Materials in the building structures and the building envelope contribute to the aesthetics of the building and, as such, are selected by the concept architects. Wood is considered to be more “warm and traditional”, whereas metals such as aluminium are considered “cool and modern”. Residential projects often favour “warmer” materials, while commercial projects prefer materials that reduce installation and maintenance costs; these are often the “colder” metal materials.

Aluminium is often used in innovative, modern structures as it offers exciting design options due to its low weight and extrusion production process. Public, commercial, and high-rise buildings require light materials

with low maintenance requirements due to the building's height and the limited access to the outside. In such instances, the architects often consider aluminium for these buildings.

- **Longevity of construction projects**

As aluminium is a relatively new material, users have limited knowledge of using aluminium products in the long term, e.g., how aluminium installations behave over time when exposed to weather, UV radiation, and electrical loads. This is especially relevant for construction and infrastructure projects which are planned for a design life of 100+ years. As construction and infrastructure applications have existed for millennia, they have developed traditional materials such as timber, stone, and concrete where data points and experience exist about their long-term use.

Aluminium requires additional information generation and promotional work to compete with traditional materials and convince architects and engineers about its preferred use. Therefore, providing usage information, testing data, long-life cost analysis, and LCA data, together with engaging with architects to understand their needs, is essential for promoting aluminium's market prospects.

In addition, aluminium's traditional applications, such as aviation and packaging, have developed alloys and technical solutions as required by those industries. Construction and infrastructure projects require different technical aluminium properties such as increasing structural strength or blocking heat conductivity of aluminium window frames. Cooperation with universities and research institutes, research, and marketing of existing innovative aluminium solutions will likely raise market shares.

Material decision-making process in transport infrastructure

Material selection in the transport infrastructure differs from the construction industry. Material decisions are made by state or private-owned transport companies that have their own design and construction teams. The available material options here are significantly reduced; the materials must be long-lasting and are often defined by regulations or codes.

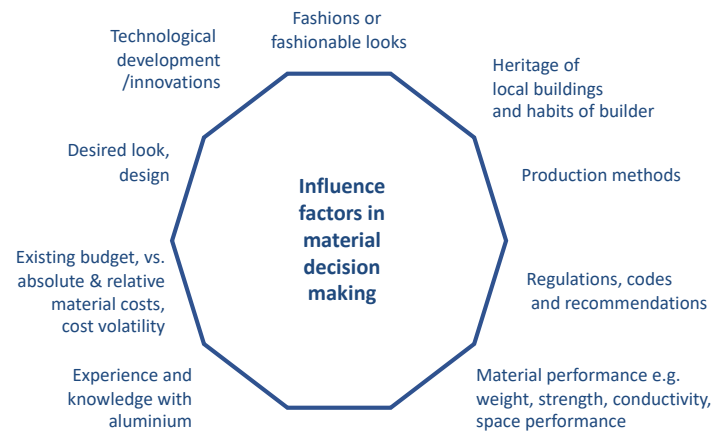
Material decision-making process by OEMs

In many applications, original equipment manufacturers (OEMs) select the materials and provide ready-made components to construction companies or end users, such as electric motors or heat exchangers for HVAC applications. OEMs typically deliver to a wide range of industries, offering the same component to different sectors. As OEMs only provide key specifications of the produced component to end-users, without mentioning the materials used, end users select the components oblivious to the materials used, and their decision is mainly based on costs. Therefore, OEMs are motivated to reduce the costs of the components by using lower-cost materials, as long as they can meet the key specifications.

It could be constructive to educate architects, construction companies and end users on the potential long-term costs/cost savings of aluminium-based solutions so that they can ask the right questions when ordering from OEMs.

Material decision-making factors

Material decision-making is guided by nine main factors, as shown in the following diagram:



- The most critical factor is the performance characteristics of materials that are required to meet specifications, such as weight, strength, conductivity, and space performance.
- Regulations also define specifications of materials, such as building codes, energy efficiency requirements, or recommendations on recyclability. These regulations converge but often vary between geographic regions.
- Production methods and costs associated with them affect material decision-making. For example, aluminium components can be produced via cold work such as extrusion, while steelwork requires hot work. This opens several applications for aluminium and reduces semi-production costs.
- The heritage of local buildings and builders' habits are slowly changing elements of local preferences for materials. As a result, the building style and materials required in the USA differ from that in China or India.
- Fashions or fashionable looks of buildings are elements of global and local preferences that are developing progressively. It is fashionable to build open, light and air-filled spaces without the restriction of columns and with large windows for light.
- Technological developments/innovations offer new ways of using existing materials; these innovations might offer a better value proposition than existing practices. New composite materials such as glass fibre reinforced materials (GFR) offer specifications similar to that of aluminium. Systems such as aluminium honeycomb panels increase the strength and stability of aluminium panels, thus opening up new applications for aluminium.
- Concept architects plan the desired look of buildings, select materials that can provide the desired look, and synchronise the overall material selection. Architects or engineers might define the remaining materials based on the specifications, requirements, and the available budget.
- Existing budgets limit the use of materials. However, if a material contributes only a small percentage of the total budget. In that case, savings are achieved not via the substitution of these materials but rather by the substitution of more abundantly used materials, via design changes or via process improvements.

- Experience and knowledge of materials and specifically of aluminium is an area where architects and engineers might simplify the selection of available materials. Currently, their selections are restricted on material they well know as they have insufficient information on how to use specific materials or have inadequate proof that a material will deliver the expected performance.

Other minor factors exist which can affect the decision-making process:

- Theft is a factor when copper or aluminium power cables are accessible, such as in utility power cables. The high resale price of copper can attract theft, and utilities often choose aluminium, among other reasons because it will not be stolen. However, theft is not a significant factor in the construction and transport infrastructure industries as besides railways and metro power cables, the applications offer limited volume of copper.
- Broader public and social trends, including sustainable purchasing and decarbonisation, are theoretically important decision-making factors. However, among the companies we spoke to, only European companies mentioned carbon footprint as a deciding factor, and according to this, aluminium was often not the selected material.

5. Regulations, codes, and recommendations

A wide range of regulations and codes underlie the construction and transport industries, especially as under-performance of materials could cause life-threatening circumstances for workers and users. We will cover only the key regulations significant for aluminium here.

- **Building codes/building regulations**

Building codes define the specifications of construction applications and the materials used in those applications. Building regulations also include electric and fire safety aspects pertaining to material selection.

For example, building wires (typically below 16 sqmm diameter) are bound by strict regulations on material performance, yet the material itself is rarely defined. Electrical installers select materials within the remit of the building regulations based on habits and traditions and are unlikely to “experiment” or try out new materials, particularly if the alternative materials lead only to marginal cost savings. Thus, although fine-stranded aluminium wires exist, which are suitable for building wires and would meet the building regulations of most buildings, these are not used by electrical installers.

A fire safety concern in residential buildings is aluminium’s low melting point, as critical wires could melt in a fire and cause further harm.

- **Carbon footprint regulations/requirements**

Public and large commercial projects are required to meet “green criteria”. However, the exact details of such green criteria vary across geographic regions. Often, meeting green criteria is a voluntary requirement rather than an obligation. The pressure to meet these requirements is mainly from the investors and the public, not the regulators or the industry.

Green criteria include creating a system within the building that, for example,

- Reserves and efficiently uses energy (fuel and power),
- Uses appliances with minimum efficiency standards,
- Uses renewable energy sources, and
- Used recycled or recyclable/environmentally-friendly materials.

- **Energy efficiency regulations**

There are many energy efficiency regulations and recommendations, which will be discussed in the section on carbon footprints. However, here we discuss a specific example impacting the use of aluminium in winding wires for electric motors.

- ***Electric motors***

One of the green criteria is the efficient use of energy by electric motors. The global electric motor market is well regulated in terms of recording and improving the energy efficiency of electric motors.

The efficiency classes of electric motors are regulated by international and regional standard boards using only a few rating systems. Generally, as the energy efficiency of a motor increases, so too the conductivity of the winding wires needs to increase. As copper is a better conductor than aluminium, copper is commonly used for highly efficient motors (IE3/IE4). In contrast, aluminium is used in motors with lower performance/ energy efficiency requirements, such as smaller motors or motors that do not need to work continuously (e.g., kitchen appliances, garage doors).

However, aluminium winding wire technology is developing quickly. For example, flat winding wires and new insulations are being developed that could potentially improve the performance of aluminium in electric motors.

- **Fire safety regulations**

After the Grenfell tower fire tragedy in the UK, fire safety related to insulated aluminium cladding became the focus of regulators. Flammable insulation of the aluminium cladding was identified as the main cause of the tragedy, leading to the death of 80 innocent people. After this tragedy, the EU strictly regulated the cladding material used in tall buildings. The USA followed suit at the time, but recently such regulations were loosened, and the use of combustible insulation with aluminium cladding is once again allowed, as this is the cheapest option on the market.

We cannot highlight enough the negative impact of such fires on the aluminium cladding market.

6. Carbon footprint/AET scenario 1.5 °C/Base case scenario 2.5 °C

CO₂ emission reduction scenarios

With the Paris Agreement, countries have agreed to a common goal of maintaining the global temperature increase to well below 2 °C, and preferably no more than 1.5 °C, by the end of the century. According to the UNEP Emissions Gap report, to be on track for the 1.5 °C goal, the world needs to reduce global emissions by over 50% by 2030, and work towards carbon neutrality by 2050. As the buildings and construction sector accounted for over 34% of the total energy demand and approximately 37% of energy and process-related CO₂ emissions in 2021², this sector will play a major part in achieving this vision.

However, building-related CO₂ emissions are rising, driven by increasing construction activity and the demand for energy-consuming services. The sector's 2021 operational energy-related CO₂ emissions increased by 5% from 2020 and were 2% higher than the pre-pandemic peak in 2019³. Moreover, progress on building energy codes is lagging, as more than two-thirds of the buildings constructed between now and 2050 are expected to be built in countries lacking building energy codes (IEA, 2017).

The 2022 Global Status Report for Building and Construction⁴ by UNEP states that investments in energy efficiency must be sustained in the face of growing crises – such as the war in Ukraine, the ensuing energy crisis, and the cost-of-living crisis – to reduce energy demand, avoid CO₂ emissions and dampen energy cost volatility.

Reductions in emissions from buildings represent one-third of the total reductions required to align with the IEA's Sustainable Development Scenario 2 (IEA, 2019a). This Scenario is designed to achieve the outcomes of the UN Sustainable Development Goals most closely related to energy, namely: to achieve universal access to energy (SDG 7), to reduce the severe health impacts of air pollution (part of SDG 3), and to tackle climate change (SDG 13).

Implementation of the CO₂ emission reduction scenarios

From the interviews in this IAI study, it was clear that energy codes were used as references in the EU and the USA. In the rest of the world, little attention was given to energy codes when selecting materials. Even when the energy codes were in place, these only covered some of the relevant levers to reducing carbon footprint. These codes often provide only a framework or implementation roadmap instead of targets or required actions.

It is possible to reach carbon neutrality and reduce embodied carbon emissions in buildings by 2050, but this requires clear and ambitious policy signals to drive a range of measures, such as passive building design, material efficiency, low-carbon materials, efficient building envelope measures, and highly efficient lighting and appliances.

Aluminium can play an important role in achieving carbon neutrality in areas such as

- light building design (permanent and temporary structures, roofing),
- efficient building envelope measures (cladding),
- material energy efficiency (window frames, roofing)

² <https://www.unep.org/news-and-stories/press-release/co2-emissions-buildings-and-construction-hit-new-high-leaving-sector>

³ <https://www.unep.org/news-and-stories/press-release/co2-emissions-buildings-and-construction-hit-new-high-leaving-sector>

⁴ <https://www.unep.org/resources/publication/2022-global-status-report-buildings-and-construction>

- optimised production processes (formwork), and
- recyclable materials (all applications).

To support decarbonising of new and existing buildings, effective policies and regulations should cover the entire building life cycle, including the design, development, operation, and decommissioning stages, and act beyond site boundaries through neighbourhood planning and clean energy. Aluminium could play a decisive role in this process.

Green buildings

Currently, “green buildings” generally mean reducing the energy emission of the building via energy-efficient windows, cladding, and heating and cooling systems, which are often classified by energy ratings. Interestingly, electric motors fall under energy efficiency ratings that are relatively strict for industry motors (IE ratings), but different rating systems can also apply to electric motors in the residential and consumer markets.

Other factors driving the growth of green building are the increasing use of green materials, green energy (mainly solar), and advancements in building technology enabling the design of buildings as closed energy systems using and recycling their own energy.

When considering materials, some materials competing with primary aluminium are deemed to be “greener” according to material decision-makers, as these materials are:

- either already “recycled”, such as medium-density fibreboard (MDF) or plasterboard, which are produced from by-products of other production processes, but also recycled aluminium,
- or are “renewable” like timber.

This view is retained even though MDF is toxic due to the dust and free formaldehyde from which it is made.

Recyclability of materials

Regarding “recyclability”, little distinction is made between recyclable aluminium, copper, uPVC, and MDF. The main factor determining the “recyclability” of a material is the ease with which the different materials in the components can be separated for recycling.

- Pure uPVC window frames can be recycled, but uPVC with steel reinforcement cannot be separated into uPVC and steel for recycling.
- Aluminium in composite cladding and roofing panels is considered difficult to recycle, as the materials cannot be separated. However, pure aluminium window frames are recyclable as they are made only from aluminium.

There is potential to improve the “recyclability” of aluminium components by helping the separation and recycling processes.

Carbon footprint of materials

For many applications, the highest carbon emissions related to the product occur during the product’s operational lifetime and not during the production or recycling of the product. Therefore, LCA or recycling rates are considered near irrelevant factors in material selection. For example, 95% of an electric motor’s emission happens during operation. Therefore, minimising the carbon footprint of the motor would predominantly focus on minimising electrical losses during operation with the most conductive material, namely copper.

Similarly, in many building applications, such as cladding, window frames, and roofing, the least heat-conductive material is selected to insulate the building and reduce the carbon footprint. Aluminium is considered a heat-conductive material unless insulation is used with the aluminium.

Green incentives

Despite the pressure to reduce CO₂ emissions, most material-related decisions are made solely based on costs, including material selection, production, and installation processes. For example, one of the interviewees commented: *“If we were using low carbon materials, we would price out our products from the market.”*

The only exception is the EU, where the general public, investors, and increasingly public procurement require measures to improve the carbon footprint and energy efficiency of construction and buildings. In the USA, some energy codes also target the energy efficiency of buildings, while China is moving towards reducing carbon emissions but focusing mainly on large contributing production industries.

Regulations about the energy efficiency of some applications are already established, but it is expected that more regulations about the recyclability of materials and carbon footprint reduction will come into force in the future, starting with the EU. Until then, and without external pressure, it will be difficult for companies to argue for reducing carbon footprint and accepting the associated higher costs.

For a company selling globally, regulations are ideally internationally synchronised as production lines are set up for using one set of materials or production processes for domestic sales and exports. These companies are even less incentivised to implement carbon footprint reduction measures and need to be “forced” by regulators, investors or the general public.

Due to the high carbon footprint of aluminium production, the aluminium industry must approach the CO₂ reduction regulations carefully. However, this is a suitable time to continue positioning the aluminium industry as a green material focusing on the light weight, longevity and recyclability of aluminium.

7. Regional differences in the preferences for aluminium

Significant differences exist in regional aluminium use (final product shipments) per capita. Highly industrialised and high per capita income countries, such as North America, have the highest per capita consumption of aluminium at 30 kg, followed by Japan at 22 kg and Europe at 18 kg. China's aluminium consumption is similar to that of Europe at 19 kg, while the Middle East's aluminium use per capita is similarly high at 16 kg.

In sharp contrast, South America has an aluminium use per capita of 8 kg, Asian countries such as India are as low as 6 kg, while the world average is 11 kg.⁵

- **China**

China's high per capita aluminium consumption is partly due to the fast growth rate of their economy and the need for quick construction solutions to manage the consequences of this rapid growth. China is also the largest producer of primary aluminium providing approximately 60% of the worldwide supply and attracting state support for domestic aluminium consumption.

In the past, the use of cheap domestic coal and the adaption of world-class technology enabled Chinese aluminium producers to offer primary aluminium at very competitive prices, supporting domestic aluminium use.

In China, aluminium-based solutions are preferred more often than in other parts of the world as these became best practice for many construction and transport infrastructure applications in China. After the 1960s, due to the limited domestic copper resources and the relative abundance of aluminium resources, aluminium-based solutions were promoted for applications where aluminium had very similar specifications to copper.

Most recently, however, China committed to a net-zero target by 2060. China's aluminium industry contributes about 5% of the country's total emissions; therefore, China is encouraging the use of decarbonisation technology in the aluminium industry. The comparably high carbon intensity of aluminium produced in China is due to its dependency on coal-fired energy. The Chinese central government singled out the aluminium industry as one of the main targets for reducing CO₂ emissions. However, creating low-carbon aluminium requires not only the transition to renewables but also using new technologies in a commercially viable way.⁶

The high aluminium consumption per capita in China and the preference for aluminium-based solutions appear to have survived the recent decarbonisation pressure by the Chinese government and continue to impact the construction and transport infrastructure markets.

- **Europe**

Europe is characterised by relatively proactive material use, but at the same time, strict construction and building regulations often limit the use of materials to the "well-known" materials. The EU is also the home of many aluminium producers who rely largely on hydro-energy sources, thus producing low-carbon primary aluminium. Europeans frequently prefer aluminium for its modern look, lightness and easy maintenance compared to alternative materials. Still, they will also often choose practicality e.g., of the

⁵ 2021 data, Source IAI

⁶ <https://www.weforum.org/agenda/2022/07/decarbonizing-china-aluminium-technology/>

lower costs steel for structural components. They will even more frequently, will be restricted by the building code, electrical safety, fire regulations and other applicable regulations that might restrict specific aluminium-based applications. European material decision-makers also consider the carbon footprint of their designs and developments under pressure from regulations, large end-users and investors.

- **USA**

The USA's primary aluminium production has been declining as the USA is a relatively high-cost producer on the back of energy costs.⁷ Our research showed that architects and construction project owners in the USA frequently prefer the more rustic or traditional look in buildings, such as ceramics or stone cladding, instead of the more modern look of aluminium.

- **India**

In India, aluminium consumption per capita is relatively low and expensive aluminium-based solutions are often out of the budget of many projects. Therefore, the preference for a modern look in buildings is restricted to highly urban developments in India.

- **Rest of the world**

Although aluminium consumption of the Middle East is relatively high, extreme temperatures often discourage the use of aluminium, as it has a high heat conductivity and a relatively low melting point. Latin America seems similar to India in terms of a lower preference for aluminium-based solutions. Russia is a special case with strong domestic low-cost aluminium production but a lower preference for aluminium-based solutions.

- **Future regional differences**

In the future, we expect countries and geographic regions with lower aluminium use per capita, e.g., Russia, Brazil, and India, to increase their aluminium consumption. Consumption in high-income countries is not expected to change significantly on a per-capita basis, but the total consumption may change modestly owing to changes in population and architecture trends.

⁷<https://crsreports.congress.gov/product/pdf/R/R47294#:~:text=Consequently%2C%20a%20major%20reason%20for,and%20the%20United%20Arab%20Emirates.>

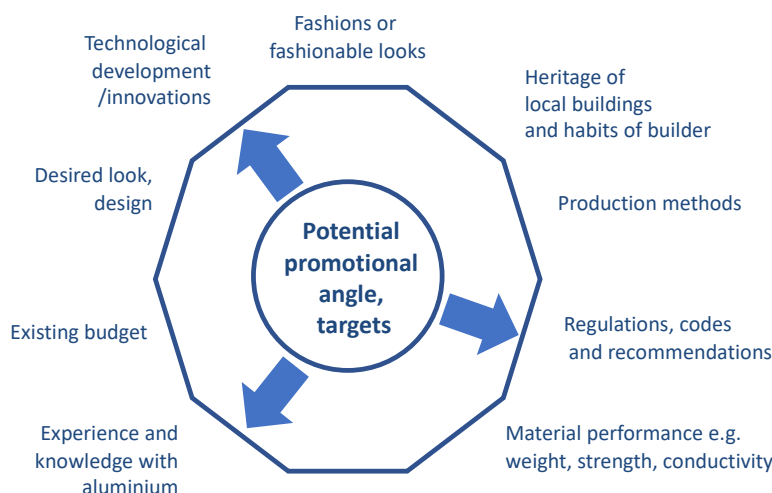
8. Suggested actions by the aluminium industry

Aluminium is an excellent material for many applications, but in the construction and transport infrastructure markets, material decision-makers have a wide selection of alternative materials. Therefore, the construction and transport infrastructure markets require a different marketing approach than used for transport, packaging or consumer goods.

Aluminium is selected in transport and packaging for its strength, light weight, longevity, and recyclability. These factors are important for the construction and transport infrastructure markets but are insufficient for aluminium to be the material of choice.

Marketing angle and targets

Based on the decision-making criteria of the material decision-makers, we see the following angles and targets for the promotion of aluminium by the producers.



- **Regulations, codes, and recommendations**

Firstly, where aluminium adds clear advantages to the application in terms of safety, energy efficiency, or carbon footprint, or where aluminium can avoid negative impacts, it should be included in the regulations and industry recommendations. Examples include steep roofing, which should be made from aluminium because of its light weight, and window frames for areas subject to high winds and snow. However, combustible aluminium cladding should be disallowed globally despite its cheapness relative to alternatives.

- **Technological development innovations**

Secondly, R&D work could develop strong aluminium alloys and other solutions to strengthen the structural stability of aluminium. Aluminium honeycomb panels could be further tested, and best-case applications developed and marketed.

- **Experience and knowledge of aluminium**

Many material decision-makers, such as concept architects, have limited knowledge about how to use aluminium beyond window frames and cladding. The overall cost advantages or recyclability of aluminium applications need to be clarified and explained to architects. The aluminium sector could develop technical data, tests, and case studies to close this knowledge gap.

9. Marketing priorities

As indicated in the following table, we colour-coded the market share potential growth or loss from 2022 to 2050 to guide us in prioritising marketing activities. The blue cells represent the forecasted potential to increase aluminium's market share, while the orange cells represent the potential decline in aluminium's market share. The darker shading indicates a greater predicted increase/decline. These darker areas are the applications IAI should monitor. These applications IAI should address and monitor are:

- Modern large lightweight permanent structures with a growth potential for the market share of 6%.
- Window frames with a threat of market shares declining by 18%
- Pedestrian bridges with a growth potential for the market share of 6%
- Formwork with a growth potential for the market share of 13%
- Road and street signs with a threat of market shares declining by 20%
- Power supply for signal wires with a growth potential for the market share of 29%
- Heat exchangers with a growth potential for the market share of 15%
- Winding wires in transformers with a growth potential for the market share of 30%
- Frames for temporary halls, housing with a growth potential for the market share of 8%
- Sound barriers in transportation with a growth potential for the market share of 7%
- Roofing with a growth potential for the market share of 6%
- Cladding with a growth potential for the market share of 5%
- Building wires with a growth potential for the market share of 2%.

		Market share difference 2022-2050						Difference 2022-2050
		EU	USA	China	India	ROW	Global	Growth potential colour coding
Construction								
Modern large lightweight permanent structures (structural components and panels)		5%	10%	5%	5%	5%	6%	20% or higher
	Pedestrian bridges (structural components and panels)	9%	4%	7%	4%	4%	6%	15-20%
Temporary structures								10-15%
	Temporary halls, housing, temp warehouse	5%	8%	10%	5%	5%	8%	5-10%
	Formwork	10%	10%	10%	20%	20%	13%	0-5%
Roofing		10%	7%	7%	3%	3%	6%	-5- -10%
Cladding, external wall panels (including structure of cladding)		5%	8%	5%	4%	4%	5%	-10- 15%
Window frames		10%	10%	-20%	-30%	-20%	-18%	-15%- -20%
Doors		0%	0%	2%	0%	0%	1%	- 20% and lower
Internal partitions (frames only)								
	Temporary internal partitioning - frames only	5%	-10%	5%	10%	10%	4%	
	Permanent, solid internal partitioning	<1%	<1%	<1%	<1%	<1%	<1%	
Road infrastructure components								
	Sound barriers in transportation	3%	3%	10%	3%	3%	7%	
	Impact barriers	<1%	<1%	<1%	<1%	<1%	<1%	
	Road and street signs (board)	-25%	-25%	-25%	-10%	-10%	-20%	
HVAC applications								
	Heat exchanger	30%	10%	10%	20%	10%	15%	
Electrical applications in construction								
	Building wires - fixed installations within	2%	2%	2%	2%	2%	2%	
	Winding wires in electric motors in construction	0%	4%	5%	4%	3%	3%	
Electrical applications in transport infrastructure								
	OLE cables in railway network	0%	0%	0%	0%	0%	0%	
	Signal cables	0%	0%	0%	0%	0%	0%	
	Signalling power supply cable	30%	20%	40%	10%	30%	29%	
	Winding wires in transformers	10%	10%	50%	10%	10%	30%	
	Winding wires in electric motors in transport	0%	0%	0%	0%	0%	0%	
Internal fittings of buildings		0%	0%	0%	0%	0%	0%	
	Underfloor heating spreading plates	-5%	-5%	-5%	-5%	-5%	-5%	

10. Application-specific marketing suggestions

Based on this study's results, there are several application-specific marketing and developments that aluminium producers could consider. The applications with the most significant potential marketing leverage are described below.

- **Modern lightweight permanent structures** – Market share growth potential 2022-50: 6%

The modern design of air- and light-filled spaces without obstructions is a key application for aluminium materials, although this is mainly for roofing, cladding, and window frames/curtain walls. The light weight of aluminium, its longevity, and the fact that it can be produced in unusual shapes via extrusion makes it a material of choice for these buildings. The introduction of stronger aluminium alloys and honeycomb aluminium panels could further strengthen aluminium's market position.

Although we allocated only a limited growth potential for this application, it is a large market, and absolute aluminium offtake can be significant. However, the drawback of this application is that modern, lightweight permanent structures and the required aluminium components require a reasonable budget. This limits the growth rate compared to alternative materials, especially in low per capita income countries.

The best marketing angle is supporting the new, organic, air- and light-filled architectural designs that automatically need lightweight aluminium for roofing/cladding and extruded aluminium window frames. Some key projects from around the world, particularly from China, together with technical data on the cost savings of using lighter aluminium in those projects and green credentials, could provide promotional case studies addressed to architects and building engineers.

The future development of composite panels should be monitored as these could significantly take over market shares from aluminium in this market.

- **Window frames** – Market shares 2022-50 potentially declining by 18%

Aluminium is well-known material in this application but currently is placed at the top (ThermoBlok, Slim Frame) and the bottom (traditional wide frames) of the market. uPVC frames are placed in the middle and are gaining market share in both directions. Without intervention, we expect aluminium's market share to decline strongly by 2050. We also expect that new high-quality materials, such as titanium alloys, will put further pressure on aluminium from the top end of the market.

The proposed way to address this market development is a combination of the following approaches:

- Incorporating aluminium into building codes for impact areas (such as areas with wind, fire, and snow), as aluminium frames can withstand impact better than alternatives.
- Innovation/further development of aluminium frame systems such as ThermoBlok and Slim Framer to lower prices and keep up with consumer trends.
- Although the low-cost traditional wide aluminium frames used in the developing world will likely be replaced by 2050, the aluminium sector could promote replacement with low-cost aluminium frames as alternatives to uPVC.
- Slim Frame aluminium frames are key window frame systems complementing the currently fashionable light- and air-filled spaces. We expect this trend to continue in the future, and as such, prominent examples from China or well-known architects could be developed into promotional material.

- Recyclability is a crucial promotional aspect. As uPVC frames are not recyclable, the message regarding aluminium should include such green credentials.

- **Pedestrian bridges** - Market share growth potential 2022-50: 6%

China highlights how lightweight, easy-to-assemble pedestrian bridges can gain market share. Although aluminium pedestrian bridges face technical and tradition-related hurdles outside of China, this application could provide a promotional showcase of best practice for aluminium. Further investigation is required regarding the unique technical challenges and providing scenario-based cost/value analyses. This would help to build the case for aluminium in pedestrian bridges, possibly using the promotional material developed by the Russian Aluminium Association.

- **Formwork** - Market share growth potential 2022-50: 13%

Although this is a smaller market, we expect strong potential growth for aluminium in the formwork market. Aluminium directly competes with steel systems and can offer significant advantages, such as being suitable for manual labour due to its light weight and excellent suitability for intricate concrete works. Furthermore, it can be used in different directions (slab/wall), is the best material for multi-storey buildings as it is lightweight and is sold at similar prices to steel systems.

Further research is needed to increase the strength of the aluminium systems to gain market share from steel in larger concrete works and to address construction companies. We expect the market share will automatically grow for aluminium without promotion, as concrete works are becoming more intricate and the increasing number of tall buildings will need to use aluminium formwork due to its technical parameters.

- **Road and street signs** - Market shares 2022-50 potentially declining by 20%

Road and street signs are another market that might need defending. It is currently dominated by aluminium, with a global market share of 90%. However, plastics offer a performance similar to aluminium but at a lower price, and even aluminium requires a plastic layer for reflecting light. Plastics currently offer limited longevity and change colour on UV exposure, but new plastics are being developed, which could offer a better value proposition than aluminium.

Promotion in this market can include aluminium's green credentials and longevity, although it should be noted that plastics are also regarded as recyclable.

- **Signalling power supply cables** - Market share growth potential 2022-50: 29%

Aluminium substitution of copper in signalling power supply cables is ongoing but slow, as these are critical applications. The potential growth of the market share is significant as many geographic regions still use copper and could potentially change to aluminium.

Promotion could focus on improving the reliability of aluminium in this application and communicating the results.

- **Heat exchangers and winding wires in transformers** - Market share growth potential 2022-50 15% vs 30%

Aluminium is a key material in heat exchanger tubes and winding wires in transformers and is continuously gaining market share against copper. This development is happening due to aluminium's on-par performance (meeting the applications' requirements) combined with lower costs. The growth of aluminium's market share will continue without necessary intervention by the aluminium industry.

We recommend investigating the market further and observing the process of substitution. However, there might be no significant leverage for aluminium producers to become involved in this market. An area to review would be the decision-making process of OEMs, specifically their motivation to select aluminium versus copper, and their investment process into new technologies.

- **Frames for temporary halls housing** - Market share growth potential 2022-50 of 8%

Temporary housing has some market share growth potential for aluminium based on the increased use of aluminium in this application in China. It would be viable to investigate why and how China prefers using aluminium in this application and communicate the Chinese example and reasoning to other geographic regions.

- **Sound barriers** - Market share growth potential 2022-50 of 7%

China has a unique preference for aluminium sound barriers in contrast to the rest of the world. Although this is a relatively small market, it could be worthwhile to determine which factors drive China's preference for aluminium in this application and whether these factors are transferable to other regions.

- **Roofing/cladding** - Market share growth potential 2022-50 of 6% vs 5%

Aluminium has significant advantages in roofing and cladding, such as its light weight, low maintenance requirements, and longevity. However, aluminium does not fully use these advantages, and architects are often unaware of the cost-saving potential of using aluminium roofing; for example, a lighter roof structure would be required, and labour would be reduced, leading to cost savings.

Aluminium roofing product options, such as coatings and colours, seem to be significantly more limited than steel. Therefore, it is suggested that this market be investigated further to develop a strategy for offering similar or even more innovative product options as steel does. In addition, a cost analysis could be conducted to justify the 50% higher price than steel roofing, together with a comparative energy efficiency investigation.

Aluminium cladding is established as a high-performance, low-cost alternative with a modern look. However, residential buildings are still reluctant to use the "cold-looking" aluminium cladding, preferring the warmer appearance of terracotta and ceramic cladding. Therefore, the promotion of coated aluminium cladding with a warmer look, together with a cost analysis, could increase the residential market share.

At the same time, it is essential to bring non-combustible insulation of aluminium cladding into all building codes across the globe to avoid fires linked to combustible insulation materials.

- **Building wires** - Market share growth potential 2022-50 of 2%

Building wires are a large market with copper firmly established as the material of choice, mainly based on habits and industry recommendations as opposed to building codes. It will take significant marketing and lobbying efforts to change this situation, despite aluminium cables' on-par performance. We recommend exploring this market further to find the most effective promotion angle.

Aluminium application analysis

Aluminium is used in many different applications in the construction and transport infrastructure markets. In this report, we have selected the most prominent applications and those with the greatest growth potential for aluminium.

11. Modern, large, lightweight, permanent structures

Lightweight aluminium is a key material where wide-span structures and roofs are considered. These modern structures are popular as they provide unrestricted, free space where columns are seen as a distraction. Architects expect wide-span structures and roofs to become even more popular in the future, especially for newly developed modern public and commercial buildings with no strict cost limitations in place.

Modern buildings often use components with unusual curves, curvature changing from panel to panel, or complicated shapes. Aluminium allows the realisation of the surface of those shapes, while steel is still used for limited load-bearing elements due to its relative strength.

Aluminium is the material of choice for organic shapes in modern, large, lightweight, permanent structures. In contrast to steel's more complicated and energy-intensive hot production process, aluminium is easily produced in different shapes via cold extrusions.

In addition, aluminium's relatively low weight requires a lighter and weaker load-bearing steel or reinforced concrete structure. Aluminium panels also require limited maintenance during their lifespan, leading to cost reduction during the lifetime of the building.



Wide-span structure of a stadium with visible steel beams, structural elements, and aluminium panels.

Strong aluminium alloys exist in the aviation and automotive industries but are not widely used in construction. Architects have insufficient information about these alloys. Furthermore, architects typically do not consider aluminium honeycomb panels or other aluminium-based structural design solutions, as they automatically select the material they have experience with, namely steel. They have insufficient information about how aluminium behaves under load/weight over long periods.

Architects, however, admit that existing stronger aluminium alloys or aluminium honeycomb panels theoretically could work for low-height structures while bearing some load.

The key argument against aluminium, particularly against strong aluminium alloys, is their significantly higher costs than steel. We expect the cost differential will remain in place, which might offset aluminium's potential in many structural elements.

Theoretically, zinc panels, new lightweight materials such as composite materials, Fibre Reinforced Plastic/Polymer (FRP), and top-end titanium panels could offer similar advantages in the future as aluminium panels, potentially at lower costs or for longer lifespans. Currently, these materials occupy marginal market shares. The development of composite panels should be monitored as these could significantly take over market shares from aluminium.

Market share of aluminium in modern, large, lightweight, permanent structures

Considering structures in their entirety, approximately 10-20% of the material used is aluminium in the form of panelling, frames, cladding and shutter walls compared with 80-90% of steel and reinforced concrete for structural elements. Steel is needed for load-bearing elements due to its strength, while aluminium is used between the load-bearing steel beams due to its low weight and low maintenance requirements.

There are slight regional differences in aluminium's market share in this sector, driven primarily by investments in construction activity and the preference for modern aesthetics and air-filled spaces in buildings which automatically attract the use of aluminium. China is leading the way with a 20% market share for aluminium, followed by the EU with 15%, the USA with 10%, and India with 5% due to its more traditional building style.

Due to the expected remaining cost differential between aluminium/aluminium alloys and steel and emerging new materials, we limited the growth potential of aluminium's market share up to 2050. The growth potential for aluminium will be linked to unique designs and wide-span, lighter organic structures where aluminium's advantages can be fully exploited. However, we expect competing materials, such as lightweight composites, to gain solid market traction over the next 10 to 30 years. Therefore, we expect the future global market share of aluminium in modern, large, lightweight, permanent structures will be limited to 19% with slight regional differences remaining.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Construction												
Modern large lightweight permanent structures (structural components and panels)	15%	10%	20%	5%	5%	13%	20%	20%	25%	10%	10%	19%

Aluminium honeycomb panels

When stronger and more rigid panels are required, aluminium honeycomb panels offer good strength with a slight load-bearing capacity. Theoretically, aluminium honeycomb panels could be used as load-bearing panels; however, there is still insufficient long-term experience with these panels. In addition, steel currently offers a better value and strength combination for structural elements.

Aluminium honeycomb panels, for instance, are widely used in modern architecture in China to support the realisation of an overall shape. For airports and railway stations, aluminium honeycomb panels can absorb vibration and have good sound insulation characteristics for locations with noise pollution.



Beijing Daxing Airport, the world's largest single-building airport terminal, widely used honeycomb panels

The unique design of the Beijing Daxing Airport was built using aluminium flat panels and hyperbolic honeycomb panels. The airport's top is directly connected to the bubble-shaped skylight, thus integrating the roof with the load-bearing structure and simplifying the building form.

Promotion suggestions

General knowledge claims that aluminium is too soft and brittle for structural elements, and architects automatically select the material they have experience with, namely steel. Aluminium is a relatively new metal with no track record of its behaviour under load/weight for 50-100 years. Architects, however, admit that these aluminium alloys and honeycomb panels could theoretically be used in low-height structures while bearing some load. This shows that there is an information gap that IAI can fill.

China and the developed Middle East are particularly active in realising modern architectural structures that benefit from the unique characteristics of aluminium and aluminium honeycomb panels. There is a potential to promote currently fashionable organic, curved-shaped buildings that will automatically require the use of aluminium panels worldwide. However, aluminium honeycomb panels and stronger aluminium alloys are less known among architects and therefore are less used. Investigating their technical specifications and design potential could raise awareness among material decision-makers.

Theoretically, using more aluminium in construction could lead to a lighter weight of the entire structure, thus requiring less foundation concrete and lower handling and installation costs. However, a clear cost analysis has yet to be presented to architects. Potentially, IAI could prepare an investigation on the structural and maintenance cost savings of using aluminium in construction and provide this to architects with case studies.

A specific example of a lightweight, permanent structure is pedestrian/footbridges, where aluminium has a particular role, especially in China.

12. Case study: Pedestrian bridges

Pedestrian bridges come in different forms, structures, and sizes. Smaller bridges with spans less than 10 m use timber, stone, and the relatively new material Fibre Reinforced Plastic/Polymer (FRP). Larger bridges with spans greater than 10 m need steel reinforcement when using the same materials, and also use concrete, steel or aluminium. Each material has advantages and disadvantages:

- **FRP/GRP**

FRP (Fibre-reinforced plastic)/GRP (Glass Reinforced Plastic) bridges are extremely lightweight, strong, durable, and virtually maintenance-free. This material is suitable for smaller bridges but can cost more than timber. FRP bridges can be supplied in kit form or delivered fully assembled to site. FRP/GRP as material for bridges is becoming immensely popular, although these bridges need further reinforcement if planned for larger spans.



FRP/GRP Footbridge

- **Steel/galvanised steel**

The traditional material for larger-span bridges is steel/galvanised steel. It is a popular choice for pedestrian bridges because painted or galvanised steel requires minimal maintenance and is strong, stiff, and durable. Steel has the drawback of being susceptible to corrosion, but weathering steel is manufactured to block corrosion. Steel has good heat and shock (vibration) resistance, and the overall cost is relatively low.



Steel footbridge

- **Reinforced concrete**

A reinforced concrete bridge structure is stable, low-cost, and can be used for large spans. The construction technology is mature but often requires in situ concrete pouring with a large amount of construction waste generated on-site. In addition, because of the in situ building process, the construction period is relatively long, and the nearby roads are periodically blocked, paralysing the traffic for a considerable period.



Concrete footbridge

- **Aluminium**

Aluminium could be used for smaller and larger bridges as it can be formed into many shapes and is strong, lightweight, corrosion-resistant, and quick to assemble and install. However, larger aluminium bridges require steel reinforcement. Aluminium bridges can be prefabricated and easily transported to site. Using bolted connections, the on-site construction period is short, and there is no need for long-term road closures.



Aluminium pedestrian bridge

However, the higher costs of aluminium and its susceptibility to large amplitude vibrations when exposed to traffic restricts the wide use of aluminium in pedestrian bridges in highly regulated jurisdictions. Controlling the excessive vibration response and assessing the serviceability are the main design criteria for pedestrian bridges (Eurocode 5, British National Annex to Eurocode 1, SÉTRA, HIVOSS). Furthermore, aluminium is difficult to weld, yet the bolted connections might be less stable than welding.

Bridge construction companies outside of China rarely build full aluminium bridges as customers do not ask for aluminium as a material. This is partially based on a lack of knowledge about the specifications and advantages of aluminium on the customer's or the civil engineers' side. However, aluminium might be used in the panelling or roofing of the bridges.



Crowd tests on an aluminium bridge to assess excessive vibration response⁸

⁸ http://sstl.cee.illinois.edu/papers/aeseancrisst15/232_Dey_Vibration.pdf

In contrast, the heavy traffic in China puts extra pressure on construction in the traffic infrastructure. In Chinese cities, pedestrian bridges are increasingly being built to manage vehicle and pedestrian traffic flows. With the conscious city planning in those cities, pedestrian bridges in China have gradually moved towards the comprehensive requirements of light structure, unique shape, large span, high bearing capacity and quick installation (for example, the aluminium pedestrian bridge in Foshan, Guangzhou). Steel and aluminium alloy structures are gradually replacing concrete as the primary material of pedestrian bridges.



Pedestrian bridge in Foshan, Guangzhou, China (aluminium alloy structure and truss bridge, steel and concrete bridge piers)

Market share of aluminium in pedestrian bridges (structural elements and panels)

In China, pedestrian bridges use more aluminium panelling than the rest of the world. The market share of aluminium in China is approximately 7-10%; the remainder is either steel used in the same bridges or pedestrian bridges using other materials. This market share is significantly higher in urban areas than in rural areas. Therefore, the market potential for aluminium in China by 2050 is 15%, assuming that aluminium panelling will take over a large share of the new pedestrian bridges in urban areas.

At this stage, China plans to build more than 600 pedestrian bridges every year, and the penetration rate of aluminium alloy pedestrian bridges is expected to reach 50% in urban areas. The market size for aluminium pedestrian bridges could reach 20-30 billion yuan, calculated based on the consumption of 100-150 tons of aluminium materials for a single aluminium alloy pedestrian bridge. An aluminium bridge can consume about 30,000 to 50,000 tons of high-end aluminium.⁹

Outside of China, the market share of aluminium pedestrian bridges is currently estimated at 1% with a long-term potential of 5-10%. In contrast, Europe has a long-term potential of 10%, while the USA, India, and the ROW are 5%.

⁹ <https://zhuanlan.zhihu.com/p/449261734>

		Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
		EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Construction													
	Pedestrian bridges (structural components and panels)	1%	1%	8%	1%	1%	3%	10%	5%	15%	5%	5%	9%

Promotion suggestions

The Chinese example of using aluminium and aluminium alloys for pedestrian bridges offers a persuasive case to promote aluminium. In addition, the Russian Aluminium Associations prepared promotional material on aluminium pedestrian bridges. However, further investigation is needed on the formulation of the technical and non-technical messaging to suit the decision-making processes of civil engineers in bridge planning.

13. Temporary structures

Emergency temporary buildings are the most likely reason for the start of the temporary structures. Emergency structures are temporary buildings needed due to a fire or possibly to get something protected and under cover. In these situations, time is critical, and buildings must be operational within hours rather than days. The shelters are anchored to the ground using steel earth anchors. On some occasions, when pins are not permitted or the ground is not suitable, concrete blocks are used to secure the safety of the shelters.

Frames are made either of aluminium or steel. Aluminium systems are more expensive but are sufficiently strong and lighter than steel. Because of their lightness, aluminium structures can cover a larger and wider area without support; therefore, aluminium frames are suitable for industrial warehousing, temporary storage shelters, event structures, and temporary sports facilities. Wall panels are generally either PVC for uninsulated buildings, single-layer steel clad, or occasionally aluminium with insulation for insulated buildings.

Temporary buildings are frequently set up the next day and can be used for manufacturing, warehouses, storage, retail space, garden centres, vehicle showrooms, and recycling operations.

For temporary buildings, the main application of aluminium is the framework. Here aluminium's light weight, ease of production via extrusion, and low maintenance provide an advantage over steel. However, the frame is generally made of steel when the structure needs to be solid or bear weight.



Aluminium tent structures (Source: <https://www.luckyinternational.net/aluminium-hanger-tent-structures.html>)

Market share of aluminium in temporary structure (frames only)

Aluminium's global market share in the frames of temporary structures (only frame) is 15%, with a potential of 20%. However, significant regional differences exist.

- In China, migration across provinces created a need for flexible and quick housing. The majority of these temporary housing systems use aluminium frames for upgraded aluminium mobile houses. These are also widely used in targeted poverty alleviation or rural areas. Aluminium's market share in temporary housing systems (frames only) in China is 50-70%, but when all types of temporary structures are included (e.g., warehouses, event tents), the market share of aluminium is at 20-30%.
- In Europe, the USA, and India, steel is the favoured material for frames with PVC or steel for the panels, resulting in a market share of aluminium at 10-20%. However, as aluminium is an expensive material, the market share in India is lower than in Europe.
- The potential market share of aluminium by 2050 depends on the availability of quick, easy-to-handle, versatile and good-value aluminium-based systems. Assuming this will be available, we expect a market share growth of 5-10% for each region.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Temporary structures												
Temporary halls, housing, temp wareho	15%	12%	25%	10%	10%	18%	20%	20%	35%	15%	15%	26%



Most widely used in China - Temporary hall with steel base, aluminium alloy frames and PVC panels,



Temporary hall with aluminium frames



Foldable aluminium gazebo for easy transport

Promotion suggestions

The best practice case of Chinese temporary housing might offer a good promotional opportunity. The aluminium-based systems used in China could offer innovative solutions using aluminium frames for many different temporary structures. However, further investigation is needed to define the best marketing drive for this market.

14. Formwork

Formwork is a temporary structure used as a mould for the final structure. It is often used for concrete and can be made from various materials.

- **Timber** is a common material used for formwork but requires specialist knowledge. In addition, timber can be reused only limited times.
- **Steel** is a key material for formwork. It is used for larger systems, as strong steel can resist the forces from larger concrete works like large walls, dams, and bridges. However, it is also heavy and must be moved by a crane or machinery. Steel systems are costly, but they can be used practically infinite times. Steel provides an excellent finish to the concrete surfaces.



Aluminium formwork for concrete work

- **Aluminium formwork**

Aluminium formwork is becoming popular because of its light weight and the resulting ease of handling. The weight of an aluminium piece is approximately 25 kg (vs 45-50 kg for steel pieces) and can be disassembled and assembled manually without using cranes and loading platforms.

Aluminium formwork provides a smooth finish similar to that of steel, and all parts of the aluminium formwork system can be reused for new layers. In addition, aluminium formwork is often more efficient than steel because it can be used for slabs and walls if the pieces are turned.

The aluminium formwork construction process is more suitable for smaller and more intricate works than steel formwork due to its lower strength. Thus it is ideal for applications such as concrete structure walls less than 3 m high, horizontal floors, columns, and beams, and is often used for pre-fabricated formwork.

Aluminium formwork is also preferred in the construction of high-rise buildings due to its light weight, the absence of a need for cranes and that it can be reused.

A disadvantage is the limited load it can handle, such that when the load reaches its maximum limit, the lighter sections may deflect.

The cost-effectiveness of aluminium versus steel systems depends on the size of the work, but they are largely similar. However, the one-time investment of aluminium formwork can be considerable.

Market share of aluminium in formwork

The global market share of aluminium in formwork is about 23%, typically found in smaller works and tall buildings, with developed countries leading the drive for more intricate concrete work requiring aluminium formwork. Long-term potential is approximately 37% as we expect the advantages of aluminium formwork will become more widespread and the concrete work will become more complicated.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Temporary structures												
Formwork	30%	30%	30%	10%	10%	23%	40%	40%	40%	30%	30%	37%

Promotion suggestions

Aluminium is already the key material for the formwork of smaller projects. We expect concrete works to become more complicated, especially in developing regions. Increasing the strength of the formwork by using stronger aluminium systems could make them competitive with steel for larger formwork projects. It is suggested that investigations be done on how the strength of aluminium could be increased without compromising the light weight.

15. Opening window frames, doors, and gates

Window frames

The purpose of window frames is to hold the panes of the window in place to allow natural light and air to enter the buildings while simultaneously minimising the heat/cool loss from the inside to the outside. Although traditionally window frames were made of wood, aluminium frames have entered the market in the last century. However, a few decades ago, uPVC window frames gained a significant market share based on better thermal insulation than traditional wood or aluminium frames.

Architects have a wide range of choices for window frames:

- **Wooden window frames**

Wooden window frames have a classic warm look and are ideal for period properties. Timber is expensive and unsuitable for large windows but offers a warm, organic traditional look. These frames require significant maintenance, repair and repainting to last up to 50 years. Due to the high maintenance requirements, timber is unsuitable for difficult access areas such as high-rise buildings. Wooden window frames are naturally insulating, preventing heat loss. Timber is a renewable resource and offers a sustainable material choice.

- **uPVC window frames**

uPVC is the most widely used material for manufacturing window frames thanks to its durability, insulating capacity, low maintenance finish, and customisation options. uPVC is not affected by rot or corrosion and is a low conductor of heat. Thus, when fitted correctly, it will form a closed-air system minimising heat loss, in contrast to non-insulating materials like simple aluminium frames. uPVC has excellent thermal values when combined with double or triple glazing. However, uPVC needs steel reinforcement for strength, which can make it too heavy for larger windows.

uPVC has a relatively low life expectancy of about 20-30 years, after which they are unrepairable. Pure uPVC is recyclable, but the steel reinforcement is difficult to separate from the uPVC, limiting the recycling of the entire frame.



uPVC window

- **Aluminium window frames**

Aluminium as a material for window frames offers cool contemporary aesthetics; it is strong and is the material of choice for larger windows where uPVC would be too heavy. Aluminium window frames can withstand impact and are preferred for areas with strong wind. It does not rust and therefore has low maintenance requirements, leading to a life span of 40-50 years. With powder coating and other surface treatments, aluminium window frames come in a wide variety of looks. Aluminium is also 100% recyclable and offers a sustainable option.

Alternative aluminium window frames

There are many different aluminium window frame systems. Only those relevant to this analysis have been listed and do not claim to be comprehensive.

- The old-fashioned wide aluminium frames with single glazing are used in many developing countries, including Latin America and India, as it is the lowest-priced option.

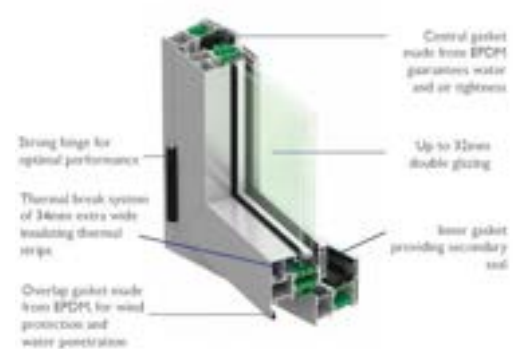
A disadvantage of simple aluminium frames is their low energy efficiency. Aluminium transfers heat to the exterior in cold climates and to the interior in hot climates, and moisture can build up inside the glazing. Currently, where energy efficiency and the carbon footprint of buildings are critical, traditional aluminium window frames might be considered inferior to alternatives.

In many developing countries, temperatures do not require high energy-efficient window systems, and air circulation is achieved by opening the windows. As such, the low-cost simple aluminium frames are sufficient. These old-fashioned aluminium frames are generally not used in the EU or the USA and only in parts of China. We expect these to be phased out in developing regions in the future.

- Slim aluminium frame systems are the most advanced aluminium frames as these minimise the width of the frames and maximise the light entry. These frames are used for larger windows, and the required enforcement leads to higher cost points.
- Aluminium frames with polyamide thermal breaking technology and double or triple glazing prevent heat transfer and can achieve an A++ energy rating. Although this makes the window frames more expensive, these ThermoBlok windows are excellent when used in cold climates or where A/C is regularly used.



Slim Frame aluminium window frames



ThermoBlok aluminium window frames

- **Composite window frames**

Composite window frames combine 2-3 materials for peak performance. These window frames have gained popularity and market share as they combine the low maintenance characteristics of aluminium on the outside and the warmth of timber inside. However, composite windows are still expensive and have a low market share.



Composite windows

- **Zinc titanium window frames**

The zinc titanium plate is a relatively new but extremely durable competitor to aluminium. The lifespan of an aluminium-framed curtain wall is about 40-50 years, but zinc titanium curtain walls can be used for 80-100 years.

Use of aluminium window frames

- Because of aluminium's strength, it is used for large glass surfaces where the frame can support large panes of glass with only a minimum frame width while providing fashionable light- and air-filled spaces. Therefore, folding doors and windows in large commercial and high-end residential projects generally use advanced slimline aluminium window frames.
- The longevity and low maintenance of advanced aluminium window frames make them the preferred option for public or commercial buildings and for buildings with multiple floors where access to the exterior of the windows for maintenance is difficult.

- The strength of aluminium frames is also preferred in impact areas, such as areas exposed to strong winds or snow. However, this is more of a general practice than one that is included in building codes.
- The excellent energy efficiency of ThermoBlok aluminium window frames is chosen in geographic areas with extreme temperatures and where the budget allows these efficient but pricy solutions, for example, Northern Europe, North of USA, and the developed Middle East.
- In normal residential developments in developed countries, the energy efficiency and shorter life of uPVC windows are sufficient as these offer lower price points. uPVC windows cost more than traditional single-glazed aluminium windows but cost approximately 40-50% less than comparable ThermoBlok aluminium windows (with all related costs involved). In contrast, period buildings or other high-end buildings often use wooden window frames.

Aluminium's market shares in window frames

The decision on the material of window frames is made based on the style of the building, climate, longevity required, windows used in the surroundings and budget.

- In Europe and the USA, aluminium's market share is approximately 20% while uPVC's is 65%, with differences in the north and the South.
- In China, aluminium's market share is 55%, a mixture of the more advanced and low-value systems. uPVC has a market share of 35% and steel 6% in China.
- In India, the low-value aluminium systems are most commonly used, resulting in a market share of 75%, with the high-end ThermoBlok frames representing only 5-7% (uPVC 17-20%, wood 5-6%, the remainder is steel).
- A similar situation is prevalent in many Latin American countries where the traditional low-cost aluminium window frames are used with a market share between 70 and 50%, depending on the temperatures in the country.
- In the developing Middle East and other hot countries, traditional aluminium windows do not work due to heat transfer, and uPVC offers a good heat insulation value, especially where the buildings are not modern and have few floors.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Window frames	20%	20%	55%	70%	60%	54%	30%	30%	35%	40%	40%	36%

The predicted future development of aluminium's market share is non-linear and depends on a variety of factors:

- uPVC is gaining market share in the lower end of the market and the residential market, as uPVC offers a good combination of price and thermal performance.
- Large windows and windows with limited access will remain aluminium. Supporting light- and air-filled buildings will increase aluminium's overall market share. It is worthwhile to monitor titanium window frames that offer longer life and could thus diminish aluminium's market share.
- We expect that the low-value aluminium frames will lose market share in developing regions to uPVC as more A/C will be installed, requiring thermal control of the rooms.

- ThermoBlok aluminium window frames might present a way to improve aluminium's market share, especially if promoted as a solution for the energy efficiency of buildings, potentially recommended by regulators.

Carbon footprint

The recyclability and carbon footprint of the production process is less important than energy efficiency during the window's lifetime, i.e., the thermal values are the dominating factor in the production process. Therefore, the overwhelming majority of the carbon footprint of window frames results from their lifetime usage.

Consumers need to be made aware of the recyclability of aluminium versus uPVC frames.

Curtain walls

Aluminium is the main material for large surface windows called curtain walls. These are often used on high-rise or public buildings where the low maintenance of aluminium frames is a key requirement.



Aluminium curtain wall

16. Case study: Conservatories and sunroom windows

Skylights and sunroom window frames must be lightweight but stronger than traditional frames. They are often installed horizontally and have minimal or no load-bearing support. Premium skylight producers prefer aluminium alloy frames since they are stronger than the standard ones, are more malleable and weldable, and are 1/3 lighter than steel. However, due to the complex production process, aluminium alloy frames are more expensive than steel alternatives.

Competitor materials: uPVC, steel.

In conservatories and sunroom windows, aluminium's market share is high, between 50 and 75%. Although some limited growth potential exists, the market is too small to be promoted independently from the windows market.



Promotion suggestions

- Developing more flexible, more on-demand and lower-cost ThermoBlok aluminium frame systems.
- Promoting ThermoBlok and slimline aluminium frames in countries with a high GDP per capita and relatively high temperature differences, such as Germany.
- Incorporating aluminium frames into building codes for geographic areas with strong wind, snow, and other possible impacts.

17. Doors

Entrance doors should be strong and meet security specifications. Pure aluminium is soft and approximately 60% more expensive and less hard-wearing than steel; therefore, it has limited potential to gain market share in the door market.

Some pure aluminium doors are used mainly as back doors in residential developments. However, most front doors are composite doors using different materials combining the strength of metal reinforcement (steel or aluminium) inside the door, insulating foam and the warm feeling of timber on both sides of the door or wooden doors. Aluminium reinforcement offers light weight but sufficient strength for the reinforcement but steel is better value and stronger.



Composition of composite doors (using steel reinforcement)

Examples of competing materials for doors are steel, timber, HDF, uPVC, composite with glass or timber panelling.

Market share of aluminium in the doors market (pure aluminium doors and composite doors)

The market share of pure aluminium doors is below 1%, and the entrance door market share of composite doors using aluminium enforcement is approximately 5%. Pure aluminium doors and the aluminium enforcement in composite doors add up to approximately 2% market share. The potential for growth in this market is limited.

- Regional differences exist between developed countries such as the EU or the USA using composite doors with steel or aluminium enforcement and developing countries such as India and Latin America using HDF doors with lamination, veneer, or pure timber.
- In China, aluminium enforcement doors are popular, with a market share among composite doors of approximately 30%. The total market share of aluminium within the door market is approximately 2-5%¹⁰, with a limited growth potential.

	Aluminium Market shares 2022							Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global		EU	USA	China	India	ROW	Global
Doors	1%	1%	3%	1%	1%	2%		1%	1%	5%	1%	1%	2%

¹⁰ The "Blue Book on the Development Trend of China's Door and Window Industry in 2021, https://pdf.dfcfw.com/pdf/H301_AP202207231576487477_1.pdf

18. Roofing

Roofing needs to be insulating, corrosion-resistant, impact-resistant, and aesthetic while also ideally being lightweight and long-lasting. However, not all roofs are the same, as location, temperatures, and roof pitches have an influence. Many different roofing materials are available to choose from:

- **Tile roofing**

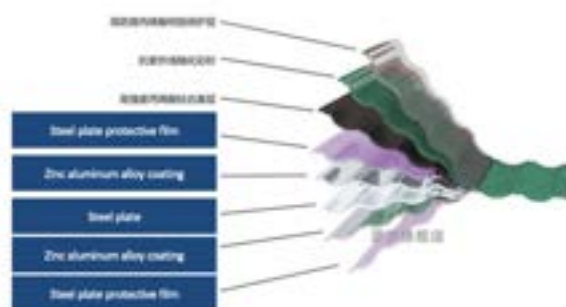
Tile is the most popular roofing material throughout the world. Clay and concrete tiles are known for their durability and ability to withstand high winds, hail, and even fire. Tile roofs in virtually every climate and geographic area provide exceptional thermal properties, reducing heat loss or gain. Natural air ventilation under the tiles creates a heat transfer barrier that can help cool a house in summer and warm it in winter, lowering energy costs by as much as 20%. Because of how durable and resistant tiles are, minimal maintenance is required, and a brand-new tile roof will last 50+ years. Tile roofs are environmentally friendly as they come from a sustainable resource. Once removed, they can be crushed and recycled, often making a base for roads.

However, clay and concrete tiles are heavy, and it is important to have the proper structural roof reinforcement to support them safely. Tile roofing can be expensive – clay or concrete roof tiles can cost twice as much as asphalt shingles and 50% more than aluminium roofing. Professional tile installation is critical to avoid roof failures and ensure longevity, but this can also increase costs.

- **Steel/painted steel roofing**

Steel roofing is made of iron and other metal compounds. It is often used in commercial buildings, but residential projects also use these roof types. It is affordable (50% of the price of aluminium roofing), low-maintenance, durable, weather-proof, and versatile, but heavy and can be difficult to install. Steel is usually zinc-coated for corrosion protection and then sealed. A coating of epoxy primer offers adhesion and a baked-on acrylic top.

Steel roofing is a mainstream, low-cost, and long-lasting material for countries with lower GDP per capita for residential and commercial developments. It also offers a good value for countries with high GDP per capita.



Composition of steel roofing with coating

- **Copper roofing**

Copper is the most expensive roofing material (approximately £80-£120 per m²) because of its durability and uniqueness. Copper roofing is rust- and corrosion-resistant and can last roughly 200 years. Depending on the climate, it often changes colour and patina from copper to a blue-green or brownish hue.

- **Zinc roofing**

Zinc roofing is similar to copper in that it generates a beautiful and stylish appearance, with its changing patina and colours, but is less expensive (approximately £60 per m²). These colour changes are mainly triggered by the formation of a protective layer, as the zinc absorbs carbon dioxide, moisture, and other natural elements. These roofs are highly resistant to moisture, have a long lifespan, and require little to no maintenance, but have limited availability.

- **Asphalt/Asphalt shingles roofing**

Asphalt is a material applied to flat, sloped, or curved roofs to form a waterproof layer. Asphalt is a useful material because it can be laid alongside thermal insulation. As asphalt is waterproof, it can lie under green roofs or roof gardens. One of the largest benefits of asphalt roofing, especially the rolled roofing form, is that it is extremely cost-effective, offering the lowest costs as a roofing material. In addition, it is quick to apply with minimum disturbance to the building. However, it is far less attractive than other roofing materials and only lasts for a short time.



Asphalt shingles roof/Asphalt flat roof

- **Aluminium roofing**

Aluminium roofing (corrugated aluminium sheet, profiled aluminium sheet, aluminium tile) is a roofing system made from lightweight, malleable, and corrosion-resistant panels. It is cheaper than copper/zinc roofing at approximately £30 per m² but twice the cost of steel roofing and significantly more expensive than asphalt shingles.

Aluminium is the lightest roofing material on the market and is durable and low maintenance, with a life span of more than 50 years. Aluminium is used for architectural roofing (panels) and not structural roofing (beams). Aluminium is a soft metal that can dent and mar easily and is less rigid than steel.

Some countries like the UK offer aluminium roofing in mill finish, i.e., with a shiny aluminium look. Here the popularity of aluminium roofing is lower than in countries offering aluminium roofing with coatings and paints. In Scandinavia, for example, aluminium roofing painted in bright red imitating tile roofing is much sought after as these offer the traditional look with the advantages of aluminium roofing.



Corrugated aluminium roofing sheets sold in the UK



Painted aluminium roofing fashionable in Scandinavia

- Key characteristics of aluminium roofing include:
 - Corrosion resistance: Arguably, one of aluminium's most significant advantages is that it does not rust, but it must be painted or coated for appearance.
 - Lightweight: Aluminium weighs as little as 5 lbs per square foot and is the lightest roofing material. Besides making it easier to move and work with, a lightweight roof puts less stress on the building structure than heavier materials. In addition, aluminium roofing allows the use of a lightweight roofing structure. Aluminium is best for high-slope roofs with a minimum slope ratio of 3:12.
 - Energy-efficient: Aluminium does not get as hot as steel and cools down faster. This is especially beneficial to maintain cooler inside temperatures and minimise electricity usage on hot summer days. Homeowners with an aluminium roof can save up to 20% on heating and cooling costs.
 - Long-lasting: Aluminium is a long-lasting roofing material. The average lifespan of an aluminium roof is 50 years, but it has been known to last beyond 70 years.
 - In frigid temperatures, metal roofing with insulation, including aluminium, provides sufficient protection from the cold.
 - Aluminium is a very soft metal that dents and mars easily and is not nearly as rigid as steel.
 - The most significant disadvantage of aluminium roofing is that it costs approximately 30-50% more than steel roofing (depending on the finish).
 - Aluminium roofing sheets and other metal roofs can be noisy when it rains. However, some regions enjoy the rain noise, especially those with limited rainfall.

The use of aluminium roofing is very much dependent on aesthetics, regional roofing structures and fashion. It is used for commercial developments with large spans and steep roofs to benefit from its light weight and where noise is not a concern. Alternative uses are the roofs of garages, sheds, carports, and porches in residential developments or where the specific coating meets the regional fashion.



Different aluminium roofing

Market shares

The current global market share of aluminium is approximately 3%, with a long-term potential of 10%. Regional market shares vary depending on the predominant roofing structure, the country's climate, the required longevity, the available budget, and the regional fashion.

- The EU shows a preference for aluminium roofing with a market share of 10%. A long-term potential market share of 20% is possible by offering different looks (coated aluminium roofing material) and emphasising the lightweight advantage of aluminium roofing to compensate for the approximately 20% cheaper coated steel roofing.
- The USA, China, and India have a lower market share for aluminium roofing at approximately 2%, with a potential for 5-9%. Again, the key aspect seems to be offering different looks and systems, meeting local roofing needs while emphasising longevity.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Roofing	10%	2%	2%	2%	2%	3%	20%	9%	9%	5%	5%	10%

Carbon footprint

The carbon footprint of the roofing forms part of the carbon footprint of the building. According to the interviewees, no one considers the recyclability/end-of-life use of the roofing materials. Although the recycling value of aluminium is positive, coated aluminium is difficult to recycle and becomes similar to the limited recyclability of bitumen. The recycling value of parts of the building is often not considered when designing the buildings, presumably because of the long-time horizon. New regulations are needed for these aspects to be considered in the material selection, as there is currently no economic case for it.

Promotion suggestions

Architects and planners that we spoke to often were unaware of the advantages of aluminium roofing and automatically selected the standard roofing options. Aluminium roofing has many advantages, but the economic and use-related case needs to be clearly prepared and presented to architects and planners.

- **Commercial buildings (e.g., warehouses)**

With commercial buildings, the general perception is that bitumen shingles or steel roofing are cheaper. However, if the costs of the strong roof structure required by bitumen are totalled, aluminium roofs can be more economical even for narrower span roofs. In addition, aluminium roofing material can be sold at the end of life of the building, while the recycling of bitumen roofs will be costly for the owners.

Commercial buildings have a life of 10-20 years, and the 50+ years longevity of aluminium roofs is often not appreciated. However, if the buildings are built for longer operation, the value proposition of aluminium roofing can be further enhanced.

More contemporary commercial and public buildings with large roof spans will generally use aluminium roofing as alternative materials are too heavy.

- **Residential buildings**

The roofs of residential buildings are visible, and planners will avoid unattractive low-cost bitumen shingle roofs. Instead, traditional buildings use tiles or painted steel, which are heavy roofing materials requiring strong roofing structures. A clear cost calculation of all related costs and long-term value will put a positive case to the architects, especially if noise reduction could be resolved.

19. Cladding and external panels

Cladding covers the façade of the building and is often seen as the most important design aspect. It protects the interior of a building from various climates, and it is the building's main feature or frontage.

Requirements for cladding is that it protects the building from weather and impact, increases the insulation of the walls, and offers pleasing aesthetics by covering the core wall materials.

Many material options exist for architects regarding cladding, such as Brick Slips, Timber, Stone, Aluminium, uPVC, Zinc, GRP, Fibre Cement, or Terracotta, depending on the underlying structure and the desired look. However, we have only considered the primary competing materials here.

- ***Aluminium cladding***

Aluminium is the main and premium material in cladding as it is lightweight, does not put pressure on the structure of the building, and does not need reinforcement. At the same time, aluminium offers excellent durability and resistance to wind and other elements. It is adaptable and offers several design options as different finishes can be applied, such as anodised, powder-coated or even stone effects. Aluminium can be extruded and pressed, creating one-of-a-kind facades, further boosting its appeal and desirability. A non-adhesive fluorine paint film is often sprayed on the outer surface to discourage pollutants from adhering to the surface; it also has good self-cleaning properties. The recyclability of aluminium also makes it a strong contender when considering the lifespan of a building.

Aluminium cladding is a very common and the least costly type of cladding.

Insulated aluminium composite panels keep cold or hot temperatures out to create more comfortable environments inside. Aluminium composite panels need regular maintenance and dust and organic growth removal, but still offer the best value insulated cladding option. A disadvantage of aluminium composite panels is that the core insulation is often made of flammable materials. Recently, in the Grenfell tower tragedy where 79 people died, the tower fire was linked to polyethylene-filled aluminium composite panels. These panels were responsible for the rapid spread of the fire. These

were most likely used as polyethylene-filled aluminium composite panels are lightweight, stiff, and cheap.



Aluminium insulated composite panel structure

Aluminium cladding

- ***Steel cladding***

Steel cladding is heavy and oxidises but is stronger and cheaper than aluminium.

- ***Terracotta cladding***

Terracotta cladding is fired at extremely high temperatures, making it fireproof. It does not burn and therefore makes an excellent cladding material. Being made from 100% clay, it is safe for humans and the environment and can be reused and recycled easily.

Terracotta cladding is durable and long-lasting. When professionally installed, terracotta's lifespan is much more than that of aluminium or concrete façades. Dust will only accumulate slowly over time, so power-washing the terracotta cladding once every 2 to 3 years will restore the terracotta to its former glory with no colour loss. In addition, these panels provide continuous insulation outside the primary wall and improve a building's thermal performance.

The disadvantage of terracotta cladding is that terracotta tiles weigh more than other roofing materials and require a particular support structure. For buildings with few storeys, this might add only marginal costs but could add substantial costs for tall buildings.



Terracotta cladding

- ***Fibre cement cladding***

Fibre cement cladding is a composite building material made from cement reinforced with cellulose fibres. It is manufactured in boards or sheets that lock together to form a weather-tight layer installed onto building exteriors. The advantages of this system include excellent weather resistance, inflammable properties, availability in a smooth or realistic timber effect wood grain finish, outstanding thermal performance, low-maintenance finish, and affordable pricing. The disadvantage is that even though the product is cheaper than the competition, labour for installation is more expensive due to its weight and labour-intensive installation requirements.



Fibre cement cladding

Use of aluminium cladding/promotion suggestions

Due to its low maintenance, strength and light weight, aluminium cladding is an excellent solution for buildings with more than two floors, multi-apartment buildings, office buildings and high-rise buildings with limited access to the external cladding panels. Steel is heavy and oxidises but has a much better value than aluminium cladding. Generally, these aluminium cladding panels include insulation to limit heat transfer.

Recent EU fire regulations restrict the use to non-combustible aluminium cladding, but other jurisdictions, for example, the USA, allow the use of combustible cores in the aluminium cladding.

Another potentially tragic fire involving aluminium cladding would tarnish the positive development of the aluminium cladding market. The suggestion is to legislate against combustible core in aluminium cladding, especially as non-combustible alternatives exist, although these are slightly more costly.

Aluminium's market share in external cladding

- Globally, the market share for aluminium in cladding is 13%, with concrete cladding leading the market with approximately a 40% market share, followed by fibre cement with 12%, and terracotta and ceramics each with 10%. We can expect a potential future market share for aluminium of 20-25% globally as modern buildings will dominate new construction.
- In the USA, the market share of aluminium cladding is approximately 10%, with a potential of 15-20%. The lead cladding system in the USA is terracotta, with a market share of approximately 35%. There is potential to increase the aluminium cladding market share to the global average of 15%.

- Europe and China consider aluminium cladding to be the best material for modern and multi-floor buildings, with a market share between 15 and 20%, with a future potential of 20-25%, assuming the construction trend continues.
- In India and many other developing countries, traditional construction either does not use cladding or uses other sealing methods. Aluminium cladding is restricted to modern commercial buildings with a market share of 5-10% with a future potential for 10-12%

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Cladding, external wall panels (including structural)	17%	10%	17%	7%	7%	13%	22%	18%	22%	11%	11%	18%

Window panels as a special cladding

Aluminium is also used as window panels in commercial, public, and high-rise buildings as aluminium offers a low-maintenance solution with an 80-year warranty. Window panels are often mobile, requiring a sliding mechanism that aluminium systems can easily provide. Lower buildings are more accessible for maintenance and use timber or UPVC for panelling. Aluminium's market share is approximately 5%.



Aluminium window panels

20. Internal partitions

Internal partitions can be load-bearing or non-load-bearing walls inside buildings. These can be temporary and easily moved to create different floor plans, or they can be fixed.

• Temporary internal partitions

Aluminium-based systems for internal partitions and wall panels are frequently used in office buildings and where partitions are frequently moved to create new layouts. These are, in the majority of cases, off-the-shelf aluminium-based systems. Aluminium is used for the frames, and the panels are either glass or MDF/wood.

A key advantage of aluminium frames is that they can be extruded without hot work to produce frames with complicated structures. Steel requires energy and time-demanding hot work and cannot be extruded. Aluminium is lightweight, formable and not flammable. Each location has specific requirements that can be met with aluminium panels; for example, offices require soundproof partitions, while line production requires fire-resisting partitions.

Aluminium could also be used for panelling, but acoustics prevent the use of plain aluminium. Instead, sound-absorbing materials such as plasterboard, foam or wood must be added for soundproofing.

Market share in temporary internal partitions (frames only)

Aluminium's market share is approximately 70%, with the remainder being timber or uPVC. This market share is generally applicable across geographic regions. The long-term potential market share is about 75% if aluminium continues to provide easy-to-build systems that can address the specific requirements of the locations.

		Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
		EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Construction													
Internal partitions (frames only)													
	Temporary internal partitioning - frames only	80%	80%	80%	50%	50%	71%	85%	70%	85%	60%	60%	75%



Temporary internal partitions using aluminium frames and structures

- Solid internal partitions (frames only)**

Aluminium can be used to frame solid internal partition walls, but the thermal and sound isolation requirements and high costs of aluminium prevent widespread use. Instead, the preferred solution is a plasterboard with timber as a low-cost insulating solution. For load-bearing internal walls, brick or concrete is used.

Competing materials: brick, concrete, timber, timber frame with plasterboard or MDF panels.



Fixed internal partitioning/wall systems

Market share in solid internal partitions (frames only)

The market share of aluminium is below 1% across geographic regions, with a maximum potential in 2050 also below 1%.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Internal partitions (frames only)												
Permanent, solid internal partitioning	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%

Road infrastructure components

Many road infrastructure components use aluminium; only selected applications are discussed here.

21. External acoustic or noise barriers in road infrastructure

A noise barrier, also called a sound wall, noise wall, sound berm, sound barrier, or acoustical barrier, is an exterior structure designed to protect inhabitants of sensitive land use areas from noise pollution. Noise barriers are the most effective method of mitigating roadway, railway, and industrial noise sources.

Acoustic or noise barriers work by either reflecting or absorbing noise pollution. The best way is absorbing noise, which is a function of the mass and density of the material. Many materials are available for noise control:

- **Wood fences:** Wood fences are an affordable and attractive option mainly used for residential noise control. However, most wood fences are ineffective as noise barriers due to their lack of mass, air gaps, damage, and height.
- **Brick/concrete barriers:** Brick or concrete barriers are a solid long-term investment due to the long-lasting and durable materials. This solution exists along the majority of highways throughout the world, and many installations are decades old. However, being one of the most expensive options available, this may not be an affordable option for many projects.
- **Steel barriers:** All metal barriers are impressive structures due to their modular construction. They can be cost-effective and are quick to install. Steel is robust and good value but prone to corrosion.
- **Aluminium sound barriers:** Aluminium is used for the panels of sound barriers as these are lightweight and offer excellent corrosion resistance and self-support. Aluminium sound barriers come in custom sizes and shapes. They are extensively used within urban areas, roads, rail and various structures, and in factories and workshops where machines cause serious noise pollution. Aluminium panels are designed with various hole patterns, such as dots or slits, to act as absorptive sound barriers. To maximise sound absorptive performance, fillings such as EPDM, fibreglass, mineral wool, or aluminium foam are required. Aluminium sound barriers offer an economical, long-lasting solution; however, the sound reduction of concrete and brick barriers is significantly higher due to their mass/density.



Aluminium absorptive sound barrier panel



Installed aluminium sound barrier

Aluminium's market share in sound barriers (panels only)

The market share of aluminium in sound barriers varies across regions, with the global market share of approximately 15-20% being an average of the regional market shares. The long-term market share potential is 20-25%.

- In China, most materials used in urban expressways and highway sound barriers use aluminium panels and often aluminium foam, acrylics, or tempered glass. The market share of aluminium is, therefore, approximately 30%. Long-term potential includes a 10% increase to 40%.
- In Europe, the USA and India, most of the companies we spoke to do not sell aluminium-based systems, with the market share of aluminium in the panels being only 5%, as other systems provide better resistance to noise pollution. In densely populated geographic regions, efficient noise control is essential. Therefore, we expect only a slight increase in the market share of aluminium to 8% and expect other systems to continue to dominate the market.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Road infrastructure components												
Sound barriers in transportation	5%	5%	30%	2%	2%	17%	8%	8%	40%	5%	5%	23%

Promotion suggestions

It is suggested that an investigation be conducted to establish why aluminium-based systems are preferred in China and promote this to noise protection solution providers. However, this market is relatively small.

22. Impact barriers

The strength of steel is required for impact barriers; aluminium is not used in these applications resulting in a market share below 1%. We expect this to continue in the future.



Different traffic impact barriers made of steel

		Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
		EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Road infrastructure components													
	Impact barriers	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%

23. Road and street signs

Aluminium composite is currently the main material of road and street signs. It can be printed with silk print, and the added films can make the aluminium sheet light-reflective. Aluminium is used for low-weight, low-maintenance and easy-to-cut shapes that are resistant to colour change.

However, plastic is emerging as a material for road and street signs. Although it still has disadvantages, such as colouration due to exposure to UV light, we expect that plastics will take over a significant share of the market by 2050.



Aluminium road sign

Market share in road and street signs

Aluminium's market share is very high at 90%, with freestanding and speciality signs using heavier steel. This market share applies across all geographic regions with limited potential to increase this market share in the future. On the contrary, we expect engineered plastics to gain market share and reduce aluminium's market share to 70% by 2050.

		EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Road infrastructure components													
	Road and street signs (board)	95%	95%	95%	80%	80%	90%	70%	70%	70%	70%	70%	70%

24. Fencing, barriers, and crowd control barriers in transport and construction

Aluminium is too soft and expensive to be used in fencing and barriers. Instead, aluminium is used for temporary, flexible crowd control barriers due to its light weight and easy production. Competing materials are steel, galvanised steel, timbre, some plastics, and composites.



Temporary, flexible crowd control barriers



Market share in fencing, barriers, crowd control barriers in transport and construction

Market share is estimated at 5%, with limited potential to increase the market share of temporary, flexible crowd control barriers.

HVAC applications

25. Heat exchanger in air conditioning and refrigeration

A heat exchanger is a common application in air-conditioning and refrigeration where good thermal conductivity of the material is important. Heat exchangers do their job by transferring heat to achieve heating or cooling. There are typically two units - the internal unit (evaporator) and the external unit (condenser).

- **Aluminium** is the main material for the fins and increasingly penetrates the tubing of heat exchangers. Aluminium's penetration is already high in the tubing of the internal unit (evaporator) of residential A/C's, and it is increasingly used for the external units (condenser) of residential A/C's. The main competing material is copper used in A/C.

In refrigeration, steel is gaining a market share in the external unit. Aluminium's advantage is its similar heat conductivity to copper, with lower costs and light weight. However, it is more difficult to repair and could be prone to leaking when exposed to humid climates and pollution in the external unit. Therefore, for this reason, India mainly uses copper tubes in heat exchangers.

Many commercial air conditioners use aluminium microchannel technology that does not require tubes. The advantage of this technology is lower costs and lower use of expensive refrigerant fluids. At the same time, the technology requires regular maintenance and repair access that commercial applications generally can provide. This is the reason aluminium microchannel technology is mainly

used in commercial applications. In the past ten years, A/C manufacturers tried to use this technology in residential applications. However, the technical issues were significant, and there is now a move away from aluminium microchannels towards round aluminium tubes.

- **Copper** is the traditional material of heat exchangers with its excellent heat conductivity and easy repairability, but copper is significantly more expensive than aluminium. Nevertheless, heat pumps (heating and cooling A/C's) generally use copper heat exchangers as these need to deliver heat transfer for both cooling and heating. The newer environmentally friendly refrigerants, such as pressurised liquid CO₂, require copper alloy heat exchangers in Europe.

Material selection

There is a different manufacturing process for copper and aluminium heat exchangers. Therefore, the heat exchanger producer OEMs need significant price incentives before changing materials. This happens when the relative and absolute material cost difference between aluminium and copper reaches a limit. Similarly, if the production line is set up for aluminium, it will be difficult to return to using copper unless aluminium solutions face technical and warranty problems. Therefore, although material costs initially drive substitution, it is relatively price-inflexible and irreversible afterwards.



Heat exchanger with aluminium fins: (a) Aluminium tubes; (b) Copper tubes



Commercial air conditioning equipment and close view of the aluminium microchannel technology

Market share of aluminium in heat exchangers in air conditioning and refrigeration

Aluminium's market share in HVAC applications is approximately 50%, with an ongoing substitution by aluminium round tubes. Slight regional differences exist, with India using 10% aluminium tubes due to the pollution and climate-causing leakage of the aluminium tubes. In contrast, Europe uses 40% aluminium tubes as quality expectations are high and European environmental regulations are punitive for refrigerant

leakage. At the same time, aluminium's market share in the USA, China and Latin America is approximately 60%.

The long-term global potential market share for aluminium is 65%, based on the assumption that only special regions and cases will use copper heat exchangers.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
HVAC applications												
Heat exchanger	40%	60%	60%	10%	60%	50%	70%	70%	70%	30%	70%	65%

Promotion

Aluminium heat exchangers are relatively new, and many OEMs, especially in Europe, doubt their performance. Promotion of the technical parameters of the use of aluminium heat exchangers to OEMs in Europe, including their use with environmental-friendly refrigerants, should persuade them to test aluminium heat exchangers. To prevent the market share of the aluminium microchannel from declining, case studies should be prepared on where and how aluminium microchannels work best.

Electrical applications in buildings

26. Fixed building wires

Fixed building wires (often below 16 sqmm diameter) are required to be copper in some countries by the building regulations and fire safety codes. In other countries, the specifications are defined by the building regulations, and any material can be used as long as it meets the requirements. In the past, aluminium building wires resulted in fire hazards leading to strict regulations on fixed building wires.

Aluminium's main advantage is lower costs, but as a percentage of the total construction costs, the savings costs are negligible and unlikely to drive substitution.

Market share of aluminium in fixed building wires

Therefore, aluminium's market share is approximately 2% across all regions, as aluminium connections are difficult to manage and potentially lead to failures. As a result, aluminium-fixed building wire applications are restricted to the service entrance area between the switchboard (to the building) and the meter (to the apartments or smaller units), especially in vertical cables where the connecting LV distribution network is aluminium. These aluminium applications are used in tall apartment buildings and simple commercial facilities such as garages or warehouses.

Aluminium's market share is unlikely to increase in the medium term. Long-term, however, there is some potential to influence building regulations to accept fine-stranded aluminium wires as fixed building wires, but tradition will limit the potential market share of aluminium below 3-5%.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Electrical applications in construction												
Building wires - fixed installations withi	2%	2%	2%	2%	2%	2%	4%	4%	4%	4%	4%	4%

Promotion suggestions

There is an undisputed perception by electrical planners and contractors that only copper works for building wires, although only a few building codes define materials. Therefore, a wider understanding and research data on fine-stranded aluminium wires and their performance are needed.

The building wire market is large but would require time and investment to market aluminium here.

27. Winding wires in electric motor construction (e.g., for elevators and garage doors)

Generally, only smaller motors below 160 kWh, single phase, FHP, and intermittent (not continuously) working motors use aluminium winding wires. In such instances, the lower conductivity and larger space requirement of aluminium are not issues as the motor is working only for a limited time. Larger motors above 200 kWh use only copper winding wires.

Motors using aluminium winding wires need to compensate for the lower conductivity by using more electrical steel, which reduces the price advantage of aluminium.

In construction, elevators and larger maintenance machinery will use larger motors with only copper winding wires. At the same time, fans and garage doors have smaller intermittent working motors and are likely to use aluminium winding wires.

The main factor reducing the attractiveness of aluminium is the energy efficiency classifications and the need for more compact motors. IE3 energy efficiency class motors can be built with aluminium winding wires, but IE4 motors are difficult. IE5 motors strictly need copper winding wires due to the low conductivity and high electricity losses with aluminium. Minimising electrical losses is even more important when energy prices are high.

Innovative technologies will improve the energy efficiency performance of aluminium in the future, but copper will always be ahead of the energy efficiency game.

Market share of aluminium in winding wires in electric motors construction

In total, we expect that electric motors in construction work continuously and generally tend to be medium-large motors. Exceptions include motors of garage doors or similar intermittent working motors. Therefore, the market share of aluminium in winding wires in electric motors construction is about 6%, with the potential to increase to 10% by 2050, as medium-sized motors will be able to reliably use the new generation of aluminium winding wires. However, regional differences remain, with China being more risk-averse in trying new materials such as aluminium, and the USA, India, and Latin America being more inclined to use aluminium in electric motors.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Electrical applications in construction												
Winding wires in electric motors in cons	5%	8%	5%	8%	8%	6%	5%	12%	10%	12%	11%	10%

Electrical applications in transport infrastructure

28. Railway and metro power cables

Railways and metro infrastructure uses different types of power cable. The three main cables are signalling cables, signalling power supply cables and overhead line equipment.

- **Signalling cables**

Signalling cables play an essential role in ensuring the smooth running and reliability of the railway network, hence their unique specifications and design. They ensure the transmission of signals and a continuous power supply across all trackside signalling equipment applications. In addition, these cables are used for control and signal conveyance and keep the rail networks, with their passengers and cargo, moving safely.

The signalling systems are based on the conductivity of copper. Changing to aluminium would mean that all the relevant signalling equipment would need to be redesigned to allow for the increase in conductor sizes and the overall diameter of cables. This is why signalling cables are still made of copper, and any change would require significant investment. At the same time, the small diameter of the signalling cables means that substitution leads only to minimal cost savings. Therefore, in addition to the currently low market share of aluminium, we expect a minimal future substitution potential for aluminium.

Aerospace and aeronautics mainly use control/signalling cables similar to rail signalling cables.



Signalling cables

- **Signalling power supply cables**

The power supply for railway signalling is a safety-critical application requiring the same constant availability, for example, airport ground lighting. It cannot be simply turned off in the event of a fault, as would happen with typical electrical engineering hazards. Furthermore, it must be entirely safe for the public and railway maintenance staff, as the equipment is frequently located at level crossings or on platforms.



Signalling power supply cable

However, with aluminium utility power cables continuously replacing copper power cables, many rail operators in developed countries replaced copper signalling power cables with aluminium.¹¹

As a signalling power supply is a critical application, substitution will be slow. It will be linked to testing and gaining trust with installing and dealing with aluminium power supply cables. We expect aluminium power cable technology and ensuring safe contacts and safe operation of this safety-critical application will significantly improve, consequently leading to a sharp increase in aluminium's market share. The majority of the increase will originate in countries currently loyal to copper (China) and developing countries.

• Overhead line equipment (OLE)

OLE refers to the overhead wires and other equipment visible on electrified railway lines. It carries 25 kV of electricity to power electric trains. It is a critical part of the railway that allows us to run faster and greener electric services instead of diesel. Metro power supply cables are similar but are often placed next to the tracks.

Generally, the OLE Cables have to manage high voltage electric current, requiring high conductivity. In this instance, aluminium's lower conductivity would create significant electrical losses and require a much larger diameter of cables than copper. Also, aluminium's lower melting point might create unacceptable fire risks, and the sagging of the cables during higher temperatures needs to be managed. Therefore, in this market, copper or copper alloys seem to be the materials of choice due to their high conductivity, high melting point and rigidity.

Market share of aluminium in railway cables

	Aluminium Market shares 2022						Aluminium Market shares 2035 (potential)						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Electrical applications in transport infrastructure																		
OLE cables in railway network	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Signal cables	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Signalling power supply cable	30%	40%	20%	40%	30%	30%	45%	50%	40%	45%	45%	44%	60%	60%	60%	50%	60%	59%

- OLE Cables: 0% with a very limited outlook for the future.
- Signal cables: 0% with limited potential for the future.
- Signalling power supply cables market share growth from 30% currently to 59% in 2050.

¹¹ <https://www.deangroup-int.co.uk/network-rail-is-replacing-copper-with-aluminium-in-their-cables/>

29. Winding wires in electric motors in transport applications

Electric motors in transport applications, such as electric trains, tend to be larger motors and/or need to deliver high performance in a highly energy-efficient way. Performance and highly efficient motors (IE4, IE5) require the superior conductivity of copper.

In this application, the market share of aluminium is below 1% across all regions, with a long-term potential of 5% if motor OEMs are able to produce highly efficient motors with aluminium winding wires. This will need to be developed by those OEMs, and R&D is ongoing with limited scope for promotion.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Electrical applications in transport infrastructure												
Winding wires in electric motors in tran	<1%	<1%	<1%	<1%	<1%	<1%	1%	1%	1%	1%	1%	1%

30. Winding wires in transformers

A transformer is an electrical apparatus that increases or decreases the level of voltage flowing through any point in a power grid. In a distribution system, the transformer decreases the voltage travelling through power lines to a level more suitable for residential and commercial use.

Aluminium's penetration in smaller distribution transformers is already well advanced. However, larger power transformers required for HV electric trains and other power infrastructure will continue using copper due to copper's higher conductivity.

Aluminium's market share in transformers

Aluminium's market share in transformers in the transport infrastructure is approximately 50%, including both power and distribution transformers. In China, the market share is lower at 30% due to the recommendation of state-owned research institutes, while aluminium's market share is roughly 70% in the rest of the world.

We expect the potential to increase this market share mainly in China as they might abandon the costly preference for copper, with some further potential to increase aluminium's market share in the rest of the world.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Electrical applications in transport infrastructure												
Winding wires in transformers	70%	70%	30%	70%	70%	50%	80%	80%	80%	80%	80%	80%

Promotion recommendations

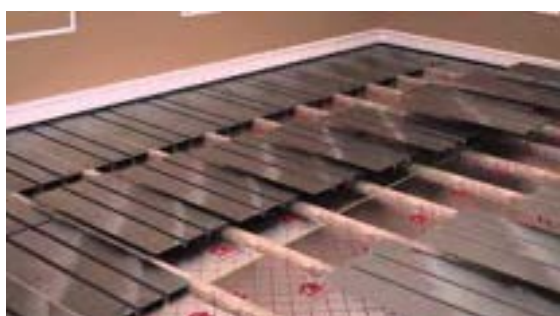
As substitution is advancing on its own in the transformer market, we suggest focussing resources on other applications.

31. Internal fittings of buildings

Aluminium is sometimes used in high-end concept developments for its look and feel. Aluminium can be used for staircases, fitting, basins, bathtubs, kitchen cabinets, and shelving. The cost of aluminium fittings is 20-30% more expensive, and the installation is more complex than using traditional materials. However, aluminium has lower transport and handling costs due to its low weight.

Architects generally do not consider using aluminium beyond window frames, roofing and cladding. Therefore, more inspirational example projects are needed to raise awareness.

Aluminium is also used in underfloor heating as spreading plates due to its good thermal conductivity.



Aluminium heat spreading plates in underfloor heating Aluminium kitchen cabinets.

Market share of aluminium in internal fittings of buildings

The market share of aluminium is below 1%, with long-term potential very much depending on future interior fashions. In underfloor heating spreading plates, we expect new materials to emerge by 2050, slightly reducing aluminium's market share.

	Aluminium Market shares 2022						Aluminium Market shares 2050 (potential)					
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global
Internal fittings of buildings	<1%	<1%	<1%	<1%	<1%	<1%	5%	3%	5%	1%	1%	4%
Underfloor heating spreading plates	95%	95%	95%	95%	95%	95%	90%	90%	90%	90%	90%	90%

Promotion suggestions

Increasing the number of inspirational projects using fashionable aluminium interiors could raise positive awareness for using aluminium in interior finishes.

32. Innovations

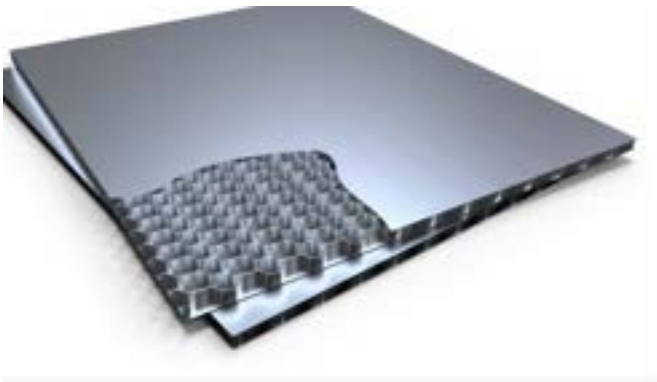
The investigation brought up only limited innovations in the sector.

- Innovations to increase aluminium's structural capacity included new alloys or the aluminium honey comb panels now frequently used in China and growth potential in the rest of the world.
- Innovations increasing the electrical conductivity of aluminium based on cable/wire/rod applications are limited to more efficient aluminium winding wires mainly for transformers.

- Structurally strong, lightweight engineered plastics applications exist that could potentially replacing aluminium for selected applications in the future.
- Carbon-based applications potentially replacing aluminium are mainly related to super conductors.

Aluminium honeycomb composite

An aluminium honeycomb structure placed between two thin layers of aluminium offers strength similar to steel. This composite structure is used for doors but could potentially be used in other applications, such as load-bearing elements.



Carbon nanotubes

Highly conductive carbon nanotubes do not require insulation and are very strong. However, they are expensive for mass use and could replace both aluminium and copper in electrical applications.



Annex 1

Companies interviewed

Name	Region/country
1 A360 architects	India
2 ACL Cables Plc	Sri Lanka
3 ACR Arquitetura	Brazil
4 Al Ajmi Engineering Consultants (AEC)	United Arab Emirates
5 appliedworkplace.co.uk	EU
6 Bharat Bijlee Ltd.	India
7 Blueprint Middle East	United Arab Emirates
8 Crossrail Ltd	United Kingdom
9 Custom Window Systems	United States
10 Danvita India Pvt Ltd	India
11 Westgate global	USA
12 UK tents ltd	EU
13 Electrical Contractors' Association	UK
14 fabrica de puertas y ventanas envolvente ltda	Chile
15 FACADE AND CLADDING DESIGN LTD	United Kingdom
16 Fenesta Windows	India
17 Fero Fensterbau GmbH	Germany
18 Foster + Partners	Global
19 Gates & Windows	India
20 mcrma.co.uk, Metal Cladding and Roofing Manufacture	EU
21 roofing today magazine	EU
22 sigdandt.co.uk	EU
23 sarumhardwood	EU
24 gianni botsford architects	EU
25 GIG FASSADEN GmbH	Austria
26 Vulcan cladding	uk
27 cambridgesound	usa
28 acoustic-supplies	eu
29 Hitachi Rail	United Arab Emirates
30 securitydirectuk	EU
31 integratedfencing	EU
32 KALZIP	EU
33 Lancor - Electric Motors	Spain
34 Rail Vikas Nigam Limited	India
35 secure-house	EU
36 SPG Dry Cooling	Belgium
37 Sterlite Power	India
38 Thermal Windows, Inc.	United States
39 Tremco Roofing and Building Maintenance	United States
40 Verband Fenster + Fassade	Germany
41 WEG Brazil	Latin America
42 Westcoast Window Systems	Global
43 Wiring.com Inc.	United States
44 Russian Aluminium Association	Russia
45 G James Extrusion Co Pty Ltd	Australia
46 Capral	Australia
47 Hindalco Industries	India
48 Elcowire	EU
49 Rashtriya Metal Industries Ltd	India
50 ZGF Architects	United States
51 Voltamp Transformers Limited	India
52 Universal Cables Ltd	India
53 superiorinsulatedpanels	EU
54 SPX Transformer Solutions	USA
55 Skyline Windows	United States
56 Saudi Diyar Consulting	Saudi Arabia
57 REA Magnet Wire Co.	North America
58 Qatar Design Consortium	Qatar
59 Precision Wires India Ltd.	India
60 FRIGUS BOHN/BOHN DE MEXICO	Mexico/USA
61 Guangdong Xingfa Aluminum Co., Ltd.	China
62 Beijing QY Research Co., Ltd.	China
63 Sichuan Yazhixuan Doors and Windows Co., Ltd.	China
64 Guangzhou Kaixia Aluminum Alloy Products Co., Ltd.	China
65 Guangzhou Yingsiteng Industrial Equipment Co., Ltd.	China
66 Guangdong Aluminum Bridge Engineering Co., Ltd.	China
67 AAG Asia Aluminum Group Co., Ltd.	China
68 Guangzhou Lvjing Building Materials Co., Ltd.	China
69 Hangzhou Zhihui Membrane Structure Co., Ltd.	China
70 Foshan Nanhai Hongtai Aluminum Co., Ltd.	China
71 Foshan Hongtai Zhishang Co., Ltd.	China
72 Guangzhou Gelante Engineering Equipment Co., Ltd.	China
Foshan Nanhai Fuxuan Door, Window and Curtain	
73 Wall Co., Ltd.	China
74 Guangzhou Junba Decoration Material Co., Ltd.	China

Annex 2

Market share quantification table

	Aluminium Market shares 2022					Aluminium Market shares 2025 (potential)					Aluminium Market shares 2050 (potential)					Market share difference 2022-2050					Difference 2022-2050				
	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global	EU	USA	China	India	ROW	Global	Growth potential colour coding
Construction																									
Modern large lightweight permanent structures (structural components and panels)	15%	10%	20%	5%	5%	13%	18%	15%	23%	8%	8%	16%	20%	20%	25%	10%	10%	19%	5%	10%	5%	5%	5%	6%	20% or higher
Pedestrian bridges (structural components and panels)	1%	1%	8%	1%	1%	3%	6%	3%	12%	3%	3%	6%	10%	5%	15%	5%	5%	9%	9%	4%	7%	4%	4%	6%	15-20%
Temporary structures																									
Temporary halls, housing, temp warehouse	15%	12%	25%	10%	10%	18%	18%	16%	30%	13%	13%	22%	20%	20%	35%	15%	15%	26%	5%	8%	10%	5%	5%	8%	10-15%
Farmwork	30%	30%	30%	10%	10%	23%	35%	35%	35%	20%	20%	30%	40%	40%	40%	30%	30%	37%	10%	10%	10%	20%	20%	13%	0-5%
Roofing	10%	2%	2%	2%	2%	3%	15%	6%	6%	4%	4%	7%	20%	9%	9%	5%	5%	10%	10%	7%	7%	3%	3%	6%	5-10%
Cadding, external wall panels (including structural)	17%	10%	17%	7%	7%	13%	20%	14%	20%	9%	9%	15%	22%	18%	22%	11%	11%	18%	5%	8%	5%	4%	4%	5%	15%-20%
Window frames	20%	20%	55%	70%	60%	54%	25%	25%	45%	55%	50%	45%	30%	30%	35%	40%	40%	36%	10%	10%	20%	30%	20%	18%	20% and lower
Doors	1%	1%	3%	1%	1%	2%	1%	1%	4%	1%	1%	2%	1%	1%	5%	1%	1%	2%	0%	0%	2%	0%	0%	1%	
Internal partitions (frames only)																									
Temporary internal partitioning - frames only	80%	80%	80%	50%	50%	71%	83%	75%	83%	55%	55%	73%	85%	70%	85%	60%	60%	75%	5%	10%	5%	10%	10%	4%	
Permanent, solid internal partitioning	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	
Road infrastructure components																									
Sound barriers in transportation	5%	5%	30%	2%	2%	17%	7%	7%	35%	4%	4%	20%	8%	8%	40%	5%	5%	23%	3%	3%	10%	3%	3%	7%	
Impact barriers	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	
Road and street signs (board)	95%	95%	95%	80%	80%	90%	83%	83%	83%	75%	75%	80%	70%	70%	70%	70%	70%	70%	25%	25%	25%	10%	10%	20%	
HVAC applications																									
Heat exchanger	40%	60%	60%	10%	60%	50%	55%	65%	65%	20%	65%	58%	70%	70%	70%	30%	70%	65%	30%	10%	10%	20%	10%	15%	
Electrical applications in construction																									
Building wires - fixed installations with	2%	2%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	4%	4%	4%	4%	4%	4%	2%	2%	2%	2%	2%	2%	
Winding wires in electric motors in core	5%	8%	5%	8%	8%	6%	5%	10%	8%	10%	10%	8%	5%	12%	10%	12%	11%	10%	0%	4%	5%	4%	3%	3%	
Electrical applications in transport infrastructure																									
OLE cables in railway network	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Signal cables	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Signalling power supply cable	30%	40%	20%	40%	30%	30%	45%	50%	40%	45%	45%	44%	60%	60%	60%	50%	60%	59%	30%	20%	40%	10%	30%	29%	
Winding wires in transformers	70%	70%	30%	70%	70%	50%	75%	75%	55%	75%	75%	65%	80%	80%	80%	80%	80%	80%	10%	10%	50%	10%	10%	30%	
Winding wires in electric motors in train	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	
Internal fittings of buildings	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	5%	3%	5%	1%	1%	4%	0%	0%	0%	0%	0%	0%	
Underfloor heating, suspended ceiling	95%	95%	95%	95%	95%	95%	93%	93%	93%	93%	93%	93%	90%	90%	90%	90%	90%	90%	0%	5%	0%	5%	0%	5%	

