



HYDRO

Aluminium,

*environment
and society*





Foreword

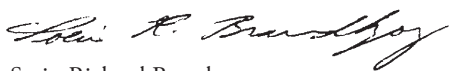
Hydro's mission is to create a more viable society by developing natural resources and products in innovative and efficient ways. Throughout Hydro's more than 100 years history we have developed businesses that begin by harnessing vital natural resources and end in benefits to the everyday lives of people around the world. We continue to improve the production of durable goods through innovative uses of aluminium.

We have a responsibility in making a conscious effort to balance the need for profit with the needs of society. We believe business demands and societal demands are inseparable and interdependent. We cannot have true, long-term business success without societal success.

Any extraction of raw materials and all production processes entail some degree of impact, on the environment and on societies, and the use of non-renewable resources which remain vital for future generations. Aluminium production is no exception.

These are challenging issues both from a scientific and an ethical point of view. Facing the issues challenges our values. Some values are universal, while others are not. Values cannot be discussed without a basis in facts. This booklet intends to be a contribution to the fact basis and a contribution to the debate on how we shape our future.

We believe that aluminium is an important part of that future.



Svein Richard Brandtzæg
President and CEO

Oslo, December 2012



**INFINITE
ALUMINIUM**

Aluminium,
*environment
and society*

CONTENTS

Foreword	2
1. Why aluminium?	6
2. Life cycle aspects of aluminium	10
3. Benefits of using aluminium	12
4. Aluminium recycling	18
5. Production of aluminium	24
6. Fabrication of aluminium products	40
7. Aluminium and health	42
8. Social issues	46
9. Research, education and international cooperation	50
10. Hydro's environmental strategy	52

1 WHY ALUMINIUM?

HIGHLY CORROSION RESISTANT

EASY TO FORM AND PROCESS

STRONG AND LIGHT

ABUNDANT RESOURCES



GOOD REFLECTIVE QUALITIES

IMPERMEABLE, NON-TOXIC AND ODOURLESS

GOOD CONDUCTIVITY

NON-COMBUSTIBLE

EASY TO RECYCLE

1 WHY ALUMINIUM?

Aluminium is present almost everywhere around us in a vast number of applications. We may not even be conscious about its presence, but we would definitely miss it.

The use of aluminium has many advantages, including from an environmental perspective. These are related to the metal's properties which benefit today's society:





STRONG AND LIGHT

Aluminium is a very light metal, with a specific weight of 2.7 (g/cm³), which is one-third of that of steel. The strength of the metal can be increased by adding small quantities of other metals (alloys). The low weight reduces energy consumption related to transportation, and hence also emissions of greenhouse gases and other pollutants.

HIGHLY CORROSION RESISTANT

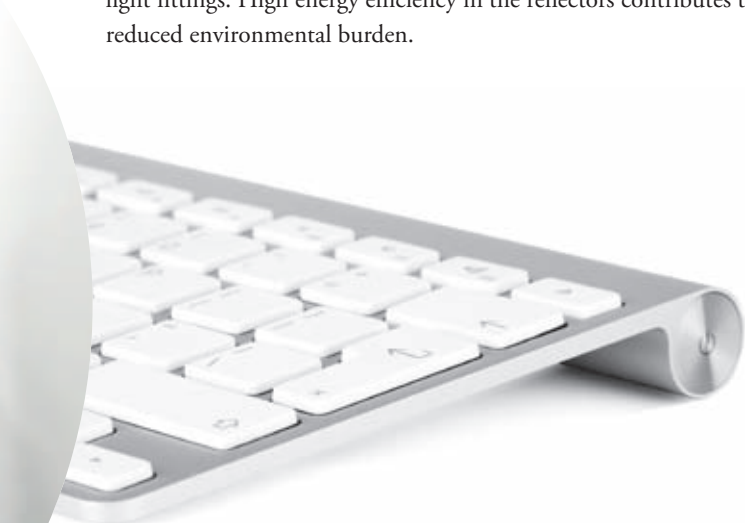
As the metal itself forms a protective oxide coating (that is immediately reformed if the metal is cut or scratched), it is highly corrosion resistant. This property can be further improved by various types of surface treatment. This property prolongs the useful life of aluminium in cars and buildings and reduces the need for maintenance. This also reduces environmental impacts related to replacement and maintenance.

GOOD CONDUCTIVITY

Aluminium is a good conductor of heat and electricity, and in relation to its weight, is almost twice as good a conductor as copper. These properties make aluminium the material of choice to achieve energy efficient systems for electrical transmission systems and other applications, such as heat transfer components.

GOOD REFLECTIVE QUALITIES

Aluminium can reflect both heat and light, and together with its low weight, makes it an ideal material for reflectors in, for example, light fittings. High energy efficiency in the reflectors contributes to reduced environmental burden.



EASY TO FORM AND PROCESS

Aluminium is ductile, and has a low melting point. It can easily be processed in a number of ways - both in a cold and hot condition. Its great ductility allows design flexibility and aluminium products to be integrated in advanced applications in transport and buildings industries.

IMPERMEABLE, NON-TOXIC AND ODORLESS

Aluminium foil, even when rolled to just a 0.007 mm thickness, is still completely impermeable and lets neither light, aroma nor taste substances in or out. Moreover, the metal itself is non-toxic, and releases no aroma or taste substances. Aluminium is therefore widely used in food and drink packaging. The efficient conservation of food reduces wastage of food, which is an important environmental and resource advantage. Furthermore, the low weight of the packaging reduces energy in transportation. The impermeability of aluminium foil also reduces cooling needs.

NON-COMBUSTIBLE

Aluminium used in buildings, constructions and transport equipment is non-combustible. It will only burn in a fine powder form or as very thin film. Aluminium will melt when temperatures exceed 660 °C - without releasing any gases.

ABUNDANT RESOURCES

Aluminium is the third most abundant element in the earth's crust, after oxygen and silicon, constituting about 7 percent by weight of the earth's crust. Bauxite is the only commercial ore used for the production of alumina today, but other sources may be feasible in the future. Known bauxite reserves will last more than 100 years at current rate of extraction.

EASY TO RECYCLE

The re-melting of aluminium requires little energy, and metal loss in the re-melting process is less than 3 per cent. Only about 5 per cent of the energy required to produce the primary metal initially is needed in the recycling process. Around 75 per cent of the aluminium ever produced is still in use, and constitutes a resource bank for use in the future.

2


LIFE CYCLE ASPECTS OF ALUMINIUM

Hydro has a long term aspiration of no net loss of biodiversity in the areas where we operate, and to develop and provide products which may contribute to reduced burden on the environment in the use phase.

Extraction of natural resources and production and fabrication of products will cause some degree of environmental disturbance. Aluminium is no exception. However, our focus is to minimize the impacts and having a longer term aspiration of no net loss for the

biodiversity and ecosystems where we operate. At the same time we strive to maximize the positive environmental contribution of aluminium used in various applications. These benefits may more than offset the initial impacts of extraction and production.





In this booklet, we will present information related to environmental and social aspects of all the steps in the value chain of aluminium, as well as some examples related to Hydro's activities and products, enabling the reader to assess the pros and the cons associated with our value chain and aluminium as a material.

A detailed scientific account of the environmental footprint of aluminium production is published by the European Aluminium Association¹⁾

3

BENEFITS OF USING ALUMINIUM

ALUMINIUM IN TRANSPORTATION

Transportation is one of the largest energy consuming sectors, using about 19 percent of the world's energy demand. Use of aluminium helps to reduce the weight of cars, buses, trucks, planes, trains and boats. When the weight is reduced, energy consumption during transport is reduced. Thus the extra energy and the extra greenhouse gas (GHG) emissions related to the production of aluminium compared to alternative materials may be paid back many times through the life cycle of the product.

Here are a few examples:

According to a study by IFEU ²⁾, each 100 kilograms of weight savings from the use of aluminium in an average family car (gasoline), amounts to an average life time fuel saving of 27.2 GJ corresponding to a reduction in fuel consumption of 800 liters. It takes about 7.7 GJ more energy to produce primary aluminium than the amount of steel it substitutes. This results in a net lifetime saving of 20 GJ, corresponding to 600 liters of gasoline.

However, aluminium in cars is to a large extent recycled metal, where the energy used for recycling loop is much less. The typical recycled content in a car is 40 percent, which means that the net lifetime energy saving is 22.7 GJ or 680 liters of gasoline. If one gives full credit to the fact that nearly all the aluminium in a car eventually will be recycled, the savings are even greater.

Similar calculations for CO₂ give a net lifetime emission saving of 1,700 kilograms of CO₂ for primary metal only and 1,950 kilograms CO₂ for a car with 40 percent recycled aluminium.

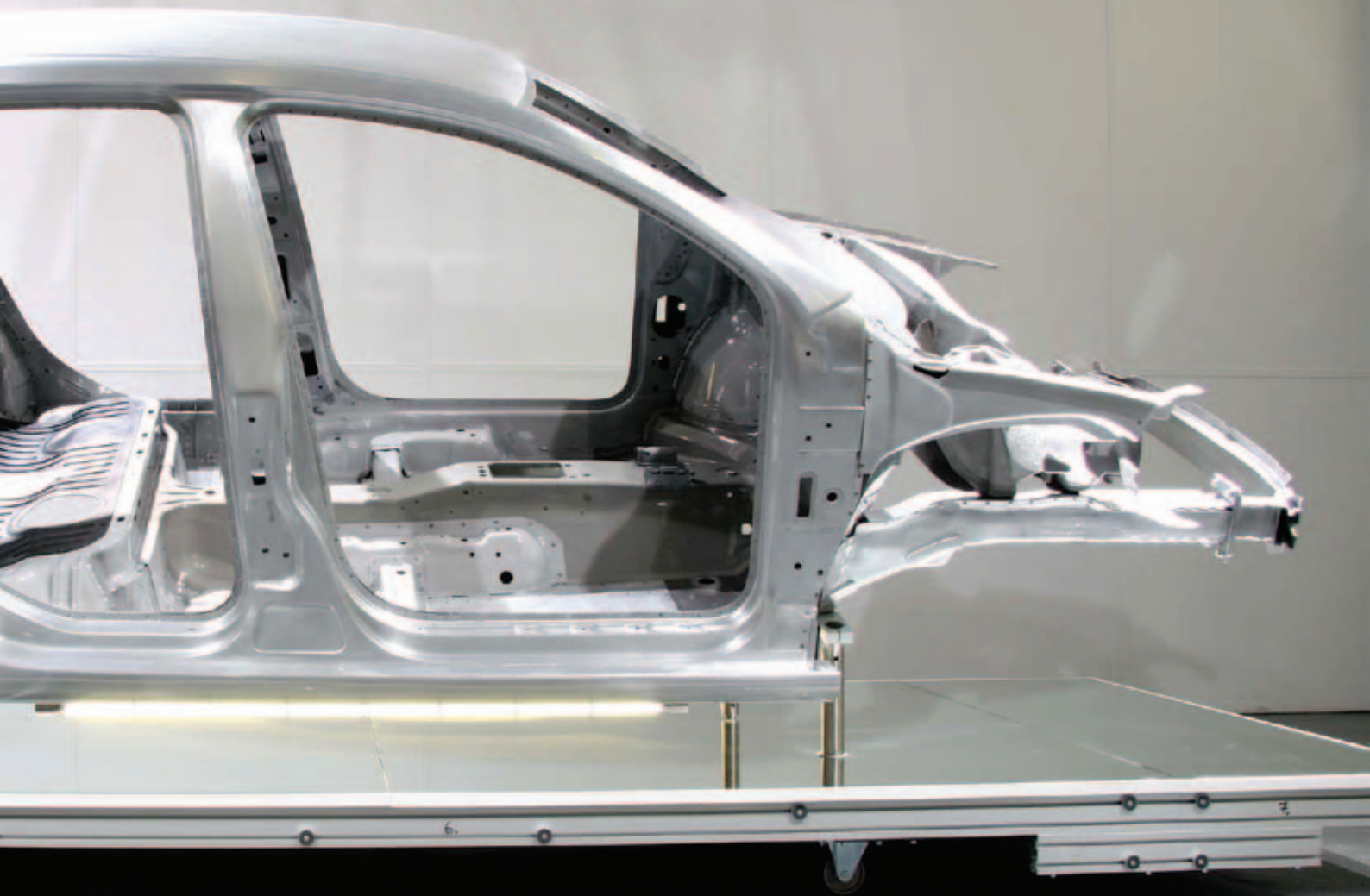
The above study also looked at the effect of light-weighting in other transportation media, such as busses, trucks, trains, air planes and ships. In many of these applications, the energy saving per kilogram weight reduction is even more pronounced. As an example, weight reduction in an aircraft has in the order of 1000 times the effect as

in an average passenger car. And this is why aluminium and other light weight materials are already extensively used in airplanes. Because of the great number of cars worldwide, the greatest global saving potential is in lightweighting the cars. Light-weighting in air crafts is already implemented to a great extent.

The IFEU study acknowledged that general technology trends are bringing the fuel consumption per km in cars down. Just replacing the current fleet of cars with new vehicles (without further weight reduction) would reduce fuel consumption by 7.5 percent. But exploring realistic potentials for further weight reduction would reduce the fuel consumption by another 3.1 percent.

On a global scale, and including similar potentials in all transport sectors, this translates to an annual saving potential of 220 million metric tonnes of CO₂. This is about four times the annual greenhouse gas emissions of Norway.³⁾

Since the IFEU study, the aluminium industry and the car makers have made further advances in finding aluminium substitution possibilities in cars. Up to 40 percent reduction of the cars body weight can be achieved by extensive use of aluminium without compromising the strength⁴⁾. This would reduce fuel consumption by 10 percent. Some car models with aluminium bodies are already in the market.



3

BENEFITS OF USING ALUMINIUM

ALUMINIUM IN BUILDINGS

Buildings are the largest energy consumer group world wide, mainly related to heating, cooling, ventilation and lighting. Buildings consume around 40 percent of the world's energy demand. Creating more energy efficient building systems is therefore fundamental to meet the challenges of climate change and the squeeze on energy resources. Aluminium has many properties that may be exploited to achieve buildings with very low energy demand, and it has even been proven that buildings may be net producers of energy.





Aluminium-based façade solutions are essential in energy-efficient buildings, where sophisticated solutions are needed. The building “skin” contains many functions, like sun shading, thermal and photovoltaic energy producers, sensors and motors, which depend on load-bearing capability.

Hydro is actively pursuing the opportunities that aluminium may have as a construction material in buildings to create innovative building designs that reduce energy demand and allows energy production and energy recovery.

The energy needed to construct an aluminium-based building (embedded energy) is higher than for most other materials. However, the embedded energy in a building is small compared to the lifetime energy consumption and small compared to the energy saving potentials. An example: using external aluminium sun blinds in buildings will reduce the cooling duty of the building. Using average German conditions, the CO₂ savings during use will exceed the CO₂ emissions related to production in less than one year, even if only primary metal is used.⁵⁾ And at the end of its useful life, nearly all the aluminium from the building may be recovered and reused.

Hydro has established a demonstration case building in Bellenberg, Germany, which has achieved net production of energy. In the period April 2010 – July 2012, the Wicona test center building has produced 108 MWh from solar panels, while its total energy consumption was 79 MWh.⁶⁾

In another demonstration project, a 5,200 square meter office building complex in Sandvika outside Oslo will be rehabilitated. Before rehabilitation, the buildings use 250 kWh/m² per year, or 1.3 GWh/year. Changing an existing building gives less architectural degrees of freedom. Still, great improvements can be made. The ambition is that the buildings will produce more energy than they consume.⁷⁾

3

BENEFITS OF USING ALUMINIUM

ALUMINIUM IN PACKAGING

Aluminium in packaging is environmentally beneficial due to weight reduction (reducing energy for transportation) and by advantageous food preservation properties. Reducing food loss due to degradation reduces the environmental foot print of food production.

Aluminium packaging consists of roughly 50 percent semi-rigid and flexible applications (menu trays and other food containers, plain foil and foil in laminates) and 50 percent rigid applications (beverage and food cans, aerosol cans, closures, tubes, etc.)

Packaging today responds to consumers' demands for choice and convenience as well as changed production and distribution conditions and systems. By safeguarding product quality, packaging allows products to be transported and distributed locally, regionally

and even globally, thereby making valuable food resources available to a wider population. In modern households, people increasingly use fully-prepared meals, canned and frozen foods, in a wide variety of portion sizes, to save time in cooking and preparing meals. Packaging makes this possible.

Aluminium packaging offers a high level of corrosion resistance. It provides optimal protection properties by offering an impermeable metal barrier to light, ultra-violet rays, water vapor, oils and fats,

CASE

CO₂-savings due to reduced cooling needs

1 kg of aluminium is enough for 650 one-liter beverage cartons, and it preserves milk or juice without cooling. Assuming average cooled storage time of 4 days, the avoided energy for cooling results in 117 grams less CO₂ emission per liter beverage. This adds up to more than 2 million metric tons less CO₂-emissions only from aluminium foil delivered by Hydro. That equals saving emissions of more than 800,000 cars a year!



oxygen and micro-organisms. When used to package sensitive products such as pharmaceuticals or food, aluminium is hygienic, non-toxic, non-tainting and retaining the product's flavor. The aluminium barrier also plays the essential role of keeping the contents fresh and protecting them from external influences, thereby guaranteeing a long shelf-life.

The main environmental benefits of using aluminium in packaging are weight reduction which reduces the energy required

for transportation and effective food and beverage preservation which reduces need for cooling and loss of food products from degradation.

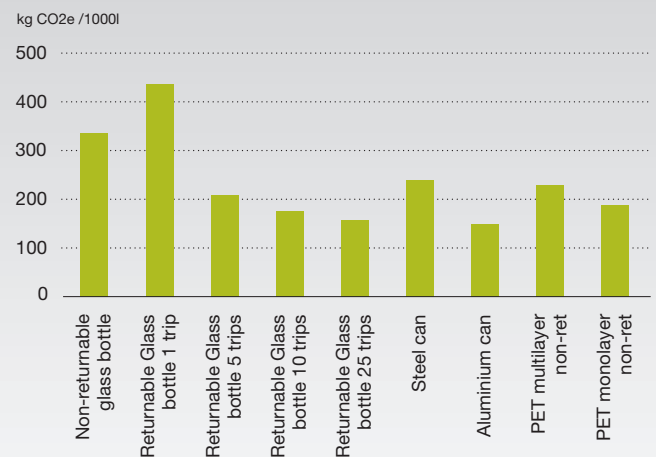
It is estimated that as much as 20 percent of the man made GHG-emissions result from food production. In Europe, one-third of all food produced is wasted. Some of this wastage is due to poor conservation of the food. Aluminium packaging contributes to reducing these losses.

CASE

CO₂-savings in transportation of beer cans vs. bottles

In a study in Germany, the CO₂-emissions related to production of beer cans or bottles, transportation of the bottles and the recycling or disposal of the empty cans / bottles were compared. With the assumptions made, the aluminium can came out with the lowest emissions. This ranking is sensitive to the recycling rate, which is high in Germany, and to the average transportation distance.⁸⁾

kg CO₂ emissions per 1000 liter beverage

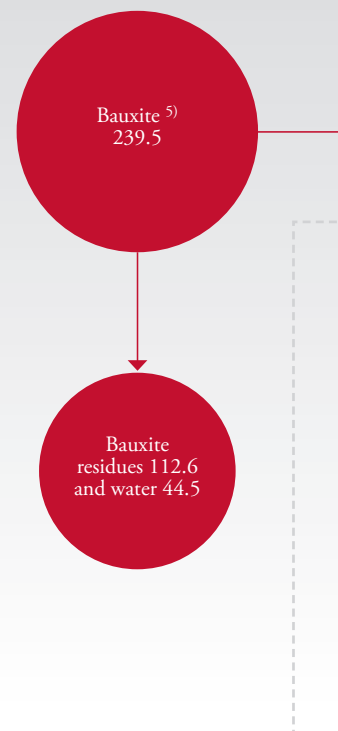


4 ALUMINIUM RECYCLING

Aluminium metal is sourced from primary aluminium and from recycled aluminium. In a resource constrained world, recycling is critical to sustainable development. It allows resources to be saved and waste to be reduced. Aluminium in use is an energy and resource bank, but due to the long life of many aluminium products, and due to growing demand, this “bank” can only supply 20-25 percent of the current demand. The rest must be produced from primary aluminium.

MATERIAL FLOW BALANCE FOR ALUMINIUM

Global aluminium flows in 2010. Taking into account the finished products entering into use (50.5 million metric tons) and the old scrap recovered for recycling (11 million metric tons), the global recycled content for aluminium is about 22 percent.



Values in millions of metric tons. Values might not add up due to rounding. * Change in stocks not shown.

- 1) Aluminium in skimmings
- 2) Scrap generated by foundries, rolling mills and extruders. Most is internal scrap and not taken into account in statistics
- 3) Such as deoxidation aluminium (metal property is lost)
- 4) Area of current research to identify final aluminium destination (reuse, recycling, recovery or disposal)
- 5) Calculated based on IAI LCI report – update 2010. Includes, depending on the ore, between 30% and 50% alumina
- 6) Calculated. Includes on a global average 52% aluminium
- 7) Scrap generated during the production of finished products from semis
- 8) Either incinerated with/without energy recovery, material recovery or disposal
- 9) Estimated stock decrease 890,000 metric tons.

(Source International Aluminium Institute IAI)

BENEFITS OF RECYCLING – AND SOME LIMITATIONS

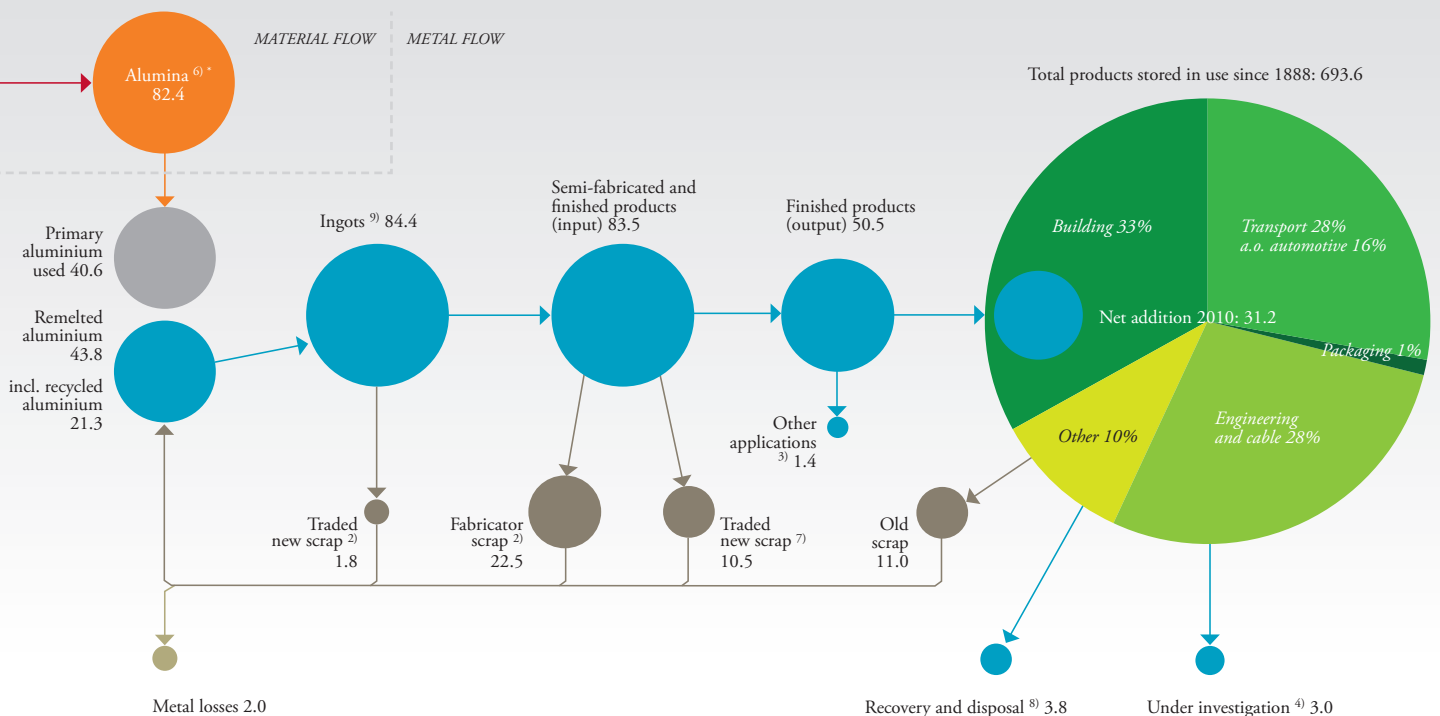
Used aluminium is valuable – it can be easily and endlessly recycled without quality loss. Aluminium recycling even benefits present and future generations by conserving energy and other natural resources. Only 5 per cent of the energy required to produce primary aluminium is needed to re-melt aluminium. In addition to the energy savings, emissions of greenhouse gases and pollutants are reduced, and encroachments in the landscape related to bauxite mining and refining are avoided. Today, recycling of post-consumer aluminium products saves over 90 million metric tons of CO₂ and over 100,000 GWh of electrical energy annually compared to primary production of the metal, equivalent to the annual power consumption of the Netherlands.

The world's increasing stock of aluminium in use acts like a resource bank, over time delivering more and more practical use and value from the energy embodied in the metal. Around 75 percent of the

almost one billion metric tons of aluminium ever produced is still in productive use, some of it having been through countless recycle loops through its lifecycle.

Most of the aluminium being produced today enters long-life products like vehicles and building products. With average lifetimes of about 15 to 20 years for vehicles and 40 to 50 years for buildings, this means that most of the aluminium will not be available for recycling for many years. As a result, access to aluminium scrap is limited. Globally, less than 25 percent of the aluminium being produced came from post-consumer scrap sources in 2010. With an expected continued growth in aluminium demand, this share is not expected to increase significantly in the future.

The figure below illustrates the material flow balance of aluminium.⁹⁾



INDUSTRY'S ROLE IN RECYCLING

The recycling industry plays an essential part of the aluminium life cycle. The amount of recycled metal has increased steadily in recent years, and the recyclers have implemented newer and better technologies to avoid harmful emissions from the smelting of scrap. Authorities in many countries have implemented incentives to enhance the recycling rate. Hydro has set strategic goals to increase its production of recycled metal.

Since 1980 the aluminium recycling industry has quadrupled its annual output of metal from old (post-consumer) and traded new scrap, from 5 million metric tons to almost 20 million metric tons. Over the same period, annual primary metal production has grown from 15 to 44 million tonnes.

A fully developed aluminium recycling industry includes both refiners and remelters. Refiners use more sophisticated processes, allowing them to produce alloys to customers' specifications from a range of scrap sources. Remelters mainly use clean and sorted wrought alloy scrap and make products of the same type as the scrap sources (such as used beverage cans into new cans or window profiles into new window frames).

The recycling industry also involves collectors, dismantlers, metal merchants and scrap processors, which deal with the collection and treatment of scrap.

In Europe and North America, scrap has been generated in sufficient quantities over the past 70 years to develop an economically strong and technically advanced aluminium recycling industry. Following the oil price shocks and energy cost increases of the 1970s, Japan ceased domestic primary aluminium production and switched to aluminium recycling in the 1980s. In addition to these traditional production centers, increasing recycling activities are evident in China, India and Russia.

RECYCLING OF ALUMINIUM PRODUCTS

At the end of their useful life, the recycled product may be the same as the original product (such as window frame recycled back into a window frame or can to can), but is more often a completely different product (for example a cylinder head recycled into a gearbox).

Transport

Around 25 percent of aluminium produced every year is destined for the transportation sector. The amount of aluminium used per car produced in Europe almost tripled between 1990 and 2012, increasing from 50kg to 140 kg. This amount is predicted to rise to 160 kg by 2020, and even reach as much as 180 kg if small and medium cars follow the evolution recorded in the upper segments of the automobile industry.¹⁰⁾

At the end of a vehicle's useful life some aluminium parts, such as wheels and cylinder heads, are removed and the remaining car body is fed into a shredder, after which the aluminium fraction is separated using various technologies. Mixed alloy aluminium scrap collected in this way is generally processed into casting alloys for the production of engines and gearboxes. Due to the increasing use of wrought alloys in car bodies, a growing volume of such scrap is anticipated and hence the separate collection of specific alloys from cars is likely to become economically viable in the future. In Europe, 95 percent of the aluminium scrap from cars is currently being recycled.¹¹⁾

Building and construction

Today around 13 million metric tons of aluminium a year are used in construction, while it is estimated that globally some 220 million metric tons of aluminium are currently in use in buildings.

In contrast to many other building materials, which are mostly landfilled after demolishing a building, aluminium may be recycled in a way that is economically and environmentally sustainable. A 2004 study by Delft University of Technology found that collection rates for aluminium in European buildings were between 92 percent and 98 percent.¹²⁾



4 ALUMINIUM RECYCLING



Packaging

There are basically two different types of packaging:

- rigid and semi-rigid packaging, food and beverage cans, aerosol cans, closures and menu trays, and
- flexible packaging, where a thin aluminium foil is laminated as a barrier material to plastics or cardboard.

For rigid and semi-rigid packaging, of which aluminium beverage cans make up the largest volume globally, techniques have been developed to recycle old scrap into ingots from which wrought products (such as can stock) can be fabricated. Such scrap has a high aluminium content and therefore a high market value.

The collection rate of used rigid and semi-rigid containers depends greatly upon individual national incentives, including deposit systems, voluntary prepaid recycling charges or advertising. In Europe the collection rate of used beverage cans varies between 30 and 90 percent, with an average of about 70 percent. For all rigid packaging, the recycling rate is 50 percent in Europe.¹³⁾

In flexible packaging, the aluminium barrier is often very thin (about 6 micrometer) and is typically laminated with paper and/or plastic layers that are the major components of the packaging. This means that flexible packaging waste has very low aluminium content. Nevertheless, aluminium can be extracted from laminates by pyrolysis and thermal plasma techniques. Alternatively, such a packaging is incinerated with a recovery of the combustion heat. Because it is so thin, the aluminium barrier will be oxidized completely, and the combustion heat of aluminium can be recovered.

END OF LIFE RECYCLING VS. RECYCLED METAL CONTENT

In life cycle analyses, recycling may be accounted for either as the percentage of recycled material in a product or as the percentage of the material which will be recycled after its useful life.

Some authorities and environmental organizations have encouraged recycling of materials through “green labels” on products with a high recycled content. For aluminium such incentives may lead



to inefficient solutions in economic and ecological terms, and to discrimination of aluminium versus other materials. Due to the overall limited availability of aluminium scrap, any attempt to increase the recycled content in one particular product would just result in decreasing the recycled content in another. It would also certainly result in inefficiency in the global scrap market and related logistics, thus wasting transportation energy. The high market value of aluminium means that, if scrap is available, it will be recycled and not wasted or stockpiled.

HYDRO'S ROLE IN RECYCLING

Hydro is a large remelter of aluminium, with nearly 30 facilities worldwide. We remelt process scrap from other companies and from our own production. Our expertise in remelting is a good basis for further expansion.

It is our ambition to grow faster than the market in recycling and take a leading position also in this part of the value chain. By 2020, we want to recover 1 million metric tons of contaminated and post-consumer scrap annually. The first step is to improve our existing capacity utilization. In the next step, we intend to invest in additional recycling assets to capture scrap volumes generated in our plants and from plants operated by partners. One of our goals is to develop recycling plants that serve internal and external customers with metal products produced from industrial and end-of-life scrap.

5 PRODUCTION OF ALUMINIUM

OVERVIEW OF THE PRODUCTION STEPS

The main raw material for primary aluminium production is bauxite. Aluminium oxide is extracted from the bauxite, and is used in an electrolytic reduction process to produce primary aluminium. It takes roughly 4 – 7 tons of bauxite to produce 2 tons of alumina, which again yield 1 ton of aluminium. Primary aluminium is alloyed with other metals and is then fabricated into a range of products through casting, extrusion and rolling.

BAUXITE MINING

Occurrence of aluminium ores

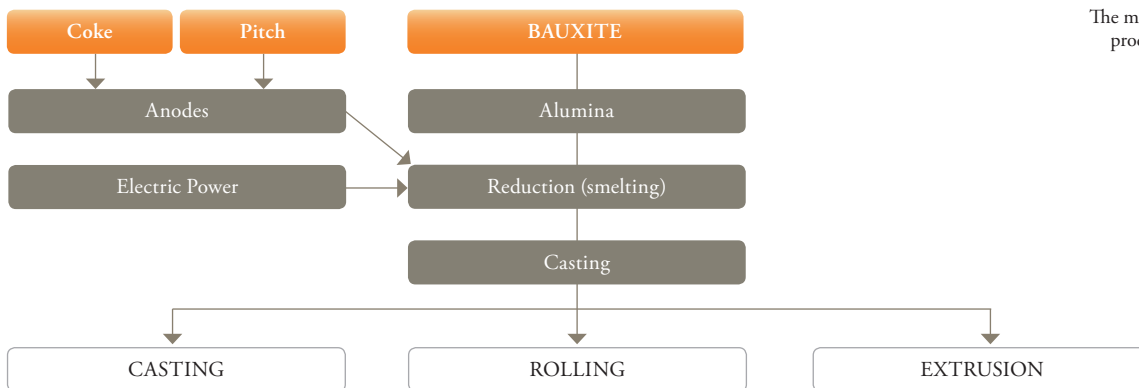
Approximately 7 percent of the earth's crust is aluminium, where it is the third most abundant element after oxygen and silicon.

Technically, aluminium can be extracted from many different ores, and the supply is then in theory unlimited. However, bauxite is the only ore that is used for commercial extraction of aluminium today. It contains 15 – 25 percent aluminium.

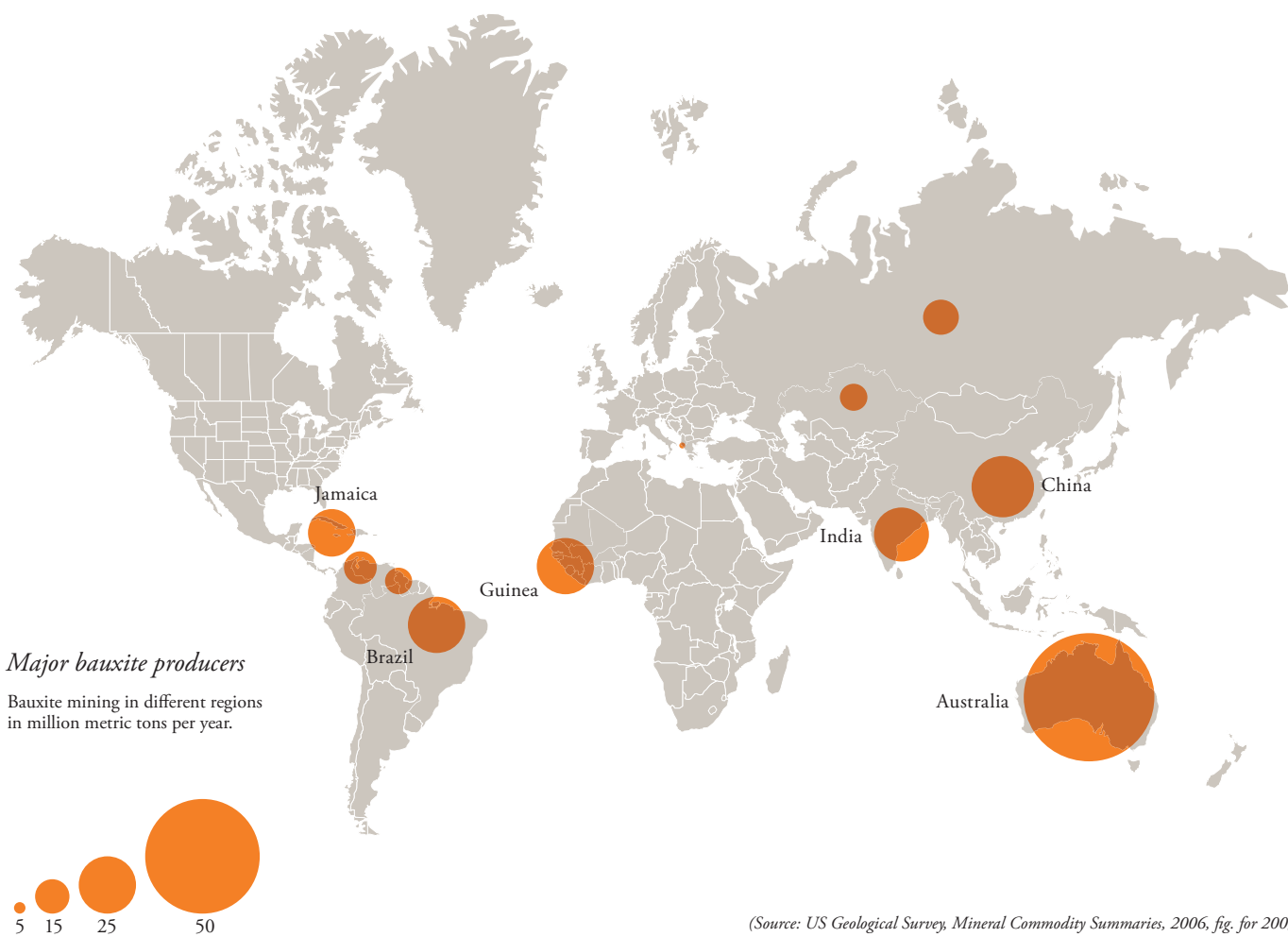
Commercially available bauxite occurs mostly in the tropics in horizontal layers normally beneath a few meters of overburden. The layers are typically in the range 2-20 meters thick¹⁴. It is usually mixed with different clay minerals, iron oxides and titanium dioxide, and the iron gives it a deep red color.

Known reserves are around 29 billion metric tons. At the current rate of extraction, these reserves will last more than 100 years. However, it is estimated that the total resources are in the order of 55 billion to 75 billion metric tons when undiscovered bauxite resources are included. This would extend the time perspective to 250 - 340 years. In recent years, prospecting has increased the reserves more rapidly than the rate of extraction: from 1995 to 2011, 2.7 billion metric tons were extracted, but the reserves increased from 23 billion metric tons to 29 billion metric tons.¹⁵

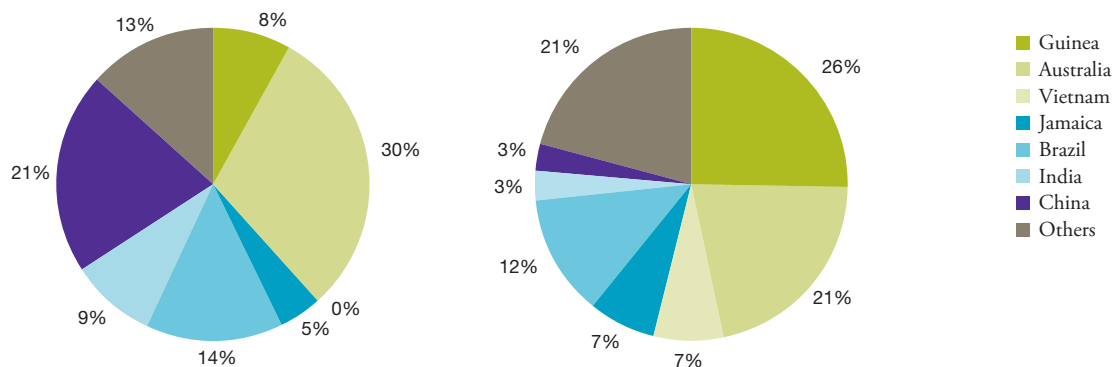
However, the aluminium industry recognizes that availability of bauxite resources may become a constraint in the longer term, and that it may have to be prepared for other ores than bauxite in the future. Research to develop extraction processes from other minerals is therefore on-going. In a long time perspective, more recycled metal from long life applications (such as buildings) will also become available.



The main steps of primary aluminium production are shown in the figure.



Percentage of world production (left) and reserves (right) of bauxite ¹⁵⁾



5

PRODUCTION OF ALUMINIUM

Bauxite mining operations

The vast majority of world bauxite production is from surface mines, while the rest, mainly from Southern Europe and Hungary, is from underground excavations.

Bauxite may be covered by an overburden of rock and clay, which has to be removed before mining of the bauxite. Mined bauxite is generally loaded into trucks or railroad cars and transported to crushing or washing plants and then to stockpiles.

Many bauxite deposits contain clay, which has to be removed by some combination of washing, wet screening and cycloning. Where washing is applied, the suspended clay is usually deposited in tailing

ponds. At the end of the life time of the tailing ponds they are normally revegetated using local species, enabling a long term re-establishment of a natural vegetation.

Environmental issues related to bauxite mining

Due to its location close to the surface and relatively shallow thickness, bauxite mining involves disturbance of relatively large land areas. On average one square meter of land is mined (including roads and infrastructure) in order to give one tonne of aluminium metal¹⁶. The annual world wide encroachment on new land related to bauxite mining is about 40-50 square kilometers. However, quickly after mining the area, it will be normally prepared and re-vegetated with local species. This means that



although the resource is spread out, the area opened at any time is normally small.

Depending on the local circumstances, the mining operations may involve a number of environmental issues:

- Removal and re-establishment of vegetation; change of landscape
- Control of erosion and run off from the mine
- Disturbance of hydrology
- Waste disposal (tailings)
- Mining operations and transport of bauxite - dusting/noise
- Opening new areas may also provide access to illegal logging, farming, settling and hunting



The aluminium industry recognizes these challenges, and the International Aluminium Institute (IAI) has carried out periodic surveys of the performance of the bauxite mines since 1991. Most bauxite mining companies have subscribed to voluntary improvement programs, involving for example land rehabilitation schemes. The latest survey, published in 2008 and covering the period 2002–2006, showed that the land rehabilitation equalled the land mined during this period for those mines covered by the survey (including 66 percent of the world's production).¹⁶⁾

Loss of bio-diversity and eco-systems are among the world's top environmental issues, and tropical forest areas are among the most threatened areas. Mining in such areas may therefore be controversial. The following figures illustrate that the aluminium industry is a minor player in the greater picture:

According to the United National Food and Agriculture Organization (FAO), it is estimated that the global rate of destruction of tropical forests is about 80 000 square kilometers per year¹⁷⁾. About 20 percent of the 40 square kilometers annual land taken by bauxite mining is in tropical forest areas. These 8 square kilometers constitute only 0.01 percent of the annual loss of tropical forest due to other causes. Considering the rehabilitation programs, aiming at no net loss of forests, the influence is even less. It is also important to note that most of this area was already impacted by logging or other impacts before the mine was established.

The IAI publication gives a good overview of the issues and the measures taken by the industry as a whole.

5

PRODUCTION OF ALUMINIUM

CASE

Reforestation in Paragominas

Hydro is majority owner in the Paragominas bauxite mine in northern Brazil since Hydro bought the Vale aluminium activities in 2011.

Bauxite extraction started in Paragominas in 2006. The reforestation program started in 2009 and will continue beyond 2040 in the area presently being mined. The landscape is systematically shaped back to how it looked before mining. The topsoil is then added and seedlings are planted in a grid in the areas prepared. The objective of the reforestation program is to lay the foundation for nature – long-term – to re-establish a forest system of the same structure as was typical for natural forests in the area.



Since the mine has only been in operation for a few years, the rate of rehabilitation has not yet reached the same rate as the rate of new impacts by mine opening. The objective is to achieve a balance between land impacted by mining operations and land rehabilitated by 2017.

The Paragominas mine is located in what is normally recognized as the deforestation belt around the central Amazon River. The mining area has been exposed to selective logging and clear cutting of forest for development of subsequent pasture land. Following a period where the municipality of Paragominas saw a reduction in its forest cover of more than 30 percent, the municipality launched a program called “Paragominas: Green municipality” in 2008. Inspired by the success of this, the Para province followed up with “Programa Municípios Verdes” in 2011. By May 2012, 91 municipalities covering more than 1 million square kilometers had committed themselves to this program. The aim is to reduce the annual deforestation by 80% within 2020. A reduction of more than 50% has already been achieved.¹⁸⁾

A reforestation assessment performed by Hydro in 2011 reviewed areas close to the mine that have been exposed to selective logging. The study found that the main structure of the forest ecosystems was still in place, even though most of the commercially interesting trees had been logged. Improvement potentials have been identified related to reforestation and wildlife management at Paragominas, and possible adjustments to the reforestation program are being evaluated.



ALUMINA REFINING

Between two and four tonnes of bauxite are required to produce one tonne of alumina. For logistic reasons, most alumina refineries are located close to the bauxite mine, or at the nearest harbour, where the alumina can be shipped out.

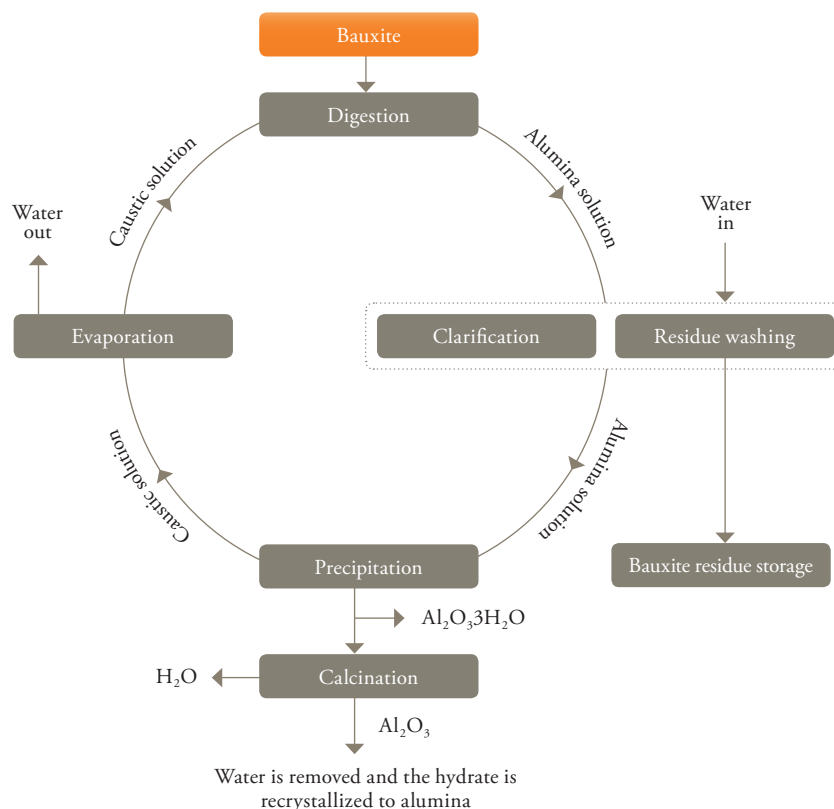
The Bayer process

The Bayer process is used to extract the alumina from the bauxite, as illustrated in the simplified block diagram:

The aluminous minerals in bauxite are dissolved in a hot solution of caustic soda (sodium hydroxide) and lime (calcium oxide). Insoluble materials are then separated from the sodium aluminate solution in thickeners and filters. The bauxite residue is then washed, combined, and then stored in a landfill. The wash water, containing caustic soda, is recycled to the process.

Aluminium hydroxide is precipitated by cooling of the liquid and adding crystal seeds. The precipitate is filtered and washed to remove and recover entrained caustic solution. The aluminium hydroxide is calcined in kilns at temperatures in excess of 960°C. Free water and water that is chemically combined are driven off, leaving commercially pure alumina.

Simplified flow diagram for the Bayer process



5 PRODUCTION OF ALUMINIUM

Environmental issues related to alumina production

The main environmental issues related to alumina production are:

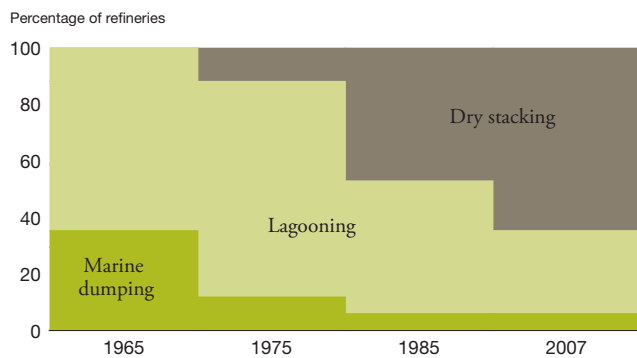
- Disposal of the bauxite residue (red mud)
- Energy consumption / energy efficiency
- Water management
- Physical footprint of the plant with infrastructure and the red mud disposal area

Disposal of the bauxite residue is a challenging aspect of alumina production due to relatively large volumes, occupying land areas, and due to the alkalinity of the residue and the run-off water. The

industry is moving away from storage of the residue in slurry form in lagoons towards dry stacking, see figure below. Dry stacking allows the residue to be stored in higher piles, using less land and eliminating risk of flooding adjacent areas. Modern bauxite residue stockpiles are lined with an HDPE (high density polyethylene) liner and enough buffer capacity to manage run-off, avoiding uncontrolled spills and leakages to the environment.

The run-off water from the stockpile is either neutralized before discharge, or recycled to the process. Dry stacking allows for better recovery of the caustic liquor entrained in the residue.

Historical evolution of disposal method



Percentage of the alumina refineries using different bauxite residue storage methods. Based on reports from 17 refineries representing 44% of the world's production in 2007.¹⁹⁾



Alunorte, the world's largest alumina refinery²⁰⁾

Alunorte is the largest alumina refinery in the world with a total production capacity of close to 6.3 million metric tons per year in seven parallel lines. This is about 7 percent of the world's production.

Energy: The plant has a specific energy utilization of 8 GJ per metric ton of alumina and is one of the most energy-efficient plants in the world. The average for the industry was 50 percent higher in 2009. Coal and heavy fuel oil are the main energy sources for steam generation, while electricity imported from the grid is mainly hydroelectric.

Greenhouse gas emissions: The plant emits about 3.8 million tonnes CO₂ per year. In terms of amount of CO₂ emitted per ton produced, Alunorte is among the best third of the world's producers.

Water usage: The plant operates with comparatively low water consumption (2.3 cubic meters/metric ton alumina).

Bauxite residue storage: Dry stacking method. This involves dewatering of the residue to less than 35 percent water, which means that the residue can be stacked in geotechnical stable piles in stead of in lagoons, thus minimizing the overall land used for the landfill. The residue storage is all lined with a HDPE liner. Groundwater wells are located around the storage to monitor the groundwater. The run-off from the residue piles is alkaline. The run off is collected together with surface water and contained within dykes. It is treated before discharge. At the end of the use, the bauxite residue stockpile will be covered through reforestation with local species.



PRODUCTION OF PRIMARY METAL

Production processes

The basis for all primary aluminium-smelting plants is the Hall-Héroult Process, invented in 1886. Alumina is dissolved in an electrolytic bath of molten cryolite (sodium aluminium fluoride, Na_3AlF_6) within a large carbon or graphite lined steel container known as a “pot”. An electric current is passed through the electrolyte at low voltage, but very high current, typically 200,000 amperes and up to 500,000 amperes for the latest generations. The electric current flows between a carbon anode (positive), made of petroleum coke and pitch, and a cathode (negative), formed by the thick carbon or graphite lining of the pot. The carbon anode is consumed in the process, releasing CO_2 with the potgas.

Molten aluminium is deposited at the bottom of the pot and is siphoned off periodically, taken to a holding furnace, often but not always blended to an alloy specification, cleaned and then cast into different semi-products.

An aluminium smelter consists of one or more “potlines”. Each of them typically counts around 300-350 pots and may produce 100-300,000 metric tons of aluminium annually. A typical smelter will produce 300,000 metric tons per year and the largest ones up to 1 million metric tons.

In modern smelters, anodes are prefabricated in a paste plant, followed by a baking process in a baking furnace. The anode blocks, which may weigh around 1 metric ton each, are then mounted on anode hangers. About 80 percent of the anode is consumed in the process before the anode has to be changed. The unused part of the anode (“butts”) are crushed and recycled in the anode production. The net consumption of carbon is approximately 400 kg per ton of metal produced.

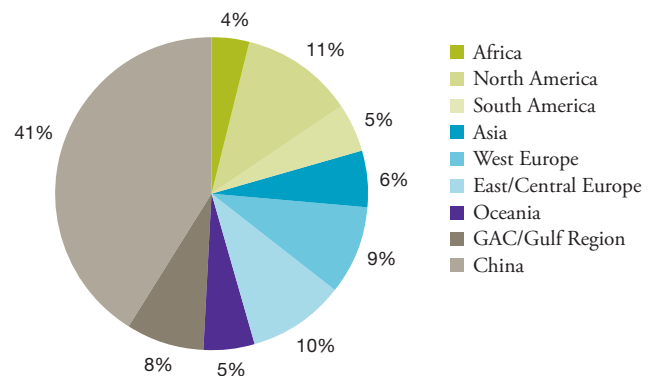
A modern smelter will usually consist of the following main units:

- Potline(s)
- Carbon plants, including paste plants and anode baking plants

- Anode service plants, for removal of butts and assembling new anodes to the anode hangers
- Cast house
- Gas treatment units
- Utility plants and storage facilities
- A harbor for import of alumina, coke and pitch and for export of product metal

Aluminium production world wide

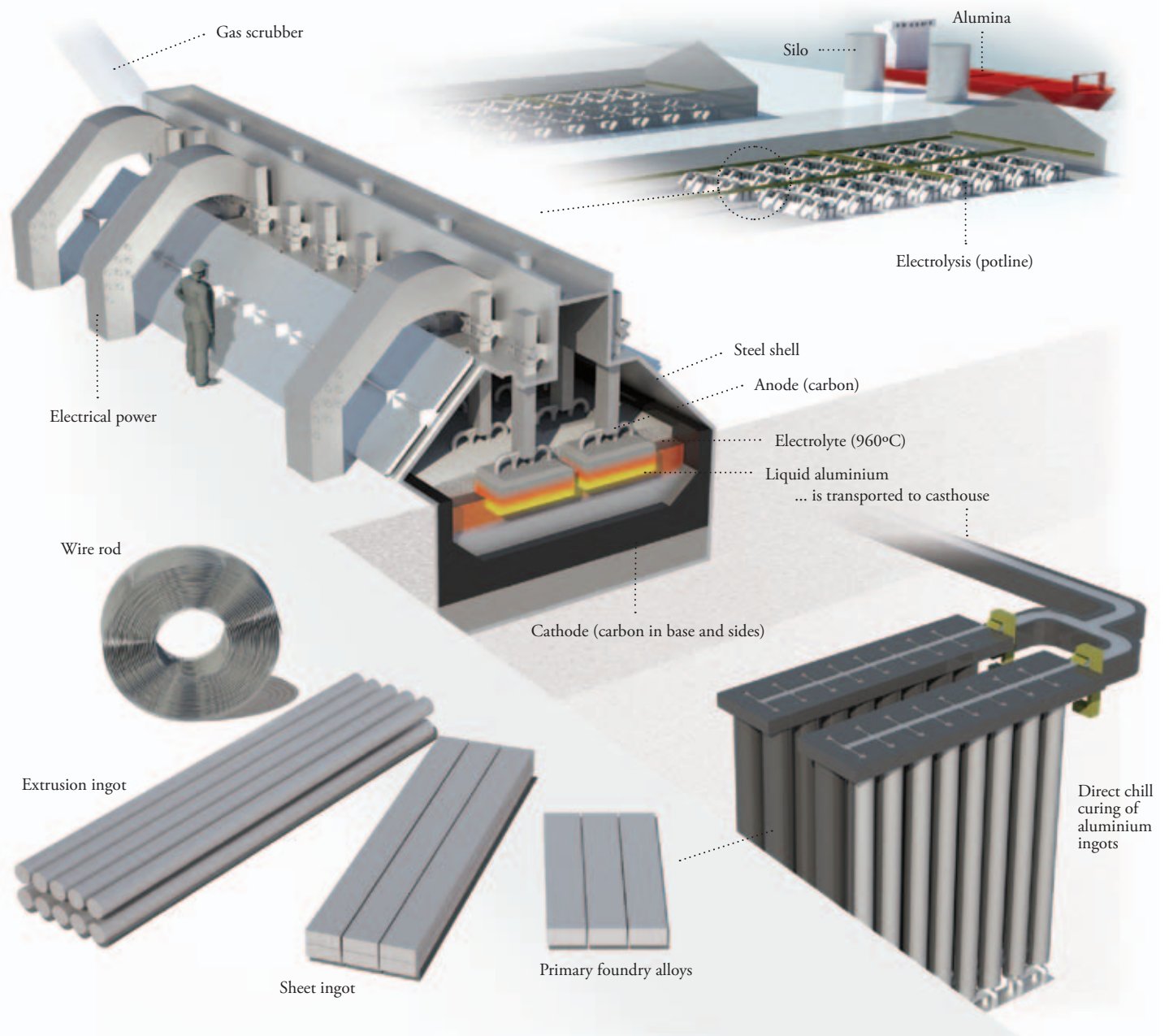
The world production of primary aluminium reached about 44 million tonnes in 2011²¹⁾. The average annual production growth over the last 20 years has been 3-4 percent. The regional distribution of the production is shown in figure below.



China is by far the largest producer, and also has the highest growth rate. The Gulf region also has a significant growth, while production in most other areas either has declined or been stagnant in recent years.

Hydro's primary production in 2011 was close to 2 million metric tons, or 4.5 percent of the world production.

Aluminium smelting process



Primary aluminium is produced in reduction plants where pure aluminium is formed from alumina by an electrolytic process. This process is carried out in electrolytic cells, in which the carbon cathode placed in the bottom of the cells forms the negative electrode. Anodes, which are made of carbon, are consumed during the electrolytic process when the anode reacts with the oxygen in the alumina to form CO_2 . The process requires electric energy, about 13 kWh per kilo aluminium produced in modern production lines.

5

PRODUCTION OF ALUMINIUM

CASE

Technology development improves environmental performance

The development of new potline technology within Hydro is focused on energy efficiency, overall economic efficiency, environmental performance and work environment. All of these aspects have to be taken into account when technology improvement programs are launched. These objectives are not contradictory, but go hand in hand.

- Increasing the amperage and the current density, while at the same time reducing power consumption per metric ton produced, are key factors for economic competitiveness. However, this will also benefit the environment by reducing energy demand, emissions and physical footprint.

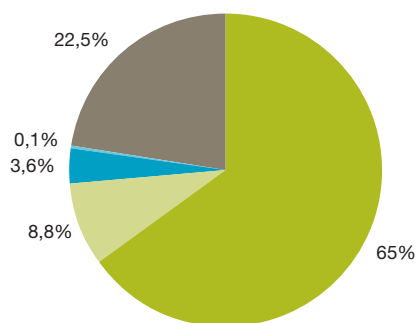
- Good process control is essential to optimize the production, but will also reduce emissions due to more stable conditions
- Efficient gas suction systems on the cells and efficient gas treatment systems benefit both the external and internal environment, and at the same time valuable resources (e.g. fluoride) are captured and recycled to the process.

Hydro is in the forefront among aluminium producers with respect to developing and implementing energy efficient cells with low emissions.

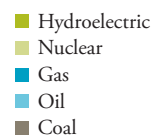
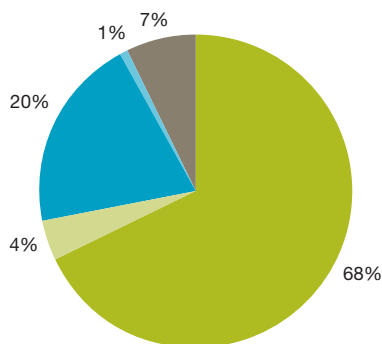


Energy base for primary aluminium production

World ex. China



Hydro



Environmental issues related to primary aluminium production

The main issues related to production of primary aluminium are:

- Energy production, transmission and consumption
- Emissions of greenhouse gases
- Emissions of fluoride, SO₂, dust and PAH
- Liquid effluents
- Waste disposal

Other issues may also be important, depending on local circumstances (e.g. water use in water scarce areas, noise, physical footprint and land use conflicts).

Energy supply issues

Because aluminium production is energy-intensive, energy costs constitute a decisive part of overall production costs of aluminium. Energy costs may account for about 20-40 percent of the total production cost, depending on local power prices.

Historically, the development of a smelter has often been a trigger for developing a local power source, and vice versa. Due to limited transmission capacity in earlier days, the smelters also had to be located close to the power source, which is why e.g. most of the Norwegian smelters are located close to water falls utilized to develop hydropower.

In industrialized countries, aluminium plants are typically exposed to market prices on energy, either directly or via long-term contracts. Several of them are struggling to survive due to increasing power prices. Power generators are transferring their costs associated with, for example, emission trading into the electricity price. Because aluminium is a globally traded commodity, producers are unable to transfer these regional costs to their customers.

This has already resulted in plant closures, although many of the plants in the EU / EEU countries have a better environmental performance than their competitors outside EU / EEU. It is therefore a major challenge for policy makers to create a “level playing field”, where those plants which are really the best, will survive.

The energy base for the world's aluminium production²²⁾ (excluding China and a few other countries) compared to Hydro's base are shown in the charts above.

Considering that China's sizeable production is largely coal based, the real percentage of hydropower world wide is probably around 55 percent, and the coal share slightly above 30 percent.

5 PRODUCTION OF ALUMINIUM

Environmental impacts of energy production

All kinds of energy production have some environmental footprints, and the aluminium industry must bear the responsibility for some of those, even if the power is purchased in the market. Depending on the type of power source and the local circumstances, the environmental effects may be categorized as follows:

Power source	Types of impacts
All	Impacts of power transmission lines (land take, aesthetic)
Hydroelectric	Changes in aquatic and terrestrial habitats along the waterways, impact on recreation, tourism, loss of arable land, flood control, emissions of methane (see below)
Coal	Emissions of CO ₂ , SO ₂ , NO _x , dust; thermal impact of cooling water, impacts of coal mining
Nuclear	Risk of radioactive emissions, radioactive waste, thermal impact of cooling water, impacts of uranium mining
Gas	Emissions of CO ₂ , NO _x , thermal impact of cooling water, impacts of gas production and transport in pipelines
Oil	Emissions of CO ₂ , SO ₂ , NO _x , dust, thermal impact of cooling water, impacts of oil production and transport

In Hydro's energy sourcing strategy renewable power has first priority (in practice hydro-power), secondly gas power with high efficiency. If new plants should be built with coal as power base, the geological conditions should preferably be present to enable carbon capture in the longer term.

Reduced energy consumption

Technology improvements and modernizations have reduced the average consumption of electricity in smelters world wide by 70 percent compared to 100 years ago. Improvements in recent years are more marginal, as the energy efficiency is approaching theoretical limits. The graph shows IAI averages for 2006 to 2010 and corresponding Hydro figures.^{23,24)}

Hydro has ambitious technology development programs to further reduce energy consumption. The latest generation of cells (HAL4e) which are operated at Hydro's research center in Årdal, Norway, achieve 12.5 MWh/metric ton²⁵⁾, and our ambition is further reduction. This technology is ready for use in a full scale smelter project.

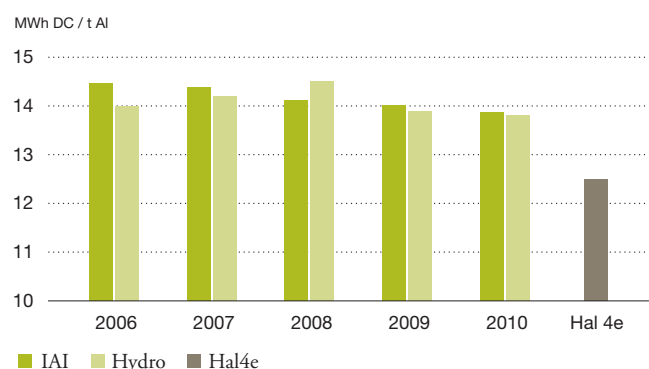
Hydro also looks for opportunities for heat recovery and utilization. The plants in Sunndal, Høyanger and Årdal, all in Norway, deliver hot water for district heating. Hydro is also active in R&D to develop technologies which may increase the economic potential for heat recovery and utilization.

Greenhouse gas emissions

The main greenhouse gas emitted from modern smelters is CO₂, and the main source of this is the consumption of the anodes in the potlines, with minor emissions from anode production, cast house and utilities.

However, the formation of perfluorocarbons (PFC) during certain operational conditions (anode effects) has been a major source of GHGs in earlier years. These emissions have been reduced by nearly 80 percent since 1990 even as production has almost doubled in the same period, see figure on next page.

Electric energy consumption development, IAI and Hydro (Electrolysis DC-current only)



PFCs are emitted in small amounts, but they absorb infrared rays very effectively, and they stay in the atmosphere for a very long time. Hence, the Global Warming Potentials (GWP) of two PFC-compounds are 6500 and 9200 times higher than CO₂ per kg emitted.²⁶⁾ Hydro has implemented extensive PFC reduction measures, so that the PFC emissions now represent about 4.2 percent of the total smelter emissions of CO₂ equivalents.

The power supply to a smelter is an indirect source of greenhouse gas emissions, depending on the power source. The figure shows that electricity to the smelter is representing nearly 60% of the overall CO₂-emissions of the mine-to-ingot value chain. This is based on world average power mix.

Coal based power production has the highest emissions, with around twice as high CO₂ emissions per kWh as gas. Nuclear power and hydropower are usually considered nearly “CO₂-free”. However, The World Commission on Dams has performed research and studies which indicate that reservoirs in warmer climates may have significant emissions of methane.²⁷⁾ Further research is being carried out to establish a consistent methodology to measure these emissions over time.

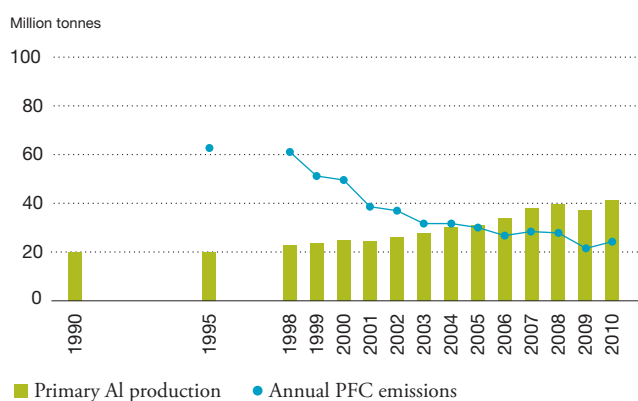
In barren mountain areas like in Norway, however, the release of methane from such reservoirs is nearly negligible since they contain little biomass, the reservoirs are very steep and deep and the climate is cold.

Other air emissions

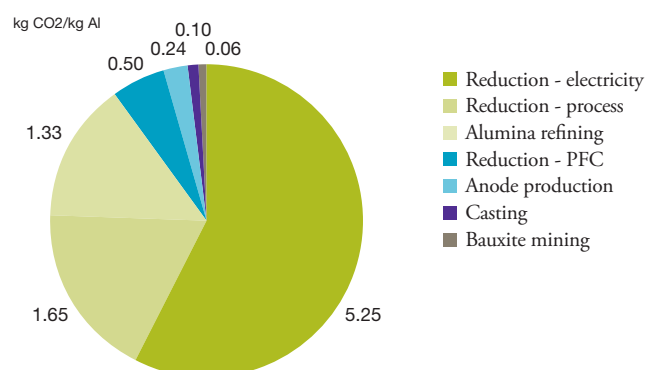
In addition to GHG gases, smelters emit fluorides, sulphur dioxide, dust and minor quantities of PAH. In a modern smelter, the level of these emissions may be controlled to very low levels per metric ton produced. However, due to the size of some smelters, there may still be some local impacts around the smelters, depending on the local setting, the level of emission control measures and the sensitivity of the surroundings.

Fluorides are mainly emitted from the pots during interventions in the pots (like anode changing). Most of the potgas (>99 percent) is collected and treated with alumina scrubbers to remove virtually all the fluoride. Remaining emissions in a modern smelter are less than 0.5 kg/metric ton Al produced, compared to 3 - 4 kg/metric ton around 1970. Hydro’s smelters in Norway are in the world’s top league with less than 0.3 kg F/metric ton Al.

Production of aluminium and emissions of PFC (as CO₂-eq.) 1990 - 2010



Contributions to CO₂ emissions from the aluminium production value chain



5

PRODUCTION OF ALUMINIUM



In the early 1990s the Norwegian Aluminium Industry engaged scientific institutes to perform an in-depth study of the effects of fluorides and other pollutants around Norwegian smelters, after a period of significant emission reductions. It was confirmed that most of the damages, especially related to fluoride emissions, had been eliminated or reduced to acceptable levels.²⁸⁾ This formed the basis for the later revisions of the permits in line with a “no significant effect” philosophy. In the following years, further emission reductions have been achieved.

Fluoride emissions from smelters are not considered a health hazard to humans.

Sulfur dioxide (SO₂) is emitted mainly from oxidation of the sulfur content in the anodes. Some smelters are located in sensitive areas where acidification of lakes or deteriorating air quality are issues. The aluminium industry is a minor contributor to these problems on a regional scale. However, local authorities may request different levels of pollution control, depending on the sensitivity of the area.

The SO₂ is often removed by wet scrubbing (such as with seawater). All the Norwegian smelters, as well as Qatalum, have such scrubbers, removing 90–99 percent of the SO₂. At other smelters, the emissions may be limited by using low sulfur anodes.

Dust is emitted from many sources, with the potlines and material handling systems as the main contributors. The coarse particles are mainly a local nuisance, but the finest particles may at elevated concentrations contribute to respiratory disorders, particularly in the work environment. Better dust control systems have reduced these problems significantly at most smelters in recent years.

PAH is a group of tar compounds which can be carcinogenic. Emissions related to older potline technologies have mostly been eliminated. Anode production is also a source, but more efficient gas treatment systems have reduced these emissions to a minimum. Some plants (Sunndal, Årdal and Qatalum) use regenerative thermal oxidizers (RTO) to destroy PAH in an energy efficient way.

Water use and liquid effluents

Use of freshwater is constrained in many areas due to scarcity of water. Sophisticated water treatment systems which allow re-use of water have been developed to meet this challenge. New smelters are therefore often built with zero discharge of fresh process water; they only purchase the make-up necessary to replace the evaporation and other small losses. Qatalum has such a design.

Most of the Norwegian smelters are located in areas with abundant rainfall and availability of fresh water. These smelters therefore use once-through cooling systems.

Seawater is used in many locations for removal of SO₂ from the potgases and in some cases from the anode baking furnaces. The effluents from these scrubbing systems are slightly acidic (pH ~ 5) and contain sulfite, which consumes oxygen in the receiving water. Due to the great capacity of seawater to neutralize acid and good local circulation, the effluent is very rapidly rendered harmless with no traceable effects.

Waste

Aluminium smelters generate solid wastes. One of the main waste products arises from the relining of pots, which has to take place every 5–8 years. The carbon part of the spent potlining (SPL) is considered a hazardous waste due to among other things its content of fluoride, cyanide, PAH and reactive metal. The refractory materials are not considered hazardous. One aim has been to minimize the volumes through extending the life time of the pots.

In addition, several uses of these materials have been identified. The cement industry can utilize both the carbon as an energy source and the inorganic fractions as an additive to the cement, and the high temperature in the cement kilns destroys the hazardous organic compounds. Steel mills and producers of insulation materials are also able to utilize SPL in their production, and a number of other initiatives are ongoing to treat and utilize this waste. In Norway the SPL is stabilized and disposed of at a secure landfill, while exploring other alternatives. At our joint venture at Albras in Brazil we deliver all the SPL to local cement plants as an alternative fuel and raw material for their processes. Hydro's objective is to eliminate landfilling of SPL within 2020.

Dross is the term for residues which are removed from the casting process. The dross has a high content of aluminium, which is recovered in specialized recycling plants. The residue from this recovery process contains aluminium oxide, salts and traces of metal. This waste is now supplied as a raw material for operators who after processing have made viable products out of it.

In addition to the SPL and dross, a number of other wastes are generated. In many cases, strict operational controls may reduce these wastes or make them useable in the production, or in some cases they may be used in other industries.



6

FABRICATION OF ALUMINIUM PRODUCTS

The most common methods for processing primary aluminium are extruding, rolling and casting. Here are some of the most important environmental aspects of these processes.

Extruded products – emissions and measures

Extrusion logs, 4 to 7 meters in length and from 15 to 30 centimeters in diameter, are the basis for extrusion. The logs are cut into suitable lengths and heated prior to extrusion. After extrusion, the sections are cooled and hardened, and then surface treated if required.

The actual extrusion process does not create emissions of any significance. Neither do the cutting, milling, drilling or machining. Surface treatment can cause emissions and discharges to air and water (anodizing or coating).

Effluents from anodizing (where the extrusions are given an extra protective coating in an electrolytic bath), contain aluminium compounds. These effluents are treated in facilities where the aluminium is precipitated as aluminium hydroxide. This is then

collected and sold to plants that can reclaim the aluminium. When coating extrusions, residues and solvents can be emitted to air or discharged in the effluents from this process. Selecting the right type of coating, and cleaning the emissions and discharges to air and water can prevent harm to the local environment.

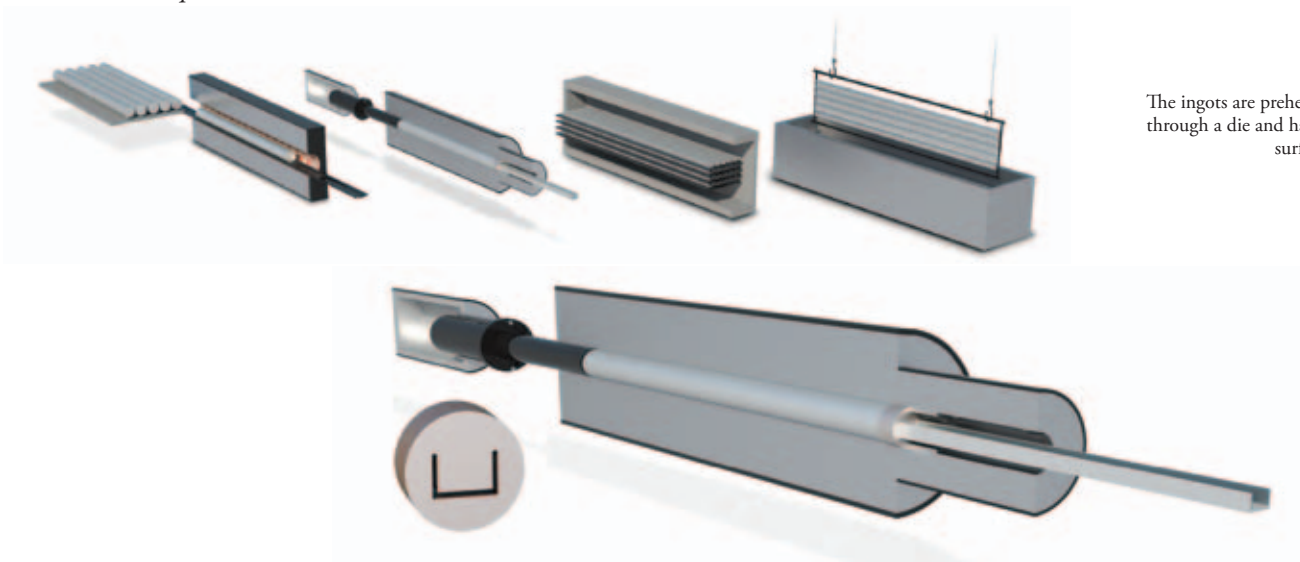
Rolled products – emissions and measures

Rolling sheet ingots, 4 - 8 meters long and up to 60 centimeters thick, are heated and rolled into strip 2 - 6 mm thick (hot rolling). Aluminium strip can also be cast directly from molten metal in 6 millimeter thicknesses (strip casting). The strip is cooled and rolled to the actual strip thicknesses (cold rolling) and heat treated. A quarter of the finished rolled strip is coated in strip coating facilities.

The oil that is added during the various rolling processes to ensure a good surface finish and to control temperatures gives rise to traces of oil in the air emissions.

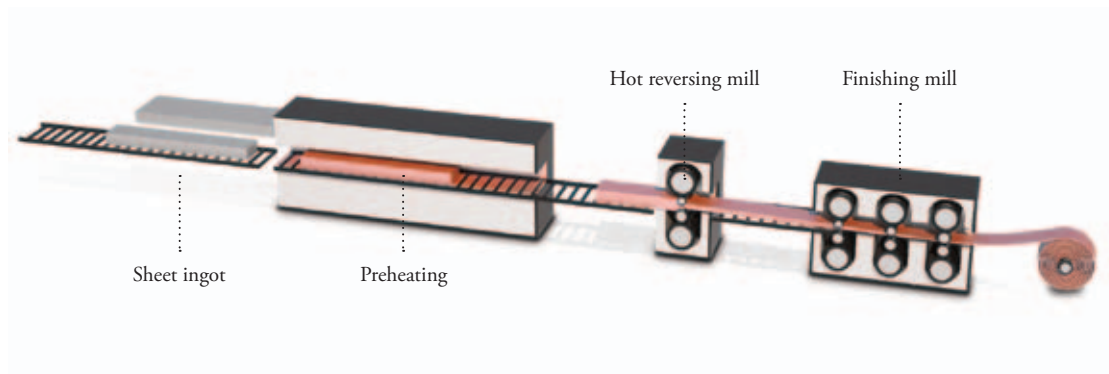
When coating rolled strip, solvents from the coatings are liberated in the drying furnace. These solvents are incinerated in thermal post-combustion, and the hot flue gases from the furnaces are

The extrusion process



The ingots are preheated, extruded through a die and hardened before surface treatment.

Hot rolling process



The slabs are preheated before entering the hot reversing mill. The sheets are rolled to the desired thickness in the finishing mill.

used to heat the hardening furnace. Research and development programmes have been initiated to reduce the amount of solvents in coatings and use of coatings with less environmental impacts.

Cast products – emissions and measures

Secondary foundry alloys are mainly used either as molten metal directly from the plants or in the form of ingots for casting finished products. The most common alloy materials added to aluminium are copper, magnesium and silicon. For reasons of quality, the grain refining substances strontium, sodium, or titanium/titanium boride, are added in small quantities.

The four main casting methods are sand casting, low pressure die casting, permanent mould casting and high pressure die casting. Generally, the raw cast product requires machine finishing and is often coated.

Melting and casting in permanent moulds does not generally have any adverse effect on the environment. When sand casting, organic compounds (resins) are used, which means it is necessary to install equipment to clean emissions and discharges and to check that the limit values of emissions to air and water are not exceeded. When coating, the emissions are the same as described above for rolled products.



7 ALUMINIUM AND HEALTH

Exposure to aluminium has been suggested to represent a health hazard in certain circumstances. However, as documented below, the scientific evidence does not support this. Life on earth has developed in an aluminium rich environment, and is therefore adapted to aluminium exposure. The use of aluminium and aluminium compounds may in some cases be beneficial from a health point of view.



The European Aluminium Association (EAA) has published health fact sheets on their website, and most of the text below is based on those.²⁹⁾ In addition, a report on the subject from the World Health Organization is referred to.³⁰⁾

PATHWAYS OF ALUMINIUM TO HUMAN EXPOSURE

Aluminium constitutes about 7 percent of the Earth's crust. It occurs in various chemical forms in most rocks and soils, in vegetation and is found naturally in most water supplies and as part of dust particles in the air. Aluminium is also present in all clays, making it a constituent of cooking vessels since earliest civilizations. Evolution of life and human civilization has developed in an aluminium rich environment.

Food and beverages

Intake through food is the most important pathway of aluminium to the human body, except when aluminium containing medicines are used.

Plants absorb limited quantities from the soil. However, some plants, like the tea bush, take up larger quantities and for this reason are called "accumulator" plants. Most of the intake of aluminium from food comes from the natural content of aluminium in fruit and vegetables.

In addition to the natural content, some food preparations contain additives containing aluminium salts. In the normal European diet, the daily aluminium intake from various foods is estimated at 3-10 milligrams, depending on the type of food.

Aluminium in the form of foils, menu trays, cans and other utensils is used extensively for the protection, storage, preservation and preparation of food and beverages. The contribution from foods cooked in aluminium saucepans or from aluminium foil and beverage cans is almost negligible (normally in the order of 0.1 mg/day or 1-3 percent of the normal daily intake). The only exception is when highly acidic or salty foods are cooked or stored in uncoated aluminium utensils for extended time periods. This should be avoided as a precautionary measure, and also to avoid tainting of the food.

Drinking water

Aluminium is a natural component in surface and ground water. Most water authorities throughout the world also use aluminium sulfate or "alum" as a flocculating agent in treating their water supplies.

At present there is a WHO guideline for aluminium in drinking water from treatment plants of 0.1 mg/l in a large water treatment facilities and 0.2 mg/l in small facilities based on practical optimization possibilities of the process. Aluminium in water accounts for less than 1 percent of the total daily aluminium intake.

Medicines, vaccines and cosmetics

The main aluminium compound used in medicine is aluminium hydroxide. This is used as an antacid in the treatment of gastric ulcers and as a phosphate binder in cases of long-standing renal failure. Alternative antacids do exist but they are not all as effective.

Aluminium compounds are present in some vaccines as an adjuvant to enhance the immune response, and certain vaccines need this in order to be effective.

Some aluminium salts are widely used in cosmetic products like deodorants. The aluminium salts work by forming a plug at the top of the sweat ducts and reduces the sweat to the surface of the skin.

Inhalation

Inhalation of aluminium through air is a minor source of exposure. According to WHO, pulmonary exposure may contribute up to 0.04 mg/day, which is less than 1 percent of the normal intake by food.

UPTAKE, ACCUMULATION AND EXCRETION OF ALUMINIUM

Most of the aluminium ingested through food, water, beverages and medicine, passes through the digestive system without being absorbed into the body fluids. The broad picture seems to be that there is no clear evidence of a correlation between the amount of aluminium ingested and uptake in 'normal' individuals, but there may be abnormal situations when the barriers are being bypassed or are defective. Also, some studies seem to show a correlation between

high intake levels and uptake and toxic effects. JECFA (Joint FAO/WHO Expert Committee on Food Additives) has therefore recommended a Provisional Tolerable Weekly Intake (PTWI) of 2 milligram/kg body weight.

Once absorbed, aluminium is carried through the blood stream to the kidneys, where it is rapidly excreted. There are abnormal situations when the barriers are being bypassed or are defective and in the event of high blood levels, bones appear to act as a “sink”, taking up aluminium and subsequently releasing it slowly over a long period.

Patients with kidney failure face a multitude of problems, including the inability to excrete absorbed aluminium. The symptoms associated with exposure to aluminium in the dialysis fluid, and/or with the long-term medical use of aluminium compounds in this patient group are recognized. Care is taken to monitor blood levels of aluminium in anyone with kidney failure. The acute neurological disease described in the early days of renal dialysis has no connection with Alzheimer’s Disease. Intravenous preparations for patients receiving regular intravenous treatment are today made without aluminium.

HEALTH EFFECTS

Based on the available scientific literature, the following main conclusions may be drawn regarding potential health effects of exposure to aluminium, aluminium oxide and aluminium hydroxide:

- Neurotoxic effects are not expected at the levels of aluminium to which the general public is typically exposed.
- There is no evidence for a chemical-specific fibrogenic effect due to aluminium metal powder.
- Aluminium oxide and aluminium hydroxide behave as “nuisance dusts” under current controlled occupational exposure conditions.
- A very limited sensitization potential (allergy, asthma) for aluminium metal, aluminium oxide, and aluminium hydroxide dusts on exposure by inhalation is suggested.

- No evidence of effects on fertility or development of foetus and infants from aluminium exposure.
- IARC (International Agency for Research on Cancer) has classified “Aluminium Production” as Group 1 carcinogenic. This is related to potential exposure to known carcinogens such as PAH. The industry has systematically reduced the PAH exposure, and the level today is below current occupational exposure limits. There is no evidence of carcinogenic, mutagenic or genotoxic effects of aluminium or common aluminium compounds.
- The weight of evidence suggests limited sensitization potential for aluminium metal, aluminium oxide, and aluminium hydroxide dusts on exposed skin.
- It has been suggested that high intake of aluminium may be a risk factor in developing Alzheimer’s Disease (AD). The current weight of evidence does not support a primary role for aluminium in causing AD or other diseases involving cognitive decline.

IMPLICATIONS FOR THE USE OF ALUMINIUM PRODUCTS

Available scientific evidence does not support proposals to exclude or reduce the use of aluminium products in any of the applications where aluminium products are commonly used today. The exceptional cases of health risks are related to patients with renal failure, who may get aluminium into the blood stream through dialysis. These cases are well known, and precautions may be taken to eliminate the risk.

Some aluminium products may have significant advantages for public health:

- Aluminium in food and beverage packaging, ensuring a safe barrier towards bacteria and contamination
- “Alum” (aluminium sulfate) used for purification of drinking water
- Aluminium compounds used as adjuvants in vaccines and medicines



8

SOCIAL ISSUES

The production of aluminium, from bauxite mining through alumina refining, smelting and fabrication, involves various social issues, both beneficial and potentially negative for employees, neighboring communities and for society at large. These effects may even extend far into the supply chains for raw materials, machinery and services.

Hydro and our partners in the aluminium industry are conscious of this, and endeavor to reduce negative impacts and maximize the benefits through individual and common initiatives.



POLICY FRAMEWORK

Some of the most challenging social issues are related to mining operations. Hydro has joined the International Council on Mining and Metals (ICMM), which has developed common principles related to business ethics, social responsibility, environment, health and safety. Hydro's Corporate Social Responsibility (CSR) policies and guidelines are based on these principles, aiming at maximizing the benefits and minimizing negative impacts on the society.

The CSR policies focus on four areas:

- Integrity and anti-corruption,
- Community and stakeholder engagement,
- Human rights
- Supply chain and product stewardship.

In addition to the ICMM framework, Hydro's policies and guidelines are also based on internationally accepted standards developed by governmental and non-governmental organizations, such as:

- The Universal Declaration of Human Rights
- UN Global Compact
- Transparency International
- Amnesty International
- International Finance Corporation's (IFC) Equator Principles and performance standards
- ILO's 8 core conventions

Implementation of the policies and guidelines is subject to reporting and auditing.

IMPACTS ON NATIONAL AND LOCAL ECONOMIES

Hydro had 22,655 permanent employees at the end of 2011. In addition, the company had 1,368 temporary employees, and contractor employees represented about 8,900 full-time equivalents. The company's highest number of employees is in Brazil, followed by Germany, Norway and the U.S.³¹⁾ Hydro's organization in 40 countries represents a great diversity in education, experience, gender, age and cultural background.

Through its activities Hydro contributes directly and indirectly in a significant way to local and national economies where we operate.

Total payroll in 2011 was NOK 8,900 million (EUR 1.2 billion, USD 1.5 billion) and the same year Hydro paid about NOK 1,900 million (EUR 250 million, USD 326 million) in income taxes.

Studies for primary aluminium plants in various countries show that our activities have even higher indirect impacts from investments and from operations. Hydro's annual investments, excluding the Vale acquisition, has over the last years been in the range of NOK 3-6 billion (Euro 0.4-0.8 billion, USD 0.5-1 billion). Operations rely to a large degree on input of raw material, energy and other goods and services from external suppliers. Estimates show that through taxes, production and consumption effects, one direct employee creates external employment equivalent to between two and five jobs. Investments have the same kind of ripple effects.³²⁾

COMMUNITY ISSUES

In most local communities, Hydro's industrial activities are welcomed as a source of employment, income, tax generation and general activity in the community. As a secondary consequence of the activity, the communities can be better equipped for health care services, education and cultural activities. However, some groups may be adversely affected by the activities, such as involuntary resettlement, loss of land for harvesting and impacts on traditional ways of life. The presence of a production plant or mine may also enlarge the economic gaps between groups of people, and generate social tensions.

Hydro has a long tradition of stakeholder dialogue in the communities where we operate. Through our membership in ICMM we are also committed to local stakeholder dialogue and engagement to discuss and respond to such issues and conflicts. This includes maintaining interaction with affected parties, including minorities and other marginalized groups. We will contribute to community development in collaboration with host communities and encourage partnerships with governments and non-governmental organizations to ensure that community services are well designed and effectively delivered. When possible, we will enhance social and economic development to address poverty.

HUMAN RIGHTS

In a number of countries, human rights are not fully respected, including:

- Freedom of expression
- Freedom of association and collective bargaining
- Labor standards
- Forced labor
- Child labor
- Minority rights
- Indigenous people
- Use of security forces.

Almost all of our production sites in Europe, Australia, Brazil and Argentina – representing 89 percent of our employees – are unionized. About 80 percent of our employees in Norway belong to unions, and a large proportion of employees in Germany and Brazil are also union members²⁵⁾. Contact between union representatives across borders is an important part of the integration process for our new activities in Brazil. We build on a strong relationship between union representatives and management that has been developed in Hydro over decades.

In countries where the right to form trade unions is restricted, like in Qatar and China, we try to find alternative forums to uphold the rights of employees to influence their work situation. In March 2011, Hydro signed an international frame agreement with four unions, aiming to secure the development of good working relations in Hydro's worldwide operations. In January 2012, we signed a new corporate agreement with the main unions regarding the European Works Council.

BUSINESS ETHICS AND INTEGRITY

Corruption is increasingly seen as a major political issue – not just limited to its legal and ethical implications. The Hydro Integrity Program Handbook and the Competition Compliance Manual have been developed to guide and support staff in handling issues related to anti-corruption and competition issues also related to business relations.

Employees may report breaches or perceived breaches of Hydro's requirements through the Alert Line served by an external company where all permanent and temporary employees can report their concerns at any time and in their own language through toll-free phone numbers or the Internet. The Alert Line can also be accessed by external stakeholders.

In 2011, as in previous years, no instances of corruption were reported in Hydro.

THE SUPPLY CHAIN

Hydro procures energy, materials and services from more than 18,000 suppliers to our global operations. Individual business units are responsible for implementing Hydro's policies towards suppliers and other business relations. Systems are required to pre-qualify new suppliers and to periodically assess active suppliers. Our policy is that contracts with a value of more than USD 3 million shall include social and environmental requirements in the contract itself or in a separate declaration signed by the supplier.



9

RESEARCH, EDUCATION AND INTERNATIONAL COOPERATION

RESEARCH AND EDUCATION

Hydro's research is aimed at improving all stages in the aluminium value chain. The processes are constantly being made more efficient, and the environmental effects reduced. Our products are regularly being adapted to new and more demanding application areas. This is essential in order to safeguard the company's future competitive abilities in a world that is continually making more stringent demands to industry with respect to both product quality, price and environmental performance.

Reduction technology

One of the main research areas is improved cell technology in order to produce more aluminium from each cell (higher amperage and current density), while reducing the energy demand and the emissions per metric ton produced. Test cells of the HAL 4e technology have been in operation at the Årdal Reference Center since 2008, and are ready for full scale industrialization. In parallel with these tests, the research is aiming at further emission reductions as well as possibilities for energy recovery and utilization.

An aluminium smelter emits significant amounts of CO₂, but far less than e.g. a coal or gas power plant. Nevertheless, the industry should be prepared if carbon capture should become a requirement to this industry. A challenge is that the pot gas is too dilute to make CO₂ scrubbing cost effective. Hydro is therefore studying possibilities to redesign the pot hoods to capture the pot gas without the dilution air which is sucked into the cell. This would also reduce the size of the gas treatment systems and make energy recovery more viable.

Casting technology

In a primary smelter, the cast house only uses about 2 percent of the total energy, since the metal comes hot and liquid from the potline. In a remelter, the energy demand is about 5 percent of the energy required in the potline. These percentage figures may seem small in an industry context, but the saving potential in a large cast house may be similar to the yearly energy demand in 4,000 – 5,000 homes. Research is therefore carried out to make more energy efficient furnaces, reduce the loss of metal in dross and increasing throughput capacity.³³⁾

Recycling

Increased return of post-consumer metal scrap in the future will create some challenges for the aluminium industry, and especially to the recycling industry. One of these challenges is to produce alloys of predictable quality from non-uniform raw materials when the ratio of recycled metal to primary metal increases, thus having less pure, primary metal available to "dilute" impurities. Other challenges are related to reducing metal loss in the melting process, recuperating energy from organic coating materials, avoiding harmful emissions and general streamlining of the whole production cycle. All these aspects are part of a research project undertaken by Hydro, NTNU and Sintef.³⁴⁾ In addition, there are studies to develop new alloys which are easier to recycle.

Special issues related to hot climates

Operating an aluminium smelter in a climate where ambient temperatures can reach more than 50 degrees has many challenges, both with respect to the work force, equipment, production performance and environment. Through the joint venture company Qatalum, Hydro has contributed to the establishment of a Hydro Aluminium Technology Centre (HTCQ) at Qatar Science and Technology Park (QSTP), part of Qatar Foundation (QF) in Doha, Qatar. The centre collaborates closely with Qatalum. Among the programs and studies are the following:

- Heat stress monitoring and management
- Effect of climate on emission profile
- Emission monitoring techniques
- Regional waste management strategies



The climate in the Gulf region and the rapidly expanding building sector also creates business opportunities for “green buildings”. Contrary to buildings in the polar regions, the main energy demand is related to cooling. Hydro Building Systems (HBS) has therefore launched a number of initiatives to develop innovative building solutions partly in collaboration with the HTCQ at QSTP. This includes amongst others:

- Mapping of energy flows (cooling, ventilation, lighting etc.)
- Use of photo-voltaic installations to produce electricity
- Hot water collectors
- Surface treatment necessary to withstand the climatic stresses on the materials (e.g. UV light, dust, heat) while maintaining good performance and minimizing maintenance.

The HTCQ at QSTP is also involved in a number of other programs related to technology development, competence building, education etc.

Environmental research in Brazil

Hydro has entered an agreement with the University in Oslo to establish an R&D program related to biodiversity issues in the rain forest areas in Brazil. The intention is to bring forward scientific support for the rehabilitation programs around the bauxite mines. The program will also involve collaboration with local scientific institutes. Hydro has also established links with other bauxite mining companies with a view to improve the quality of reforestation programs.

INTERNATIONAL COOPERATION

While there is strong competition between aluminium companies world wide, the industry has realized that cooperation within the

fields of environment and corporate responsibility is necessary to meet the challenges ahead. The main bodies of cooperation are:

- International Aluminium Institute (IAI)
- European Aluminium Association (EAA)
- International Council on Mining and Metals (ICMM)

Many of the programs and initiatives undertaken by these organizations have already been mentioned, and Hydro is an active driving force in many of these. Hydro personnel have also taken prominent positions in the organizations and their many sub-committees.

Hydro extracts and refines natural resources into products that are an important part of everyday life for more and more people. Nature and what it provides to us form the foundation of everything we do. This is why we cannot be indifferent to how our production and our products affect the environment.

Our ambition is to be an industry frontrunner in:

- Reducing our environmental footprint through improving our performance in all business areas. We will do this through innovation in technology as well as through specific improvement programs
- Helping customers reduce to their footprint. We will contribute to this through increased recycling of aluminium as well as engagement with and support to customers. We believe that through partnerships we can together find good business solutions supporting our common ambition of also reducing the footprint throughout the value chain
- Improving aluminium as a material. We believe that through product and technology innovation we will improve the functional use of aluminium. We also strongly believe that active engagement with stakeholders both directly and via associations will support the long term sustainability of aluminium in various applications

ENERGY AND CLIMATE CHANGE

Climate change is one of the most pressing issues facing mankind. The energy intensity of primary aluminium production leads to significant emissions of greenhouse gases. This gives Hydro a huge responsibility for developing proper solutions.

Our objective is to develop our business, products and solutions in a way that will support a reduction in global greenhouse gas emissions in a life cycle perspective.



We are committed to do this by

- Generating more “green energy”. About two-thirds of the electricity used in our primary production is already from renewable sources, and we intend to use this as a platform for developing more renewable sources around the world.
- Produce more and emit less. Our next generation technologies are already moving us towards this goal, by increasing production output while reducing energy consumption.

- Develop products and solutions that save energy. Lighter cars and packaging products, as well as intelligent aluminium facades reduces energy consumption and thus greenhouse gas emissions. Further innovations and marketing of such products and solutions are key elements of our business strategy
- Recycle more aluminium. Recycling of aluminium requires only 5 per cent of the energy used for primary production, thus saving both energy and greenhouse gas emissions.

EMISSIONS

Emissions from our operations are in principle loss of resources. High emissions from operations to the surrounding environment could cause unwanted impacts.

Our objective is that we want to be an industry frontrunner

Hydro has for decades been in the forefront when it comes to running efficient operations with low emissions. Our primary smelters have been benchmark within the industry when it comes to low emissions of fluoride, SO₂ and dust. Even in the narrow valleys at the West coast of Norway we have demonstrated that we can operate in harmony with the local communities and the environment.

WASTE AND WATER

Resource scarcity makes it necessary to have efficient production processes and to recycle/reuse waste and products after its end of life. In addition water is a scarce commodity in many areas of the world. We need to minimize the water footprint in such water stressed areas.

Our objective is efficient use of resources

In Hydro we are pursuing opportunities to be more efficient. We have set a target for 2020 to reduce landfilled waste by 60% compared to 2010. This will make our operations more efficient and also lead to more reuse/recycling of by-products from our operations.

Only a small share of our operations is located in water stressed areas, and they are already efficient in their use of water. Nevertheless, we will reduce our water consumption in water stressed areas by 15% in 2020 compared with 2010

ECOSYSTEMS AND BIODIVERSITY

Biodiversity world wide is lost at an alarming rate. Viable ecosystems are essential for providing for example food, energy, flood dampening, medicine, pollination, aesthetic and cultural values. Protecting ecosystems and biodiversity is all the more important in order to provide future generations the basis for a good life.

Our aspiration is to achieve no net loss of biodiversity

Hydro was a pioneer in the late 1980-ies and early 1990-ies to establish a scientific basis for critical emission levels for the Norwegian smelters. In parallel with the scientific studies, the local communities were engaged in stakeholder dialogues to establish consensus and support for the emission reduction targets and measures.

In the Paragominas Bauxite operations we have decided that there should be a balance between the areas opened for mining with areas being reforested no later in 2017. The reforestation program has as a vision to lay the long term foundation for nature to re-establish the ecosystems to their original state.

PRODUCT STEWARDSHIP

Product stewardship has traditionally been related to safe handling of products throughout their life cycle, including safe use and safe recycling for new products. In recent years the product stewardship concept has broadened to include several environmental and social aspects along the whole valuechain.

Our objective is to provide proactive communication and documentation along with our materials and products to the customers

We are therefore actively providing our customers with life cycle data from our value chain along with relevant information and guidance, enabling our customers to make their own evaluations and right decisions. Choosing the right product, correct use of the product and correct disposal after the use phase are essential elements to achieve the potential benefits and reduce the environmental footprint of our products.

SOME OF THE THINGS WE DO, AND SOME OF THE PLACES WE ARE



1 *Aluminerie Alouette*
Primary aluminium
Capacity: 575 000 tons
20% Hydro



2 *Hydro Aluminium Henderson*
Remelter
Capacity: 90 000 tons



3 *Mineração Paragominas*
Bauxite mine
Capacity: 10 mill. tons



4 *Hydro Aluminium Sunndal*
Primary aluminium
Capacity: 390 000 tons



5 *Roldal-Suldal*
Hydropower plants
Capacity: 584 MW
95.2% Hydro



6 *Hydro Aluminium, Grevenbroich*
Rolling mill
Capacity: 440 000 tons



7 *Qatalum*
Primary aluminium
Capacity: 585 000 tons
50% Hydro



8 *Hydro Aluminium Malaysia*
Rolling mill
Capacity: 12 000 tons



REFERENCE LIST

- 1) EAA, 2008: Environmental Profile Report for the European Aluminium Industry
- 2) Energy savings by light-weighting – II. IFEU, 2004
- 3) <http://www.miljostatus.no/miljodata/Norge>
- 4) Stiffness Relevance and Strength Relevance in Crash of Car Body Components. EAA, 2010
- 5) Klimawirkungen des Material- und Produktstroms von Hydro Aluminium Rolled Products 2011: Eine Sekundärstudie an ökobilanziell untersuchten Fallbeispielen. HARP, September 2012
- 6) <http://www.wiconafinder.com/bellenberg/WiconabellenbergMicrosite.swf>
- 7) <http://powerhouse.no>
- 8) Life Cycle Assessment of various packaging systems for beer. IFEU, May 2010.
- 9) <http://recycling.world-aluminium.org/review/global-metal-flow.html>
- 10) <http://www.alueurope.eu/aludrive-ducker-study/>
- 11) <http://www.alueurope.eu/sustainability-of-the-european-aluminium-industry2010/>
- 12) <http://www.alueurope.eu/wp-content/uploads/2011/10/814.pdf>
- 13) http://www.alueurope.eu/wp-content/uploads/2012/04/Alu-Pack-Recycling-Progress-Deposits-March2011_updated1.pdf
- 14) IAI, fourth sustainable bauxite mining report 2008
- 15) U.S. Geological Survey, Mineral Commodity Summaries, January 2012
- 16) <http://bauxite.world-aluminium.org/mining/rehabilitation.html>
- 17) Global forest land-use change from 1990 to 2005. FAO, <http://www.fao.org/forestry/fra/fra2010/en/>
- 18) <http://municipiosverdes.com.br/>
- 19) Review of current bauxite residue management, disposal and storage: Practices, Engineering and Science. CSIRO document DMR-3608, May 2009
- 20) Alunorte Global Energy Efficiency. Light Metals, 2011.
- 21) https://stats.world-aluminium.org/iai/stats_new/formServer.asp?form=16
- 22) https://stats.world-aluminium.org/iai/stats_new/formServer.asp?form=7
- 23) Global Aluminium Industry Sustainability Performance 2010. IAI, 2011.
- 24) Hydro Annual report 2006-2010
- 25) Hydro Annual Report, 2011
- 26) http://unfccc.int/ghg_data/items/3825.php
- 27) Dams and development.... The report of the world commission on dams, nov. 2000.
- 28) The Norwegian Aluminium Industry and the Local Environment, Summary Report, Hydro 1994
- 29) <http://www.alueurope.eu/health-fact-sheets>
- 30) Safety evaluation of certain food additives and contaminants. WHO, 2007
- 31) Hydro's Annual Report 2011.
- 32) Limited Social Impact assessment, Environmental Resources Management (ERM), 30.05.2012
- 33) Energy Efficient Aluminium Cast House (CastAl). Collaboration project between Hydro, SAPA, NTNU and Sintef.
- 34) Conservation of energy and quality by utilizing post-consumed aluminium. (AlEnergy) Collaboration project between Hydro, NTNU and Sintef.

Hydro is a global supplier of aluminium with activities throughout the value chain, from bauxite extraction to the production of rolled and extruded aluminium products and building systems. Based in Norway, the company employs 22,000 people in more than 40 countries.

Rooted in a century of experience in renewable energy production, technology development and progressive partnerships, Hydro is committed to strengthening the viability of the customers and communities we serve.

Hydro

Drammensveien 260
NO-0240 Oslo
Norway

Tel.: +47 22 53 81 00
Fax: +47 22 53 27 25
www.hydro.com

Design and production: Hydro and Artbox 12/2012
Photo credit: Rosangela Aguiar, Marcos Xavier Almeida,
Christian Charlier, Tony Hall, Dag Jensen, Simon McComb,
Jo Michael, Paulo Santos, Kimm Saatvedt, Hydro, Snøhetta/
MIR, Scanpix, Wicona.

© Hydro 2012



HYDRO

Infinite aluminium