Chapter 6
Building a global industry

While Alcoa built a strong monopoly in North America, aluminum producers were springing up across Europe and other parts of the world. By 1909, European aluminum companies produced 60% of the world's primary aluminum, while the U.S. was the world's leading consumer of aluminum. European companies were capable of producing aluminum at a lower cost because of nearby deposits of high-grade bauxite, cheap labor and well-located sources of hydroelectric power. Furthermore, aluminum prices in Europe were low due to competition and over-production at smelter plants. Alcoa was protected from this European competition by a 15-cent per pound tariff in 1890. The tariff was lowered to 8 cents per pound in 1897 and to 7 cents per pound by 1909. Duties also existed on fabricated aluminum goods. [1]

The Swiss aluminum industry

The nearly synchronous discovery of the Hall-Heroult reduction process in 1886 gave the Europeans a head-start in developing an aluminum industry. In May 1887, a Swiss iron manufacturer agreed to try the new aluminum producing process discovered by Paul Heroult, which led to the start of the Schweizerische Metallurgische Gesellschaft company by mid-1887. The company was producing about two tons of aluminum-bronze per day by 1888. Needing capital to expand, the company incorporated on Nov. 12, 1888, as Aluminium-Industrie AG Neuhausen with the assistance of Allgemeine Elektrizitats Gesellschaft of Berlin. [2] Schweizerische Metallurgische Gesellschaft signed an agreement with the German industrialist Walter Rathenau to establish a joint stock company with a total value of 10 million Swiss francs. [3]

Heroult joined with Gustave Naville, Georg Neher and Peter Huber in 1889 to establish a company in Zurich, Switzerland, to produce aluminum metal. [4] Heroult had gone to Neuhausen with the goal of using Rhenish Falls above the Rhine River to produce electricity to power aluminum smelters. The new company adopted the logo of a sun rising from an ingot of aluminum. [5] The company began to produce pure aluminum in 1889 and spent the last decade of the 19th century developing markets for the new metal. [6] The production of aluminum metal increased in efficiency from 40 tons per year in 1890 to 450 tons by 1895. [7] The company built a new smelter at Rheinfelden, Germany, in 1896 and another smelter in Lend, Austria in 1897. The company eventually operated as Aluminium-Industrie A.G. Chippis. The company's bauxite mines and alumina refineries in France were confiscated by the French government during World War I. The company's largest smelting operation was built at Chippis, in Canton Wallis,

Switzerland in 1907. [8] In 1908, an alumina refinery began operating in Neuhausen with a capacity of 26 tons per day using the Bayer process. It was the largest alumina refinery in Europe at the time. [9]

Aluminium Industrie AG began to invest in the Valais, Switzerland region in 1899 to take advantage of its rich hydroelectric opportunities and built a plant in Chippis in 1908 using hydropower from the Navisence River. But the market for aluminum did not meet expectations, and the company began to use the electrical power to produce nitric acid using the Birkeland-Eyde process. It also sold power to municipal customers during the Great Depression. Aluminium Industrie AG built a rolling mill in Sierre in 1929, a factory at Ernen in the 1950s and a factory in Steg in 1962. The company employed more than 3,000 workers in the Valais region in 1942 and about 2,000 in 1970. [10]

In 1963, the company was renamed Schweizerische Aluminium AG. [11] By 1967, under its common name Alusuisse, the company was the sixth largest aluminum producer in the world and comparable in size to the French aluminum company Pechiney. It was the only company among the top six aluminum producers in 1967 that did not have a strong domestic base of operations and instead operated worldwide. Alusuisse mined for bauxite in France, Italy, Greece and Sierra Leone, with a minor share in the Fria complex in Guinea, West Africa. The company's alumina was refined in Germany, France, Italy and Guinea, and Alusuisse headed a consortium to build a new alumina refinery near the Gove bauxite deposits in Australia. In most cases, Alusuisse owned its smelters, which were located in Germany, Switzerland, Italy, Austria, Norway and the U.S. [12] In 1974, the company took over the Swiss-German company Lonza, which was founded in 1897 and specialized in hydropower, construction and electrochemical industrial production. Aluminum production at Alusuisse-Lonza Holding AG reached its maximum in 1980 with more than 800,000 tons per year. During the 1980s, the company restructured its organization, closed outdated plants, downsized and modernized its semi-finished aluminum production facilities. It acquired the Canadian packaging company Lawson Mardon Group in 1994. By 1997, the company employed 31,000 workers worldwide, of which 5,800 were Swiss. The company renamed itself Algroup in 1998 and merged into Alcan in 2000. [13]

The French aluminum history

Witnessing the early success of Swiss aluminum production, the first French company to use the Heroult patent began operating around 1888 at Froges, in the Isere Valley near Grenoble, where a hydroelectric facility already existed. The company was called the Societe Electrometallurgique Francaise, or the Societe de Froges as it became commonly known. [14] Over the next 80 years, this small company joined other French aluminum

producers to form the global aluminum giant Pechiney. The parent company traced its origins to 1854 as Produits Chimique Alais & Camarque Salindres, which merged with Electrometallurgique Froges in 1888, La Barasse Ugine in 1908, Industrie Alumine St. Louis Aygalades in 1909 and Ugine Kuhlmann in 1965. The final combined company, Pechiney, emerged in 1981. [15]

Henri Merle, a producer of caustic soda at Salindres, France, established the Compagnie de Produits Chimiques in 1855 to produce aluminum using the non-electrolytic process developed by Henri Sainte-Claire Deville in 1854 and operating under a 30-year monopoly authorized by the French government. The company changed its name to Societe des Produits Chimiques d'Alais et de la Camargue in 1897. [16] A.R Pechiney, the company manager, had initially turned down Heroult's offer to use his discovery and the whole idea of producing pure aluminum rather than bronze alloys, but his philosophy changed by 1897. Heroult meanwhile took his patented process to Societe Electrometallurgique Francaise, which built the France's first aluminum smelter at Froges. Faced with increased competition from Froges, Pechiney stopped aluminum production by non-electrolytic means at Salindres in 1889. Eight years later in 1897, Pechiney bought out a competing company and turned to producing aluminum by the Hall-Heroult process. [17]

In the years leading up to World War I, Societe des Produits Chimiques d'Alais et de la Camargue established new smelter plants in the Alps and the Pyrenees mountains and became France's second largest aluminum producer. The company also had an operation in Norway, but its most ambitious project was to build a hydroelectric dam and smelter in the U.S. in the mountains of North Carolina starting in 1912. The new town for the facility was Badin, N.C., named for the managing director who succeeded A.R. Pechiney, Adrien Badin. The company was not seriously impacted by World War I because its facilities were located in southern France, but the company was forced to sell its unfinished Badin facility to Alcoa during the war. The economic crises following World War I led to a period of industrial concentration in France from 1920 to 1921. The company merged with its competitor in Froges to create Compagnie des Produits Chimiques et Electrometallurgiques d'Alais, Froges et Camargue. The enlarged company expanded operations between the two world wars from producing 11,000 tons of aluminum in 1918 to 50,000 tons in 1939. [18] The company changed its name to Pechiney in 1948 and expanded into Africa in 1954. [19]

By 1967, Pechiney was the fifth largest aluminum producer in the free world, with a dominant position in the French market. It mined bauxite in southern France, Australia and Greece, and it had an interest in a major new bauxite operation in Guinea, West Africa. Pechiney owned alumina refineries in southern France and Guinea. The

company's smelters were located in the Southern Alps, the Pyrenees and in Cameroon, West Africa. Although significantly smaller than Alcan, Alcoa, Reynolds and Kaiser, Pechiney was recognized to be among the technical leaders of the world aluminum industry. [20] The company eventually grew to be the fourth largest aluminum producer in the world, with 34,000 employees at 320 manufacturing and sales facilities in 50 countries by the time it was acquired by Alcan in 2003. Alcan was taken over by Rio Tinto in 2007. [21]

France's first industrial alumina refinery began operating in February 1894 in Gardanne, in southern France. Owned by the Societe Francaise de l'Alumine Pure, the plant was founded a year earlier to supply 1.5 tons of alumina per day to the smelter operated by the Societe Electrometallurgique Francaise. The reason for siting the plant in Gardanne was to be near lignite coal – at the time, the cost of shipping bauxite was considered less than the cost of shipping coal. The refinery site was near Marseille, a port city with a large supply of available manpower. Karl Josef Bayer was present as the plant started operating to ensure his process worked properly, but there were many mechanical difficulties, including a boiler explosion that required additional capital that the company lacked. The plant's efficiency was a low 40% and the purity of the alumina was not good. An agreement to merge the refinery and smelting companies was drawn up in February 1895. Additional alumina refineries using the Bayer process were built in France at Salindres in 1901, Ugine in 1908 and St. Auban in 1918. After manufacturing difficulties were ironed out, the plants were merged to form the Pechiney Company. [22]

British aluminum plants

The first major aluminum producing company in England began operating on May 7, 1894, as British Aluminium Co. Ltd. (BACO). The company obtained the British and British Colonial patent rights to the Heroult process from the Societe Anonyme pour l'Industrie de l'Aluminium in Neuhausen and began aluminum smelting using hydroelectric power at Foyers, Inverness-Shire, Scotland in June 1896 and with a second smelter plant in Argyllshire, Scotland in December 1907. [23] BACO was founded in 1894 by Emmanuel Ristori, the company's director, and Lord Kelvin, the technical advisor who became the company's director in 1898. The company held rights to the Bayer process and acquired rolling mills from the Cowles Syndicate. [24] BACO was a smaller but more vertically integrated aluminum producer than others entering the new industry. [25] Turning to the Scottish Highlands for hydroelectric power, the company's first aluminum ingots were produced at Foyers in 1895, but the first hydro-powered smelter began operating at Foyers in 1896, followed by Scottish smelters at Kinlochleven in 1909 and Lochaber in 1929. Carbon was produced at three different locations in Scotland. The company also operated four rolling mills in England. [26]

BACO's first alumina refinery began operating in Larne, County Antrim in northern Ireland, in the spring of 1896. The company acquired extensive bauxite deposits in County Atrim, but the ore was of low grade and the company turned to importing French bauxite in 1897. [27] The company acquired a controlling interest in Union des Bauxites of Southern France and later established bauxite mines in British Guiana during World War I and then the Gold Coast of Africa in 1928. [28] The Larne alumina refinery in Ireland marked the second industrial application in the world of the Bayer process. Bauxite had been mined in Larne since 1875 for the production of aluminum sulfate, and mud from the Larne refinery was sold for use as a dye. BACO began operating a second alumina refinery on Burnt Island in Fifeshire, Scotland in 1913. [29] By 2008, the aluminum industry in Great Britain employed 20,000 workers. The 145,000 ton-per-year Anglesey Aluminum plant closed in September 2009, and the 178,000 ton-per-year Lynemouth plant closed in May 2002, leaving the 43,000 ton-per-year Lochaber plant the only smelter left operating in Great Britain in 2012. The Lynemouth smelter was opened by Alcan in 1973. High energy costs were blamed for the closures. [30]

The British recognized early the possibilities for hydroelectric power along the mountainous west coastline of Norway and invested in aluminum facilities there. [31] BACO acquired a small Norwegian company that was developing a hydroelectric power facility at Stongfjord in 1906. A smelter was built and production of aluminum began at Stongfjord in January 1908. [32] The Stongfjorden Aluminum plant ran from 1908 to 1945. The Germans took over the plant during World War II, but no bauxite was available to run the plant during the war. [33]

In April 1907, the Anglo-Norwegian Aluminium Co. Ltd. was formed to develop hydroelectric power for an aluminum smelter at Vigelands in southern Norway. [34] The English company hired two Swiss engineering companies to build the Vigeland Brug plant and operate it using the Heroult patent. The plant used alumina produced by the bauxite company Giulini, which was not part of the international bauxite-aluminum cartel. Falling aluminum prices in 1910-1911, technical problems in the smelter, a malfunctioning sales organization and labor unrest led to heavy debt, and the company was eventually taken over by BACO. [35]

During the 1940s and 1950s, BACO opened or invested in aluminum plants and infrastructure in Norway, India, Canada and British Guiana and acquired additional bauxite resources in Australia. Financial difficulties in 1958 led to the company being taken over by Reynolds Metals and TI Group. Construction began on a large nuclear-powered smelter at Invergordon, Scotland in the 1960s, despite signs of aluminum production overcapacity at the time, and the smelter went into production in 1971. The British aluminum company was taken over by Alcan in 1982, with operations merging

into British Alcan Ltd. In 1994, the company produced 357,000 tons of aluminum, improving the company's financial status from a loss of 22.7 million pounds in 1993 to a profit of 30.9 million pounds in 1994. Despite the turnaround, Alcan sold the company to a group of institutional investors in February 1996, and it was renamed British Aluminium Ltd. In 2000, Alcoa acquired the company's plate, sheet and soft-alloy extrusion operations and distribution businesses, and in 2002 Alcoa shut down the company's plant at Dolgarrog in North Wales. The Dolgarrog site permanently closed in 2007 after 100 years of operation. [36] The Dolgarrog smelter initially obtained its alumina from a plant at Hebburn-on-Tyne near New Castle, which was operated by a subsidiary, the International Aluminium Co. [37]

The Norwegian aluminum industry

Norway offered two advantages to aluminum companies – protected fjords for shipping ports and abundant hydroelectric power potential. But it lacked other key elements, particularly bauxite. In 1906, as the first aluminum plant in Norway was under construction, an influential Norwegian engineer warned that the Norwegian aluminum industry would "become controlled by a cartel who disposes bauxite." In those early years, Norway's abundant hydroelectric potential offset the country's lack of domestic demand or knowledge about aluminum production. Norwegian companies were interested in entering the aluminum industry, but the lack of raw materials, technical know-how, venture capital, access to markets and distribution channels directed these companies toward other industries, and Norway's aluminum industry initially was left in the hands of foreign companies. [38]

In 1904, Norwegian entrepreneur Sam Eyde founded the Norwegian company Elektrokjemisk Industri with plans to develop furnaces and processes for electro-metals. By 1917, a ferroalloy plant was acquired. [39] In 1907, the German company Badische formed a partnership with Eyde's company to develop hydroelectric power using Tyin Lake, about 3,000 feet above the farming community of Ardal, for manufacturing nitrogen from the atmosphere and using it to make fertilizer. Eyde purchased the Rjukan waterfall in 1912 to produce hydroelectricity under the name Norsk Hydro. [40] The Birkeland-Eyde nitrogen production process required large amounts of electricity, so power plants were constructed at the Svelgfossen waterfall near Notodden and later the Rjukanfossen waterfall near the village of Rjukan. [41] By 1910, two hundred men were building a road, but Badische pulled out the next fall. Norsk Hydro took over the shares for the company as Tyinfaldene. The company continued to work on the project until World War I halted construction. By 1918, as work commenced again, the question of what to do with the hydroelectric power was debated. One possibility was to build an alumina refinery. [42] By the 1920s, the energy-intensive arc-based Birkeland-Eyde process

for making nitrogen was no longer competitive with the newly developed Haber-Bosch process, and in 1927 Norsk Hydro formed a partnership with the German company IG Farben. [43] Work at the site continued at a very slow pace, and by the end of the 1930s talk turned again to building an aluminum smelter plant. But by the time World War II started, no aluminum plants existed at Ardal. [44]

Elektrokjemisk operated from 1904 to 1954. During that time, the company controlled the patents to the Soderberg carbon anode technology, which by 1950 was used in about half of the world's aluminum smelters. But Elektrokjemisk was unable to become a producer of primary aluminum because it lacked the finances, networks or market access to produce and sell aluminum. Pechiney, other French investors and Elektrokjemisk joined forces in 1912 to form the Norwegian chemical company Det Norske Nitridaktieselskap (DNN). [45] The joint venture's goal was to use Norwegian hydroelectric power to produce nitrate and alumina at the same time through the Serpek process. The Serpek process, however, didn't work. [46] Elektrokjemisk sold its DNN shares in 1913, and Pechiney ended up building aluminum smelters instead of a nitrate plant. The move by Pechiney effectively stopped Elektrokjemisk from entering the aluminum business. DNN aluminum smelters were built at Eydehavn near Arendal and at Tyssedal. Together, the two plants made DNN the largest aluminum producer in Norway until 1947. [47] The Eydehavn smelter used hydroelectric power from Boejlefoss and started production in 1914. The Eydehavn smelter doubled production to 5,000 tons per year by 1917, and DNN built a second plant at Tyssedal with a 6,000 ton-per-year capacity. In 1925, the Tyssedal plant increased capacity to 10,000 tons per year. [48]

In 1924, Alcoa acquired a little over half interest in DNN to gain control of Electrokemisk and the Soderberg anode patent rights. For a time, Alcoa owned the exclusive license to the Soderberg process in the U.S. In 1940, the patents became non-exclusive, and after World War II both Reynolds and Kaiser obtained licenses to use the technology. Electrokjemisk reserved the right to any improvements on the process that were discovered and used by licensees, but allowed the licensees to use their discoveries during the term of their licenses. The basic royalty rate for the Soderberg process was one mill per pound of aluminum. Alcoa paid Electrokjemisk $88,500 on average per year between 1942 and 1948. [49] Two years after the corporate breakup of Alcoa in 1928, DNN was jointly owned by the BACO, Compagnie AFC of France and Alcoa's successor to foreign investments, Aluminium Ltd. of Canada. [50]

Other aluminum plants sprung up in Norway. Norsk Aluminium Co. built an aluminum smelter at Sognefjord in 1916 with a capacity of 6,500 tons per year. The Sognefjord plant was acquired by Alcoa after World War I, and was transferred to Alcan by 1930. [51] Actieselkapet Norsk Aluminium Co. (NACO) started operating an aluminum plant at

Hoyanger in 1917. The company began as a Norwegian company with plans for total vertical integration, using bauxite from France and a fabrication plant that could manufacture cans by 1920. But lack of technical expertise and loss of bauxite supplies from France during World War I, because of Norway's neutrality, led to NACO's bankruptcy. Alcoa acquired NACO in 1923. The British International Aluminium Co. started operating the Haugvik Smelteverk aluminum plant in Glomfjor in 1926. Shares of the plant were sold in 1932 to a cartel consisting of the Canadian company Alcan, the French company Pechiney, the German company Vereinigte Aluminium Werke (VAW), the Swiss company Aluminium Industrie AG and the British company BACO. [52]

The history of the Norwegian aluminum industry after World War II continued to be complex, involving numerous foreign investments or joint ventures. During the 1960s, the international character of the aluminum industry had become increasingly marked by joint ventures in new plants and companies sharing in both raw material supplies and markets. By 1970, the U.S. companies Alcoa, Reynolds and Kaiser had interests in Brazil, India, Mexico, Suriname, Venezuela, United Kingdom, Norway, Ghana, Australia and Canada. European companies had interests in several U.S. operations. This internationalization had ramifications on aluminum supply, fabrication, marketing and technical knowledge exchange. It was expected that future growth in capacity by U.S. producers could take place in foreign countries, particularly near bauxite sources. With increased demand forecasted for the U.S., it was expected that the U.S. would end up a net aluminum importer. [53] In Norway, one native company slowly acquired hydroelectric dams and aluminum smelters to add to its metals and chemicals business. In 1947, Norsk Hydro acquired a power plant at Glomfjord, where zinc and aluminum had been produced, and changed the plant to an ammonia producer. In the 1950s, Norsk Hydro began operating a magnesium plant in Heroya. [54] It wasn't until long after World War II that the Norwegian smelters were consolidated into the global aluminum giant Norsk Hydro.

In 1946, Ardal og Sunndal Verk, a Norwegian state-owned aluminum company, was founded to continue the unfinished construction of the Ardal aluminum plant started by the Germans during World War II. In 1954, construction began on a plant in Sunndal. By 1986, when Ardal og Sunndal Verk merged with Norsk Hydro, the state-owned company was operating aluminum plants in Ardal, Sunndal, Hoyanger and Holmestrand, using hydroelectric facilities at all four of the small villages. [55] The merger created a strong player in the global aluminum industry – Hydro Aluminium. The state-owned Ardal og Sunndal Verk's strength was in technology, while Norsk Hydro's strength was in commerce. Over the next five years, the new company produced 500,000 tons of alumina per year, of which about 75% went to Hydro's own plants. Activities across the board increased by 50%, and within five years Hydro Aluminium was the fifth largest

aluminum company in the world. During those five years, Hydro acquired five extrusion plants in Central Europe from Alcan, expanded aluminum smelting capacity at Karmoy, Norway, purchased Alpart's alumina refinery in Jamaica, and took over the Wicona building-system company in Germany. [56]

Other companies built aluminum smelters along Norway's rugged coastline. On June 29, 1962, Sor-Norge Aluminium (SORAL) was formed to develop an aluminum smelter at Husnes, Kvinnherad. Talk about building an aluminum plant there began in 1959 following two seasons of bad fishing. The first phase of the SORAL plant began operating in November 1965, and the second phase began operating in March 1966. The plant had a capacity of 60,000 tons per year, and production remained steady through the 1970s, 1980s and 1990s despite difficulties finding enough workers. The fall of aluminum prices in the 2000s led to cutbacks and serious concerns about SORAL's future. In 2014, Norsk Hydro purchased the plant and renamed it Hydro Husnes. In 2015, the plant had 400 employees and a capacity of 180,000 tons per year. [57]

Some projects were joint ventures. On June 11, 1963, Norsk Hydro announced plans to build an aluminum plant on the island of Karmoy in Norway. The area had been hard hit by the first failure of the herring fishery in 50 years. More than 1,000 local workers needed jobs. Norsk Hydro's fertilizer business was also beginning to face unexpected global competition from new companies. One hurdle to establishing an aluminum plant at Karmoy was to get approval for transmitting power east to west across the country from Roldal-Suldal. Once the decision was made not to produce fertilizer or polyvinyl chloride plastic at the site, Norsk Hydro began to look for a partner in the aluminum business. They contacted Pechiney, Alcan and Alcoa, who were interested, but turned in the end to Harvey Aluminum of California. The advantages to Norsk Hydro of working with Harvey was that the company was independent, not too large and able to supply sound technology for building up an integrated aluminum operation such as Norsk Hydro had in mind. Norsk Hydro struck a deal with Harvey to create a new company, Alnor Aluminium Norway A/S, with Norsk Hydro holding 51% and Harvey holding 49%. The partnership lasted 10 years, but Norsk Hydro was always intent on taking over the entire company. The opportunity came when Harvey was acquired by Martin Marietta, which resisted Norsk Hydro's initial offers and then relented, selling the Karmoy facilities to Norsk Hydro for $20 million on May 3, 1973 – a very low price. Norsk Hydro earned back the $20 million in two years of aluminum production. [58]

The original plan for Karmoy was first to build an extrusion plant that would use purchased metal and later to build a smelter, casthouse and rolling mill. Harvey had good experience with extrusion plants. The potroom and rolling mill, however, were built first and were running by June 17, 1968. While the rolling mill was small by

European standards, it was the first to use metal from an adjacent potroom. The rolling mill employed Harvey's strip-cast method, which saw good results in the first years but was later a victim of business cycles. The first shipment of metal from Karmoy went to China, but the plant's biggest success came from selling to European markets. By 1982, the Karmoy smelter's capacity was increased from 110,000 tons per year to 162,000 using advanced Pechiney reduction pot technology. The smelter's capacity was increased to 220,000 tons per year in 1987, making the Karmoy smelter the largest in Europe at the time. [59]

By the 1980s, Norway was the fifth largest aluminum producer in the world, exporting about 90% of its metal to West Germany, The Netherlands, Italy and the United Kingdom. Norsk Hydro's four smelters accounted for about 75% of Norway's capacity. The company also had tolling contracts with aluminum smelters in the Pacific Northwest, including the aluminum plant in Columbia Falls, Mont., and held a share in Alpart's bauxite facilities in Jamaica. [60] By 1996, seven aluminum smelters were operating in Norway with a total capacity of 934,000 tons per year. [61] On Nov. 4, 2004, Norsk Hydro announced construction work was completed at its 300,000 ton-per-year aluminum smelter in Sunndal, Norway. The plant was the newest and largest in Europe and came in under budget. The smelter was also 10% more efficient than originally estimated. The plant's casthouse was also remodeled and extended, and the project included building facilities for producing 80,000 tons per year of primary foundry alloys. A total of 930 workers were employed at the site of the 50-year-old smelter facility. [62] By 2016, Norway was the seventh largest aluminum-producing nation, with seven smelters and 1 million tons per year in capacity. One Norwegian smelter was rated at more than 350,000 tons per year. The Norwegian smelters relied on hydropower. [63]

Downstream facilities sprung up to handle all the Norwegian metal. Skandinaviska Aluminiumprofiler AB (Sapa) set up its first extrusion plant in Vetlanda, Norway in 1963, selling its products out of Sweden beginning in 1967. The Orkla Group acquired Sapa in 2005 and delisted it from the Stockholm Stock Exchange. Sapa joined with Alcoa in 2007 to create one of the leading extrusion companies in the world. In December 2008, the Orkla Group took over Alcoa's soft aluminum alloy extrusion business in an asset swap, and the business was organized under the Sapa name. In 2009, Sapa acquired six extrusion plants in the U.S. and four in Canada owned by Indalex, which was under bankruptcy protection. In October 2012, Orkla and Norsk Hydro announced an agreement to combine the two companies' extrusion businesses under the Sapa name. The merged company was established in September 2013. As of 2015, Sapa had 100 production sites in more than 40 countries employing about 23,500 workers. [64]

In 2000, Norsk Hydro acquired Wells Aluminum, a network of extrusion plants in the U.S. Two years later, Norsk Hydro acquired Vereinigte Aluminium Werke (VAW), a leading German aluminum producer. Nine years later, Norsk Hydro acquired aluminum assets in Brazil from Vale, which brought bauxite and alumina refining to the company, creating a vertically-integrated company. In 2010, Norsk Hydro formed a 50/50 joint venture with Qatar Petroleum to construct the largest aluminum plant ever built in one step, a 585,000 ton-per-year smelter using power from a 1,350 megawatt gas-fired power plant. By 2015, Norsk Hydro employed about 12,500 workers in 50 countries and had a strong presence in the oil industry since 2007. The company operated aluminum plants in Norway at Rjukan, Raufoss, Vennesla, Karmoy, Hoyanger, Ardal, Sunndalsora and Holmestrand. The Norwegian government held a 34.3% stake in Norsk Hydro. [65]

The Canadian powerhouse

The Canadian aluminum industry began as an expansion of a U.S. company's interests. In 1899, the company that eventually became Alcan was created as a Canadian subsidiary of the Pittsburgh Reduction Co. [66] Aluminum was produced for the first time in Canada at the company's new smelter near the Shawinigan, Quebec, hydroelectric dam on Oct. 22, 1901. The Canadian operation was incorporated as the Northern Aluminum Co. in 1902, and the Alcoa subsidiary changed its name to the Aluminum Co. of Canada Ltd. in 1925. That same year, Alcoa acquired the rights to establish hydroelectric dams at Chute-a-Caron and at Shipsaw on the Saguenay River. The next year, Alcoa began building a second aluminum smelter at the town of Arvida, which later became part of the city of Jonquiere, to use this additional hydroelectric power. [67] Aluminium Ltd. separated from Alcoa in 1928, registered the name Alcan in 1945 and added the French name Aluminium du Canada Limited in 1965. The company's name became Alcan Inc. in 2001 and then Rio Tinto Alcan Inc. in 2007. [68]

In 1928, Alcoa decided to divest itself of all its principal subsidiaries located outside the U.S, including the Aluminum Co. of Canada Ltd. Alcoa's shares were transferred to an independent Canadian company. From 1928 onwards, the directors and management of the Canadian company were independent of Alcoa. This was firmly established in a final adjudication in 1950 "which ensured that any common identity of major shareholders in the two companies was also removed." During World War II, to meet a growing demand for aluminum for defense purposes, the company built additional hydroelectric dams in Quebec and increased its total primary aluminum production capacity to 500,000 tons. Fabricating plants were also built in Canada and the U.S. After the war, the company built more hydroelectric dams in Quebec and in British Columbia, doubling its production capacity to 1 million tons by the end of the 1960s. [69] The company benefited from government financial assistance during World War II from both the U.S. and the

United Kingdom. Further assistance came during a period of metal shortage during the Korean War, which enabled Alcan to make long-term contracts in the U.S. [70]

By 1950, Alcan was the largest aluminum producer in the world. Most of its production facilities were located in Canada, but it also owned plants in Norway, Sweden, Italy and India. In 1948, despite water shortages that caused electrical shortages, Alcan's Canadian plants produced about 367,000 tons of primary aluminum. Total capacity was estimated at about 496,000 tons per year. Unlike the Big 3 U.S. aluminum producers at the time, Alcoa, Reynolds and Kaiser, Alcan was essentially a supplier of ingot aluminum, not fabricated products. The Canadian company was in a strong financial condition, but the concentration of stock ownership that was discovered in the 1937 anti-trust case brought by the U.S. government against Alcoa continued to exist by 1950. Arthur Vining Davis, Edward K. Davis, Roy A. Hunt and six members of the Mellon family owned 46.43% of Alcoa's common stock and 44.65% of Alcan's common stock. With the addition of Doris Duke and the trustees of the Duke Endowment, which had been involved in early negotiations for hydroelectric power, 11 stockholders held a majority of the shares in both Alcoa and Alcan. Therefore it could be said that three families held total control over the two largest aluminum producing companies in the world – the Davis, Hunt and Mellon families. In his 1950 ruling in the long-running Alcoa anti-trust case, Judge John C. Knox wrote, "To permit this potential power to continue where it now resides, and thus supplement Alcoa's relatively large resources, may constitute a hazard of the utmost danger to the competitive efforts of Reynolds and Kaiser." [71]

Since its inception in 1928, Aluminium Ltd. continuously improved its facilities and operations. By 1950, its production costs had dropped to the point that its aluminum was cheaper than Reynolds' or Kaiser's – despite a 2-cent per pound tariff. The Canadian plants enjoyed both inexpensive electric power and transportation costs. Out of about 400,000 tons of aluminum produced by its Canadian plants, about 55,000 tons were consumed in Canada and 80,000 tons were shipped to the U.S., primarily to Alcoa. Alcan and Alcoa signed a sales contract for about 150,000 tons between April 1, 1948 and March 31, 1950. Alcoa explained that it needed Canadian aluminum to meet anticipated rapid growth in demand that would outstrip Alcoa's production capacity. In turn, Alcan needed an outlet for its primary aluminum, and neither Reynolds nor Kaiser was in a strong enough financial condition to enter into so large a contract. U.S. government attorneys, however, believed Alcoa actually controlled the distribution of Canadian aluminum. Judge Knox questioned the degree of control by Alcoa raised by the U.S. attorneys in the anti-trust lawsuit, but he did point to the familial connections between Alcoa and Alcan where the president, Nathaniel Davis, at 34 years old and president of the Canadian company for only two years, was the nephew of Arthur Vining Davis, chairman of the board at Alcoa. Nathaniel Davis owned only 275 shares in the Canadian

company, while his uncle owned 10 times more shares than even his father, Edward K. Davis. Judge Knox stated that "it is easy, and even natural, to suppose that family influences played some part in his (Nathaniel Davis's) elevation to office. Now that (Alcan) is a vital competitive factor in the domestic market, some cognizance of these family ties must be taken into account." [72]

In 1951, Alcan began work on a $500 million project to build an aluminum smelter in British Columbia, the largest public-private partnership in Canada's history to that time. The British Columbian provincial government had invited Alcan to look at the potential of building a smelter at the mouth of the Kitimat River on the mountainous Pacific Ocean coastline. The project included construction of a smelter in Kitimat, which started producing aluminum in 1954; construction of a 112-megawatt hydroelectric plant at Kenamo; and construction of a 51-mile long transmission line. [73] By 1955, Aluminium Ltd.'s smelters in Canada were capable of producing about 650,000 tons of aluminum per year. A new smelter was under construction at Isle Maligne in Quebec with a capacity of about 22,000 tons per year. The company also announced plans to expand production at its Kitimat smelter by about 240,000 tons per year in successive stages through 1959. The company was also negotiating with the government of Quebec to obtain enough hydroelectric power to expand capacity at its Saguenay operations by about 120,000 tons per year. [74]

By 1967, Alcan was the largest aluminum exporter in the world, with the U.S. and the United Kingdom being its main markets. Alcan was a fully integrated company, with bauxite holdings in Guyana, Jamaica, France and Malaysia at Sarawak. Alcan was participating in building a large alumina refinery in Queensland, Australia, and the company sold substantial amounts of alumina to Norway in exchange for metal. Most of Alcan's smelter capacity was located in Quebec, with a secondary facility in British Columbia. The Canadian-based smelters were powered by Alcan's own hydroelectric facilities. Alcan also had interests in smelters in Brazil, India, Italy, Norway and Japan. [75] During the 1970s, the company built smelters in Australia, Brazil, the United Kingdom and India, along with alumina refineries in Jamaica, Australia and Ireland. In 1982, the company merged with the British Aluminium Co. Plc (BACO). [76]

By 1980, Alcan was the second largest producer of primary aluminum, after Alcoa, but first in sales worldwide. Alcan operated 14 smelters worldwide, including a 476,000 ton-per-year plant in Arvida, Quebec; a 295,000 ton-per-year plant in Kitimat, British Columbia; a 188,000 ton-per-year plant in Grande Baie, Quebec; a 93,000 ton-per-year plant in Shawinigan, Quebec; a 80,000 ton-per-year plant in Isle Maligne, Quebec; and a 52,000 ton-per-year plant in Beauharnois, Quebec. Alcan also produced a number of value-added aluminum products, including rod, bar, sheet, casting, wire, cable,

extrusions, plate, foil, paste, powder and flake. [77] Alcan built a fifth smelter at La Baie, Quebec, during the 1980s and a sixth smelter at Chicoutimi on the Saguenay River in Quebec in the 1990s. [78] Alcan acquired most of the Atlantic Richfield Co.'s aluminum assets in 1985, including the former Anaconda Company's smelter at Sebree, Ky. [79] The company also planned to build a new smelter at Laterriere, Quebec in 1999 to replace aging potlines at its Arvida smelter. [80]

Alcan was a low-cost ingot producer that moved quickly in the global primary aluminum market to keep up prices and demand. Alcan achieved its global leadership position among aluminum producers by the 1980s despite owning no bauxite mines and having very little alumina refining capacity inside Canada. Major sources of alumina included Jamaica and Australia. Alcan's sole alumina refinery at Jonquiere, Quebec, supplied about 30% of Canada's alumina needs. Bauxite sources included Brazil, Guyana and Guinea. Alcan's foreign investments included bauxite mines in Brazil, Guinea, Ghana, Jamaica, India and Malaysia; alumina refineries in Australia, Brazil, Guinea, Jamaica, India, Ireland, the United Kingdom and Japan; and aluminum smelters in Australia, the U.S., Brazil, India, the United Kingdom, Japan and Spain. [81] During the 1990s, as cheap aluminum from Russia flooded the world market, Alcan sold off many of its international subsidiaries, including its alumina refinery in Ireland, and restructured its holdings. [82]

Alcan was not alone in taking advantage of Quebec's abundant hydroelectric potential for aluminum smelting. The Canadian British Aluminum Co. built a smelter at Baie-Comeau in Quebec in the 1950s, which was later bought by the Canadian Reynolds Metals Co. In 1987, a consortium made up of Reynolds, Pechiney and Alumax built a smelter in Quebec at Becancour. About 75% of the aluminum produced in Canada was exported, with the U.S. taking about 75% that production in 1984 through 1988. A consortium of German, Austrian, Dutch, Japanese and Canadian companies called Alouette, including VAW, Austria Metall, Hoogovens, Albecour, Marubeni and Kobe, built a 278,000 ton-per-year smelter at Sept-Iles, Quebec in 1992. A subsidiary of Alumax operated a 200,000 ton-per-year smelter in Quebec at Deschambault in 1993. [83] By 1992, Reynolds' large but older smelter at Baie Comeau in Quebec accounted for about 19% of Canadian smelting capacity and plans were made to expand the Baie Comeau smelter by 120,000 tons per year. A consortium of Reynolds, Pechiney, Alumax and Albecour, an arm of the Quebec government, owned the Becancour smelter in Quebec, which started production in 1986 and accounted for about 13% of Canadian capacity. Plans were made to expand the Becancour smelter by 120,000 tons per year. If all completed by 1992, the expansion projects and new smelters was expected to make Canada the largest aluminum producer in the world. [84]

The German aluminum industry

Little aluminum was produced in Germany prior to 1914, but World War I brought an urgent demand and several smelters went quickly into operation. [85] The German aluminum industry began with Aluminium Industrie's smelter plant in Rheinfelden in 1897. The Swiss-owned plant's annual production was about 800 tons, far less than needed by Germany when war broke out and Germany was isolated from international supplies. Construction of three aluminum smelters with a combined capacity of 6,000 tons per year was planned by Chemische Fabrik Griesheim Elektron in association with the Metallbank und Metallurgische Gesellschaft. By April 21, 1917, a new German company was formed to produce aluminum, Vereinigte Aluminium-Werke Aktiengesellschaft (VAW). Coal was used in Germany to generate electric power by steam turbine, bauxite was brought in from Bihar, Hungary, and an alumina refinery with a capacity of 3,000 tons per month was constructed. [86]

The VAW smelter at Innwerke began operating in 1925 and closed in 1996. [87] A third company, Innwerke Aktiengsesellschaft, began operating in Germany in 1917 using hydroelectric power in Upper Bavaria. Production, however, did not begin until January 1925. By 1930, Germany was capable of producing 30,000 tons of ingot aluminum per year. [88] World War II totally disrupted the German aluminum industry, but it slowly returned after the war. By the 1980s, West Germany was the second-largest aluminum producer in Europe after Norway. Alumina refiners included Aluminum Oxide Stade, owned by Reynolds and VAW, with 60% of national production, followed by Alusuisse and VAW. Aluminum smelters included VAW, with about half the nation's capacity; Alusuisse, with about a quarter; Hamburg Aluminum, owned by Reynolds, VAW and the city of Hamburg; and Hoogovens. Alumina was supplied from Australia, Italy and Guinea. [89]

Russian and Soviet aluminum

Attempts to industrialize Russia under the Tsar did not include aluminum production because there were no proven reserves of bauxite in the country and limited electrical power generation. In 1916-1917, bauxite deposits were discovered in Tikhvin, about 120 miles from St. Petersburg. [90] Karl Bayer had discovered the industrial process for alumina refining while working in Russia, and alumina refineries were built at the Tentelev Chemical Plant near St. Petersburg and at Yelabuga in the Tatar region near the Ural Mountains. [91] But the boehmite bauxite at Tikhvin was not suitable for the Bayer process, so Russian scientists turned to the Muller and Packard patents to develop a fractional decomposition method that was ultimately utilized at the Volkhov aluminum complex near Leningrad and the Tikhvin refinery. Following the Bolshevik Revolution,

the new government adopted a state plan in 1920 to electrify Russia using hydropower. Included in the plan was the development of an aluminum industry with a capacity of about 10,000 tons per year. [92]

The 1929 Decree of Government Structures issued by the Soviet of Labor and Defense approved the construction of two aluminum complexes, in Volkhov and Dnepr, with a combined capacity of 20,000 tons per year. Construction of the two smelters began in 1930, but the Soviet Union lacked the expertise to finish the job and the French company Ale Forge Comarg was commissioned to assist in the project. Tikhvin bauxite was first refined into alumina at Volkhov in September 1932 and at Dnepr in April 1934. After the discovery of additional bauxite deposits in the Ural Mountains, the government decided to increase the aluminum production goal to 70,000 tons per year. Plans were made to construct a 40,000 ton-per-year alumina refinery near the Tikhvin mines and a 60,000 ton-per-year refinery near the deposits in the Urals. Development of the bauxite mines in the northern Urals near Nadejdinsk began in 1933, as was construction of the Ural aluminum complex near Kamensk-Ural, which was near both bauxite and coal deposits. Using some Pechiney design concepts, the first alumina was produced at the Ural complex in 1939. [93]

The Volkhov aluminum smelter produced the first aluminum ingots in the Soviet Union on May 14, 1932. One year later, aluminum was produced at the Dneprovsky smelter in the Ukraine. To meet increasing demand, the 400,000 ton-per-year Tikhvin Alumina Refinery went into operation. In 1939, the Urals Aluminium and Alumina Complex was commissioned with an annual capacity of 700,000 tons of alumina and 250,000 tons of aluminum. [94] By 1941, four alumina refineries were in operation, but the German invasion in June forced the Soviets to shut down industrial operations throughout the European part of the Soviet Union. Operations at Dnepr and Volkhov were dismantled and moved to the Urals, and a new alumina refinery was built in the northern Urals as part of the Bogoslovsk aluminum smelter. [95]

Following World War II, work began on restoring the aluminum smelter at Volkhov and the alumina refinery at Tikhvin. In the 1950s, a new alumina refinery was built near Pilalevo, and a large alumina and aluminum complex was built near Achinsk in Krasnoyarsk. The alumina produced in Achinsk was destined for new aluminum smelters to be built in Siberia. [96] Because of the type of bauxite available at Tikhvin, scientists did not employ the Bayer process but instead sintered the nepheline concentrates with limestone, a process that produced cement, soda, potash and alumina. The process was stepped up to an industrial scale at the Volkhov plant by 1952 with an output of 53,000 tons of alumina per year. By 1953, alumina production at Tikhvin was 50,000 tons per year. By the mid-1950s, construction had begun on a new alumina refinery near

Pikalevo utilizing the same nepheline process used at Tikhvin. In the late 1950s, construction of a new aluminum complex near Achinsk in Krasnoyarsk was begun, near the region's largest coal deposits. The Achinsk plant was intended to provide alumina to the growing smelting capacity in Eastern Siberia. [97]

The Soviet Union began selling primary aluminum on the world market in 1955, setting prices for its ingots so low that it hurt Canadian aluminum sales. In the long run, however, Soviet aluminum did not make a significant impact on Western markets until the fall of the Soviet government around 1990. [98] The U.S. led the world in aluminum production in 1957 with 44% of the total, while the Soviet Union ranked second with 19%. During years when the aluminum market was tight and demand exceeded supply, the Soviet Union did not export aluminum. In the last half of 1957, the Soviet Union exported 20,000 tons of aluminum to Great Britain at a price well below that of Canadian producers. [99] Low metal prices and weak demand in 1958 affected some U.S. smelters. One aluminum producer in Washington State laid off 1,000 workers, and many U.S. producers were unable to sell their inventory. The price drop of 2 cents per pound, the first price drop in 17 years, resulted from price reductions by Alcan, which in turn was reacting to competitive pricing by Soviet and European producers. [100]

By May 1958, the world market experienced a surplus of aluminum. Production of aluminum in the U.S. since World War II had increased by 300%, in Western Europe by 400%, in Canada by 190% and in the Soviet Union by 560%. The Soviet share of global aluminum production was said to have increased by 21%, which amounted to about 80% of the total increase worldwide. In May 1958, the Soviet Union reportedly was exporting 50,000 tons per year to Great Britain. Canadian producers attempted to meet this market challenge by lowering prices, but the Soviet Union kept its price one cent per pound lower than the Canadians. The Canadians asked the British Board of Trade to invoke its anti-dumping law against the Soviet Union, but the burden of proof fell on the Canadians, and the Soviet economy's internal domestic pricing system was meaningless under communist rules. The political implications of Soviet aluminum in the global marketplace suggested a new type of warfare in which the Soviets intended to destroy capitalism by undercutting a key industry. [101] By 1963, the Soviet Union was no longer dumping aluminum on the world market – global competition came from France, Norway, Japan and Canada. [102]

In the mid-1960s, two giant aluminum smelters were commissioned in the Soviet Union, the Bratsk and Krasnoyarsk smelters in Siberia, each with a capacity of 1 million tons per year. Production levels at the two smelters remained the largest in the world by 2015. [103] On May 1, 1964, Soviet officials announced the start of operations at the giant new aluminum smelter in Krasnoyarsk in Siberia, with the first phase ready to produce

300,000 tons of aluminum per year. The plant was one of four major new industrial centers slated to begin operating in 1964. Statistics from the Soviet Union were difficult to ascertain, but best estimates put aluminum production there at about 1 million tons per year, or about half of total U.S. production. Aluminum production in the Soviet Union had doubled since 1957, and more expansion plans were in the works despite a raw materials problem. The Soviet Union possessed very limited supplies of high-grade bauxite and, for political and strategic reasons did not want to become dependent upon foreign sources. [104]

To maintain its independence, the Soviet Union expended significant time and money on research developing ways to use other aluminum-bearing substances, such as nephelite and alunite. An alumina-producing plant using alunite was set to begin operating at a plant in Kirovabad in Azerbaijan by the end of 1964. Sulfuric acid and fertilizer were byproducts of the Kirovabad plant. Another alumina-producing plant was scheduled for completion in Pavlodar in Kazakhstan that would process high-silica bauxite. A third alumina-producing project was to be located in Achinsk in Siberia, where large nearby deposits of nephelite would be processed using French-made machinery into alumina, with cement as a byproduct. The largest deposits of bauxite in the Soviet Union were in the Ural Mountains, and those deposits would be utilized by the new Krasnoyarsk smelter. These bauxite deposits accounted for three-fourths of the Soviet Union's aluminum production and were utilized by the Novokuznetsk and Shelekhov smelters in Siberia, the Sumgait smelter near Baku, Azerbaijan, and the Erevan smelter in Armenia. An aluminum-making complex using local sources of bauxite and nephelite was also in operation near Leningrad and the Kola Peninsula. [105] By April 1970, the Soviet Union was the second largest producer of primary aluminum in the world after the U.S. The Soviet government announced the start-up of an 800,000 ton-per-year alumina refinery at Achinsk in Siberia near the large aluminum smelter at Krasnoyarsk, which reduced the expense of shipping bauxite from the Ural Mountains, the only source of high-grade bauxite in the Soviet Union. Soviet smelters were located in Siberia to be near sources of hydroelectric power. [106]

The Bratsk aluminum smelter in Irkutsk, Siberia was typical among Russian smelters for operational costs. It began as a large high-amperage Soderberg plant with contracted hydroelectric power. Labor costs in 1991 were $10 per employee per month per ton of aluminum produced. By December 1995, that figure had increased to $200. By 1997, it had increased again to $300. Projects were underway to upgrade the plant's equipment and operations, but the biggest problem was the Bratsk smelter's distance from ocean transport. The plant was dependent on the Trans-Siberian railroad for raw materials. Energy consumption at Bratsk was about 16 kilowatt-hours per kilogram. [107] In October

1993, the Bratsk smelter provided the livelihood for about 300,000 city residents with 20,000 direct jobs and 77% of the city's income. [108]

The global aluminum market felt the impacts of Soviet aluminum dumping in the early 1990s following the collapse of the Soviet Union. To generate hard currency, the Russians shipped large quantities of ingot to the world market – just as the market hit an economic downturn and could not absorb all that Russian metal. [109] Russia's alumina refineries and aluminum smelters needed to adapt to a market economy. The plants had been built to operate under a "closed" economy, with lower power and fuel prices than would be found in an "open" market-based economy. One of the first priorities was to optimize power efficiency at the aluminum plants. This included adopting different methods to process the nephelite bauxite used in the former Soviet refineries, as well as adopting improved process control and shipping in boehmite bauxite from the Middle Tyman deposits. [110] By April 1992, aluminum prices had fallen to 58 cents a pound, and the global stockpile was about twice its normal size – around a million tons. Demand was down for building materials and automobiles. Part of the blame was also placed on the cyclical nature of the aluminum industry. [111]

By October 1993, Russian primary aluminum exports to the U.S. grew from about 14,000 tons per year in 1992 to 230,000 tons for the first seven months of 1993 – a 15-fold increase. During the same time period, U.S. aluminum production was cut back by about 600,000 tons, and more than 5% of U.S. aluminum plant workers were idled. [112] In 1994, U.S. primary aluminum production fell to its lowest level in seven years. Thirteen companies operated 22 reduction plants in the U.S., with one smelter temporarily closed. With continued rising inventories and depressed prices during the first half of 1994, U.S. smelters announced temporary curtailments, with Russian aluminum exports taking the blame. Primary aluminum was produced in 43 nations, with the U.S. on top with 17% of the total followed by Russia with 14% and Canada with 12%. But global production fell by 3% during 1994. [113]

On Jan. 28, 1994, representatives from Australia, Canada, the European Union, Norway, the Russian Federation and the U.S. met in Brussels, Belgium, where they signed a memorandum of understanding recognizing the grave, exceptional and unforeseen situation caused by an excess global supply of primary aluminum. The Russian Federation agreed to reduce production of primary aluminum by 500,000 tons per year over two stages beginning in February 1994. The memorandum stated that the best response would be based on action by individual companies on the basis of fair competition, and that assistance would be provided to the Russian Federation to modernize its aluminum plants. In March 1994, a follow-up meeting took place in

Canada where it was decided to set up a Working Group of Experts to help promote a free and competitive world aluminum market. [114]

Australian mining, refining and smelting

Australia's entry into the global aluminum industry began as an important source of bauxite. After World War II, global bauxite reserves grew geometrically. This rate of growth was linked to the discovery of new uses for aluminum in electrical, transportation and construction sectors. In 1965, the U.S. Bureau of Mines estimated bauxite reserves in Guinea at 150 million tons; but by 1979, Guinea's reserves had increased 6,000% to 9 billion tons. Bauxite reserves in Brazil were estimated as nonexistent in 1965 but increased to an estimated 3 billion tons by 1980. Bauxite reserves in Australia in 1965 were estimated to be 2 billion tons but increased to 5 billion tons by 1980. Australia passed over Jamaica as the world's leading producer of bauxite in 1971. But while Australian bauxite production was highly cost-efficient, shipping to the U.S. accounted for about 75% of the total cost to refineries. The cost of shipping bauxite to alumina refineries in 1980 ranged from $15 to $40 per ton, and the trend worldwide was to locate alumina refineries close to the source of the bauxite. The wide variation in bauxite prices reflected shipping costs as well as the quality of the bauxite – the amount of bauxite needed to produce one ton of aluminum could range from four to six tons. By 1980, Guinea and Australia accounted for about half the world's total bauxite production. Bauxite production exceeded 100 million tons, an increase of 50% over 1970 and an increase of 240% over 1960. Worldwide bauxite reserves were thought to be sufficient to last from 225 to 300 years at 1980 consumption rates, so there was little economic incentive to prove additional reserves. [115]

The Australian bauxite industry kicked off when deposits of commercial-grade bauxite were discovered at Weipa in Northeast Australia in 1955. The Port of Gladstone in Queensland was chosen as a site for a new alumina refinery in 1963 with a capacity of 732,000 tons per year. Plant construction lasted from 1964 through 1966, and production commenced in 1967. The plant expanded through 1973, trebling its output. Production improvements in the 1980s and 1990s increased capacity further. By 2000, operating as Queensland Alumina Ltd. of Australia, the refinery produced alumina for a consortium of companies, including Alcan at a 21.4% share, Comalco at 30.3%, Kaiser at 28.3% and Pechiney at 20%. Replacement cost for the plant was about $4 billion. The Port of Gladstone plant was the world's largest alumina refinery, with about 1,100 workers. [116] Reynolds and British Aluminium also began developing the Weipa deposits but then sold their interests to Comalco, a joint venture between Kaiser and Rio Tinto Conzinc. [117]

Consolidated Zinc Corporation announced it had established the existence of huge bauxite deposits in the Cape York Peninsula of northeastern Australia in June 1957. The deposits were described as the largest in the non-Communist part of the world and included two 100-square-mile deposits containing hundreds of millions of tons of bauxite. British Aluminium Ltd. was already making plans to invest resources and knowledge in Consolidated Zinc's efforts to develop the deposits. Plans were underway to produce 1 million tons of bauxite per year. Lack of electrical power in the Cape York Peninsula, however, made plans for aluminum smelting difficult. One suggested solution involved producing hydroelectric power on the Purari River in New Guinea, 400 miles to the north across the ocean, and another involved building an atomic power plant. [118] On March 20, 1969, Joh Bjelke-Petersen, premier of Queensland, announced his government's plans to expand the Queensland Alumina plant in northeastern Australia to 1.2 million tons per year, which would make the facility the largest alumina refinery in the world. [119]

Vast deposits of bauxite were also discovered in the Pinjarra area of Western Australia, which were developed in a joint venture between Alcoa and the Western Mining Co. of Australia in 1961. After serious negotiations involving various interested parties, Alcoa bought a 51% interest in the Pinjarra mine for $100 million. In 1979, Alcoa of Australia Limited began construction of an alumina refinery in Wagerup and a smelting complex in Portland. [120] Over time, the development grew into the world's largest integrated mining, refining, smelting and rolling facility. [121] Alcoa developed bauxite mines along the Darling Range from east of Perth to Collie. The first mine at Jarrahdale opened in 1963. [122]

In 1966, Amax discovered a major bauxite deposit in Australia and formed a new subsidiary called Amax Pacific. [123] By 1967, Kaiser, Conzinc-Rio Tinto of Britain, Pechiney and Alcan had joined to build a new alumina refinery. [124] At the same time, Alusuisse headed a consortium to build a new alumina refinery near the Gove Peninsula bauxite deposits in Northeastern Australia. [125] In July 1977, the Anaconda Company looked into forming a partnership with the Reynolds Metals Co. to build a $600 million alumina refinery in Western Australia – just two weeks after Alcoa and Reynolds canceled their plans for a partnership in a $650 million alumina refinery in Western Australia. [126] In 1977, Australia overtook the U.S. as the world's largest alumina producer. By 1980, Australia and the U.S. produced 25% of the world's alumina. Alumina refineries had tended to be located near aluminum smelters rather than bauxite deposits for political and economic reasons. During the 1970s, bauxite-producing nations made increasing demands to have alumina refineries located in their countries. By 1977, about one-half of the world's metallurgical-grade bauxite was refined in the country where it was mined. [127]

In 1972, the global bauxite industry was dominated by four nations, which together held about 60% of the global share – Australia at 20%, Jamaica at 18%, Suriname at 11% and the Soviet Union at 10%. By 2012, only Australia remained a top producer of bauxite. More than 45% of the world's alumina was produced in five industrialized nations in 1972 – the U.S. at 25%, Japan at 7%, Canada at 5%, France at 5% and Germany at 4%. The other major alumina producers were Australia at 13%, Soviet Union at 12%, Jamaica at 9% and Suriname at 6%. By 2012, only Australia remained a top producer of alumina. [128] Australia moved beyond bauxite mining and alumina refining in 1979. The Australian government began an effort to limit the export of raw materials with plans toward exporting finished aluminum and earmarking more than $1.7 billion in loans for local aluminum companies. A consortium of American, Japanese and local companies made plans for a $570 million aluminum smelter at Port of Gladstone in Queensland. Alcoa planned on spending $96 million expanding its Port Henry smelter in Victoria. Alumax planned to expand capacity at its Kurri Kurri smelter in New South Wales. Proposals also were made to expand refining capacity near bauxite deposits in Western Australia. [129] By the 1980s, Australia was first in the world in bauxite mining and alumina refining and third in aluminum smelting. About 95% of the aluminum content of the mined bauxite was exported – about 25% as bauxite, 60% as alumina and the rest as aluminum. More than half of the aluminum went to Japan, with the rest going to Asian markets. [130]

Alcoa of Australia, owned by Alcoa and Western Mining, was Australia's largest bauxite miner in the 1980s, with three large mines in Jarrahdale, Huntley-Del Park and Willowdale. The company also owned three alumina refineries in the Darling Range of Western Australia and was the largest alumina seller in the world. The company also owned the Point Henry smelter and held a 45% stake in the Portland smelter, both near Melbourne. Comalco was Australia's second largest aluminum company, with bauxite mines at Weipa-Andoom and Mitchell Plateau, both in northern Australia. Comalco's bauxite was refined at the Port of Gladstone plant by Queensland Alumina, owned by Comalco, Kaiser, Alcan and Pechiney, or exported directly to Japan or Europe. The Gladstone refinery supplied alumina to the nearby Boyne smelter, owned by Comalco, Kaiser and a Japanese consortium, and to the Bell Bay smelter in Tasmania, owned by Comalco. The Gove Project in Australia's Northern Territories, owned by Gove and Alusuisse, included a bauxite mine and alumina refinery. Tomago, partially owned by Gove, Pechiney and VAW, ran a smelter in New South Wales. Worsley, owned by Reynolds, Billiton/Shell Australia and Kobe Alumina, operated the Mt. Saddleback bauxite mine and Worsley refinery in the Darling Range of Western Australia. Alcan Australia ran the Kurri Kurri smelter in New South Wales. [131]

World demand for alumina picked up by the middle of 1995 after global aluminum production dropped in 1993-1994 following a flood of cheap ingot aluminum from the

former-Soviet Union. By 1995, after several years of modernization efforts, the Russian aluminum industry became more dependent on alumina imports. In 1994, Alcoa of Australia and Comalco Ltd. negotiated to send $147.5 million worth of alumina to six Russian smelters. Australia was looking at a potential 1 million ton-per-year market for alumina in Russia. [132] But there was growing interest in building smelters in Australia that could take advantage of vast bauxite reserves, existing alumina refineries, coal deposits for power generation and proximity to the new and growing Asian market. By 1990, a new group of "integrated" aluminum-producing countries had emerged over the past 20 years. The global aluminum industry after World War II had been divided into "miners" and "smelters." Bauxite was mined in developing countries in the tropics, including Guyana, Guinea, Jamaica and Suriname. Aluminum was smelted in developed nations in North America and Europe which possessed large amounts of electrical power. Alumina refining initially took place in the developed countries before being re-located closer to bauxite mines. Two countries that emerged as "integrated" producers between 1970 and 1990 were Australia and Brazil. By 1990, Australia was the largest bauxite miner and alumina refiner and third largest aluminum smelter in the nonsocialist world. [133] Six aluminum smelting plants operated in Australia in 1996, with a total capacity of 1.4 million tons per year. [134]

By 2016, four aluminum smelters still operated in Australia – Bell Bay and Boyne Island, owned by Pacific Aluminium; Portland, owned by Alcoa of Australia; and Tomago, owned by Rio Tinto Alcan, CSR Ltd. and Hydro Aluminium. Together they produced 1.94 million tons of primary aluminum in 2011, of which 1.6 million tons was exported. The Kurri Kurri smelter owned by Hydro Aluminium closed in October 2012, and the Point Henry smelter owned by Alcoa of Australia closed in July 2014. About 75% of all the electrical power in Australia was generated by coal-fired plants. The 178,000 ton-per-year Bell Bay smelter in Tasmania, which started operating in 1955, the first aluminum smelter in the southern hemisphere, was energized by hydropower. The Boyne Island smelter started operating in 1982 and was expanded in 1997 to more than 568,000 tons per year. The Portland Aluminium smelter began operating in 1986 and was expanded to a capacity of 358,000 tons per year. The Tomago smelter began operating in 1983, the world's first large-scale plant with AP30 reduction pots. The plant was expanded in 1991 and in 2001, when it was upgraded to AP22 technology and had a capacity of 530,000 tons per year. The Kurri Kurri smelter, which began operating in 1969, was acquired by Hydro Aluminium in 2002 and closed in 2012. The Point Henry smelter – established in 1963, one of the first aluminum smelters in Australia – and the adjacent rolling mill ceased operating in 2014. [135]

Bauxite and alumina production continued to be important in Australia. In 1991, the global bauxite reserves were estimated at 23 billion tons. Guinea and Australia each had

about 24% of the total reserves. [136] In November 1997, Alcoa World Alumina and Chemicals announced a $257.5 million expansion of its alumina refinery at Wagerup. Expected to be completed by 1999, the expansion would increase alumina production by 440,000 tons to 2.19 million tons. [137] In 1998, Kaiser also held a 28.3% stake in the Port of Gladstone alumina refinery, which had a rated capacity of 3.65 million tons per year – the largest alumina refinery in the world. Bauxite for the refinery came from Australian mines and was paid for by Kaiser's Port of Gladstone partners – Alcan, Pechiney and Comalco. Kaiser's share of the alumina was shipped to its primary aluminum plants in the Pacific Northwest. [138] Alcoa produced about 70 million tons of bauxite in Australia in 2010. [139]

Five bauxite mines were operating in Australia in 2016 – Boddington, owned by the BHP Billiton spin-off South32 and Worsley Alumina; Gove, owned by Pacific Aluminium; Huntly, owned by Alcoa of Australia; and Willowdale and Weipa, both owned by Rio Tinto Alcan. The Gove and Weipa deposits had close to 50% alumina content, among the highest-grade reserves in the world. The Boddington, Huntly and Willowdale deposits in Western Australia were relatively low grade at around 30% alumina. Australian bauxite deposits were also relatively high in silica, requiring more caustic soda when refining, but the deposits were also relatively shallow and easy to mine. Six alumina refineries operated in Australia – Yarwun, owned by Rio Tinto Alcan; Kwinana, Pinjarra and Wagerup, all owned by Alcoa of Australia; Queensland, owned by Rio Tinto Alcan and Rusal; and Worsley, owned by South32 and Worsley Alumina. Operations were suspended at a seventh refinery, Gove, owned by Pacific Aluminium, in 2014. [140]

In 1996, global aluminum production was estimated at 19.3 million tons and total capacity was estimated at 22.2 million tons. According to one analyst from the U.S. Bureau of Mines, the aluminum industry tracked well with the general economy of the world. Some analysts believed that aluminum trends anticipated and predicted the rest of the worldwide economy. The global aluminum industry was expected to handle a growth rate of 2% to 4% annually. Aluminum prices had taken a roller-coaster ride since the 1980s, largely as a result of the collapse of the Soviet Union and the flood of cheap aluminum into the world market – prices had plunged from $1.10 per pound in 1988 to 53 cents per pound in 1993, the lowest price for aluminum in 16 years. According to a statistics manager at the Aluminum Association, the former Soviet Union had greatly understated its production capacity. According to some industry experts, the cyclical nature of the aluminum market had much to do with the manufacturing process, which involved potlines that were difficult to shut down and long-term electrical contracts, with the result that plants were forced to operate even when prices were depressed. [141]

But even bigger changes were to come. In 1990, total global aluminum production was about 19 million tons, with more than 5 million tons in North America, about 4 million tons in Europe, about 3 million tons in the former Soviet republics including Russia, about negligible production in the Gulf Cooperation Council (Dubai and Persian Gulf countries) and less than 1 million tons in China. Total production grew each year to a record 51 million tons by 2013, with the exception of 2009, which saw about a 2.5 million ton decrease from 2008, at the start of the "great recession." Production by 2013 declined slightly in North America to 5 million tons, declined slightly in Europe to about 3.5 million tons, increased slightly in the former Soviet republics to about 4 million tons, increased in the Gulf Cooperation Council to about 4 million tons – and increased significantly in China to about 25 million tons, about half of total production. [142]

The Chinese industry unleashed

Much of China's economy was dominated by foreign interests and empires from the 19th century until the communist government took complete control of the country after World War II. Foreign interests, weak imperial government in Peking and war with Japan followed by a civil war all prevented significant industrial growth until after World War II – despite the country's vast coal and hydroelectric resources. In the midst of all this disarray, the Fushan Aluminum Co. plant, China's first aluminum smelter, began operating in Fushan, Liaoning in 1929. [143] The phenomenal growth of the Chinese aluminum industry began in the 1990s. A total of 152 major aluminum smelting plants operated worldwide in 1996, with a total capacity of 23.7 million tons per year. Numerous smaller smelters operated in China at that time, producing about 1 million tons per year, which was included in this total. Another 23 major aluminum smelters brought China's total capacity to about 2.3 million tons per year. [144]

Global aluminum prices began to see the impacts of China's growing aluminum industry in 1997. The average price for aluminum at the London Metal Exchange had increased to 72.5 cents per pound from 68.3 cents in 1996 then fell toward the end of 1997 to 68.3 cents per pound as a result of the Asian economic depression and increased exports by China. [145] By 1998, the largest primary aluminum-producing countries in the world were the U.S. with 4.2 million tons, Russia with 3.1 million tons, China with 2.5 million tons, Canada with 2.3 million tons, Australia with 1.4 million tons and Brazil with 1.2 million tons. [146] Massive construction plans were being made in China in 1998 that would increase domestic aluminum demand, mostly for infrastructure, housing and repairing flood damage. According to industry experts cited by AME Mineral Economics, China's gross domestic product needed to grow more than 5% per year to maintain social stability and political survival for the current government. To boost this domestic

growth, the communist government turned to traditional Keynesian economics, employing enormous public works projects. According to an industry insider, “This level of stimulatory spending is naturally unsustainable.” [147]

The sustainability question also applied to the global aluminum industry. In March 1998, Chris Adams at the Wall Street Journal asked the question, “Are aluminum makers setting themselves up for another glut?” Only several years earlier, the global market suffered from an oversupply of aluminum worldwide, mostly the result of huge exports by the former Soviet Union. By March 1998, Alcoa announced plans to build a $843 million smelter in British Columbia, Alumax announced plans to build a 250,000 ton-per-year smelter also in British Columbia, Alcan was planning a new smelter in Quebec, and Reynolds announced it was restarting much of its idled capacity. In China, proposed aluminum projects would expand capacity by 600,000 tons per year. One explanation for the worldwide expansion was the belief that aluminum would be used more and more in transportation, particularly for aluminum automobiles. Demand for aluminum cans was only expected to grow by 1% per year. [148]

Alcoa showed early interest in the burgeoning Chinese aluminum industry. On Nov. 8, 1999, Alcoa announced it had signed a memorandum of understanding with the China Aluminum Corp. (Chalco) to form a strategic partnership. The new agreement superseded an agreement made in 1998 with the China State Nonferrous Metals Industry Administration, which at that time oversaw development of China’s aluminum industry. By late 1999, much of China’s aluminum facilities were consolidated under Chalco. [149] On Nov. 6, 2001, Alcoa announced it had finalized a memorandum of understanding with Chalco to form a strategic partnership. The plan called for a 50-50 joint venture at Chalco’s Pingguo alumina and aluminum facility, one of the most efficient in China. The Chinese aluminum industry at the time was the fastest growing in the world. [150] Alcoa and Chalco announced they would invest $540 million in the Pingguo aluminum facility in southwest China. Chalco was the third largest alumina producer in the world and was making an initial public stock offering. Chalco’s chairman said the company planned to spend $1.85 billion over the next five years, including $830 million to expand aluminum production and $1 billion to expand alumina production, and he expected world aluminum prices to recover from a 2 1/2-year low. [151]

Chalco was established when the six largest alumina producers in China combined to form the state-run Aluminum Corporation of China (Chinalco), with total assets of $4.3 billion. The new corporation hoped to eliminate the redundant construction of small and inefficient aluminum plants by controlling alumina production. The merger also included several research institutes and construction firms and created the third largest alumina producer in the world after Alcoa and Alcan. The new corporation was expected

to supply 70% of China's alumina and 23% of its aluminum, and it forecast exporting about 30% of its alumina production. Chinalco planned to produce 4.3 million tons of alumina and 680,000 tons of aluminum per year. [152] Chalco was established as a joint stock limited company in the People's Republic of China by way of a promotion by Chinalco, the Guangxi Investment Co. and the Guizhou Provincial Materials Development and Investment Corporation. The Chinese government through Chinalco was the controlling shareholder. [153]

As established, Chalco stock would be sold on the New York and Hong Kong stock exchanges by mid-2001. [154] Alcoa and Chalco were committed to increasing refining and smelting capacities at Pingguo, including doubling its current 400,000 tons per year of alumina by 2003 and expanding aluminum production from 135,000 tons per year to 355,000 by 2006. According to the agreement, Alcoa would become a strategic investor in Chalco stocks, which would be sold on the New York and Hong Kong stock exchanges, and Alcoa would have one seat on the Chalco board. Alcoa Chairman and CEO Alain Belda reported that "ready and reliable access to aluminum produced in China, the fastest economy in the world" would help Alcoa, particularly in selling its fabricated products. Chalco was the sole producer of alumina in China and the third largest alumina producer in the world at that time, and the largest producer of primary aluminum in China. [155] Alcoa sold its 8% stake in Chalco on Sept. 2, 2007 for about $2 billion. [156]

For the first nine months of 2001, China exported 217,904 tons of primary aluminum, more than three times what it exported in 2000, making it a net exporter of aluminum for the first time. [157] In a 2002 report, AME Mineral Economics noted that global demand for aluminum was down about 4% in 2001, the first appreciable decline since 1993. While demand fell in 2001, global primary aluminum production increased by 3.9%. AME Mineral Economics expected China would account for about 40% of the future six-year increase in consumption of aluminum – all told, China would consume about 20% of the world's primary aluminum, and the rest of the world would lag behind China. The world was oversupplied with alumina in 2001 – global alumina production in 2001 was 55 million tons, but after consumption by smelters and non-metallurgical sectors, a surplus of 4.3 million tons was left. [158]

China was the fastest growing aluminum market in the world in 2004, and growth there was expected to continue. At the same time, China was committed to shutting down smaller, inefficient and environmentally damaging smelters. China had more than 120 aluminum smelters in 2004, of which about 70 had less than 10,000 tons per year capacity, another 30 were between 10,000 and 50,000 tons, about 15 were between 50,000 and 100,000 tons, and about 10 had more than 100,000 tons per year capacity.

Meanwhile, domestic demand soared – the Chinese construction boom was going strong by that time. China consumed about 4 million tons of semi-fabricated aluminum per year in 2000, with that number expected to climb to about 7 million tons by 2010. [159]

Upstream, the Shanxi Aluminum Factory in north China was producing 1.2 million tons of alumina by 2000. The Shanxi refinery was the largest in China and produced about one-third of China's alumina. The plant began operating in 1987 and produced 7 million tons of alumina between 1987 and 2000. Construction of the plant took 20 years and cost $614 million. [160] But Chinese alumina production was not enough to meet the huge domestic demand resulting from China's construction boom. In mid-December 2000, aluminum market analysts reported that global alumina prices were slightly higher because of higher demand by Chinese aluminum producers, but they were optimistic that surpluses would exist in 2001 – as much as 800,000 tons. Alumina spot prices had climbed to $175 per ton, but they expected prices to drop back down to about $150. They also cited higher aluminum metal prices, meaning aluminum producers could afford these higher alumina prices. [161]

By May 2001, construction was well under way at the Pingguo Aluminum Mine project in southwest China, which was expected to produce 1.1 million tons per year of bauxite and 400,000 tons per year of alumina at a nearby refinery. The mine's cost was estimated at about $230 million. China produced about 4.29 million tons of alumina in 2000, ranking third in world production, but that was not enough to meet demand in China's rapidly growing economy. It was forecast that China would need to import 1.8 million tons of alumina per year without new mines and refineries. By 2005, the new Pingguo mine and refinery facility was expected to produce 1.25 million tons of alumina. [162]

In June 2004, Chalco announced an agreement to acquire 29% of Lanzhou Aluminium Corp., as the state-controlled company began to rein in expansion of the nation's rapidly growing aluminum industry by merging the largest producers and closing older plants. Lanzhou was the nation's third largest aluminum producer, and the acquisition was thought to be worth about $120 million. The government had announced earlier it would clamp down on investment in aluminum, steel and automobile manufacturing to slow inflation. Demand for aluminum rose 23% in 2003, and the Chinese government was concerned over-investment in aluminum smelters could lead to over-capacity, plunging prices, a rise in bad loans at the nation's banks as smelters failed to make payments, and energy consumption creating power shortages. China's aluminum smelters, with 8.3 million tons per year of capacity, used 4% of the nation's power

supply in 2003, and 1.16 million tons of capacity was idled as a result of higher alumina and energy prices. [163]

Alumina prices rose 46% in 2003, causing Lanzhou to halve its production. Chalco, on the other hand, made 80% of its profit in 2003 selling alumina, up from 44% in 2002. Chalco planned to increase alumina production by 34%, from 5.95 million tons in 2003 to 8 million tons in 2005. Once the sole supplier of alumina to the Chinese aluminum industry, Chalco sold about half the alumina used in China, but expansion of alumina production by Alcoa and Rio Tinto was expected to challenge Chalco's dominance of the China's alumina market, and Chalco would turn more to aluminum production. Chalco produced 704,000 tons of aluminum in 2003, and was expected to increase that to 1.64 million tons by 2005, of which 700,000 tons would come through acquisition, not newly built plants. Lanzhou produced 209,000 tons in 2003, but at least 86,000 tons of Lanzhou's capacity was considered outdated. Lanzhou had recently announced it had received government approval for construction of three coal-fired power plants capable of producing a total of about 900 megawatts by 2006. Other, smaller aluminum companies in China were feeling the squeeze of rising alumina and power prices, making them vulnerable to Chalco acquisition or control. [164]

In February 2009, Alcoa announced it had formed a strategic-cooperation agreement with the People's Government of Henan Province in China to develop world-class projects for primary aluminum and fabricated aluminum products. Henan Province had 107 varieties of discovered mineral resources, including 960 million tons of bauxite, the second largest reserves in China. The province also had seven alumina refineries with a total capacity of 2 million tons per year and 14 aluminum smelters with a total capacity of 1.3 million tons per year. [165] Three years later, Alcoa announced it would cut back production at all of its U.S. facilities by 12%, including shutting down its Alcoa, Tenn., smelter for good. Aluminum prices had fallen more than 27% from their peak in 2011 as a result of slowed housing construction in China along with debt problems and the depressed economy in Europe. About half of all global aluminum production by then went to China. [166]

Chalco employed 103,493 workers in 2013 and was divided into three distinct business segments – bauxite mining and alumina refining, primary aluminum smelting and energy. Chalco sold its aluminum fabrication business in 2013 and pursued other foreign interests, including a $3 billion investment in a copper mine in Peru and a 9% stake in Rio Tinto. By 2016, Chalco was the only alumina producer in China and the second largest alumina producer in the world. It was also the largest primary aluminum producer in China and the third largest in the world. [167] China's 120 aluminum smelters had a total capacity of 29.2 million tons per year in 2016 – accounting for more than half

of the world's total capacity, which included 215 aluminum smelters operating in 45 different countries. Forty-two of the Chinese smelters boasted more than 350,000 ton-per-year capacity. Many Chinese smelters were powered by coal-fired generating plants, but some used hydropower. [168]

In 2014, China Hongqiao Group Ltd., a private aluminum company with smelters in China's Shandong Province, was expected to produce 4 million tons of primary aluminum, a 36.2% increase from 2.9 million tons in 2013. To feed all that smelting capacity, the company had invested in a joint venture to build a 1 million ton-per-year alumina refinery in Indonesia that would begin production by the end of 2015. China Hongqiao also had invested in bauxite mining in Australia, India, Malaysia and Guinea. [169] On Jan. 4, 2016, the brokerage firm Galaxy Futures reported that plans were underway to increase the aluminum smelting capacity in China by 7 million tons per year. The new smelters would be located in Shandong Province and the autonomous regions of Guangxi, Xinjiang and Inner Mongolia. How much of that new capacity would be put on line would depend on the availability and cost of power, aluminum prices, demand and feed stock levels. According to the China Nonferrous Metals Industry Association, more than 5 million tons per year of new aluminum smelting capacity was added in China in 2015, mostly in Shandong Province and the north China and northwest China regions, where power costs were relatively low compared to the rest of China. But about 4.91 million tons per year of aluminum smelting capacity was idled in 2015 because of poor aluminum prices, over supply and high stocks. The idled smelters were in Liaoning, Hubei, Hunan, Gansu, Yunnan and Qinghai provinces, Chongqing City and the autonomous regions of Xinjiang and Inner Mongolia. The Chinese trade association said total smelting capacity in China by the end of 2015 was 40 million tons per year. If the new smelting capacity planned for 2016 was not put online, then the total idled smelting capacity in China would be 12 million tons per year in 2016. [170]

On March 14, 2016, it was reported that China Hongqiao, by then the world's largest producer of primary aluminum by capacity, planned to increase capacity in 2016 despite the global aluminum glut and depressed metal prices. Plans called for increasing its smelting capacity from 5.19 million tons by the end of 2015 to 6 million tons by the end of 2016, depending on market conditions. "If demand is good, we will stick with the plan," China Hongqiao Chief Executive Zhang Bo said. "If not, we can slow down new capacity expansion or even suspend it." Plans called for spending $2.3 billion on expanding capacity and retrofitting coal-fired power plants to meet China's stricter emission requirements. Chinese aluminum smelters benefited from cheap power but were driven by loan obligations to keep producing, resulting in flooded international aluminum markets. This in turn forced some Western producers to cut output and led to "dumping" allegations by U.S. companies and organizations. China Hongqiao was one of

several Chinese smelting companies which set up other companies to purchase excess inventory, which helped bolster prices but did not address the underlying fundamental problem – oversupply. Private aluminum producers in China, like China Hongqiao, benefited from electrical generating plants they controlled or from the cheap power from hydropower dams and coal-fired plants built during China's construction binge over the past decade. Many of China Hongqiao's customers were also located close to the China Hongqiao's Shandong smelter, creating efficiencies. On the other hand, large Chinese smelting companies, including China Hongqiao, were forced to build expensive alumina refineries in Indonesia after the Indonesian government outlawed bauxite shipments as a way to attract industrial investment. China Hongqiao was also planning to prioritize shipments from a new bauxite mine in Guinea in 2016. China Hongqiao's imported bauxite accounted for about a quarter of all China's imported bauxite. [171]

On June 7, 2016, the China Nonferrous Metals Industry Association announced that Chinese primary aluminum companies planned to restart idled smelter capacity because prices on the Shanghai Futures Exchange had increased by 20%. The Chinese producers had idled 3.8 million tons in 2015, and an agreement had been brokered in December 2015 that allowed the companies to restart idled capacity if prices changed significantly. A China Nonferrous Metals Industry Association official said a strict limit would continue on increasing smelter capacity, but companies were encouraged to restart idled smelters because demand was good – half of China's smelters were profitable at current prices, the group said. Chinese exports in recent years had created a global glut and hurt aluminum companies in the U.S., India and elsewhere. Analysts at Goldman Sachs Group Inc. forecast that aluminum prices would decline from $1,515 per ton on June 7, 2015, to $1,350 in 12 months time. While aluminum prices in Shanghai had increased 20% since November 2015, global prices had increased less than 6%. China Hongqio had already announced it would increase its capacity in 2016 by 16% to 6 million tons. Smelters in the southern provinces were expected to restore 1.4 million tons of smelting capacity. The new supply was expected to reach the market by June 2016. [172]

China's rapid growth and the resulting impacts on supply and demand in the global alumina and aluminum markets drew criticism from the Aluminum Association in a May 2016 opinion piece. China produced about 11% of the aluminum in the world in 2000 and more than half by 2016. The Aluminum Association criticized China for subsidizing aluminum production with incentives and central planning and not addressing unfair and illegal trading practices. The Association called for establishing a level playing field between China and the rest of the global aluminum industry. The result of incentives and central planning was construction of new aluminum smelters when doing so made little economic or environmental sense, the Association said. Chinese smelters heavily relied on coal-fired power plants, with the result that Chinese smelters produced about

64% of the global aluminum industry's climate-changing carbon emissions. If Chinese smelters were considered a standalone nation, they would rank 16th highest in carbon emissions among all the nations in the world. [173]

At the same time that Chinese production was increasing, U.S. aluminum production had fallen to an historic low, the Aluminum Association said – eight U.S. smelters had closed since 2015, leaving only two fully operational, the lowest level of production since World War II. While upstream employment in the U.S. aluminum industry was up, the number of workers in the primary production sector had dropped from more than 12,000 in 2013 to about 5,000 in 2016 – a 60% decrease in three years. The Association called for a negotiated agreement between the U.S. and Chinese governments to address China's overcapacity issue and unfair trade practices. The Association wanted the Chinese government to minimize subsidies and to allow inefficient and antiquated facilities to close. The Association accused Chinese producers of misclassifying shipments or using third-party countries to avoid paying trade duties. The Association also supported a coalition of aluminum, steel, textile, chemical and other industries called Manufacturers for Trade Enforcement that opposed granting China market economy status by the end of 2016. The Association also wanted China's market to be more transparent, with real-time data on aluminum production, including shipments and emissions. And the Association wanted China to be held to commitments on greenhouse gas reduction. [174]

India's vertically integrated plants

Growth of the Indian aluminum industry, like China's, came late in the 20th century, but the proximity of coal and bauxite deposits in the subcontinent promoted some development prior to World War II. In 1938, a 2,500 ton-per-year aluminum plant owned by the Aluminium Corporation of India (Indalco) began operating in India with technical cooperation from Alcan and using imported ingot to make rolled sheet. The Hindustan Aluminium Corporation (Hindalco) began operating a 20,000 ton-per-year smelter in Uttar Pradesh in 1959. The Madras Aluminium Company Ltd. (Malco) started operating a 10,000 ton-per-year aluminum smelter in 1965. The state-owned National Aluminium Company (Nalco) started operating a 218,000 ton-per-year smelter in 1987. The Indian government began to regulate and control the aluminum industry in India in the 1970s through the Aluminium Control Order, which required that 50% of all aluminum production go to electrical products. The order was removed in 1989 and de-licensing of the industry followed in 1991, allowing the liberal import of new technologies and capital goods. The result was a 12% growth rate in the Indian aluminum industry, double the rate in 1980. [175]

Formed in 1958, Hindalco set up India's first integrated aluminum facility at Renukoot, at the eastern edge of Uttar Pradesh, in 1962. The Renukoot smelter, with one 20,000 ton-per-year potline, was expanded over the years. The vertically-integrated facility included bauxite mining, alumina refining, aluminum smelting, rolling and extrusions. Hindalco built a captive coal-fired plant devoted to the complex at Renusagar in 1967 – the first captive power plant in India. The Hirakud smelter in Odisha, built by Indalco in 1959 as India's second aluminum smelter and using power from the Hirakud Dam, was acquired by Hindalco when it merged with Indalco. Facing power shortages, Hindalco built a captive coal-fired plant for the Hirakud smelter that began operating in 1993 – the first plant in India to use clean-coal combustion technology. Hindalco acquired Novelis, the world's largest aluminum rolling company, in 2007. [176] Hindalco grew to become one of India's largest integrated aluminum producers by 2008 and was ranked among the top quartile of aluminum companies in the world for low cost. Plans were in the works in 2008 for the $1.8 billion Aditya Aluminium Project, which would include a 1 million ton-per-year alumina refinery and a 250,000 ton-per-year aluminum smelter. [177]

By 2016, Hindalco was the flagship company of the Aditya Birla Group, a global leader in aluminum and copper production, the world's largest aluminum rolling company and one of Asia's largest producers of primary aluminum. The company's smelters included Renukoot in Uttar Pradesh, Aditya Aluminium at Lapanga in Odish, Mahan Aluminium in Madhya Pradesh, and Hirakud in Odisha. The four smelters combined to produce 1.3 million tons per year in 2016. The Aditya smelter had a 360,000 ton-per-year capacity powered by captive coal-fired plants and using AP36 reduction cells from Pechiney and alumina from the Utkal Alumina plant, a 100% subsidiary of Hindalco. The state-of-the-art Mahan smelter started up in 2016 with a 360,000 ton-per-year capacity, a captive coal-fired power plant, and alumina from Hindalco's Utkal Alumina plant. All told, Hindalco operated alumina refineries at Utkal, Renukoot, Muri and Belgaum. Most of the alumina went to Hindalco's own smelters. Hindalco's refineries produced 1.2 million tons in 2015. The company's newest refinery was located at Utkal, Odisha. [178]

Malco was incorporated in India in 1961 with technical and financial assistance from Montecatine of Italy. An integrated facility was built in Tamil Nadu and started production with a 10,000 ton-per-year smelter in 1965. The company was taken over in February 1995 by Agarwal Associates, the promoters of the Sterlite group. Malco was also vertically integrated, with bauxite mines at Yeercaud in the Salem district and Kolli Hills in the Namakkal district, a 55,000 ton-per-year alumina refinery, a 29,500 ton-per-year aluminum smelter and a captive coal-fired power plant. [179]

Balco was incorporated in 1965 as a public sector undertaking – the first vertically integrated aluminum company in India and the first to have a captive power plant. [180]

Balco commissioned a 10,000 ton-per-year smelter in 1975. [181] The government of India divested 51% of its equity in Balco in 2001 in favor of Sterlite Industries Ltd. and retained a 49% stake in Balco. The company's bauxite operations included the 7.5 million ton-per-year mine at Mainpat and the 12.5 million ton-per-year mine at Kawardha. The 100,000 ton-per-year smelter at Korba in Chhattisgarh began operating with Soderberg technology and was later expanded to 345,000 tons per year using prebake technology. A new 245,000 ton-per-year smelter was built in 2004, and plans were in the works in 2016 to build a 550,000 ton-per-year smelter. The company owned captive coal-fired power plants at Jamnipali, Korba and at the smelter site. New power plants were under construction or partially operating. [182]

Nalco formed in India under the government's Ministry of Mines on Jan. 7, 1981. The company's Panchpatmali Hills open-cast mine in Orissa, operating since November 1985, held an estimated 310 million tons of bauxite. Nalco started operating a 218,000 ton-per-year smelter in 1987 with collaboration from Pechiney. [183] Plans were in the works to increase capacity to 460,000 tons. Nalco was one of the largest vertically integrated aluminum producers in Asia in 1987. The Indian government held an 87.15% stake in the company. [184] The Panchpatmali mine produced 6.8 million tons of bauxite in 2016. Nalco's 2.2 million ton-per-year alumina refinery was located at Damanjodi, about 10 miles from the bauxite mine. Nearly all the alumina was used at Nalco's 460,000 ton-per-year smelter at Angul. The molten metal was used to produce ingots, sow ingots, T-ingots, billets, wire rods, cast strips and alloy ingots. Nalco acquired and merged with International Aluminium Products Ltd. to create a 50,000 ton-per-year export-oriented rolled-products unit. By 2016, Nalco had formed a joint venture with the Nuclear Power Corporation of India Ltd. to build a 1,400 megawatt nuclear power plant to power its aluminum facilities. [185] In early November 2002, Alcoa was negotiating for a 29% stake in the Nalco smelter. Other companies interested in the smelter included Glencore, Alcan, Pechiney, Rusal, Hindalco and Sterlite Industries. [186]

In 1970, India's five smelter plants produced 175,000 tons per year, making India the ninth largest aluminum producer in the non-Communist world. Global primary aluminum smelter capacity was estimated at the time at 11.4 million tons. [187] By the 1980s, India was a medium-sized bauxite miner and alumina refiner. Expansion projects were in the works that were expected to be completed in the 1990s. Four integrated companies produced aluminum in India – Nalco and Balco, both owned by the government; Indalco, partially owned by Alcan; Hindalco, at one time partially owned by Kaiser; and Malco, which had a refinery and smelter but no mines. [188] By 1996, there were seven aluminum smelting plants in India with a total capacity of 650,000 tons per year. [189]

In April 2003, India's alumina producers were considering exporting to China. India had six refineries capable of producing 2.7 million tons of alumina per year but only 700,000 tons per year of smelter capacity, leaving a substantial surplus. Chinese aluminum producers were expected to produce 6 million tons of aluminum per year by 2005, but China already imported about 3.35 million tons of alumina per year. India had large reserves of high quality bauxite estimated at more than 3 billion tons, ranking India at number five in the world. Bauxite reserves had been recently discovered in Andhara Pradesh and Orissa. More than 70% of India's bauxite was located in those two states. [190] In November 2006, it was reported that Alcoa was considering building an aluminum smelter in Orissa. High-placed Indian government officials confirmed that Alcoa personnel were taking stock of Indian bauxite supplies and mining regulations. [191]

By 2008, the five major players in the Indian aluminum industry had shrunk to three – Hindalco, operating under the name Aditya Birla Group, along with Balco and Nalco. Indal had merged with Hindalco, and Malco had been acquired by Sterlite Industries, which already owned Balco, under the larger name Vedanta. India's five smelters were controlled by two private groups and one public sector unit. The three-company oligopoly in India was the result of several factors – economies of scale, capital investments, time required to set up, control over bauxite mines, scarcity of power, environmental regulations, difficulty finding available land for a greenfield project, and locating plants near bauxite reserves. Each of India's smelters had its own captive power unit, providing relatively inexpensive and uninterruptible power. India was the fifth largest aluminum producer in the world in 2008 and held about 5% of the world's bauxite reserves – about 3 billion tons out of 65 billion worldwide. India produced about 2.7 million tons of alumina, out of 58 million tons worldwide. Most of India's bauxite mines were located in Bihar, Karnataka and Orissa. Balco was partially integrated, with two bauxite mines, one refinery, two smelters, a fabrication facility and two captive power plants at Korba in central India. Malco was fully integrated with two bauxite mines, a captive power plant, and refining, smelting and fabrication facilities at Mettur in southern India. Malco's primary products were ingots, rods and rolled products. Balco's and Malco's smelters together produced 380,000 tons in 2007, slightly more than rated capacity. Plans were in the works for a new 500,000 ton-per-year smelter in Jharsuda, Orissa, to be operational by 2009. [192]

On June 8, 2015, it was reported that the Indian aluminum industry planned to increase production despite the fact that surplus Chinese aluminum was coming into India. In early June 2015, Nalco announced plans to build a 1 million ton-per-year $860 million alumina refinery in Odisha using bauxite from one of the company's mines. Nalco also planned to sell 50,000 tons of aluminum per year to Angul Aluminium Park, a joint venture between Nalco and the Industrial Development Corporation of Odisha.

Meanwhile, Sterlite planned to increase capacity at its Jharsugda smelter plant in Odisha. Sterlite was operating at 25% of installed capacity because of problems obtaining sufficient electrical power and bauxite. Hindalco already had been increasing smelting capacity by 720,000 tons per year since April 2013. The company said it was trying to fill gaps left by smelters that closed in North America, Australia and Europe. Indian exports of aluminum had significantly increased in recent years as domestic consumption fell because of depressed economic conditions. [193] By 2016, India retained its position as fifth largest aluminum producer in the world, with about 2.7 million tons per year, about 5% of global production. The growth of the Indian smelting industry took off starting in 2006, when the nation produced 1.1 million tons. Much of India's aluminum production was for export – domestic consumption was very low, less than 1 kilogram per capita compared to 25 to 30 kilograms in the U.S. and Western Europe. [194]

Aluminum investments in Iceland

Iceland, which until the 20th century was the poorest country in Europe, offered an unusual opportunity to aluminum producers – abundant and untapped geothermal and hydropower resources. The small island country had been dependent on fishing and farming for centuries. An aluminum smelter in Straumsvik near Halnarfjordur was established in 1969 with a capacity of 33,000 tons per year. Over the years, capacity was increased to about 189,000 tons per year, and Rio Tinto took over ownership. [195] In November 1997, Columbia Ventures Corporation announced that financing and construction of its $110 million Nordic Aluminum Corp. (Nordural) aluminum smelter in Grundartangi, Iceland, was about half complete and a buyer for the plant's entire output was lined up. The 60,000 ton-per-year smelter would employ about 120 workers and produce about $100 million worth of aluminum a year. The company had initially proposed building a smelter in either Iceland or Venezuela in 1995. Columbia Ventures President and CEO Ken Peterson was the founder of the Columbia Aluminum Corp., which resurrected the idled aluminum smelter in Goldendale, Wash., in the late 1980s. He was ousted from Columbia Aluminum in 1995 when the company was reorganized under an employee stock-ownership plan and his proposal to build smelters in foreign locations was not appreciated. The reorganization, however, left Peterson with ownership of Columbia Aluminum's recycling, anodizing and extrusion businesses and more than $70 million in cash, which became the core of Columbia Ventures launched by Peterson in May 1996. [196]

The Nordural smelter was completed and operational in 1998, powered by hydropower and geothermal energy. The plant increased its production capacity by 50% in 2001. [197] Peterson raised $165 million from a syndicate of European banks for the expansion. [198] In March 2004, Century Aluminum announced it had agreed to pay $75 million for a

49.9% stake in the Nordural smelter. Century expected to eventually acquire the rest of the 90,000 ton-per-year plant for a total of $150 million. Nordural, which had $190 million in outstanding debt, had planned to double the smelter's capacity to 180,000 tons per year by 2006. The Icelandic smelter was considered a good acquisition because of its cheap hydroelectric and geothermal power. [199] In November 2004, Century Aluminum announced plans to increase capacity at the 90,000 ton-per-year Nordural plant by 122,000 tons per year. The additional capacity would cost $454 million and was expected to be online by October 2006. Following completion of the expansion, the plant would have infrastructure in place for another 260,000 ton-per-year expansion in the future. [200] In 2012, the Nordural plant produced 280,000 tons of primary aluminum worth $610 million. In October 2013, Nordural announced the start of a five-year project to increase production by another 50,000 tons per year. [201]

Norsk-Hydro considered building an aluminum smelter on the east coast of Iceland in a joint venture with the Icelandic government in mid 1999, but a version of the plan ended up in the hands of Alcoa instead. [202] On Jan. 10, 2003, Alcoa announced plans to build a 322,000 ton-per-year aluminum smelter in eastern Iceland. The $1.1 billion Reydarfjordur facility, which Alcoa claimed would be the most environmentally friendly aluminum smelter in the world, would begin production in 2007 and provide 750 jobs. The project was part of a much larger overall economic plan by the Icelandic government. The plant would be about 25% smaller than originally planned and there would be no onsite disposal of spent potliner. Alcoa was looking at ways to meet its goal for zero process-water discharge. Carbon anodes would not be manufactured at the plant. Alcoa claimed carbon dioxide emissions would be 25% less than an earlier plan, perfluorocarbon emissions would be 40% less and nitrogen oxide emissions would be 80% less. [203]

Alcoa entered into a 40-year long contract with Iceland's national power company for the Reydarfjordur smelter. In the largest construction investment in the nation's history, Iceland borrowed $1.5 billion to build a hydroelectric facility to provide 4,600 gigawatt-hours for the new smelter. The government had been trying to bring aluminum companies to the island since the 1960s to make use of abundant hydropower opportunities. The country's fishing industry had been set back by overfishing and new quotas. By 2006, the 690-megawatt 650-foot high Karahnjukar Dam blocked the Jokulsa a Dal River to provide hydroelectric power for Alcoa's smelter. Alcoa implemented its new "Sustainability Initiative" at the 344,000 ton-per-year Reydarfjordur smelter, which was intended to be the most efficient, safe and eco-friendly aluminum smelter in the world. Groups including businesses, government, churches, communities and the power company devised standards for Alcoa to abide by, including raising the standard of living of residents in the area. [204]

Reydarfjordur was Alcoa's first greenfield smelter in 20 years and became Alcoa's second largest smelter. The Karahnjukar Dam was the largest concrete-faded rock-filled embankment dam in the world, and it drew much criticism from environmental groups. Iceland used its surplus hydroelectric capacity to provide power to three aluminum smelters which produced up to 820 million tons of aluminum per year for Alcoa and Rio Tinto. In 2006, Alcoa and Iceland signed an agreement to investigate the feasibility of constructing a 250,000 ton-per-year smelter in Bakki in northern Iceland. The project was dropped because of the availability and cost of proposed power. [205] In July 2003, the Russian-Icelandic aluminum company Atlantsal announced plans to build a 360,000 ton-per-year aluminum smelter in Iceland at Husavik that would be in production by 2006. The company set aside plans to build a 2 million ton-per-year alumina refinery in Iceland after its partner, Rusal, made plans for other projects. Atlantsal began environmental research into the smelter project in 2002 and hoped to begin construction in 2004. Atlantsal was 80% owned by Transal of Britain and 20% owned by the Icelandic engineering firm Altech. The company planned to use geothermal and hydroelectric power for the smelter. [206] The Atlantsal project was never built. By 2016, three aluminum smelters were operating in Iceland, giving the nation a total capacity of 800,000 tons per year and 11th place in the global aluminum production. [207]

The Middle East's giant plants

The vast amount of Middle Eastern natural gas was another untapped energy resource suited for aluminum smelting. The 150,000 ton-per-year Alba aluminum smelter began operating in Bahrain on the Persian Gulf in the early 1970s. It was followed by the Dubai Aluminium Co. (Dubal) smelter of similar capacity in Dubai. Both smelters continued to expand. In 2002, the Alba smelter produced 514,000 tons per year, and Dubal produced 536,000 tons per year with plans to expand 39% to 1.46 million tons by 2006. [208] In 1979, the 1 million ton-per-year Jebel Ali aluminum smelter began operating in Dubai powered by a 2,350 megawatt power station. The facility was operated by Dubal, a subsidiary of Emirates Global Aluminium, which owned and operated the 1.3 million ton per year Al Taweelah smelter facility in the United Arab Emirates that was commissioned in 2009. Emirates Global Aluminium had a combined aluminum production of 2.4 million tons per year, ranking the company in the top-five primary aluminum producers in the world. [209] By November 2001, the Dubal smelter in Dubai and the Alba smelter in Bahrain boasted the lowest aluminum-smelting costs in the world. The average aluminum smelting cost worldwide was about $1,100 per ton, but Dubal and Alba averaged between $750 and $800 per ton. Dubal and Alba claimed the cost of electricity accounted for only 12% to 15% of their production cost, compared to an average of 20% to 30% around the world. The Persian Gulf states accounted for

about 4% of world aluminum production in 2001, and feasibility studies were being conducted for future aluminum plants in Saudi Arabia, Qatar, Kuwait and Oman. [210]

On May 25, 2003, plans were announced for a $2.1 billion aluminum smelter to be built in Qatar in a joint venture of Dubal and United Development Co. of Qatar. The smelter would initially produce 516,000 tons per year with the potential of increasing to 1 million tons. The smelter would be located near the largest natural gas field in the world and powered by a gas-fired generating plant supplied by a joint venture between Qatar Petroleum and Exxon. Meanwhile, the Dubal aluminum smelter in Dubai was scheduled for expansion to 710,000 tons per year by 2006, and the Alba smelter in Bahrain was scheduled to expand to 750,000 tons per year by 2005. [211] Dubal announced in November 2006 that it had started construction of the world's largest aluminum smelter, with a capacity of 1.4 million tons per year when built out. [212] In 2010, Norsk Hydro joined Qatar Petroleum in a 50-50 joint venture to build the largest aluminum plant ever built in a single phase. The 585,000 ton-per-year Qatalum smelter started operating in September 2011 using power from a 1,350 megawatt natural gas power plant. [213]

Large aluminum projects were also planned in Saudi Arabia. In March 2009, Rio Tinto Alcan announced two agreements had been signed with the Saudi Arabian Mining Co. (Ma'aden) for a $10.5 billion mine-to-metal aluminum project in Zubairah, in the Qassim province of Saudi Arabia. The Ras al Zour complex would include an alumina refinery and an aluminum smelter. Plans called for commercial production by 2012, with more than 70% of the output for export. Rio Tinto would provide technical services, personnel, research and development assistance, management services and aluminum off-take support. Maaden originally agreed to undertake the project with Alcan, but Rio Tinto acquired Alcan in 2007, and the global financial crisis following the 2008 Wall Street meltdown threw much of the plans into doubt. In December 2008, Rio Tinto announced it would cut 14,000 jobs worldwide and slash investment budgets for 2009. [214]

The Ma'aden project was taken up by Alcoa, which began construction of the enormous aluminum facility in 2010. The project included a bauxite mine, alumina refinery, aluminum smelter and rolling mill with an ocean-going shipping terminal. [215] In full operation, about 4 million tons of bauxite per year would be transported from the bauxite mine at Al Ba'itha by rail about 372 miles to the 1.8 million ton-per-year alumina refinery at Ras Al Khair. Alumina from the refinery would go to the nearby 740,000 ton-per-year smelter, and produced metal would go to the nearby 380,000 ton-per-year rolling mill. The facility, which also included a 120,000 ton-per-year aluminum recycling plant, was expected to be the lowest cost aluminum complex in the world. [216] The

smelter ran into a few technical glitches when starting up in 2014, but it produced more aluminum than in its initial capacity forecast by May 2014. The refinery was producing up to 60% of capacity by then, and about 70% to 80% of the smelter's production was being exported. Alcoa owned about 25% of the $10.8 billion aluminum project. [217]

South America's rise and fall

South America held two key natural resources for aluminum production – large reserves of bauxite along with abundant hydropower potential. Most of the bauxite from British Guiana and Dutch Guiana was exported with some going to a local alumina refinery. In the case of Venezuela, attempts were made to establish vertically-integrated facilities. The Venezuelan government obtained or established numerous mining enterprises in the 1970s as a way to promote heavy industrial development in the country. By the 1980s, however, large debts incurred by these ventures led to the government's decision to consider new policies restricting foreign investment while at the same time liberalizing mining laws to encourage private-sector mining. The country's major regional development corporation, the Corporation Venezolana de Guayana (CVG), continued to enter into joint ventures, and by the 1990s the company had for the first time agreed to accept a minority role in some projects. Significant increases in capacity took place in the 1980s, and aluminum exports became the country's second leading foreign exchange earner. By 1990, Venezuela had the largest installed capacity for aluminum smelting in all Latin America. With its high-quality bauxite reserves, abundant and cheap energy, and well-developed infrastructure, Venezuela was considered the most economical aluminum producer in the world. Venezuela's proven bauxite reserves in 1990 were 500 million tons, with probable reserves as high as 5 billion tons. With 1,500 small foundries and several large smelters combined, Venezuela produced about 443,000 tons of primary aluminum in 1988. About 60% was exported, worth $1 billion. The Alcasa smelters at Ciudad Guyana and Guacara had a 120,000 ton-per-year capacity by 1990, and Alcasa had plans to double that in the 1990s to as much as 300,000 tons. [218]

Venezuela got into bauxite mining in 1987 with the opening of the Bauxiven mine, owned by CVG and Alusuisse. The bauxite mine was rated at 4 million tons per year at full capacity, which would make Venezuela the world's fifth largest bauxite producer. Interalumina, owned by CVG and Alusuisse, ran Venezuela's sole alumina refinery. Two adjacent smelters included one run by Vanalum, owned by CVG and a consortium of six Japanese companies, and another run by Alcasa, owned by CVG and Reynolds. An aggressive expansion program was underway in Venezuela, with plans for expanding facilities and building new plants. If completed, smelting capacity could reach 1.4 million tons per year by 1994, making Venezuela one of the top three or four aluminum

producing countries in the nonsocialist world. [219] But economic and political problems stalled further development in Venezuela.

In March 1998, a consortium of aluminum companies interested in acquiring a large aluminum smelting complex in Venezuela was reconsidering whether to bid at all. The consortium consisted of Billiton, Pechiney, Century Aluminum and both Sural and Alentuy of Venezuela. The CVG facilities had a smelting capacity of 640,000 tons per year but were suffering from labor difficulties and high debt levels. [220] In June 1998, a consortium of aluminum companies led by Kaiser sent a letter to the president of the Venezuelan Investment Fund stating their intent to bid for acquisition of the four CVG aluminum plants. The Kaiser consortium included Kaiser, Daewoo, Inelectra, Ormet, Alumax, Comalco, Mitsubishi, Marubeni, Mitsui, Samsung and Glencore. Alcan, Alcoa and a partnership of Norsk Hydro and Reynolds had all withdrawn from the bidding process earlier, a severe blow to the government. The president of the Venezuelan Aluminum Industry Association called for legal action to be taken against Alcoa for using false pretenses for withdrawing. [221]

In July 1999, a possible alliance emerged between Alcoa, Pechiney and Billiton aimed at purchasing the CVG-Bauxilum bauxite and alumina facility. At the same time a possible partnership between Glencore and an unnamed Slovakian company were looking at investing in the CVG-Alcasa aluminum smelter. The effect of both joint ventures would be to break up the state-owned CVG aluminum operations. [222] In January 2000, the Venezuelan government attempted once more to privatize its state-owned aluminum plants. Several options were considered, including breaking up the group into smaller producers. The Venezuelan Aluminum Corporation included the aluminum smelters CVG-Alcasa and CVG-Venalum, the alumina refinery CVG-Bauxilum, the anode producer CVG-Carbonorca, and the hydroelectric power company CVG-Edelca. The first plant expected to be privatized was the port facility at CVG-Alcasa. [223] By 2014, aluminum production in Venezuela had fallen to its lowest level in three decades as a result of limited investment, aging machinery and chronic labor conflict, according to the Venezuela industry ministry. Production at the state-run Venalum aluminum smelter fell 14% from 2013 to 109,536 tons, and the company acknowledged in March 2015 that it could no longer meet purity standards because of its deteriorating financial situation. Production in 2014 at the CVG-Alcasa smelter reached only 17% of the plant's 170,000 ton-per-year capacity. [224]

Alcoa's first venture into Brazil took place in the 1960s when it bought a bauxite mining operation in Pocos de Caldas in the state of Minas Gerais. The bauxite operation there had been in operation since 1930. Alcoa organized Compania Mineira de Aluminio in 1967 to operate the resources at Pocos de Caldas. By 1970, Alcoa had a primary

aluminum operation in the area on a plateau about 115 miles from Sao Paulo. In 1980, Alcoa developed an ambitious alumina and aluminum complex on the island of Sao Luiz in Brazilian state of Maranhao called Alumar. [225] In 1979, the Mineracao Rio do Norte bauxite mine started operating in northern Brazil, marking a movement away from bauxite mining in the Minas Gerais area in southern Brazil, which had more limited reserves. At that time, Brazil had 260,000 tons per year of smelting capacity, and about 15% of the alumina supply for the smelters was imported. With the Mineracao Rio do Norte mine operating, several large alumina refining and aluminum smelting plants were built in the 1980s. [226] Global bauxite reserves in 1991 were estimated at 23 billion tons. Guinea and Australia each had about 24% of the total reserves, followed by Brazil at 12.8%. [227]

By mid-1993, Brazil's smelting capacity had increased to 1.2 million tons per year. By 1995, Brazil was the world's third largest bauxite producer, accounting for about 10% of the world total. Reserves were estimated at 2.7 billion tons, about 11% of the world's reserves, of which 95% were located in northern state of Para. In 1995, about 6 million tons of bauxite was exported from Brazil every year. Brazil was also the world's fifth largest aluminum producer and sixth largest exporter of aluminum ingots, semi-fabricated and fabricated products. Alunorte planned to increase alumina refining capacity from 1.8 million tons per year to 2.9 million, eliminating the need to import 700,000 tons per year of alumina. The increased alumina refining would require increasing bauxite mining to about 2.3 million tons. The Mineracao Rio do Norte bauxite mine was expected to increase production from 8.5 million tons per year to 12 million. The Brazilian aluminum industry was strongly affected by international prices and domestic energy prices, and the cost of electrical power in Brazil was relatively high at $28 to $32 per megawatt-hour compared to $10 in Canada, $15 in Norway and $16 in Australia. [228] In July 1999, Norsk Hydro was close to acquiring a 25.3% stake in the Alunorte alumina refinery. The plant had an annual capacity of 1.5 million tons of alumina per year and had one of the lowest conversion costs in the world. [229] Power problems became more severe by May 2001 when Alcan announced it curtailed production at its smelters in Brazil by 12,000 tons per year. The Brazilian government asked major power users to cut back on power consumption by 18%. Alcoa cut production at its Pocos de Caldas aluminum smelter by 25%. On June 28, the Brazilian highest court ruled that the government's energy-rationing program was constitutional, and three days later Alcoa announced a 63% curtailment at its 54%-owned Alumar smelter. [230]

By 2013, Brazil was the ninth largest producer of primary aluminum in the world, behind China, Russia, Canada, the United Arab Emirates, Australia, the U.S., India and Norway. Brazil was the fourth largest bauxite producer, behind Australia, Indonesia and China.

Brazil was the third largest alumina producer, behind China and Australia. Brazil produced 1.3 million tons of aluminum and consumed 1.5 million tons. The country produced 33 million tons of bauxite and exported 8.4 million tons, and it produced 9.9 million tons of alumina, consuming 2.6 million tons and exporting 7.1 million tons. [231] The Brazilian aluminum industry took a downturn after that. Alcoa announced in March 2014 that it would curtail 147,000 tons of smelting capacity at its Sao Luis and Pocos de Caldas plants. The company cited increased costs and challenging global aluminum prices. "Across the globe, we are taking measures to curtail high cost smelting capacity that is not competitive and reshape our cost profile," said Bob Wilt, president of Alcoa Global Primary Products. [232]

In April 2015, Alcoa announced plans to completely close down its Alumar smelter. This marked the fifth and largest smelter to be closed permanently in Brazil since 2009, a significant change for a country that had once been among the world's top aluminum producers. The Alumar plant started operating in 1984 with a single 127,000 ton-per-year potline. Alcoa was attracted to the area because of abundant hydroelectric power opportunities. Compulsory power rationing in 2001 was a sign of things to come, but Alcoa and its minor-partner Billiton had installed a third potline in 2006. However, by 2013 the plant was the most expensive Alcoa smelter, and the company began to curtail production. The Pocos de Caldas smelter in the southern state of Minas Gerais was Alcoa's first smelter in Brazil, starting up in 1970, but it was closed down permanently in May 2014. The Valesul smelter in Brazil closed in 2009, the Aratu plant closed in 2010, and the Ouro Prato plant closed in 2014. That left only two smelters operating in 2015 – Norsk Hydro's 460,000 ton-per-year plant in Albras and Companhia Brasileira de Aluminio's 475,000 ton-per-year plant in Sorocaba. Total aluminum production in Brazil had fallen from 1.67 million tons per year in 2007 to 962,000 tons in 2014. The decline in production was largely attributed to rising power costs, as chronic drought impacted power production. Brazil began to import electrical power from Argentina and Uruguay in 2015. [233]

Argentina's aluminum industry grew out of a partnership in 1970 between the synthetic rubber manufacturer FATE, businessman Jose Be Gelbard and other private investors that led to the construction of Argentina's first and only aluminum smelter, in Puerto Madryn. With an exclusive license from the military regime of Gen. Alejandro Lanusse, the 140,000 ton-per-year Aluar smelter began operating in 1974 using power from the state-financed Futaleufu hydropower dam in Trevelin. Aluar invested in fabrication businesses starting in 1983. The government sold its 472 megawatt Futaleufu Dam in 1993, which doubled the available power to Aluar. The smelter expanded capacity to 275,000 tons per year in 2006 and then to 410,000 tons per year in 2008. The company employed 2,200 workers. [234] By 2015, as other South American aluminum plants cut

back production because of labor or drought, Aluar continued to operate after securing a new power contract. Overall, South America was once a major metal exporter, but it had declined from a peak of 2.7 million tons in 2008 to 1.33 million tons in 2014. [235]

Africa's aluminum industry

The aluminum industry in Africa began with bauxite mining. Lawrence Litchfield, head of Alcoa's bauxite operations, contracted to enter a consortium of French, Swiss and Canadian companies to mine bauxite in Guinea in 1957. [236] In 1968, Harvey Aluminum, operating under the name Halco Mining, joined with Alcoa, Alcan, Aluminum Canada and Compagnie des Bauxites de Guinee to finance a bauxite mine in the Boke region of Guinea. The government of the Republic of Guinea participated by taking out loans from the World Bank and the Agency for International Development to construct infrastructure. [237] During the 1980s, Guinea ranked second in the nonsocialist world for bauxite production, but it had little refining or smelting capacity. About two-thirds of the bauxite came from the Sangaredi-Boke mine, which was owned by the government, and Halco, a consortium composed by then of Alcoa, Alcan, Pechiney, VAW, Comalco, Aluminia SpA, Reynolds and Billiton. Most of the bauxite was exported on long-term contracts to Europe and the U.S. The Endasa refinery in Spain and the Aughinish refinery in Ireland were major recipients. The second largest mine in Guinea was the Debele, which was operated by the Guinea government but financed by the Soviet Union, which took much of the bauxite on a barter arrangement. Friguia, owned by the Guinea government and a consortium of Noranda, Pechiney, British Alcan, Alusuisse and VAW, ran a mine and the country's only alumina refinery. The sole bauxite producer in Sierra Leone was owned by Alusuisse. [238]

In March 2004, the Guinea Aluminum Products Corp. announced plans to spend $2 billion building a 2.6 million ton-per-year alumina refinery. The project, which included building a power generating plant and upgrading railroad and port infrastructure, would be located in the Boke region of Guinea near one of the largest bauxite reserves in the world, estimated at 7.4 billion tons of high quality bauxite. Strong demand and tight supplies in the world market drove alumina prices up from $160 per ton in late 2002 to $500 per ton in 2004. [239] On May 13, 2004, Alcoa and Alcan officials announced an interest in jointly developing a 1.5 million ton-per-year alumina refinery in the Boke area. Through subsidiaries, Alcoa and Alcan owned 49% of Halco Mining Inc., which in turn owned 51% of Compagnie des Bauxites de Guinee, which held exclusive rights to bauxite reserves and resources across 10,000 square miles of land in the Boke region through 2038. The government of the Republic of Guinea held the remaining 49% of Compagnie des Bauxites de Guinee. [240]

The Republic of South Africa lacked bauxite reserves and had no alumina refineries, but BHP Billiton operated two aluminum smelters at Hillside and Bayside in Richards Bay. The 195,000 ton-per-year Bayside smelter began operating in 1971 and shut down in 2014. Construction of the Hillside Aluminium smelter began in 1993. The first metal was cast in June 1995, and Hillside achieved its first million tons of ingots in January 1998. Hillside expanded with a further half-potline in February 2003, bringing the total capacity to 710,000 tons per year. First metal was poured from this half-potline in October 2003. South32, which was spun out of BHP Billiton in May 2015, owned and operated the Hillside smelter as well as held an 86% interest in the Worsley Alumina bauxite mine and alumina refinery in Australia. [241]

BHP Billiton next turned north for a new African smelting project. In 1998, a joint venture emerged between BHP Billiton, Mitsubishi, the Industrial Development Corp. of South Africa and the Government of Mozambique to build an aluminum smelter in Mozambique. The first primary aluminum was cast at the new Mozal smelter in June 2000. The new smelter had 288 reduction cells, and production would be gradually raised to 250,000 tons per year. It took 25 months between start of construction and first metal casting, six months ahead of schedule, believed to be a world record for a greenfield smelter of that size. At $1.3 billion, the Mozal smelter was the largest single investment in Mozambique history. More than 9,000 workers were at the construction site, of which 64% were Mozambicans. Power consumption when Mozal was fully on line would be 450 megawatts, compared to 220 megawatts for the rest of the country. [242]

In February 2002, BHP Billiton announced that construction synergies in the $1.2 billion expansion of the Mozal 2 aluminum smelter in Mozambique and the Hillside 3 aluminum smelter in South Africa would result in significant cost savings. The Hillside smelter was expected to be the largest smelter in the southern hemisphere, with Mozal coming in third. [243] The first aluminum was cast at the Mozal smelter in April 2003. In the first phase, the $860 million plant would be capable of producing 253,000 tons of aluminum per year, but the final phase called for a $1.3 billion plant producing 506,000 tons per year. Together, the Hillside and Mozal smelters accounted for 5% of the world's aluminum production. Pechiney had expressed interest by 2003 in building a $1.6 billion aluminum smelter in the same area near Port Elizabeth, South Africa, using the same cheap power available to the area. [244] The second phase expansion at the Mozal smelter was completed in 2004. The aluminum smelter employed 1,024 workers, accounted for about 30% of Mozambique's export earnings and used about 45% of the country's electrical production. In February 2013, Mozal agreed to supply 50,000 tons per year to Midal, one of the world's largest manufacturers of aluminum cables, with a factory set up in Mozambique. Until then, all the Mozal aluminum had been exported. [245]

In 1928, only 10 countries in the world produced aluminum, and only the U.S., the Soviet Union and Canada produced substantial amounts. In the 1970s, fifteen countries produced at least 100,000 tons of primary aluminum per year. [246] By 2016, global production by 237 primary aluminum smelters in 45 different countries had grown to 49.3 million tons per year. [247] Through the 20th century and especially after World War II, bauxite mines, alumina refineries and aluminum smelters were established across the globe – in North, South and Central America, in Europe and Asia, and in Africa and Australia. Aluminum companies built refineries in underdeveloped tropical countries near bauxite mines and built smelters anywhere plentiful electrical power was available – whether it was powered by dams, coal, natural gas or even nuclear. Aluminum smelters can be found on mountainous island countries like Iceland and New Zealand and in Middle Eastern desert countries like Egypt and Saudi Arabia. Countries that had little global economic presence before World War II grew into powerhouses that took the top spots in aluminum production – China, Russia and India – while the U.S., which had dominated the industry for a century, shut down smelter after smelter in the 21st century.

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