Iceland: A 100% renewables example in the modern era

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Iceland's famous for its breathtaking scenery, its geysers, its Blue Lagoon–and for sitting astride the Mid-Atlantic Ridge. Among energy wonks, Iceland is also well known for using its abundant renewable energy, and especially for tapping the volcanic roots of the island in developing its geothermal resources.

Iceland today generates 100% of its electricity with renewables: 75% of that from large hydro, and 25% from geothermal. Equally significant, Iceland provides 87% of its demand for hot water and heat with geothermal energy, primarily through an extensive district heating system.

Altogether, hydro and geothermal sources meet 81% of Iceland's primary energy requirements for electricity, heat, and transportation. This must be a record in the modern era. Certainly Icelandic politicians think so, because they frequently make reference to it.

Iceland Renewable Energy 2011

	Primary Energy	Electricity	Electricity TWh
Hydro	15%	75.5%	12.5
Geothermal	66%	24.5%	4.0
Fossil fuels	19%	0	0.0
Total	100%	100%	16.5

Primary energy includes energy used in transportation and heating.
http://www.nea.is/

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What Icelandic politicians don't mention as often is that half of all the electricity the country produces is provided at low cost to aluminum smelters. And no, there's no bauxite in Iceland. The country uses the low cost of its renewably-generated electricity–and just as importantly the stable price it represents over the long term–to lure smelters to the island. Iceland profits from the value added by smelting the aluminum ore from other countries.

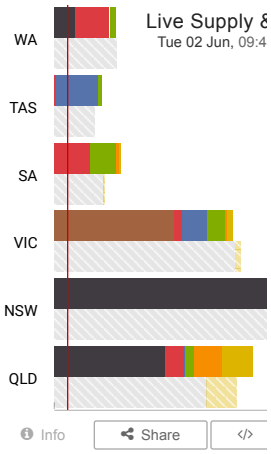
In the spring of 2011, my wife Nancy Nies and I passed through Iceland on our way to Europe. We chose to spend a few days in Reykjavik to see first hand what modern geothermal power plants and geothermal heating look like–and to take a plunge into that famous Blue Lagoon.

Despite its economic collapse in 2008, Iceland (http://t.ymlp292.net/mqseaoaheqmanaueeatauqbh/click.php) still has one of the world's highest standards of living.

As anyone who tried to fly to Europe in the spring of 2011 knows, the island of Iceland is geologically active–very active. The island is in the midst of an active spreading zone: half of the country lies on the North American tectonic plate, the other half lies on the Eurasian plate.

Yes, Iceland is a very small country. Despite a land area of 100,000 km², only 300,000 people inhabit the island, two-thirds of those in the capital Reykjavik. Yet, Iceland shows what can be done when a nation puts its mind to the task of eliminating fossil fuels.

Until the extensive development of the island's hydro and geothermal resources, the country was dependent upon coal and oil for providing transportation, fueling its fishing fleet, and heating its homes. The latter is not something to take lightly in a nation just south of the Arctic Circle. Iceland's older residents can remember a time when coal smoke, not steam from the island's famed fumaroles, shrouded the capital.



Iceland is a leader in geothermal development and exports its technical expertise worldwide. The country, along with the Philippines and El Salvador, is among countries with the highest penetration of geothermal energy in electricity generation worldwide. On a per capita basis, Iceland is an order of magnitude ahead of any other nation in installed geothermal generating capacity.

World Geothermal Penetration 2010

		2010 Capacity MW	% Consumption	W/capita
1	Iceland	575	30.0%	1,806
2	Philippines	1,904	27.0%	21
3	El Salvador	204	25.0%	33
4	Costa Rica	166	14.0%	39
5	Kenya	167	11.2%	4
6	New Zealand	628	10.0%	143
7	Nicaragua	88	10.0%	15
8	Indonesia	1,197	3.7%	5
9	Mexico	958	3.0%	9
10	Italy	843	1.6%	14
	http://en.wikipedia.org/wiki/Geothermal_electricity			

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Geothermal Development in Iceland

Travelers in transit through Iceland may know nothing about the country's geothermal resources, but as their flight arrives at the Keflavik the airport they may look askance at their seatmates. They might sniff the air and wrinkle their noses. But it's not the passengers that stink. It's Keflavik. And that rotten-egg smell is characteristic of geothermal areas around the world. The airport sits near the end of the Reykjanes (http://t.ymlp292.net/mqsmavaheqmakaueeavauqbh/click.php) peninsula, one of the geothermal fields serving the capital, an hour's drive southwest of Reykjavik.

You know you're in Iceland when you can see the steam plumes from fumaroles and vents along the road from the airport to Reykjavik.

Icelanders use geothermal energy in two ways: for generating electricity, and for heating. They generate electricity in what is, for all practical purposes, conventional thermal power plants. Instead of burning coal in a boiler to create steam, Icelanders use steam directly from the earth.

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Iceland also heats most of its domestic water, swimming pools, and buildings with geothermal fluids. In older systems, they use the geothermal fluids directly. In more modern applications, they use heat exchangers that transfer the heat of geothermal fluids to fresh water.

Maybe because of their rugged Viking roots, Icelanders swim all year–outdoors as well as indoors–in heated pools, to be sure. They've taken their national pastime and the waste heat from one geothermal power plant and turned it into a tourist attraction.

Only minutes from the international airport at Keflavik is the Blue Lagoo (http://t.ymlp292.net/mqsjaxaheqmavaueeakauqbh/click.php)n, a posh spa built on the waste fluids from Svartsengi geothermal power plant. It's common for transit passengers to spend a few hours luxuriating at the Blue Lagoon before catching their next flight.

Power

We met up with Guðmundur Ómar Friðleifsson, chief geologist with HS ORKA, the company that operates Svartsengi and another plant nearby on the Reykjanes peninsula.

Guðmundur, or Omar for short, picked us up in Reykjavik and took us by the hot springs and swimming complex of Laugardalur (http://t.ymlp292.net/mqsbalaheqmaxaueeavauqbh/click.php) near our hotel. (Because everyone is related to everyone else, Icelanders go by first or middle names.)

Formerly with the Icelandic Geologic Survey, Omar speaks English with a Scottish brogue from his years in Edinburgh pioneering the study of resistivity in rock for locating high-temperature geothermal resources. The silver-haired geologist could be a stand-in for Professor Lidenbrock in Jules Verne's *Journey to the Center of the Earth*. (Icelanders are quick to point out that Jules Verne's novel is eerily similar to an earlier Icelandic tale.)

On the drive to Reykjanesvirkjun–the Reykjanes power plant–at the end of peninsula jutting into the North Atlantic, Omar explained how within one generation, following the oil crises of the 1970s, Iceland moved almost completely from heating with fossil fuels to geothermal energy.

Before deregulation and privatization swept over Iceland, HS ORKA was a municipal utility that generated electricity and provided heat to nearby communities on the Reykjanes peninsula. HS ORKA was eventually privatized and the communities leased the geothermal resource to the company. In turn they now receive royalties for the sale of electricity and heat.

Iceland Geothermal Power Plants

Plant	MWel	MWth	Flow l/s	Temp °C	TWh/yr	Company	Location	District Heating
Svartsengi	77	80	475	90	0.54	HS Orka	Keflavik	x
Reykjanes	100			320	0.70	HS Orka	Reykjanes	
Nesjavellir	120		1,800		0.84	Orkuveita Reykjavikur	Thingvellir	x
Hellisheiði	213	400			1.49	Orkuveita Reykjavikur	Hengill	x
Krafla	60				0.48	Landsvirkjun	Krafla	
Total	570				4.05			

http://en.wikipedia.org/wiki/Geothermal_power_in_Iceland

For a more complete list see Geothermal Power Plants, Third Edition, by Ronald DiPippo, Table A.6.1.

(https://reneweconomy.com.au/2012/iceland-a-100-renewables-example-in-the-modern-era-56428/iceland-geothermal-power-plants)

The area around the plant at Svartsengi, or "black meadow" in Icelandic, was open to the public. There were no chain-link fences. No guards. And at one fumarole field, there was an open boardwalk for tourists. With the exception of the wind, the cold, and the gray sky, you could imagine you were in Yellowstone National Park.

Originally the Svartsengi site was developed to heat the nearby harbor town of Grindavik after the oil crisis, but geologists found a much greater resource than expected and the plant has steadily grown.

The plant now produces 75 MW of electricity from 12 wells. Svartsengi also produces an equivalent amount of thermal fluids for district heating.

HS Orka returns the waste geothermal fluids back in into 12 recharge wells, and of course, feeds some of the waste geothermal fluids to the Blue Lagoon.

The evaporation pond of the Blue Lagoon has become the pearl of Iceland, receiving some 500,000 visitors per year.

What is most striking to an American visitor is the appearance of the plants–not just the interior but also the exterior. The interiors of most power plants today are spotless, even polished. Managers–and, more importantly, insurers–learned that if you can't keep the floor clean, you're not likely to do much of anything else right, ultimately endangering employees and expensive equipment.

Iceland's power plants go beyond spotless. They are works of art.

Iceland takes architecture seriously. And this is evident in the most utilitarian of structures, their power plants.

Both Svartsengi and the nearby Reykanes plant are stunning examples of modern industrial architecture. Rather than being a blot on the landscape, they are literally shining examples that Iceland takes renewable energy and its place in the landscape seriously. It's a lesson that power-plant developers should take to heart outside Iceland.

Heat

While Iceland has become famous for generating electricity with its geothermal resources, it has achieved even greater success with using geothermal energy for heating.

We next met up with Einar Gunnlaugsson at Orkuveita Reykjavikur, the municipal utility serving Reykjavik with electricity and heat.

Geothermal heating in Reykjavik began at the Laugardalur hot springs, where women took their laundry.

To this day the main shopping street of the capital, Laugavegur (http://t.ymlp292.net/mqsbalaheqmaxaueeavauqbh/click.php), remains the "road to the hot springs," and is now a part of the city and the site of a major swimming, sport, and hotel complex, including the Hilton Nordica.

There are ten wells on ¼ km² centers providing low-temperature (120 C at an average flow rate of 330 l/s) water for the district. Here, the hot springs were at the surface, and geothermal development used the water directly, in the process drawing down the water table.

In the complex dance between surface springs and urban development, geothermal exploitation allowed the city to expand to new building sites. Now that the district is urbanized, the wells must continue pumping not only for the heat they provide, but now also for dewatering the district. Einar points this out as an illustration of the challenge faced by those who want to build sustainable cities.

Reykjavik has come a long way. In 1933 only 3% of the capital's population was served by a district heating system. Nearly everyone used coal to heat, and the sky was black as a result.

By the 1960s, says Einar, half of the city was heated by oil and the population was vulnerable when the oil crises hit in the 1970s.

Following the first oil crisis, most buildings were switched to the district heating system. One unexpected benefit was a dramatic drop in emissions. The fall in emissions continued into the 1990s as more of the city, and even rural areas converted to geothermal heating.

Einar proudly points to the near elimination of global warming gases in Iceland, noting that emissions of CO2 from electricity generation and heating are now only found in some off-gases from the city's newly developed high-temperature geothermal field.

No other city has developed district heating on the scale of Reykjavik. As a result, city residents benefit from low-cost heat at a stable price not dependent upon the volatility in the price of fossil fuels. Einar argues that the cost of heating in Reykjavik is one-fourth that of heating in Copenhagen. For example, he lives in a 180 m² (2,000 ft²) home and pays only 60,000 IKR (€400, $500 USD) per year for heat.

Of the geothermal fluids used for heating, 85% is used to heat buildings and the remainder for domestic hot water. Einar says that the volume of geothermal fluids used for heating has steadily decreased since the 1980s as Iceland tightens up building insulation standards.

Like their counterparts at HS Orka, Orkuveita Reykjavikur takes the architectural appearance of its well sites and power plants seriously. Only a well trained eye can detect a faint wisp of steam from its stainless-steel well enclosures in the Laugardalur hotel district.

Orkuveita Reykjavikur operates two plants in a large high-temperature geothermal field southeast of the capital: Nesjavellir, and Hellisheiði. Both plants generate electricity and in 2010 a 30-kilometer insulated pipeline was completed that carries geothermal fluids to Reykjavik.

The plants are big by geothermal standards and are continually being expanded. Two more units were added in 2011, bringing total electrical capacity to more than 300 MW, and an equivalent amount of geothermal heat for the capital.

Power House for Britain?

Iceland not only points to its success in meeting its own needs with renewables but also aggressively markets its renewable resources to energy-intensive industries. Now it wants to go even further–specifically, to the British Isles.

In an ambitious–some might say foolhardy–move, Iceland has injected itself into Britain's Electricity Market Reform debate by proposing an unprecedented 700 mile sub-sea cable to Scotland. The $2 billion project would carry 5 TWh of Iceland's renewable electricity to Britain's energy market reports Bloomberg (http://t.ymlp292.net/mqshakaheqmalaueeagauqbh/click.php). That's a third more electricity than produced in all of Iceland today and as much as all the currently developed geothermal on the island.

Iceland's proposal is roughly equivalent to the target of Britain's microgeneration feed-in tariff of 8 TWh per year, but is less than half that generated by wind in Britain in 2011. More controversial, the 5 TWh is also roughly equivalent to the output of a typical nuclear reactor and Britain is struggling to find a way to justify new reactors.

Whether such a project is technically feasible or economically viable remains to be seen. Iceland certainly has the untapped geothermal potential to do so. But it's an open questoin as to whether geothermal resources developed in Iceland and transmitted such a long distance would be cheaper than if Britain developed its own geothermal resources.

And if Britain launches its EMR as planned, what would be the "strike price" of Icelandic geothermal energy delivered to Britain? Would it be cheaper than new nuclear? Intriguing questions all.

Regardless of whether such a mega-project is feasible or whether Iceland's citizens would be willing to tolerate the financial risk of developing the project after all they've lost in the country's banking boondoggle, Iceland remains a model of what can be accomplished with renewable energy both in electricity generation–and equally as important in heating–when a nation puts its mind to it.

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