Development of Iceland's geothermal energy potential for aluminium production – a critical analysis

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Abstract
Iceland is developing its hydro and geothermal resources in the context of an energy master plan, mainly to provide power for expansion of the aluminium industry. This paper tests perceptions of geothermal energy as low-carbon, renewable and environmentally benign, using Icelandic geothermal industry as a case study.
The application of geothermal energy for aluminium smelting is discussed as well as environmental and human rights record of the aluminium industry in general. Despite application of renewable energy technologies, emission of greenhouse gases by aluminium production is set to increase.
Our analysis further shows that carbon emissions of geothermal installations can approximate those of gas-powered plants. In intensely exploited reservoirs, life of boreholes is limited and reservoirs need extensive recovery time after exploitation, making geothermal exploitation at these sites not renewable in the short to medium term. Pollution and landscape impacts are extensive when geothermal technology is applied on a large scale.

Background
Iceland is known for its geysers, glaciers, geology and Björk, for its relatively successful fisheries management and its rather unsuccessful financial management. But this northern country also harbours the largest remaining wilderness in Europe, an endless landscape of volcanoes, glaciers, powerful rivers in grand canyons, lava fields, swamps and wetlands teeming with birds in summer, and plains of tundra covered with bright coloured mosses and dwarf willow.

In 2006, 57 km^2 of one of the most magnificent areas of the country, the wild highland plateau north-east of the large Vatnajokull glacier, was inundated for Europe's largest hydro complex, the 690 MW Karahnjukar dams. The energy from the dams went to a single new aluminium smelter built by the American transnational corporation Alcoa. On the day of the flooding, 15.000 people (out of a population of 320.000) demonstrated against the project. The protests against the Karahnjukar dams launched a wider movement aimed at protecting Iceland's wilderness from heavy industry.
Icelanders, who had been divided over the perceived costs and benefits, were shocked by the devastation wrought by the project. Since the flooding, strong winds in the highlands have eroded silt from the rising and falling water table and dust storms are affecting an area much vaster than the reservoir. Mud rains fall in the East fjords where many local industries closed after the smelter was built. Seal colonies in the delta of the dammed rivers are diminished and some of the most important breeding

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grounds of vast colonies of rare skua, geese and duck species are gone. 3% of the Iceland's landmass is affected by the Karahnjukar project[2].
Impact of large dams on climate has been found to be higher than previously assumed due to methane emissions from reservoirs[3] and it has recently become clear that this is also significant for high latitude reservoirs such as Karahnjukar[4]. Damming Iceland's glacial rivers prevents the flow of mineral rich silt (containing calcium and magnesium) to the sea. These nutrients feed marine phytoplankton, the start of most marine food chains. The damming of Iceland's glacial rivers not only decreases food supply for fish stocks in the North Atlantic, but also impacts oceanic carbon absorption, and therefore the global climate[5].
The promise of environmentally friendly hydropower turned out to be a false one for the dams in east Iceland. Now, similar promises are being made for geothermal energy as a clean power source. In this chapter we review the development of geothermal energy in particular and examine its sustainability, environmental impact and some of the associated social and economic issues related to recent industrialisation in Iceland.

Cheap energy, minimum red tape
Iceland, with its vast possibilities of hydroelectric and geothermal energy, became an appealing target for heavy industry corporations such as Alcoa, RioTinto-Alcan and Century Aluminum. In a world increasingly concerned about carbon emissions, the clean image of hydroelectric and geothermal energy is appealing. Though heavy industry processes have an implicitly high environmental impact, they can be made to appear greener by using 'renewable' energy. To this end Iceland was granted an exemption for 'green-powered' industrial emissions under Kyoto, and pollution control schemes are lenient, encouraging industrial investment[6].

The wholesale of Iceland's energy resources began in 1995 when the Ministry of Industry and Landsvirkjun, the national power company, published a brochure entitled "Lowest energy prices!!"[7]. The brochure glorified the country as having the cheapest, most hard working and healthiest labour force in the world, the cleanest air and purest water – as well as the cheapest energy and "a minimum of environmental red tape".
For ten years former Prime Minister Davíd Oddsson (who became the central bank director largely blamed for the collapse of the Icelandic economy) led the campaign to attract energy intensive, and therefore often highly polluting industries. In 1998, Century Aluminum constructed their first smelter in Iceland at Hvalfjordur, to be expanded eight years later. Three to five new aluminium smelters were planned. The existing Alcan (now Rio Tinto) smelter and a steel factory was to be expanded and an

[2] Icelandic Society for the Protection of Birds. 2008. Environmental facts and figures of the Kárahnjúkar project [online]. URL http://www.fuglavernd.is/enska/karahnjukar/statistics.html [Accessed 3-12-2008].
[3] Krater, J. 2006. Elke stuwdam is een ramp. *Trouw*, 20-1-2008.
[4] Duchemin, E., Lucotte, M., Canuel, R., Soumis, N., 2006. First assessment of methane and carbon dioxide emissions from shallow and deep zones of boreal reservoirs upon ice break-up. Lakes & Reservoirs: Research and Management 11, 9-19.
[5] Gislason, S.R., Oelkers, E.H., Snorrason, A., 2006. Role of river-suspended material in the global carbon cycle. Geology 34, 49-52.
[6] For example, RT-Alcan's smelter at Straumsvik is allowed to dispose of it's highly toxic spent potlining in an adjacent landfill site that is exposed to regular sea flooding, ten miles south of Reykjavik. Rio Tinto Alcan. 2008. Pot linings [online]. URL http://www.riotintoalcan.is/?PageID=111 [Accessed 12-12-2008].
[7] Icelandic Marketing Agency (MIL) (1995). Lowest energy prices in Europe for new contracts; your springboard into Europe. MIL, Reykjavik.

anode factory erected. An energy master plan was drawn up to harness the 30 Twh of electricity needed; dozens of dams would be built in every major glacial river, and nearly all geothermal areas would be exploited.

Not everyone agreed with the projects. In 2004, at the third European Social Forum in London, Icelandic environmentalists made an international call for help. That year, the international campaign Saving Iceland was formed to oppose the masterplan[8]. In consecutive years, four summer action camps were held. A number of years of direct action as well as mainstream protests by celebrities such as Sigur Ros and Björk and Icelandic intellectuals have seen the cancellation of some of the most damaging projects. Still, construction of a number of new dams in rivers Thjorsá and Tungnaá is planned to start this year (2009) to provide power for expansion at Rio Tinto-Alcan's existing smelter, a data centre and a number of silicon refining plants by corporations who's names are kept hidden by Landsvirkjun.

Cheap imported labour

Large dam projects in the majority world have been associated with mass displacements and 'cultural genocide' on an enormous scale[9]. Comparatively, the social impact of the developments in Iceland is small. Nonetheless cheap energy and labour is just as important to corporations operating in Iceland as elsewhere. Special arrangements are made by governments for subsidised borrowing and tax cuts, loans for expensive dam and geothermal projects are taken by the state-owned power company at the taxpayers risk, while the price paid for energy is kept secret, and depends on world price of aluminium. Thus the taxpayer directly subsidises every ton of aluminium when its market price drops.

Imported cheap labour and low workers rights standards are routinely employed on construction sites. More than a dozen Chinese and other foreign workers died in construction of Karahnjukar, and more recently two Romanian workers suffocated in geothermal drill pipes on the site of a work camp near Reykjavik where they sometimes work up to 72 hour a week and shifts of sometimes 17 hours[10]. Workers are effectively confined to the camps for their 3-5 month work periods, going out to the capital once a month.

'Kuwait of the North'

Now that Icelanders have realised the full impact of Karahnjukar, public opinion is less favourable to large dams, and power companies have shifted their focus to geothermal exploitation. Currently the Hengill area east of Reykjavik is being developed on a large scale for the recently completed expansion of the Century Aluminum smelter in Hvalfjordur. Test drilling is taking place in four fields (Krafla, Bjarnarflag, Theistareykir and Gjastykki) in the north of the country for a new Alcoa smelter near Husavik. Brennisteinsfjöll, Krísuvík and Reykjanes fields, southwest of Reykjavik, are planned to be developed for a new Century smelter. The national power company plans to triple geothermal power capacity to 1500 MW, on top of the 575 MW currently generated by geothermal, of which a large proportion already goes to the two existing smelters in the Reykjavík area. Also, a new public-private consortium has been formed to develop deeper drilling of geothermal fields, which

[8] Saving Iceland: www.savingiceland.org.
[9] McCully, P., 2001. Silenced rivers: the ecology and politics of large dams. Blackwell Publishing, New York.
[10] Personal communication with a number of anonymous workers at Hellisheidi.

would amplify the scale of geothermal production and power generation potential.[11] Ultimately, it is proposed that all of the economically feasible hot spring areas in Iceland will be exploited for industrial use, including a number of sites located in Iceland's central highlands, the beautiful heart of Iceland's undisturbed wilderness[12]. Landsvirkjun, without any irony, has termed Iceland 'the Kuwait of the North'[13]

Geothermal promises

Geothermal potential with current technology is found at hotspots on the earth's surface, where magma intrudes into the rock bed and heats porous rock to high temperatures[14]. Electricity is generated by drilling into these reservoirs and powering turbines with high-pressure steam emitted from boreholes. The original geothermal power stations and boreholes supplying domestic needs in Reykjavik are small-scale installations that efficiently provide electricity, hot water, and heat, from sources in close proximity to the city, and are fairly sustainable.

As with any form of energy generation, there are environmental issues with geothermal exploitation that should be taken into account. These impacts are exacerbated significantly by the greater scale and intensity of production that energy-intensive industries require. But the quick-to-embrace enthusiasm for any technological solutions that promise to be a way out of our fossil fuel addiction, have tended to gloss over the downsides of geothermal exploitation and promote its intensive commercial use. Geothermal energy has the image of being sustainable, carbon neutral and of low environmental impact. How does this image compare to reality?

Renewable

Geothermal reservoirs have a sustainable production level if the surface release of heat is balanced by heat and fluid recharge within the underground reservoir[15]. This happens naturally in undisturbed hot springs, which have remained at more or less constant temperature over hundreds of years, but these recharge rates are generally not sufficient for exploiting economically[16]. The Geyser hot springs at Calistoga, USA experienced a 150% decrease in production over ten years, due to rapid exploitation to meet economic requirements, and there have been many similar cases[17].

Extracting super heated steam and fluids eventually causes a drop in pressure and temperature of the reservoir. Re-injection of fluids maintains pressure but has a cooling effect and best available technology cannot fully re-inject all extracted fluids, as significant amounts of steam and wastewater is released into the environment[18].

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[11] At the time of writing, investments in most projects were put on hold because of Alcoa and Century ceasing capital injection due to economic uncertainty and the slump of aluminium demand. Also, opposition has surged as the link between borrowing for previous heavy industry projects and Iceland's severe economic depression has become evident (Krater, J. 2008. More power plants may cause more economic instability. *Morgunbladid*, 26-10-2008.)

[12] Pálsson, B. 2007. Iceland deep drilling: a project at risk. Presentation produced by NORDNET for Landsvirkjun [online]. URL www.vsf.is/files/691972290Innovation%201.pdf [Accessed 13/12/2008].

[13] Landsvirkjun. 2004. Now to tame the waterfalls of Iceland. *Living Science*, 8, 50-55.

[14] For an overview of global geothermal potential in a sustainability context, see MacKay, D.J.C. 2008. Without the hot air. UIT, Cambridge.

[15] Rybach. L. and Mongillo, M. 2006. Geothermal Sustainability: A Review with Identified Research Needs. GRC Transactions, 30, 1083 – 1090.

[16] Rybach, L., 2003. Geothermal energy: sustainability and the environment. Geothermics 32, 463-470.

[17] Sanyal, S.K., Butler, S.J., Brown, P.J., Goyal, K., Box, T., 2000. An investigation of productivity and pressure decline trends in geothermal steam reservoirs. Proceedings World Geothermal Congress, Japan, 5, 873–877.

[18] Þórleifsdóttir. Á. 2007. Geothermal exploitation in the Reykjanes peninsula area. Saving Iceland winter

Boreholes are usually modelled for only 30 years of production[19]. Recovery of reservoirs used for commercial energy generation takes 100-250 years before being viable for exploitation again, while in shallow, decentralised heat pump systems used for home heating, recovery time roughly equals production time[20]. Another problem is that geothermal hotspots like Iceland are seismically active zones. In Iceland, it has occurred that two thirds of boreholes in a field were destroyed by quakes.[21]
Compared to the geological time scale of oil regeneration, geothermal energy *is* relatively renewable. However geothermal energy cannot truly be called a renewable energy source and boreholes need to be decommissioned after a few decades.

Carbon-neutral
Geothermal gases are rich in various elements and chemical compounds (such as sulfur). Carbon dioxide is present in quantities reflecting of this chemical make up which is distinct to each area. In Krafla (North Iceland), CO_2 makes up 90-98%, the rest being hydrogen sulphide[22].
Calculations based on the national power company (Landsvirkjun)'s site study for current North Icelandic geothermal developments reveal that the 400 MW of boreholes planned for a single Alcoa smelter in Húsavík will release 1300 tonnes CO_2 per MW[23]. An average gas powered plant would produce only slightly more, 1595 tonne per MW[24]. The total of 520,000 tonnes CO_2 for these fields alone is almost equivalent to all road transport in Iceland[25].
In Iceland, a single site emitting over 30,000 tonnes requires an emissions permit. Conveniently, figures for current geothermal power stations hover just under that figure. Either way, Icelandic authorities do not consider emissions from geothermal plants anthropogenic and do not include them in greenhouse gas inventories, although currently operating plants emit 8-16% of the country's total emissions[26].

Minimal environmental impact
Geothermal fluids contain high concentrations of heavy metals and other toxic

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conference, 01-12-2007. Reykjavik.
[19] E.g. VGK (2005), Environmental Impact Assesment for Helisheidarvirkjun [online]. URL http://www.vgk.is/hs/Skjol/UES/SH_matsskyrsla.pdf [Accessed August 15, 2007].
[20] Rybach, L., 2003. Geothermal energy: sustainability and the environment. Geothermics 32, 463-470.
[21] Sæmundsson, K. (2006). Assessing Volcanic risk in north Iceland. ISOR – Icelandic Geosurvey. http://www.hrv.is/media/files/Volcanic%20risk_web.pdf [Accessed August 4th, 2008].
[22] Landsvirkjun (2008). Krafla key figures and specifications [online]. URL http://www.lv.is/EN/article.asp?catID=277&ArtId=306 [Accessed 13-12-2008].
[23] Sigurðardóttir, R. Unpublished. Energy good and green. In: Bæ bæ Ísland (bye bye Iceland), to be published by the University of Akureyri and Akureyri Art Museum.
The data in this study is arrived at by calculation of the figures in site surveys for the Krafla, Bjarnarflag and Þeistareykir geothermal plants.
Sigurðardóttir has experienced threats and harassment by Landsvirkjun, the national power company, since 2000. In that year, she concluded the formal environmental impact assessment for a proposed large dam, Þjórsárver, a Ramsar treaty area, by stating there were significant, irreversible environmental impacts. The national power company did not pay her and refused to publish the report. Since then Sigurðardóttir has been refused all Icelandic government commissions. Since then, practically all EIAs for geothermal and hydro plants and smelters have been commissioned to the companies HRV and VGK, construction engineers rather than ecological consultancies and "the leading project management and consulting engineering companies within the primary aluminum production sector" (HRV. 2008. Primary aluminium production [online]. URL http://www.hrv.is/hrv/Info/PrimaryAluminumProduction/ [Accessed 13-12-2008]).
[24] US Govt. Energy Information Administration. 2008. Voluntary reporting of greenhouse gases program. [online]. URL http://www.eia.doe.gov/oiaf/1605/coefficients.html [Accessed 13-12-2008].
[25] Ministry of the Environment, Iceland (2006). Iceland's Fourth National Communication on Climate Change. http://unfccc.int/resource/docs/natc/islnc4.pdf [Accessed August 15, 2007].
[26] Armannsson, H., Fridriksson, T., Kristjansson, B.R., 2005. CO2 emissions from geothermal power plants and natural geothermal activity in Iceland. Geothermics 34, 286-296.

elements, including radon, arsenic, mercury, ammonia and boron, which are damaging to the freshwater systems into which they are released as waste water. Arsenic concentrations of 0.5 to 4.6 ppm are found in wastewater released from geothermal power plants; the WHO recommends a maximum 0.01 ppm in drinking water[27]. Hydrogensulphide (H_2S) is a main component of geothermal steam and is responsible for the rotten egg smell of geothermal areas. It is corrosive and classed as very toxic[28]. H_2S is a heavy gas and can linger in valleys, polluting local populations[29]. It forms sulphurdioxide (SO_2) in the atmosphere causing acid rain. Geothermal power accounts for 79% of Iceland's H_2S and SO_2 emissions[30].

In 2004, sulphur pollution in Reykjavik had reached levels regarded as "dangerous"[31]. In 2008, sulphur pollution from the Hellisheiði power station, 30 km away, was reported to be turning lamposts and jewelry in Reykjavík black. A record number of objections was filed to two more large geothermal plants in the same area, which would have produced more sulphur and carbon emissions than the planned smelter they were supposed to power, and plans were put on hold.
In the North the town of Reykahlið will become exposed to 32,000 tons of H_2S per year[32] if the geothermal power plants (for which feasibility studies are now complete) are built. High levels of sulphur pollution are associated with increased mortality from respiratory diseases[33].

Landscape impact is another significant factor. Each geothermal borehole drilled only produces a few megawatts of power, and may be located across a large area, connected to the main power station with pipes and roads. Numerous test holes are drilled for every borehole that goes into production. A currently ongoing project, the proposed expansion of Hellisheiði, demands more than 100 boreholes in a stunning area of wilderness, providing 160 MW, less than half of what is needed by the smelter it will power[34].
Areas such as Hellisheiði are globally rare, very beautiful and scientifically interesting. Icelandic geothermal areas are characterised by colourful striking landscapes, hot springs, lavas and glaciers, and are biologically and geologically endemic to the country. In the extreme conditions of heat and salt found at each hot spring or cave, extremophiles, unique mosses and bacteria, develop, such as Hveraburst, a heat tolerant moss found only in Iceland's Hveragerði hot spring area. Research into these primeval species is in its infancy, and already has led to greater understanding of the formation of life on earth, and the possibilities of evolution of extraplanetary life. Irreversible disturbance to these wild areas for power plants includes roads, powerlines, heavy lorries and loud drilling equipment. It has also been suggested that depletion of one geothermal reservoir can result in the drying of

[27] Kristmannsdottir, H., Armannsson, H., 2003. Environmental aspects of geothermal energy utilization. Geothermics 32, 451-461.
[28] European Economic Commission. 1967. Council directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances. Brussels, Belgium.
[29] Ibidem 23.
[30] Statistics Iceland. 2007. Emission of sulphur dioxides (SO2) by source 1990-2006 [online]. URL http://www.statice.is/Statistics/Geography-and-environment/Gas-emission [Accessed 12/12/2008]
[31] Benediktsson, O. 2004. Open letter to the minister for the environment regarding operating licenses for an anode factory at Katanes in Hvalfjordur. University of Iceland, Reykjavik.
[32] Ibidem 23.
[33] Shwela, D. 2000. Air pollution and health in urban Areas. Review of Environmental Health. 15, 13-42.
[34] VGK (2005), Environmental impact assesment for Helisheidarvirkjun [online]. URL http://www.vgk.is/hs/Skjol/UES/SH_matsskyrsla.pdf [Accessed August 15, 2007].

surrounding hot spring areas[35]. Thus the direct environmental impact of geothermal extraction may be much larger than previously thought, and landscape is a key consideration.

100% renewable, double the emissions

In conclusion, the impacts from geothermal energy that is developed on a large scale such as is currently happening in Iceland, are greater than generally assumed. As regards climate issues, Iceland may end up in an extraordinary position. The Icelandic ministry of environment has calculated that if only some of the planned industrial projects continue[36], greenhouse gas emissions in 2020 will be 63% higher than in 1990 (assuming that emissions from geothermal and hydro plants are nil)[37]. If all projects continue and emissions are taken into account, Iceland's climate footprint, powered by 100% 'green' energy could double (again, this figure excludes emissions from geothermal or hydro plants).

This is made possible because the country was not just granted a generous 10% increase under Annex 1 of the Kyoto Protocol, but also took advantage of a specific exemption for emissions of heavy industry powered by 'renewables'.

Iceland has also been mentioned in proposals for a European (or even global) green energy super grid[38]. The calculations brought forward here suggest that it is not worthwhile to replace gas-powered plants by Icelandic geothermal. If that electricity is to be used for growth of heavy industry, it is quite arbitrary for the climate whether that would be in Iceland or mainland Europe. The aluminium industry is set to increase its emissions by a fifth by 2020 (see Box 1: The aluminium industry, climate and green energy) and this includes its embrace of non-fossil energy.

As an alternative, Landsvirkjun has taken to lobbying data centre corporations, silicon refineries and other energy intensive industries with better public images than Rio Tinto to come to Iceland. If such plans go ahead, Iceland would become a large hard disk for the global Internet. Again, moving gas-powered servers from Europe to geothermal-powered servers in Iceland does not significantly decrease emissions.

And there is another reason not to embrace these projects. Wilderness areas are becoming rare globally, with over 83% of the earth's landmass directly affected by humans[39], and the Icelandic wilderness is one of the largest left in Europe. It provides important regulating ecosystem services and has aesthetic, scientific, medical, cultural and spiritual significance for humans. However, we believe all landscapes, ecological systems and forms of life have their own intrinsic value and right to develop for themselves, rather than for the sole benefit of mankind. We believe the dominant world-view that sees the natural world as a collection of 'resources' has greatly

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[35] Ibidem 27.

[36] Enlargement of RT-Alcan and Century smelters, of the Icelandic Alloys/Elkem steel factory and construction of an Anode plant. This does not include the new Century Aluminum (Helguvik) and Alcoa (Husavik) smelters. Century has recently received smelter has an emissions permit for the new smelter but Alcoa hasn't. RTA is not expanding production at it's smelter by as much as originally planned and the status of the Elkem expansion and Anode plant is currently unclear.

[37] Ministry of the Environment. 2006. Iceland's Fourth National Communication on Climate Change. Ministry of the Environment, Reykjavik, Iceland.

[38] E.g. Monbiot, G. 2008. Build a Europe-wide 'super grid' [online]. URL http://e-day.org.uk/solutions/charities/14536/george-monbiot--build-a-europewide-super-grid.thtml [Accessed 13-12-2008].

[39] Columbia University and Wildlife Conservation Society. 2008. Last of the wild database and human footprint atlas. Center for International Earth Science Information Network, Columbia University. URL http://www.ciesin.columbia.edu/wild_areas [Accessed 13-12-2008].

contributed to severe ecological and social crises. To recover from the consumption paradigm we must redefine our environmental ethic and what it means to be human, to include a profound sense of the fragile and beautiful interconnection of life on earth.

Proponents of heavy industry in Iceland have stated that it is the country's 'ethical obligation' to sacrifice the country's wild areas for the sake of the environment[40]. While this is more likely than not moral opportunism on the side of those who are to benefit from the projects, the technological or pragmatic environmentalism in favour of super grids and mega data centres comes down to a proposal to sacrifice unique ecological areas for the of greater good of living a resource-intensive i-life style 'sustainably'. In contrast, for anyone who identifies with a natural area, it is easy to understand why it has a value of it's own. Given the rarity of wild lands in this context, the value can be seen as far greater than that of any of our possessions; it is in a sense, invaluable.

What can perhaps be concluded from this Icelandic green energy case study, is that application of a technology that has been thought of as renewable, climate-friendly and low-impact, on the large scale that is associated with fossil fuels, makes it a lot like the technology it was supposed to replace. It has certainly been argued that technological systems tend to reproduce themselves independent of the specific technologies[41] [42]. Simply applying a different technology to address issues that are not entirely technological, is not addressing the problem of our over consumptive lifestyles. But it can end the existence of a place that is not like any other, irrevocably.

[40] The Economist. 2008. Testing metal - when thinking globally requires unpleasant action locally, Economist.com, Green.view, 29-9-2008. URL http://www.economist.com/world/international/displaystory.cfm?story_id=12323257 [Accessed 12-12-2008].
[41] E.g. Mander, J. 1992. In the absence of the sacred. Sierra Club, San Francisco, CA.
[42] Krater, J. 2007. Duurzame technologie, een contradictie? Buiten de Orde, zomer 2007.

Box 1. The aluminium industry, climate and green energy

The aluminium industry is the world's most energy–intensive industry, and also one of the most polluting[43]. Aluminium is derived from bauxite soils, mainly found in the tropics and subtropics. Five tonnes of bauxite is strip mined to produce one tonne of aluminium. Large scale deforestation of tropical forests caused by shallow open cast mining creates soil erosion and water pollution and has displaced and destroyed the livelihood of numerous indigenous peoples in Australia, India, Brazil and elsewhere, a process which continues to this day[44] [45]. Bauxite is refined to produce alumina and leave red mud, a caustic mixture of heavy metals and radionuclides, which is known to cause silicosis, cancer, and other diseases associated with radiation[46].

Alumina is smelted using carbon anodes and aluminium fluoride to remove the strongly bonded oxygen. This part of the process is most energy intensive and produces inorganic fluorides, SO_2, CO_2 and perfluorocarbons (very strong greenhouse agents) in the airborne waste, as well as solid spent pot linings containing cyanides and fluorides. Approximately 30% of aluminium is used for arms production and defence; the remainder is used for cars, planes and construction, packaging and disposables[47] [48].

Cradle to grave

Metal giants have not enjoyed a particularly good environmental reputation. Rio Tinto was described by motion in the British parliament in 1997 as "the most uncaring and ruthless company in the world", for human rights, anti-unionising and total disregard for indigenous people[49], and was pulled up again in 2000, for war crimes, environmental destruction and racism[50]. Recently the corporation was thrown out of the Norwegian Government pension fund for similar reasons[51].

Century Aluminum's Icelandic smelter has been accused of forcing injured workers back to work[52] and of producing illegal amounts of fluorine pollution causing health problems[53]. The company is working with the Sassou government of Congo-Brazzaville, a single-party regime which came to power in fraudulent elections in 2002, to develop large scale open cast bauxite mining[54] [55]. It's bauxite mining and

[43] Switkes, G. 2005. Foiling the aluminum industry: a toolkit for communities, activists, consumers, and workers. International Rivers, Berkeley, CA.

[44] Das, S. and Padel, F., 2005. Double death: aluminium's links with genocide Economic and Political Weekly, December 2005.

[45] For example, the Dongria Kondh in Orissa, Eastern India, are under threat of being forcefully removed from their land to allow mining of Niamgiri mountain, a rich bauxite reserve, by Vedanta, a UK based mining corporation. Pressured by Vedanta, the Indian supreme court removed the Dongria's constitutional right as tribal people to decide on development of their land. (Survival International. 2008. Dongria Kondh [online]. URL http://www.survival-international.org/tribes/dongria [Accessed 13-12-2008]).

[46] Cooke, K. and Gould, M.H. 1991. The health effects of aluminium, a review. *The Journal of the Royal Society for the Promotion of Health*. 111, 163-8.

[47] Ibidem 37.

[48] Das. S and Padel, F. (unpublished). Out of This Earth: East India Adivasis and the Aluminium Cartel.

[49] Clapham, M., UK Parliament, House of Commons. 1998. Rio Tinto Corporation. Early day motion 1194. HMSO, London.

[50] UK Parliament, House of Commons. 2000. Weekly Information Bulletin, 16-12-2000. HMSO, London.

[51] Survival International. 2008. Norway sells shares of unethical Rio Tinto [online]. http://www.survival-international.org/news/3700 [Accessed 16-12-2008].

[52] Morgunbladid. 20008. Injured Century and Elkem workers forced back to work [online]. URL http://www.mbl.is/mm/frettir/innlent/2008/08/11/thryst_a_ad_ovinnufaerir_starfsmenn_snui_aftur_til_/ [Accessed 14-12-2008].

[53] Iceland Review. 2008. Pollution from smelter damages teeth in sheep [online]. URL http://www.icelandreview.com/icelandreview/daily_news/?cat_id=16539&ew_0_a_id=309548 [Accessed 14-12-2008].

[54] AZ Materials News (2007). Century Aluminium to Build Aluminium Smelter in Republic of Congo. http://www.azom.com/News.asp?NewsID=7734 [Accessed 20-6-08]

refining in Jamaica has been responsible for large-scale rainforest destruction and water pollution[56] [57] [58]. Alcoa has been convicted numerous times for toxic waste dumping in the US[59], old-growth and rainforest destruction and displacement of indigenous people in countries such as Brazil, Suriname and Australia[60] [61] [62]. Alcoa has lost popularity in Iceland for its intimate association with the US military, which is categorically denied by Alcoa Iceland (although it has a website dedicated to it's military products)[63]. In Honduras, an Alcoa car parts factory was accused of treating workers worse than sweatshops. The basic pay of 74 cents an hour covered 37% of an average family's most essential needs, and in the last three years, wages fell by 13%. Workers would be forced to urinate and defecate in their clothes after being repeatedly denied to use the bathroom and women would have to take off clothes to prove they were menstruating. Protests by workers in 2007 led to 90% of the trade union leaders being fired[64].

Nonetheless, Alcoa claims to be one of the worlds most ethical and sustainable companies, according to a host of international awards listed by the company[65]. Their website (subtitled 'Eco-Alcoa' – 'Click here to see how Alcoa is part of the solution') is dominated by articles on community projects and energy saving initiatives, and with former Greenpeace and WWF directors at the helm, they are doing well to promote a green image. In a recent presentation, Alcoa state they are on the cutting edge of green corporate thinking, embracing recycling and green energy and even claiming to be carbon-neutral, as a whole industry, by 2020[66]. Are these promises coming true?

Recycling

Recyclability of aluminium is probably the most important selling point for the industry: "It's more like reincarnation than recycling"[67]. Recycling aluminium is indeed 95% more efficient than primary production; still, it takes the same amount of energy as producing new steel[68]. Alcoa sources only 20% of its aluminium from recycling. Overall recycling rates are 33% and, according to US Aluminium

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[67] Ibidem 66.
[68] Das, S. and Padel, F. (unpublished). Out of this earth: East India Adivasis and the aluminium cartel.

Association figures, going down[69] [70].

Renewable energies
The aluminium industry has long been closely tied to the hydro-industry[71] and over half of smelting is hydro-powered[72]. Due to the low economic return per energy unit, smelting is increasingly geared towards countries with low energy and labour costs[73] [74] whether hydro (e.g. Brazil, Congo, Iceland, Greenland), natural gas (Trinidad, Congo-Brazzaville) or coal (South Africa, India). Indirect greenhouse gas production from dams and geothermal power stations are not included in the industry's audits.

Reducing greenhouse gas emissions
Aluminium production accounts for ca. 1% of global greenhouse gas emissions, producing 13.1 tons of CO_2 equivalent per ton of aluminium[75]. Technological advances have led to 20-25% emissions savings in the smelting process in recent decades but overall emissions are increasing and there is no concrete intention to reduce them. In fact, Alcoa predicts a 20% increase of CO_2e emitted per year from ca. 335 million tonnes of CO2e in 2000 to ca. 400 million tonnes in 2020[76] (see figure).

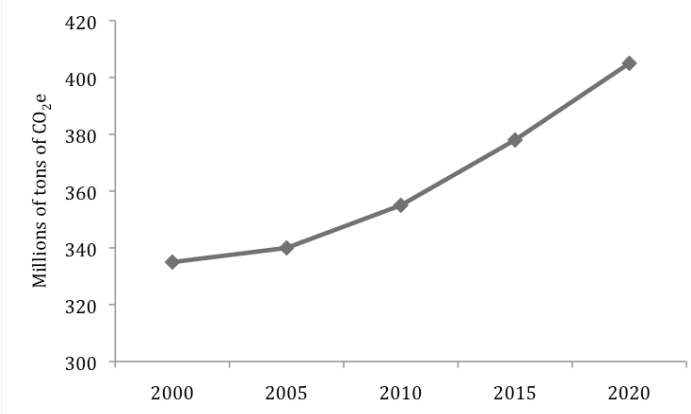

Figure 1. Projection of greenhouse gas production by the aluminium industry (Adapted from Overbey, 2005[77])

Carbon neutral
However, Alcoa states that around that time, cars will contain more aluminium, be lighter and thus save fuel. This saves carbon emissions, and in 2017, the amount

[69] Container Recycling Institute. 2004. Aluminum can waste reaches the one trillion mark - recycling rates drop to lowest point in 25 years [online]. URL http://www.container-recycling.org/assets/pdfs/trillionthcan/UBC2004CRIPressRel.pdf [Accessed 12-11-2007].
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[74] Ibidem 72.
[75] Das, S. and Padel, F., 2005. Double death: aluminium's links with genocide Economic and Political Weekly, December 2005.
[76] Overbey, R., 2005. Sustainability, what more should companies do?, In Alcoa Conference Board Session on Sustainability. Alcoa. URL http://www.alcoa.com/global/en/news/pdf/conference_board.pdf [Accessed 12-12-2008].
[77] Ibidem 76.

saved will be roughly the same as the increase in emissions by the aluminium industry. Thus, the industry can be carbon neutral whilst producing 20% more greenhouse gases. The fallacy of this reasoning is easy to see: imagine we would drive even more and in larger vehicles than Alcoa is projecting. In that case the industry would be carbon neutral even earlier: if I buy an aluminium hummer, I save more than when I buy an aluminium fiesta. Even if crediting would work that way, Alcoa assumes the aluminium industry get all the credits, not the car manufacturer or consumer.

The aluminium industry, like all mining industries, has a severe environmental impact and a consistent record of human rights violations. Because the industry is in all aspects ‘part of the problem’, it is vitally important for corporations such as Alcoa, to join the green bandwagon and proclaim ‘it is part of the solution’. However, ecologically responsible primary aluminium production is not a reality. If Iceland is the model for green heavy industry, one must question whether that is possible at all.

Box 2. How heavy industry contributed to Iceland's economic crisis

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In times of economic crisis, it is tempting to embrace new megaprojects such as new power plants and aluminium smelters. But will this realistically improve Iceland's economic prospects?
Prime minister Geir Haarde recently explained on Stöd 2's chat show Mannamál that one of the main reasons for the fall of the Krona, was due to the execution of heavy industry projects: the construction of Kárahnjúkar and Alcoa's smelter in Reyðarfjörður. If more large projects are executed, what will the cost be for the Icelandic taxpayer?

Haarde's comments were not surprising. Before construction of Kárahnjúkar many economists predicted the negative impact on inflation, foreign debt and the exchange rate of the ISK.
Of course there is some economic benefit from new smelters, but "it is probably outweighed by the developments' indirect impact on demand, inflation, interest rates and the ISK exchange rate," stated a report by Glitnir in 2006 on the impact of aluminium expansion in Iceland. The report expected an increase in inflation and a depreciation of the ISK.
"Kárahnjúkar will never make a profit, and the Icelandic taxpayer may well end up subsidising Alcoa," said the eminent economist Thorsteinn Siglaugsson after publishing another report on the profitability of the Alcoa dam in East Iceland before construction commenced.

How did the Fjardaal smelter contribute to Iceland's economic crisis? The two billion dollars for the construction of the country's largest dam had to be borrowed by the state. That led to a more than significant increase in the current account deficit, which is now felt in increased inflation and depreciation of the currency. The economic cost now needs to be coughed up.

Note that any schemes that demand new power plants associated with a significant amount of borrowed capital will have this effect, whether an expensive dam or power plant is meant for aluminium, a silicon refinery, data centre or some other purpose. It is quite simple. If you borrow money, you will have to pay back in one-way or the other.

Of course, once they are built, smelters bring in some degree of income to the country and, so it is argued, there are local economic benefits from a new smelter. Smelters provide jobs. What has hardly been researched in Iceland, though, is how much these new jobs displace jobs in existing local industries.
Local industries around Reyðarfjörður have had to shut down as a consequence of employment competition from the smelter. Many new houses that were built are empty. Between 2002-2008, on average 73 more people moved each year from the Eastfjords to the southwest than the other way round. The smelter still depends on many foreign workers. Local communities where large projects such as Fjardaal get constructed become completely dependent on foreign investment, an undesired and unsustainable condition that destroys local resilience.

There is another reason not to construct more smelters in Iceland. The price that the aluminium giants pay for energy to Landsvirkjun is linked to the world price of aluminium. If supply is increased this will lower the price of aluminium, decreasing revenue for Iceland. One might think that a few hundred thousand tons of aluminium more or less will not impact the global market. The reality is that it is not the sum of production that determines the price but rather the friction between supply and demand. A small amount of difference can have a significant effect in terms of pricing. Demand for aluminium is already slumping in the US and Europe. It will too in China when growth slows down there, which is likely to happen before Alcoa's and Century's planned new smelters could come online, considering the world economic outlook.

The metal corporations compete between themselves. Because of this is not just the global price that determines their profitability. The bottom line is eventually determined by how cheaply they can produce. For aluminium, profitability is fundamentally determined by one thing: energy costs. In Iceland, energy prices are rock bottom – the lowest in the world. It is not a coincidence that as Alcoa's Fjardaal smelter went online, 400 workers in Rockdale, Texas were laid off as smelter operations there closed down. In the US, Alcoa pays much more for power.

This is why Alcoa, Century, Rio Tinto and Norsk Hydro all want new smelters in Iceland and in third world countries with cheap energy such as Trinidad and the Congo. When demand slumps, expensive plants can then be shut down in favour of cheap ones such as the proposed smelters at Husavik and Bakki. As inflation stays high and energy revenues low, the Icelandic taxpayer pays the price.

Construction of new power plants, smelters or other large scale projects will have some short term economic benefit as funds are infused into the economy. But, as Geir Haarde recently confirmed, after execution comes the economic backlash. These megaprojects in a small economy have been compared to a 'heroin addiction'. Short-term 'shots' lead to a long-term collapse. The choice is between a short-term infuse or long-term sustainable economic development.

The 'shot' of Fjardaal overheated the Icelandic economy. What was called the 'Kárahnjúkar problem' led to an all time high in the value of the Krona, hurting export and the fish industry in particular. With the all-powerful currency, banks overplayed their hand and went into a spending spree. Drugs make you lose sight of reality.

There has been a lot of critique on the proposed plans to develop Iceland's unique energy resources. Those in favour of it have generally argued that it is good for the economy. Anyone who gives it a moment of thought can conclude that that is a myth. Supposed economic benefits from new power plants and industrial plants need to be assessed and discussed critically and realistically. Iceland is coming down from a high. Will it have another shot, or a cold turkey?