MATTER DIS//ASSEMBLED: Revealing the Economies and Ecologies of Aluminum

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MATTER DIS//ASSEMBLED
Revealing the Economies and Ecologies of Aluminum

Noah Anderson

“When the bombers got back to their base, the steel cylinders were taken from the racks and shipped back to the United States of America, where factories were operating night and day, dismantling the cylinders, separating the dangerous contents into minerals... ....The minerals were then shipped to specialists in remote areas. It was their business to put them into the ground, to hide them cleverly, so they would never hurt anybody ever again.”
- Kurt Vonnegut, Slaughterhouse V
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This project seeks to understand matter through the environments it creates. These environments, created through production, end-use, and disposal, extend to the scale of the world, the territory and the product. In a globalized world, the separate environments of a single material are highly external, and while we may know where a material comes from, the consequences of its extraction and manufacture are out-of-site, out-of-mind.

This externalization is evident for Aluminum, which has a diverse and often contradictory range of environments. Historically, Aluminum’s cultural understandings lead to the following conclusions:

**Velocity**
Its extremely low weight, less than half that of steel, allowed humans to build structures for movement at unprecedented speeds on land, sea, and air travel.

**Tectonics**
From airplanes to automobiles to curtain walls, aluminum can be machined, shaped, and extruded into a wide variety of assemblies.

**Future**
Since the early 20th Century, aluminum has been a symbol for Modernity and the future, due to its strength, lightness, and luminosity.

While this characterizes its manufacture and end use, the extraction, refining, reduction, and disposal of aluminum have much different realities. These realities present a counter-thesis:

**Intensive**
At 279 MJ/kg, Aluminum’s embodied energy is one of the highest in any building material. That is over 6 times more energy than Copper, and 10 times more energy than low-carbon steel.

**Landscape**
Bauxite Mining, Red Mud, Hydroelectric: The primary production of aluminum requires the permanent alteration of landscapes at massive scales, often displacing populations in the thousands.

**Garbage**
In 2012, 55 million aluminum cans were not recycled, filling landfills and requiring the massive amounts of primary energy to produce more.
Proposal

In architecture, aluminum is utilized through The Assembly. In Matter Disassembled, I propose formal disassembly as a basis for revealing the hidden realities of aluminum. I contend that a didactic architecture of aluminum can be achieved through the identification of parts, connections, and ensembles, followed by meaningful reassembly.

Archigram - Plug-in City - 1964
Lebbeus Woods - Nine Reconstructed Boxes 1999
Yona Friedman - Villa Spatial - 1959
Rania Ghosn and El Hadi Jazairy - Geographies of Trash: Collect - 2015

China bans the import of foreign scrap and recycling waste. This causes the global price of scrap to plummet, since the largest buyer left the market.

2000-2001: Due to spikes in energy costs, most Alcoa smelting facilities in the Pacific Northwest shut down.

2018: Raw Aluminum Price (USA)

2018: The US enters a trade war with China, raising tariffs on steel and aluminum. This is causing the price of aluminum in the US to skyrocket.

2018: Raw Aluminum Production (USA)

2018: Scrap Aluminum Price (USA)
## Properties & Uses

<table>
<thead>
<tr>
<th>Metal</th>
<th>Matter Density (g/cm³)</th>
<th>Melting Point (ºC)</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Electrical Resistivity (Ohm•cm)</th>
<th>Modulus of Elasticity (GPa)</th>
<th>Shear Modulus (GPa)</th>
<th>Hardness (Vickers Scale)</th>
<th>Primary Embodied Energy (MJ/kg)</th>
<th>Secondary Embodied Energy (MJ/kg)</th>
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</thead>
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<tr>
<td>Al</td>
<td>2.7</td>
<td>660.4</td>
<td>210</td>
<td>2.70 x 10⁻⁶</td>
<td>68</td>
<td>25</td>
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<td>1.70 x 10⁶</td>
<td>80</td>
<td>46</td>
<td>126</td>
<td>26</td>
<td>7.3</td>
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<tr>
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<td>112</td>
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<td>43</td>
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</table>
Transportation: 36%
Packaging & Containers: 23%
Building & Construction: 16%
Consumer Durables: 7%
Electrical: 7%
Machinery & Equipment: 7%
1808: Alumina is discovered as an oxide of Aluminum by Sir Humphry Davy.

1821: Pierre Berthier discovers Bauxite, the ore containing alumina, in Les Baux-en-Provence, France.

1845: Friedrich Wohler discovers aluminum's density and weight.

1861: The electrochemical smelting process, now known as the Hall-Héroult Process, is developed simultaneously by Charles Hall (USA) and Paul Heroult (France). This process, still used today, allows for the large scale production of aluminum.

1866: The electrochemical smelting process, now known as the Hall-Héroult Process, is developed simultaneously by Charles Hall (USA) and Paul Heroult (France). This process, still used today, allows for the large scale production of aluminum.

1873: The recently formed Aluminum Company of America (Alcoa) opens a smelter near Niagara Falls to make use of the hydroelectric power plant.

1884: Being a luxury material at the time, a 100 oz aluminum cap was placed at the top of the Washington Monument, for both ornament and to serve as a lightning cap.

1885: The Washington Monument is completed, and it is the first large monolithic aluminum exhibit models the city Point Spring, CA, in the Desert Modernism style, using corrugated aluminum for its design.

1909: The Futurist Manifesto is published by F.T. Marinetti, declaring, “We declare that the splendor of the world has been enriched by a new beauty, a beauty of speed.”

1910: Walter Gropius, cofounder of the Bauhaus, praises aluminum’s “homogeneous, Dymaxion House, a prototype for an ideal home, is designed as a weather resistant, sun-protected, multi-functional, collectable, transportable, and environmentally efficient prototype, its success to be dependent on prefabrication, transportability, and environmental efficiency of parts, and the beauty of detail on the facade.”

1914: Jean Prouvé designs the first in a line of pre-fabricated aluminum houses for war refugees, known as the Maison Coloniale, using aluminum frames, walls, electrical systems, and floor area with the minimum material usage.

1927: Buckminster Fuller designs the Dymaxion House, a prototype for an ideal home, is designed as a weather resistant, sun-protected, multi-functional, collectable, transportable, and environmentally efficient prototype, its success to be dependent on prefabrication, transportability, and environmental efficiency of parts, and the beauty of detail on the facade.

1931: Alcoa advertises the properties of aluminum through the Fortune Magazine ad, “Peer into the Future.”

1939: At the New York World’s Fair, General Motors’ Futurama exhibit models the city Point Spring, CA, in the Desert Modernism style, using corrugated aluminum for its design.

1940: Albert Frey designs Frey House I in Palm Springs, CA in the Desert Modernism style, using corrugated aluminum for the exterior walls, aluminum frame windows, and aluminum furniture.

1941: Buckminster Fuller and Edward Graebe, architects, use aluminum in their design of the Aluminum City House in New Kensington, PA. It looked like moss, and the roof was covered with solar panels.

1949: Jean Prouvé designs the first in a line of pre-fabricated aluminum houses for war refugees, known as the Maison Coloniale, using aluminum frames, walls, electrical systems, and floor area with the minimum material usage.

1953: Alcoa’s new corporate headquarters opens in Pittsburgh, complete with aluminum curtain walls, electrical systems, and plumbing.

1954: Buckminster Fuller designs the geodesic dome, capturing the maximum floor area with the minimum material usage.

1965: NASA's Vehicle Assembly Building is built in Cape Canaveral. At the time, it was the largest building ever built, and used over 3 million pounds of aluminum.

1969: The John Hancock Center is built in Chicago, using 2.5 million pounds of aluminum sheathing.

1971: Toyo Ito’s Aluminum House is built, merging Tokyo’s contemporary artificiality with the traditional pagoda typology.

2009: SANAA designs the Serpentine Gallery Pavilion in Hyde Park, London. It is representative of the “extraordinary lightness” of our times.
1909: Alfred Wilm develops the first Aluminum Alloy, which becomes the structural basis for German WWI zeppelins. This development allowed the destructive task for German WWI zeppelins, power of bombs to increase exponentially in the coming decades.

1914-1918: To meet the demands of the First World War, Alcoa increases production 40%, producing 152 million pounds of Aluminum for the Allied forces.

1901: Thermite is invented through the mixture of aluminum powder and iron oxide. This development allowed the destructive power of bombs to rise exponentially in the coming decades.

1933: The USSR builds its first aluminum smelting plant based on designs stolen from the United States. Its operations were critical to the Allied victory of WWII.

1938-1944: US production of aluminum in this period increases from 143,000 tons per year to 766,000 tons per year.

1932: Mussolini’s fascist government embraces the potentials of light metal, describing aluminum as “not only the metal of the Fatherland; it is also the metal of progress, the real material of unreal velocities.”

1926: A sheet metal alloy of aluminum is developed, called Alclad, and is used extensively in both military and civil aircraft.

1939-1943: With more than 600% increase in aluminum production, 304,000 military airplanes are produced using 3.5 billion pounds of aluminum, or more than 85% of Alcoa’s output.

1957: The USSR launches Sputnik, a mostly aluminum satellite, and the initial move of the space race in the Cold War.

1969: Buzz Aldrin and Neil Armstrong land on the moon, the US’s crowning achievement in the space race.

1968: The Lockheed C-5 Galaxy is introduced as “essentially an all-aluminum aircraft” and is one of the largest aircraft in the world, capable of carrying up to six Apache helicopters.

1968: Aluminum can ends make up over 80% of the canned beer market, due in part to the development of the ring pull tabs in 1932.

1974-5: Alcoa begins to advertise and expand their recycling operations, recycling 85 million cans in 1974.

1989: The Slow Food Manifesto is published, spearheading the slow food movement.

2001: In the United States, over 51 million aluminum cans were not recycled.

1930: An Alcoa ad in the Saturday Evening Post predicts “soon – nearly all trucks and buses will have aluminum bodies.”

1914-1918: To meet the demands of the First World War, Alcoa increases production 40%, producing 152 million pounds of Aluminum for the Allied forces.

1942: Eight Nazi Saboteurs arrive in the USA with the specific goal of sabotaging US aluminum production, knowing it was key to the Allied war effort.

1943: In a single year, the US uses 18 million kWh to produce 920,000 tons of aluminum. That was the equivalent amount of energy to power half the entire country.

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### Aluminum in the USA

- **1920s:** Throughout the 1920s, Alcoa began building hydroelectric dams in the US and Canada to power their aluminum smelters. These dams damaged the environment and displaced indigenous communities on a massive scale.

- **1954:** By this year, Alcoa employs over 50,000 workers and uses over 17 hydroelectric power plants in the United States.

- **1952:** The U.S.S United States beats the record for the highest average speed, thanks to its aluminum body.

- **1958:** The first large-scale commercial airplane, the Boeing 707, begins non-stop Atlantic flights.

- **1967:** Alcoa uses over 20 billion kWh in the US alone, or the equivalent of 4 million single-family homes.

- **2008:** The US housing market collapses, resulting in a global economic recession. Alcoa's output reduces 13%.

### Global Industrialization

- **1917:** Alcoa's first bauxite mine opens in Suriname.

- **1921:** Alcoa begins to operate in Equatorial Guinea, a French colony at the time.

- **1941:** Aluminum production begins in Suriname.

- **1944:** The Minerals (Vesting) Act and The Mining Act are passed in Jamaica, creating extremely low tariffs for Alcoa to mine bauxite.

- **1965:** The Akosomba Dam in Ghana creates the world's largest man-made lake and displaced 84,000 people. The dam was built to power nearby aluminum smelting facilities.

- **1967:** The Afobaka dam is built to supply power to an Alcoa smelter in Suriname. It creates an artificial lake on the Suriname River in the illegally appropriated Saamaka Maroon territory, covering about 43 villages.

- **1970:** Guyana nationalizes their bauxite resources.

- **1984:** General Lansana Conte takes power in Guinea, one of the world's largest bauxite producers.

- **2000-2001:** Due to spikes in energy costs, almost every Alcoa facility in the Pacific Northwest shuts down.

- **2009:** The Sayano-Shushenskaya Dam in Siberia had a catastrophic failure, resulting in 17 people dead and 58 people missing. 70% of the dam's power was dedicated to RUSAL, the Russian aluminum company.

- **2010:** A catastrophe occurred in Hungary in which a massive spill of highly caustic red mud killed several people, wiped out villages and streams, and threatened the Danube River. The toxic spill brought global attention to the pollution caused by bauxite mining, an issue that has usually been ignored outside of activist social movements.
Aluminum is the 3rd most Abundant element in the Earth’s crust, but is rarely found in its pure state. Usually, it is mined as bauxite ore, a red, rocky substance usually found in tropical and subtropical regions. Some of the largest Bauxite deposits can be found in Australia, Brazil, Ghana, and Jamaica. Bauxite mining occurs through the blasting and collection of the stone, where it is then ground into smaller, more workable pieces and shipped to an alumina refinery.
From the mine, bauxite is refined into alumina through the Bayer Process. This process removes the silica, iron oxides, and titanium dioxide from the ore mixture, leaving a fine white powder. However, these excess compounds form an alkaline red mud, known as bauxite tailings. This mud must be kept in retention ponds, filling miles and miles of land, where it contaminates the soil permanently.
99.9% Pure Aluminum

Embodied Energy: 193.6 MJ/kg (240.4 MJ/kg total)

Aluminum Reduction Facility: Pingguo, China

The alumina is further processed into pure aluminum through the electrochemical smelting process known as the Herroult-Hall Process. From bauxite ore, about 25% of the original mass is reduced to Aluminum. This process uses exorbitant amounts of energy, often requiring the capacity of an entire power plant. Currently, the largest producer of Aluminum through primary smelting is China.
Aluminum’s unique properties as a light metal make it desirable for a wide variety of applications. The three primary means of shaping and machining aluminum are casting, rolling, and extruding. Aluminum is cast into blocks, blooms, and ingots for transportation to manufacturing plants, but is also cast into a variety of geometries that could not otherwise be machined or shaped. Aluminum is rolled into sheets of varying thickness, from plate to foil, which can then be bent or die cast into a variety of shapes. Aluminum is extruded into everything from wire to curtain wall members.
Much like matter’s sites of production, our perception of the sites of end use and disposal are now becoming externalized. Online services grow popular as brick and mortar stores close; more and more cities are starting curbside single-stream recycling programs, creating further dissociation with the processes of matter. This trend applies to aluminum products, especially in packaging and electronics.
Any aluminum waste that is not recycled ends up in a landfill. In a landfill, a large hole is dug, where tons of garbage is piled up, sealed in plastic barriers, and buried. There is no chance of reclamation of this material, and very little in the way of long-term plans to maintain these sites.
Some forms of excess and hazardous waste are illegally exported to the third world. This is the case at the Agbobloshie E-waste Dump in Ghana. At sites like these, informal economies form for the harvesting of precious metals from the dumps. E-waste is burned, melted, and disassembled, leaving aluminum, copper, iron, and other precious metals to be collected. These processes lead to large amounts of air, soil, and water pollution, to the point that many pickers do not live past their twenties.
Typically, when aluminum properly recycled in the US, it is processed through single stream recycling. At a recycling facility such as this, waste is separated by size with a trommel separator, and then by material type with an eddy current and electromagnet. When the aluminum is fully isolated, it is bailed with a hydraulic press to be shipped to a secondary aluminum smelter. Since China banned the import of scrap metal, however, much of the scrap in the US has either piled up with no purpose, or been sent to a landfill.
Alumina (Al₂O₃)

Calcination

Precipitation

Bauxite (Al(OH₃))

Embodied Energy: 2.3 MJ/kg

Caustic Soda Repurposed

Digestion

Fe₂O₃

Caustic Soda Input

SiO₂

H₂O

Aluminum: Full Cycle
Matter Disassembled

In architecture, aluminum is utilized through The Assembly. In Matter Disassembled, I propose formal disassembly as a basis for revealing the hidden realities of aluminum. I contend that a didactic architecture of aluminum can be achieved through the identification of parts, connections, and ensembles, followed by meaningful reassembly.
Parts: Aluminum Curtain Walls
Original Assemblies: Exploration of Expression


