PART II

Chapter 4

Energy and environment

Iceland has by far the highest share of renewables in energy supply among OECD countries. After an overview of the country's energy mix, this chapter examines the environmental impact of the energy sector, including on landscape, water, biodiversity and emissions of greenhouse gases and air pollutants. The energy market and prices, as well as the role of energy-intensive industry, are also discussed. This chapter studies the institutional and policy framework for integrating energy and environment, with a focus on the planning of renewable energy infrastructure. Finally, it reviews the opportunities and obstacles to improve energy efficiency in residential heating, transport and the fishing industry.

Assessment and recommendations

Among OECD countries, Iceland has by far the highest share of renewables in the energy supply: all electricity and 95% of heat are generated from hydro and geothermal power. As these sources can be produced at relatively low cost in Iceland, there has been no need for support measures such as those often used in many other countries.

The abundant supply of cheap energy has attracted energy-intensive industries, notably aluminium smelting. To meet industry demand, electricity production has more than doubled since 2000, and is now five times the amount needed by the population alone. As a result, Iceland's energy intensity has grown, and it is the highest in the OECD. While power generation emits virtually no greenhouse gas (GHG) emissions, the expansion of aluminium production has resulted in growing GHG emissions.

Over many years, the expansion of Iceland's power capacity and electricity transmission and transport infrastructure has generated intense debate about environmental and social impacts. Many areas with potential for hydropower or geothermal development are sites of exceptional beauty and unique biodiversity, and they are often major tourist attractions. Geothermal power plants also discharge wastewater containing chemicals and nutrients, and they emit hydrogen sulphide (H_2S). This gas has an unpleasant odour and is toxic and corrosive in high concentrations; the health and environmental impact of long-term exposure to low concentrations of H_2S are not yet known. Emissions of H_2S have more than doubled since 2000, and concentrations in ambient air, especially in the area around Reykjavík, have often exceeded ambient standards. In 2010, the environment ministry introduced a daily H_2S limit that is three times as strict as the World Health Organization's guideline value.

Iceland is effectively locked into providing energy-intensive industries with low-price energy through long-term contracts. Electricity is generally provided at below average commercial rates, and it is not clear if the rate of return earned by public utilities is sufficient to cover all costs, including environmental costs. Further expansion of the aluminium sector would exacerbate the vulnerability of the economy to the fortunes of the aluminium industry and further reduce diversity in the energy market. There appears to be scope for Iceland to leverage its low-cost renewables without significantly increasing production capacity by developing smaller energy-intensive industries that exert less pressure on the environment, e.g. greenhouses and data treatment centres.

Another option under discussion is the potential for constructing an undersea cable to Scotland to export excess electricity. Such a project could result in significantly higher electricity prices, which would benefit electricity generators at the expense of Iceland's consumers, although the overall effect on prices is difficult to predict. Introducing a resource rent tax would capture part of generators' excess profits and generate revenue to compensate the consumers most affected by higher prices. More recently, two areas off the coast have been identified as having potential for commercial extraction of oil and gas. Work is still exploratory, but if it were to go ahead, there could be significant environmental risks, particularly associated with deep-sea drilling. Given the low level of oil consumption in Iceland and the absence of refineries, oil and gas extraction would not materially affect energy security, but would generate additional revenue.

Conflicts over energy-related developments prompted the Icelandic government to change its approach to decision making in this area. In the late 1990s, it launched an initiative to develop the Master Plan for Hydro and Geothermal Energy Resources. The development of the master plan involved many features of strategic environmental assessment, and was based on scientific analysis and wide public participation. The plan, adopted by the Parliament in 2013, classifies some 80 areas with potential for hydro or geothermal development as suitable for development, not suitable, or needing further research. Final decisions on whether to issue a licence will be based on environmental impact assessment. The master plan provides a valuable model for building consensus on complex energy-environment issues. The next phase and the four-year review of the master plan should further reinforce the independence and quality of the scientific assessment, strengthen the economic analysis of options and broaden the scope of activities covered (to include, for example, power lines).

Iceland's energy-related legislation is generally in line with that of the EU, except in the area of energy efficiency. The government claims that EU energy efficiency policies would not sufficiently benefit Iceland's consumers or the environment due to the cheap and abundant geothermal heating. Reflecting the low cost of energy and relatively poor insulation, consumption of heat in residential buildings grew by about 12% over 2000-11. However, evidence from other countries suggests that geothermal energy is not inexhaustible. Thus a prudent policy would be to implement cost-effective measures promoting energy efficiency. Iceland could consider tightening energy efficiency requirements in the building code on the basis of those applied in other Nordic countries.

About 10% of the population does not have access to geothermal heat, using electricity or oil instead. The price for the latter is aligned with the price of geothermal heat through a subsidy, and these customers benefit from favourable tax treatment. Removing these support measures could strengthen incentives for energy efficiency and for connection to the geothermal heat supply, even if the impact on overall energy use and emissions of GHGs and air pollutants is likely to be small.

Transport and fishing are the main consumers of fossil fuels, together accounting for about 17% of total final energy consumption in 2011. While there has been considerable progress in improving energy efficiency and reducing fossil fuel use in the fishing sector, transport energy use has continued to rise. Iceland has one of the highest per capita vehicle ownership levels in the OECD. It introduced a CO_2-based vehicle tax, but average fuel efficiency is low and CO_2 emissions from new cars are well above those in other European countries. These features are linked to the low population density, limited transport mode alternatives and frequently difficult driving conditions. The government expects to achieve the 2020 target of 10% renewables in transport mostly by using biogas and other biofuels, but this seems neither feasible nor cost-effective. The use of electric vehicles in Iceland is in its infancy, but increasing it is technically feasible within the current electricity system. However, costs would need to be reduced and other obstacles addressed to boost demand for this mode of transport.

Recommendations

- Ensure that decisions on future energy developments (e.g. expansion of power capacity, connecting the Icelandic electricity system to Europe, exploration of offshore oil reserves) are based on independent scientific advice, are subject to cost-benefit analysis and involve open public dialogue.
- Ensure that electricity prices are adequate to cover the long-term costs of power installation projects, including the environmental costs.
- Reinforce the independence of scientific assessment, make better use of economic analysis and integrate power lines into the next phase of the Master Plan for Hydro and Geothermal Energy Resources.
- Develop a better understanding of the sustainability of geothermal fields and development limits.
- Consider how the combination of a tax and an air quality standard for hydrogen sulphide could accelerate the development of low- or no-emissions technology.
- Review the energy efficiency requirements in the building code, and consider introducing a maximum total energy need for residential buildings; complement energy efficiency regulations with information and awareness-raising campaigns.
- Review the cost and benefits of heating subsidies with a view to removing those that encourage geothermal energy waste and that conflict with improved home insulation and geothermal space heating development.
- Strengthen co-ordination among municipalities in the Reykjavík area in urban planning and infrastructure development to reduce urban sprawl and private car use; promote alternatives to private car use, including public transport; assess opportunities for, and obstacles to, the wider use of electric vehicles.

1. Introduction

Iceland is an island of volcanic origin; it is geologically active, with considerable geothermal development potential. The large glaciers and numerous rivers flowing from the highlands to the sea also provide major potential for hydropower development. The energy sector is unique because of its isolation from other European networks, the very high share of renewable sources in the energy supply, the absence of natural gas and refinery infrastructure, and the full dependence on imports for the supply of refined oil products. The cold climate and sparse population necessitate high energy use for space heating and transport, and key export industries such as fishmeal and metal production are energy intensive.

Since the oil price crisis in the 1970s, energy policy has focused on replacing oil with geothermal and hydropower to meet Iceland's energy needs. Currently, the vast majority of energy supply is from renewables: Iceland is the only OECD country where energy for electricity and heat generation is almost fully based on renewables.

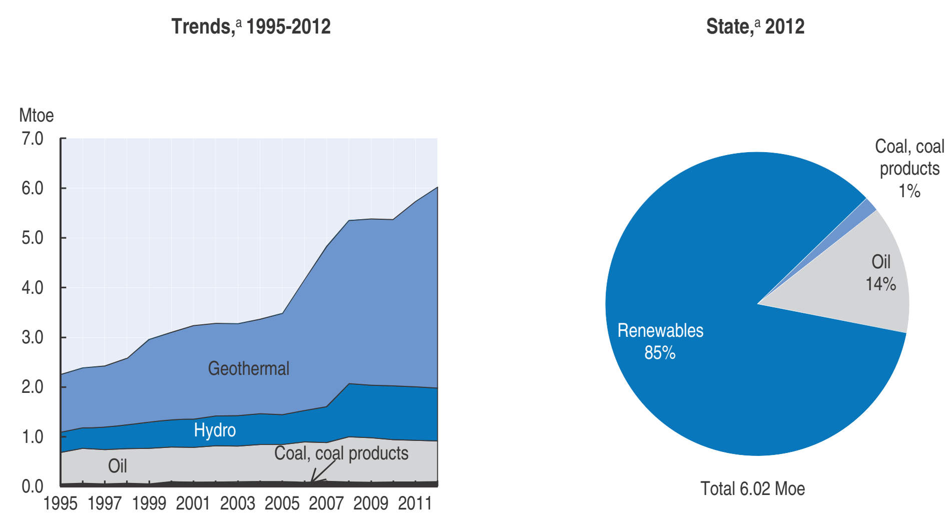
In the last decade Iceland embarked on a major expansion of generation capacity to provide power for energy-intensive industries such as aluminium smelting. These industries were attracted to the country largely because of its comparatively cheap, low-emission energy. The government's goal has been to diversify the export base by reducing its reliance on fisheries while at the same time taking advantage of its wealth of renewable energy resources. While these industries provided a significant stimulus to the economy, the development of the associated power plants and infrastructure has had an impact on the environment.

2. Key energy trends

2.1. The energy mix

While the economy grew by 30% between 2000 and 2012, Iceland's total primary energy supply (TPES) almost doubled. This mainly reflects booming energy demand associated with the installation of heavy industrial plants (Figure 4.1). The primary energy sources are hydropower and geothermal for electricity generation and heat production. The contribution of renewables to TPES increased from 74% in 2000 to 85% in 2012, a share significantly higher than in any other OECD country (Annex I.A; Figure 1.3). Geothermal power accounted for more than two-thirds of TPES (Figure 4.1). Iceland is the only Nordic country having geothermal as its main energy source. Iceland is dependent on imported fossil fuels, which accounted for the remaining 15% of TPES in 2012. Fossil fuels are used primarily in transport and fishing, and to a minor extent to produce electricity and heat in remote locations and as a backup power source.

Figure 4.1. **Energy supply by source**



a) Total primary energy supply, excluding trade of electricity and heat.
Source: IEA (2013), *IEA World Energy Statistics and Balances* (database).

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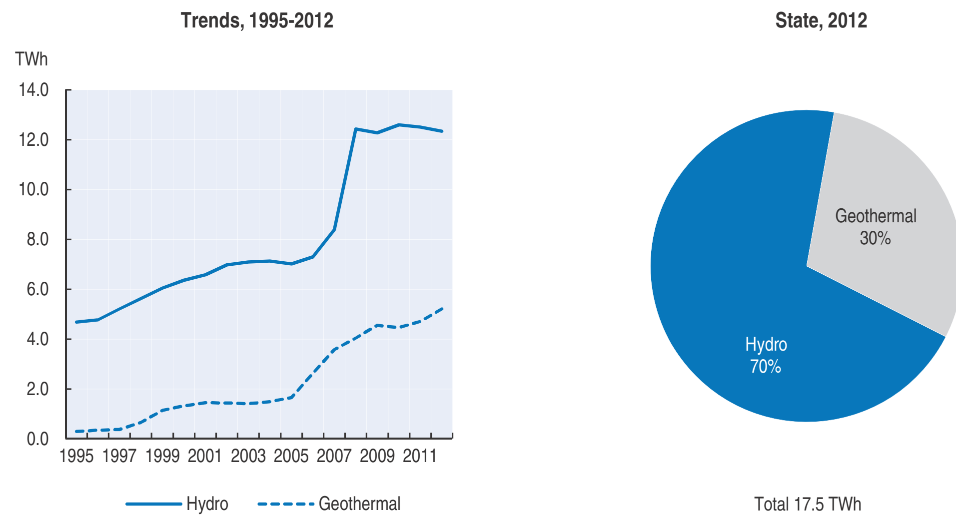
Over the last decade, net hydroelectric capacity nearly doubled and geothermal capacity more than trebled. The significant growth of the aluminium industry is the main factor underlying this increase of power generation capacity and the corresponding expansion of the transmission grid. As a result, electricity production has more than doubled. After steep growth in 2006-09, hydroelectric power production levelled off to reach 70% of total power generation in Iceland in 2012. Geothermal electricity generation, which accounted for the remaining 30%, has grown steadily since the mid-2000s (Figure 4.2).

Geothermal power is primarily used to produce heat for several purposes, including heating homes, swimming pools and greenhouses (Figure 4.3). Since the 1970s, Iceland has

Figure 4.2. **Electricity generation by source**



Source: IEA (2013), *IEA World Energy Statistics and Balances* (database).

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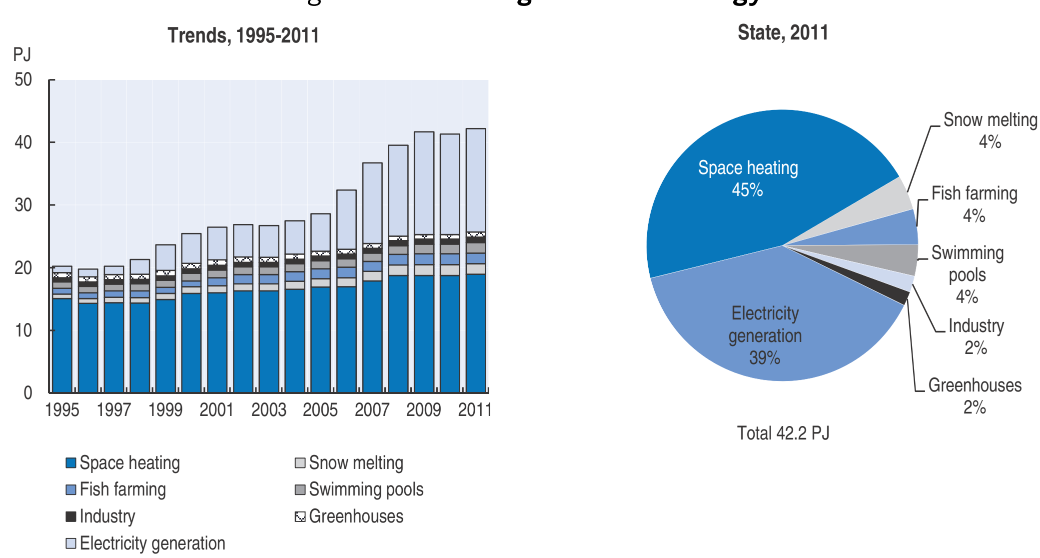
heavily invested in expanding geothermal space heating, which accounted for 45% of geothermal use in 2011. Geothermal energy met 90% of space heating needs that year, and electricity about 9% (one-third via district heating systems). The share of oil in heating fell to about 1% (Orkustofnun, 2012). Geothermal water is also used for industrial and commercial purposes.[1] Geothermal heating of swimming pools has a long tradition in Iceland, which has more than 160 geothermal swimming pools with a total surface area of about 37 550 m^2.

Figure 4.3. **Use of geothermal energy**



Source: Orkustofnun (2014), "Geothermal Utilisation", Iceland Energy Portal.

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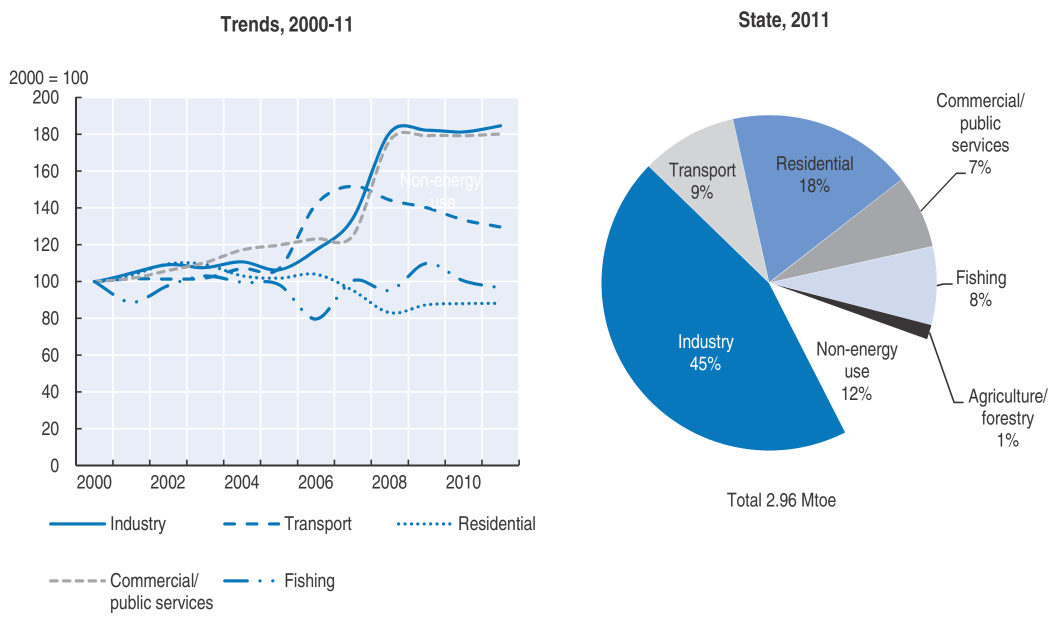
2.2. Energy use and intensity

Between 2000 and 2011, total final consumption of energy (TFC) increased by 40%, driven by massive growth in electricity consumption. It has stabilised since the 2008 economic crisis. In 2011, industry was the largest consumer of energy, using 45% of all energy and 87% of electricity, the latter mostly for aluminium smelting (Figures 4.4 and 4.5). The residential sector was the next largest end-use sector, accounting for 18%, followed by transport (9%) and fishing (8%). Residential consumption decreased by 12% relative to 2000, mainly in the second half of the 2000s as a result of the impact of the recession on household income. Energy consumption from transport also declined with the recession, but by 2011 it still was 30% above the 2000 level (Figure 4.4; Section 7.2).

Figure 4.4. **Final energy consumption by sector**



Source: IEA (2013), *IEA World Energy Statistics and Balances* (database).

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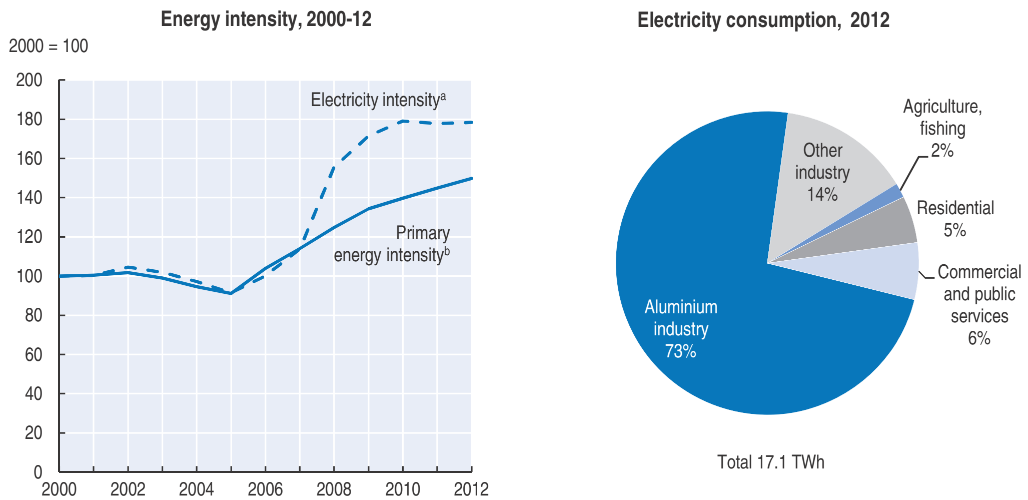
The consequence of the concentration of electricity-intensive industry has been a steep rise in energy and electricity intensity (Figure 4.5). Energy intensity (TPES per unit of GDP) increased by 50% over 2000-12 to nearly four times the OECD average (Annex I.A). Iceland has 3.5 times the energy intensity of the United States, and also of New Zealand, another hydro- and geothermal-reliant island country.

3. Environmental impact of the energy sector

3.1. Impact on landscape, water and biodiversity

Development of large hydropower and geothermal power capacity has a potentially significant environmental impact. Both types of plant affect Iceland's landscape and wilderness areas. In addition, the installation of pipes, transmission lines, roads and other infrastructure can affect a much wider area than the locations of the plants themselves.

Figure 4.5. **Energy intensity and electricity consumption**



a) Electricity consumption per unit of GDP at 2005 prices and purchasing power parities.
b) Total primary energy supply per unit of GDP at 2005 prices and purchasing power parities.
Source: IEA (2013), *IEA World Energy Statistics and Balances* (database); OECD (2013), *OECD Economic Outlook No. 93* (database); Orkustofnun (2014), Iceland Energy Portal.

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Iceland's high-temperature geothermal fields are restricted to active volcanic zones, which often have little organic soil and biodiversity. Yet the environmental impact of geothermal plants may be high. Many geothermal areas are distinctive and exceptionally scenic landscapes, with hot springs, lava, glaciers and some of the main tourist destinations and hiking trails (Thórhallsdóttir, 2007a). In addition, operating the plants can cause minor land subsidence in neighbouring areas. Wastewater from geothermal installations contains substances such as heavy metals and nutrients. Wastewater discharges into surface waters can thus affect the ecosystem and are subject to pollution limits indicated in the plant licence. Some power plants operated by the National Power Company pump the wastewater back into the geothermal reservoir to reduce environmental contamination (Landsvirkjun, 2013).

Hydropower is generally considered as having greater environmental impact than geothermal in Iceland, primarily because it is associated with potentially irreversible biodiversity, landscape and cultural loss. Hydropower plant capacity is dependent on the river flow rate and the elevation from which water falls (hydraulic head). Significant storage and hydraulic head are usually associated with lakes and waterfalls, both of which are likely to have high scenic value. Large water reservoirs generally provide habitats for wildlife and water for irrigation. Flooding to form large reservoirs poses considerable problems in an ecologically fragile environment where less than 2.5% of the land area is arable (Figure 1.10). For example, in the central highlands, potential sites for hydro storage reservoirs are located in depressions where vegetation, organic soils and the bulk of the biodiversity are concentrated, while the surrounding flats and hills are mostly barren with very low vegetation cover and negligible organic soil (Thórhallsdóttir, 2007a). Regulating river flows may have consequences for flora and fauna and alter conditions for fish migration; part of the young salmon (smolt) population going downriver can be lost in hydropower plant turbines.

Landscape and nature are the main features attracting foreign visitors and Icelanders alike to the highlands (Chapter 5). Many Icelanders consider landscape their most important national symbol (Thórhallsdóttir, 2007a). Concerns over the potential impact of energy development have often led to heated public debate, prompting the government to revise the decision-making processes for power plants (Section 6).

3.2. Emissions from energy production and use

Greenhouse gas emissions

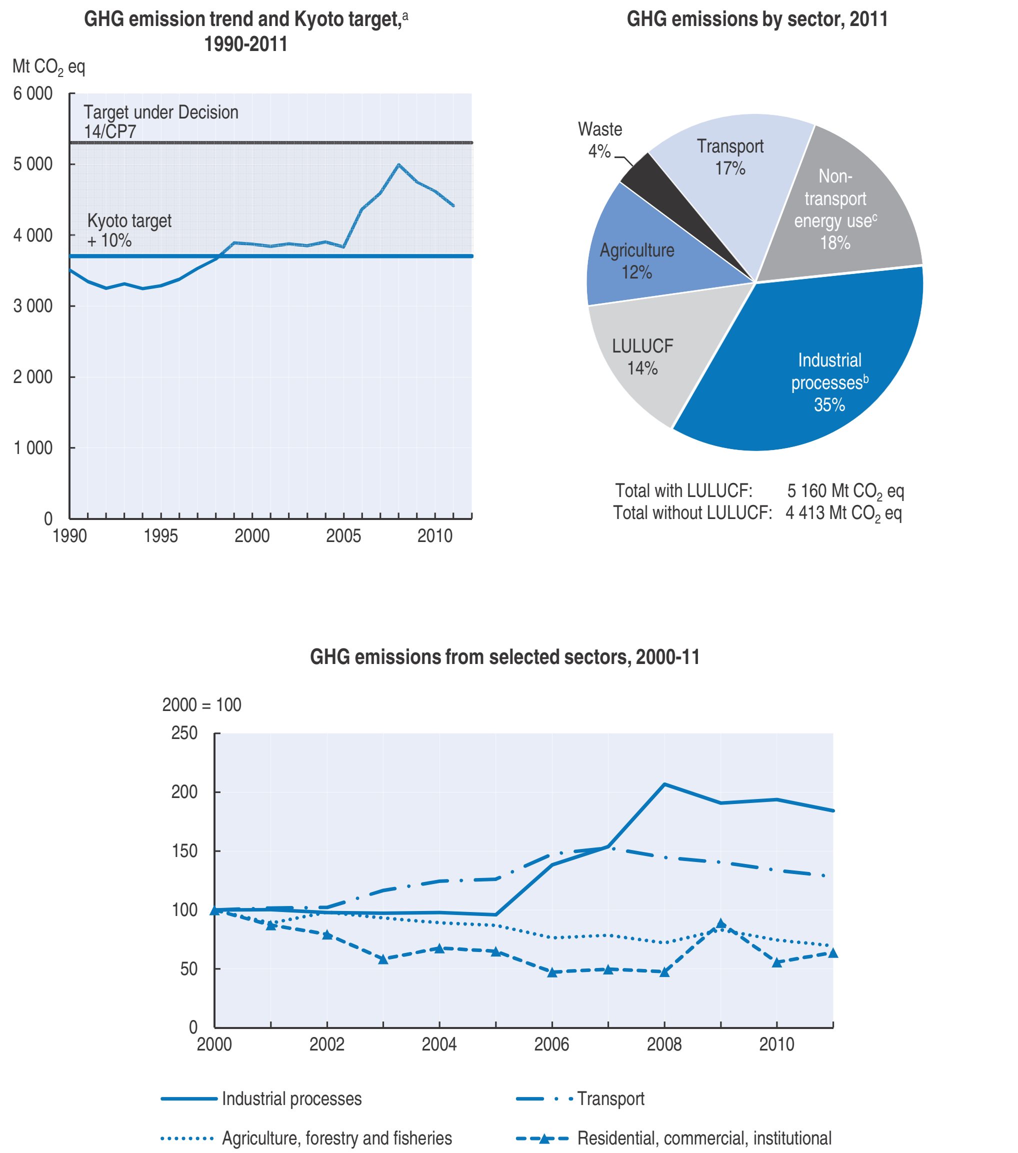
With the highest share of renewables in energy supply among OECD countries, Iceland has also the lowest carbon intensity in electricity and heat generation (0.154 g CO_2/kWh in 2011). Electricity and heat production generate virtually no greenhouse gas (GHG) emissions: geothermal processing emits an insignificant amount of carbon dioxide (CO_2) from boreholes; hydropower generates even lower CO_2 emissions from reservoirs, due to loss in vegetated areas when reservoirs are filled (Landsvirkjun, 2013).

Overall, GHG emissions (excluding emissions and removals from land use, land-use change and forestry) have increased by 14% since 2000, although at a lower rate than GDP (Figure 1.2). As of 2011, Iceland was on track to reach its Kyoto Protocol target to keep the increase in GHG emissions within 10% from the 1990 level in 2008-12, excluding CO_2 emissions from new heavy industry that complies with Decision 14/CP.7 (Figure 4.6; Section 5.3).[2]

Industrial processes, mainly three aluminium smelters and a ferrosilicon plant, form the largest source of GHG emissions (35%), which is unique in the OECD (Figure 4.6). Aluminium production mainly emits CO_2 and perfluorocarbons (PFCs).[3] Aluminium smelters in Iceland are among the least GHG-intensive in the world thanks to the use of renewables-based electricity: for example, the Alcan smelter in Straumsvík and the Norðurál smelter at Grundartangi emit 1.4 to 1.7 t CO_2 eq per tonne of aluminium produced, compared to an international average of 10-12 t CO_2 eq per tonne of aluminium produced (Institute of Economic Studies, 2009). However, capacity growth has led to an increase in industrial process emissions, especially since 2005 (EAI, 2013). GHG emissions from industrial processes grew by 83% between 2000 and 2011 and were the main driver of total GHG emission growth. Reducing process-related emissions in the aluminium industry would require radical changes in the production process (IEA, 2013).

Energy use in transport, mainly by road, is the second largest single GHG emission source (17% of total emissions). Energy consumption and GHG emissions from road transport increased dramatically between 2000 and 2007 owing to increases in the number of cars per capita, in the number of larger, more powerful vehicles and in mileage driven. Despite a decline since 2007, with the crisis and higher fuel prices, in 2011 transport emissions were 28% above the 2000 levels. In recent years more fuel-efficient vehicles have been imported (EAI, 2013). Emissions from energy in the residential and service sectors declined by 36%, reflecting progress in replacing oil with geothermal power in space heating (Figure 4.6). Space heating contributes only 0.5% of GHG emissions in Iceland, compared to 36% in the EU (MII, 2012). GHG emissions from agriculture, forestry and fisheries declined by over 30% from 2000 to 2011. In particular, CO_2 emissions from fuel use in fishing fell by 24%, reflecting a reduction in the fishing effort and improved efficiency (Section 7.3).

Figure 4.6. **Greenhouse gas emissions**



a) Excluding emissions/removals from land use, land-use change and forestry (LULUCF).
b) Includes solvents.
c) Includes emissions from energy use in the following sectors: manufacturing and construction; agriculture forestry and fisheries; and residential, commercial and institutional.
Source: OECD (2013), *OECD Economic Outlook No. 93* (database); UNFCCC (2013), *Greenhouse Gas Inventory Data* (database).

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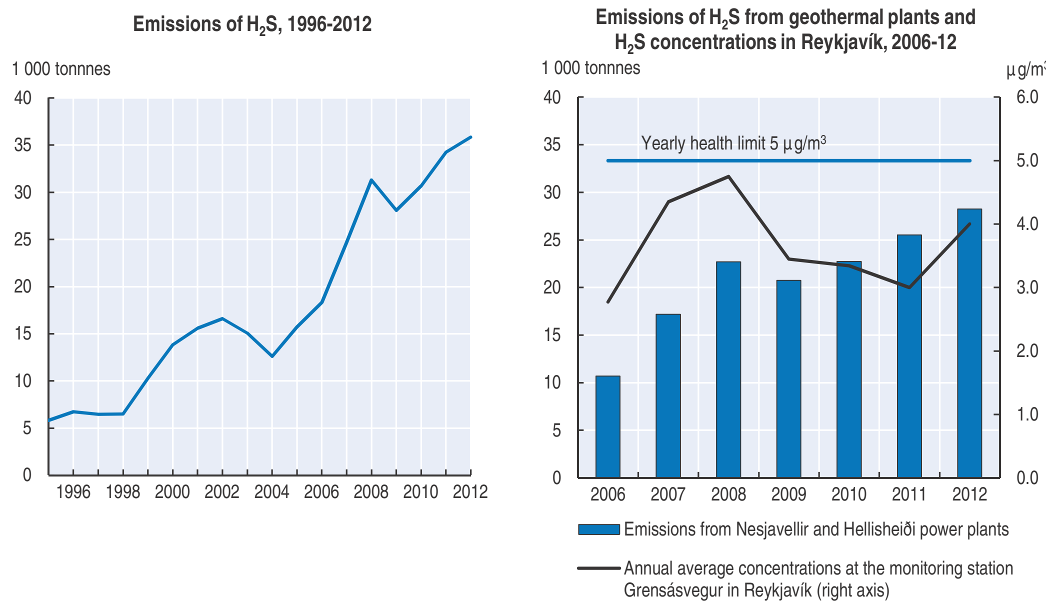
Hydrogen sulphide

Hydrogen sulphide (H_2S) is a potential air pollutant from geothermal power plants. It is a colourless gas with the characteristic foul odour of rotten eggs. In low concentrations it is mainly an irritant to eyes and respiratory systems. In high concentrations H_2S can be corrosive, flammable and explosive, and can affect respiratory organs. The impact on human health and the environment of continuous exposure to low concentrations of H_2S over the medium and long term is still unknown. As Figure 4.7 shows, emissions of H_2S have more than doubled since 2000 with the increase in geothermal power capacity.

Figure 4.7. **Emissions and concentrations of H_2S**



Source: Country submission; Orkustofnun (2014), Iceland Energy Portal.

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The concentration of H_2S has risen significantly in the Reykjavík area since construction of the Hellisheiði power station, the largest geothermal plant in the world, with capacity of 303 MW of electricity and 400 MW of hot water.[4] Emissions of H_2S from the plant are estimated at 16 000 tonnes per year, nearly half the total H_2S emissions from all Icelandic geothermal plants.

Since Hellisheiði started operating in 2006, the Ministry for the Environment and Natural Resources (MENR) has received many complaints from the public about emissions of H_2S. Ambient monitoring in the vicinity of the plant showed concentration levels persistently above the WHO guideline value for occupational exposure of 150 $\mu g/m^3$ (reaching 170 $\mu g/m^3$). An examination of vegetation in the Hellisheiði area showed that H_2S was damaging moss. A study in 2011 showed a link between the plant's emissions and increased purchase of asthma medicines in the greater Reykjavík area (Saving Iceland, 2012). Local media have reported on damage to electronic equipment linked to H_2S. To respond to these concerns, the MENR tightened regulations on H_2S, and the energy companies are looking at possible ways to reduce the emissions (Box 4.1). The introduction of a tax on H_2S emissions could encourage energy companies to further reduce emissions, provided that they can be accurately measured.

4. The energy market and prices

Iceland has liberalised its electricity market in line with EU policy but has not established a wholesale electricity trading system (Box 4.2). All major producers sell electricity through bilateral contracts with power-intensive industrial and retail companies under fixed agreements running one to twelve years. The electricity prices are among the lowest in Europe, reflecting the renewable nature of power generation, which is capital intensive but entails no fuel costs.

Box 4.1. **Standards limiting concentrations of hydrogen sulphide in ambient air**

In 2010 the Ministry of the Environment and Natural Resources announced a regulation to limit the concentration levels of H_2S in the atmosphere at 50 µg/m^3, measured as an average over 24 hours. The daily limit is three times stricter than the WHO guideline value of 150 µg/m^3. The limit for the maximum annual average is 5 µg/m^3. According to the WHO guidelines, H_2S concentrations should not exceed 7 µg/m^3 on average over 30 minutes to avoid substantial odour annoyance.

The regulation allows levels higher than 50 µg/m^3 five times a year until July 2014. Icelandic energy companies have asked for the stricter rules to be delayed until 2020 to allow them to develop a cost-effective and environment-friendly way to reduce H_2S emissions. As from July 2014, exceedances of the ambient standards trigger financial penalties, and the authorities will be obliged to inform the public each time the pollution exceeds the limit.

Reykjavík Energy, which operates the Hellisheiði power plant, is currently exploring emission reduction options, including dissolving H_2S in condensate water and injecting it back into the high-temperature geothermal reservoir, allowing its mineralisation. This technology is more environment-friendly than the current method of surface-processing H_2S gas into sulphur powder, which then needs to be disposed of (Reykjavík Energy, 2012). A pilot project due to start in 2014 will allow 15-30% of the gas from the Hellisheiði power plant to be dissolved in water for reinjection, and it is hoped that zero emissions can be achieved by 2020. The trials have been successful, but increased seismic activity in the area has been reported.

4.1. *Electricity contracts with aluminium smelters*

Nearly 80% of the electricity generated in Iceland is sold to energy-intensive industry, notably three aluminium smelters – Alcoa in Reyðarfjörður, Norðurál in Grundartangi and Rio Tinto Alcan in Straumsvík. As with similar contracts in other countries, electricity for power-intensive projects is sold via long-term contracts, frequently for 20 years or more, and renewable. The price is generally below average commercial rates and special transmission tariffs apply. New supply contracts index the electricity price to the US consumer price index, while older ones were indexed to the global price of aluminium, exposing the National Power Company and its owner, the state, to the aluminium price risk (OECD, 2013a). In line with common international practice, the contracts are frequently "take or pay", obliging the customer to either take electricity from the supplier or pay a penalty. This, combined with the below-market price, may discourage efficient energy use. While energy prices for power-intensive industry are not publicly available, the European Free Trade Association (EFTA) Surveillance Authority has verified that the contracts do not involve state aid.

The very high share of energy-intensive industry in total consumption has prompted local criticism that these customers receive a disproportionate benefit from cheap power prices, to the detriment of other consumers. A study by the Institute of Economic Studies (2009) indicated that high electricity demand by the aluminium industry has not resulted in a massive price increase for households (Section 4.2), and that the overall economy has gained net benefits from the smelters. However, the study did not take environmental costs and risks into account. Current contracts between public utilities and the foreign aluminium companies make it difficult to evaluate how profitable the related energy

Box 4.2. **The liberalisation of Iceland's electricity market**

Iceland's energy system has no connection to other countries' networks. The 2003 Electricity Act implemented the EU Electricity Directive (2003/54/EC) concerning common rules for the internal market in electricity. The act consolidates various laws into comprehensive legislation on generation, transmission, distribution and sale of electricity. It liberalised the electricity market and defined the generation and sale of electricity as competitive activities subject to public licensing. Licences can only be given for power plants that run on renewable energy sources.

Most of the energy sector is publicly owned and subject to foreign ownership restrictions. There are three major producers of electricity. The state-owned National Power Company (Landsvirkjun) is the dominant producer, with a 73% market share. It and two other large companies, Orkuveita Reykjavíkur/Reykjavík Energy and HS Orka, generate 97% of the country's electricity. There are also companies with limited generation capacity, including small private hydropower producers. The introduction of wholesale electricity trading would allow small generators to participate in the market without having to commit their entire output to long-term bilateral contracts. It would also facilitate implementation of demand-response systems. However, the small size of Iceland's energy market – with a limited number of wholesale sellers and purchasers – lack of interconnection with other markets, and low price of electricity are barriers to a fully competitive and transparent market in the near term.

The transmission system operator owns and manages the power transmission system. Six distribution system operators manage the regional electricity grids, and most also provide hot and cold water distribution. All but one are owned by either the state or one or more municipalities. There are eight retail companies, and the electricity market was opened to all customers in 2006. Reykjavík Energy is the largest; it is almost fully owned by the municipality of Reykjavík and supplies the greater capital area with electricity, heat and water.

Source: Ólafsson et al. (2011), *Report on Regulation and the Electricity Market 2010 Iceland.*

investments are. It is unclear whether the public utilities earn an appropriate return on the use of natural resources including the environmental costs and risks. As energy companies are mostly in public hands, this means taxpayers may be subsidising and bearing the risks of insufficiently profitable investment by power companies (OECD, 2006; Krater and Rose, 2009).

Further expansion of the aluminium sector would make the economy overly dependent on export earnings from a single sector and reduce diversity in the energy market (OECD, 2006). The large size of the aluminium industry, compared to domestic electricity demand, means that if industry demand were to decline, there would be no alternative uses for the current electricity production. While Iceland has been exploring the development of sectors such as data centres and greenhouse expansion, these are expected to lead to comparatively low growth in electricity demand. Thus Iceland would be quite vulnerable to future change in the aluminium industry's situation, should the smelters seek to renegotiate contract prices. Renegotiations of this type, seeking more favourable terms, are not unknown internationally.[5]

The OECD (2013a) concluded that the net benefits to Icelanders from energy-intensive industry may not be maximised. It recommended that future expansion of electricity generation for powering such industry should be evaluated on the basis of a broad, transparent cost-benefit framework. Such analysis should ensure that electricity prices are adequate to cover the long-term costs of the projects, including the environmental costs.

4.2. Household energy prices

Iceland has the lowest household electricity prices in the OECD. Table 4.1 tabulates EU electricity prices against a representative tariff for Icelandic households. It shows that the latter, expressed in euros, is lower than those of major EU countries. Commercial and industrial prices follow a similar pattern. The decline in prices expressed in euros is partly the result of the strong depreciation of the króna due to the financial crisis; expressed in krónur, nominal prices for domestic users rose.

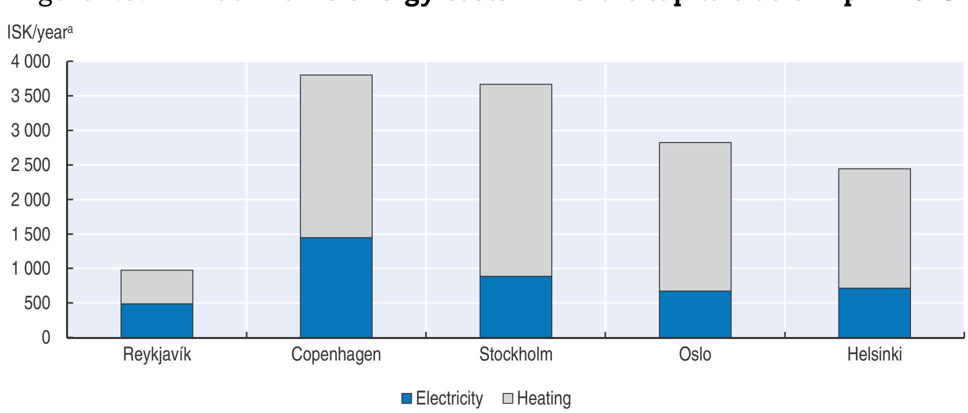
Table 4.1. **Household electricity prices in selected OECD countries in 2012-13**

Country	2012	2013
	EUR/kWh	
France	0.099	0.101
Germany	0.144	0.149
Iceland	0.088	0.083
Norway	0.136	0.137
Sweden	0.131	0.136
United Kingdom	0.160	0.166
EU27	0.134	0.137

Note: Average national price in EUR per kWh without taxes applicable for the first semester of each year for medium size household consumers (with annual consumption between 2 500 and 5 000 kWh).
Source: Eurostat (2014), *Energy Statistics* (database).

Geothermal space heating is used throughout the country. Municipalities operate district heating systems under concession agreements, often through municipal utilities. They distribute and sell hot water and steam from geothermal fields or heating stations within their area, at tariffs approved by the industry minister. The low cost of geothermal heating means Icelandic households incur much lower total energy costs than their Nordic neighbours. As Figure 4.8 shows, Iceland's electricity cost for a typical home is similar to (though cheaper than) those of Norway and Finland, but with much cheaper space heating.

Figure 4.8. **Annual home energy costs in Nordic capitals as of April 2013**



a) For annual consumption of 4 800 kWh of electricity and 495 cubic metres of hot water.
Source: Reykjavík Energy, August 2013.

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5. Institutional and policy framework for integrating energy and environment

5.1. Institutional framework

As in other OECD countries, the institutions responsible for developing and implementing energy policy include line ministries and supporting agencies. The Ministry of Industries and Innovation (MII) is responsible for energy policies and the MENR for environmental policies (Chapter 2). In particular, the MENR has overall responsibility for climate policy and works in close co-operation with the industry ministry. The Environment Agency of Iceland and the Agricultural University estimate GHG emissions. An interministerial committee oversees implementation of the action plan for climate change mitigation (Section 5.3), reports on progress and provide advice to the MENR.[6]

The Competition Authority oversees electricity generation and sales. The Orkustofnun, or National Energy Authority, is the energy market regulator; it issues and monitors operating licences of competing firms and regulates transmission and distribution companies, especially as concerns revenue caps, tariffs and service quality. It also licenses exploration for, and use of, energy and mineral resources. The National Planning Agency (NPA) is responsible for assessing the quality of environmental impact assessment (EIA), including for power plant and energy infrastructure projects (Chapter 2).

Municipal authorities play a strong role in various areas related to energy and climate policies, including physical plans, public transport and construction permits for energy infrastructure (subject to favourable assessment by the planning agency). Local authorities also oversee industry licensing and other issues under the Health and Pollution Control Act (Chapter 2).

5.2. Energy policy framework

Energy policy is grounded in the Comprehensive Energy Strategy for Iceland, a document based on a report presented and discussed in the Parliament in 2012. The main objectives of the strategy include reducing fossil fuel imports by fostering renewables; developing hydroelectric and geothermal sources with a precautionary and protection approach; supporting diversified, sustainable and eco-conscious industry; encouraging better energy use and energy efficiency; and examining the possibility of connecting the Icelandic and EU electricity grids (Box 4.3) (MII, 2012).

Much of the EU legislation on energy policy is part of the agreement on the European Economic Area, which Iceland joined in 1994 (Chapter 2). Iceland's energy-related legislation is thus broadly in line with EU law. However, some differences exist due to Iceland's unique energy mix and isolated market. Its energy efficiency policy is not fully consistent with the EU legislation, as the country requested derogation from some related directives (Section 7.1).

In 2013, Iceland adopted a national renewable energy action plan in compliance with the Renewables Directive (2009/28/EC). The objective of the plan is to increase renewables' share in gross final consumption to 72% by 2020, a target Iceland has already exceeded (Table 4.2).

There is no room for further improvement in electricity, and only minimal room in heating and cooling, which are close to saturation in gross final energy from renewables. Unlike most OECD countries, Iceland needs no support measures in this regard, given the magnitude of its renewables potential and the absence of domestic fossil fuel reserves. Its

Box 4.3. **Connecting Iceland's electricity system to Europe?**

Studies carried out by the National Power Company indicate that a submarine cable between Iceland and Scotland is technically feasible and financially expedient, although it would be challenging as it would be the longest and deepest interconnector in the world (Landsvirkjun, 2012a).

The MII co-ordinated a committee to review the social, environmental and macroeconomic impact on Iceland of a submarine cable. Its report, released in June 2013, reached no firm conclusions; the issue will require further debate and analysis as the technology and economic conditions develop.

A potential effect of any connection of Iceland to the EU electricity market would be to link Iceland to the electricity prices prevailing in the EU. Given Iceland's low energy production cost and delivered energy price, this could result in a rise in electricity prices for local domestic and commercial consumers, and a corresponding decline in real income. At the same time, the electricity generators would likely benefit from significantly higher prices per kilowatt-hour generated. The overall effect would be, however, difficult to predict.

One way to address such a potential outcome would be through a resource rent tax on windfall profits to capture a large part of generators' excess gains for the benefit of society.* Part of the revenue from such a tax could be used to compensate the consumers most affected by higher electricity prices. With a cable connection, real-time electricity trading would probably become necessary.

* Taxes on resource rents are levied on the extra profit, beyond a normal rate of return on capital, which the exploitation of certain natural resources can entail. They fall outside a strict definition of environmentally related taxes since the tax base (profit) has no particular environmental impact as such (Chapter 3). These taxes can, nevertheless, be important from a resource management point of view.

Table 4.2. **Progress towards the 2020 target for the share of energy from renewable sources**

	2005 baseline	2010 actual	2020 target
Heating and cooling	89.9	95.2	96.1
Electricity	100.0	100.0	100.0
Transport	0.1	0.35	9.9
Total	63.4	75.2	72.0

Source: MII (2012), *The Icelandic National Renewable Energy Action Plan.*

situation is similar to that of New Zealand, another island country with large geothermal potential.

Yet Iceland is far from reaching the target of 10% renewables in transport, which includes the fishing fleet (Table 4.2). Hence the government's policy effort is focused on reducing fossil fuel dependency in transport and fishing. In early 2013, Iceland approved a bill to promote the use of renewables in transport and to introduce sustainability criteria for biofuels and other renewables-based fuels (Section 7.2). Reaching these renewables-based targets is expected to help Iceland achieve its climate mitigation targets as well.

5.3. Climate policy framework

Climate change policy is largely shaped by the United Nations Framework Convention on Climate Change and the Kyoto Protocol, which Iceland ratified in 2002. For the first commitment period (2008-12), Iceland agreed not to increase its GHG emissions by more than 10% from 1990 levels, excluding emissions from heavy industry that use renewables and best available technology and were established after 1990 (Decision 14/CP.7).[7] For the second period (2013-20), it committed to a quantified GHG emission reduction of 20% from the 1990 level, a target based on the understanding that it will be fulfilled jointly with the European Union and its member states.

To meet these objectives, Iceland adopted a national climate change strategy in 2002, which was revised in 2007. The 2002 strategy aimed at curbing emissions in conformity with the country's obligations under the Kyoto Protocol and increasing the level of carbon sequestration through afforestation and revegetation programmes (Ministry for the Environment, 2010). Under the 2007 strategy, Iceland is committed to the long-term goal of reducing GHG emissions by 50-75% by 2050, compared to the 1990 level.

In 2010, the government adopted an action plan for climate change mitigation. It set a target of reducing emissions from sectors outside the EU Emissions Trading System (EU ETS) by 30% from 2005 to 2020. Almost half this reduction would come from afforestation and reforestation. Iceland's energy and industrial mix gives it limited abatement potential in sectors outside the EU ETS, except road transport. For example, unlike many OECD countries, it has little scope to reduce emissions from buildings (Section 3.2). The plan sets the basis for adopting the EU Effort Sharing Decision on GHG emission mitigation targets. In June 2012, the Parliament passed a law on climate change (Act No. 70/2012), aimed at tackling reduction of GHGs efficiently and effectively, increasing carbon sequestration, promoting mitigation and creating conditions for the government to fulfil its international obligations (EAI, 2013).

5.4. *Key energy and climate policy measures*

Table 4.3 presents an overview of measures to achieve the renewables targets, improve energy efficiency and reduce GHG emissions. In recent years Iceland has implemented several economic instruments to encourage energy savings and reduce GHG emissions, especially in industry and transport (MII, 2012).

Iceland has been part of the EU ETS for GHGs since 2007. Its participation in the trading mechanisms has been very limited so far because of the absence of fossil fuel-based power generation and refineries and the exclusion of the aluminium sector, fishmeal production and aviation until 2013.[8] With these sectors now included, the EU ETS covers about 40% of Iceland's GHG emissions. Emissions of PFCs from aluminium smelters are also regulated in environmental licences, which set emission limits per tonne of industrial output (0.14 tonne of CO_2 eq per tonne of aluminium).

In 2010, Iceland introduced a carbon tax and CO_2-based vehicle taxes (Section 7.2). Most of the GHG emissions excluded from the EU ETS are subject to the carbon tax. It applies to fossil fuels used in sectors not participating in the EU ETS, including those used to power fishing vessels, which is uncommon among OECD countries. However, the effective tax rate on CO_2 emissions (the combination of energy and carbon taxes) is lower in Iceland than in other countries that also apply a carbon tax (Chapter 3). The OECD (2013a) judged the carbon pricing to be too weak to meet future goals. In addition, the use of coal is fully exempt from energy and carbon taxation, and oil products used in sectors other than road transport (including home heating and fishing) are exempt from the energy excise duty. As the OECD (2013a) recommended, Iceland should broaden the base for the carbon tax and raise its rate to increase cost-effective abatement of GHG emissions.

Table 4.3. **Key energy and climate policy measures**

Sector	Price instruments	Subsidies	Others
General	CO_2 tax on fossil fuels used in sectors outside the EU ETS Excise duty on energy products		
Energy supply		Grants and loans to find usable geothermal water for heating in areas where resources have not yet been found Subsidy for the construction of district heating systems	Master Plan for Hydro and Geothermal Energy Resources
Industry	EU ETS		Limit on emissions of PFCs from aluminium smelters (included in the licence)
Transport	CO_2-based semi-annual road tax on passenger cars CO_2-based excise duty on motor vehicles	Exemption from excise and CO_2 tax for CO_2 neutral fuels (biodiesel, methane, methanol) Discount from excise duty for methane cars (1 000-car limit) VAT exemption on zero-emission vehicles, hydrogen and electricity, with a cap (2012-13) Parking benefits for zero-emission cars (2007-12)	Procurement of environment-friendly vehicles by the central government (2009-12) and municipalities (2006-15) Investment plan to expand public transport and cycling (2012-22)
Buildings		Lump-sum grants for switching from fossil-fuel or electric heating to heat pumps (when geothermal district heating is unavailable)	Energy efficiency requirements in building codes.

Source: Adapted from MII (2012), *The Icelandic National Renewable Energy Action Plan*.

Iceland is engaged in research and development on climate-friendly technology and renewables. Notable examples include deep drilling for superheated geothermal fluid; carbon capture and storage by mineralisation in basaltic rock; production of methanol from CO_2 in geothermal steam; information technology to reduce emissions from ships; and use of hydrogen as fuel in cars and ships (Ministry of Environment, 2010). The National Energy Fund promotes research on geothermal energy in cold areas and supports research projects in the energy sector with the primary focus on alternative fuels, renewables to replace fossil fuels, and energy conservation.

While emissions have declined since the economic crisis, a stronger economic recovery and new energy-intensive projects could result in new emission increases. In the aftermath of the crisis, and in light of the high government debt, public resources to finance GHG mitigation projects are limited. Phasing out the exemption from energy and carbon taxes and the subsidy for electric and oil heating (Section 7.1) would help improve public finances. Companies and households are also heavily indebted, which reduces their ability to invest in low-carbon technology such as more climate-friendly vehicles.

6. Planning and permitting for renewable energy infrastructure

6.1. Master Plan for Hydro and Geothermal Energy Resources

Long-term investment needs in the electricity sector are primarily based on developments in power-intensive industry. Total electricity production is already five times the level needed for a society of comparable size without large energy-intensive industries. Annual growth in electricity demand excluding power-intensive industry is expected to be about 1.5%, requiring investment in energy generation and infrastructure of ISK 1 billion to ISK 2 billion per year in the medium and long term. But investment needs due to increased demand from power-intensive industry in the medium and long term, although uncertain, could amount to ISK 10 billion to ISK 20 billion (Ólafsson et al., 2011).

However, as Section 3 indicated, power-intensive investment projects and the associated expansion in electricity generation capacity have a significant, often long-term impact on the environment. Some possible problems, e.g. affecting flora and fauna, would become apparent only over time, with possible impact on landscape, nature and cultural heritage. As natural areas are Iceland's key resource for tourism, there are also potential land-use conflicts between the power and tourism industries (Chapter 5). Energy generation development projects have often prompted heated public debates, such as that occasioned by Kárahnjukar, a major hydro project (Box 4.4). If Iceland aims to develop its economy based on both power-intensive industry and nature-based tourism, these conflicts have to be addressed and the location of new power plants and infrastructure needs to be carefully planned (Sæþórsdóttir, 2012).

In response to such concerns, in the late 1990s the government decided to develop a Master Plan for Hydro and Geothermal Energy Resources. Its purpose was to evaluate and categorise all potential areas for hydro and geothermal development on the basis of energy and technical potential, economic profitability, implications for employment and regional development, and environmental impact.[9]

The MENR is responsible for the plan, in co-operation with the MII. The plan was developed in two phases (1999-2003 and 2004-10),[10] and was partly based on the example of the Norwegian master plan for water resources (Einarsson, 2011). In both phases, the ministries appointed a steering committee to co-ordinate the work of expert groups.[11] The committees included representatives of various central and local institutions, as well as environmental NGOs and the tourism industry. The results of both phases were made available to the public and public hearings were conducted (Steingrímsson et al., 2007). The plan development process is an example of application of the key elements of strategic environmental assessment (SEA), even though SEA only became mandatory in Iceland in 2006 (Chapter 2).

After more than a decade of analysis and debate, the draft parliamentary resolution approving the plan was submitted to SEA and public consultation. More than 200 comments were received from individuals, NGOs and power companies. The master plan was approved as a parliamentary resolution in 2013 and became binding on all municipalities, which must incorporate its provisions in their land-use plans.

The approved plan classifies some 80 areas for potential hydro and geothermal power plant development into three categories: "green" or suitable for development, i.e. the projects face no obstacles and can apply for licences (8.5 TWh); "yellow" or pending further research on feasibility and environmental impact (12.5 TWh); and "red" or "protection", which does not allow development (11.3 TWh). Building all the "green" capacity and half the "yellow" would nearly double Iceland's current power generation. The MII and MENR decided to move six power plant proposals from the "green" to the "yellow" category in response to comments received in the SEA consultation. Most projects in the "green" category are geothermal power projects, which were generally found to have a lower environmental impact (Thórhallsdóttir, 2007a).

The Master Plan for Hydro and Geothermal Energy Resources is a major step towards broad consensus about future energy development. It is an example of complex decision making and consensus building based on an independent scientific assessment, which is an approach not commonly used (Sæþórsdóttir, 2012). The final ranking of projects was mainly based on scientific assessment of environmental and tourism-related impact

Box 4.4. **Public concerns about energy-related projects**

Iceland witnessed controversies over construction of hydropower projects as early as the 1970s. More than 100 farmers officially claimed responsibility for an explosion on 25 August 1970 that destroyed a small dam on the Laxá River near Lake Mývatn in the north. Locals were determined to prevent the construction of a bigger dam that, according to the farmers involved, would have destroyed a vast natural area as well as most of the surrounding farmlands. A number of other attempts to use rivers for hydropower production, especially in the eastern highlands, failed because of public opposition (Jónsson Úlfhildarson, 2013).

In 2002, the government, Landsvirkjun and the multinational Alcoa agreed to build an aluminium smelter in the eastern town of Reyðarfjörður; the associated 690 MW Kárahnjukar hydropower plant generated much of the public debate. The government argued that development of a clean renewable energy source would offer great marketing opportunities that could form the basis for increased exports and a stronger image of the country, while the industrial plant would provide much needed tax revenue and create jobs. Environmentalists argued that creation of a new reservoir would affect the second largest unspoilt wilderness in Europe, hurt the flows and ecosystems of rivers from Europe's largest glacier, Vatnajökull, and expose the surroundings to accelerated soil erosion. Concerns were also expressed about air and soil pollution, especially by fluorides, which can lead to serious health effects (Del Giudice, 2008).

The NPA first rejected the EIA of the hydropower plant because of the considerable environmental damage involved and insufficient information provided about the construction and its environmental effects. Following extensive analyses, however, despite protests by NGOs, the EIA and permits were given. The conditions set by the environment ministry are estimated to have increased the cost of construction by 2-3% and reduced the amount of energy generated by 4% (OECD, 2005). In particular, several river diversions could not be carried out, and the design and arrangement of the largest dam had to be changed so as to avoid damage that would result from an overflow. Water from the hydroelectric dams is diverted through tunnels to the underground Fljótsdals power station. Power is then sent through high-voltage transmission lines to the Fjarðaál aluminium smelter.

The Fjarðaál smelter was completed in 2007 and reached its full operational capacity of 346 000 tonnes of aluminium per year in 2008. The hydropower project development was completed in 2009. To address environmental impact concerns, the smelter employed a group of Icelandic and foreign scientists to analyse the baseline state of the environment and develop an extensive monitoring process to evaluate and reduce the impact on human health and natural resources. Nearly all lowland area near the smelter is monitored, including air, water and soil. Among the substances measured are gaseous fluoride, particulate matter and sulphur dioxide. The best available technology was used in designing the smelter to minimise pollution and protect the air, water and soil.

In 2006, Alcoa began planning another aluminium smelter in Bakki, near Húsavík in the north. After a six-year process its plans to build a 250 000 tonne smelter were abandoned in 2012 following a negative EIA and negative power supply prospects. The EIA stated that the project's impact would be high and could not be mitigated; its GHG emissions would constitute 14% of Iceland's total and 17 000 ha of pristine wilderness would be affected.

because of the strong correlation between them (Jóhannesson, 2012). Nevertheless, some effects were inadequately considered due to methodological constraints and lack of data. They included groundwater contamination from geothermal wastewater and downstream impact of hydropower projects as well as potential indirect and cumulative effects (Thórhallsdóttir, 2007a; 2007b). In addition, the plan did not assess the environmental impact of power lines.

No compromise will please everyone, however, and Icelandic generators have expressed concerns that some sites they believe could be developed were excluded. Some claim that the steering committees were not independent and that politics should not have been involved at the last stage of the process to change the ranking, which should have been based purely on the scientific work (Sæþórsdóttir, 2012). Environmentalists argued, meanwhile, that the plan listed some areas or projects inappropriately as "exploitable". These include the glacial Þjórsá River and a dam proposed above the Urriðafoss waterfall, which they claim would disrupt salmon spawning and breeding grounds.

Current development, especially for electricity generation, is putting increased pressure on geothermal resources. Iceland needs to consider the long-term sustainability of geothermal development. International experience has shown that geothermal resources are not inexhaustible and some countries have depleted fields faster than their natural replenishment rate, or have subsequently found that geothermal plant could not operate at design capacity due to pressure limitations. Recent reports of diminishing yields at the geothermal plant at Hellisheiði would indicate that Iceland is not immune to this risk.[12] More generally, it seems Iceland has insufficiently explored ways to limit the amount of new capacity and infrastructure it may need in the future by increasing efficiency in energy use and improving demand management (Sections 4.1 and 7.1).

The 2011 Act on a Master Plan for Protection and Development of Energy Resources (No. 48/2011) institutionalised the master plan preparation process, requiring that the plan be reviewed and re-voted by the Parliament every four years. The act also requires that the master plan take the river basin management plan into account (Einarsson, 2011). A third phase of the plan was launched in 2013, and a new steering committee appointed, to assess the areas classified as yellow and needing additional analysis, as well as additional sites (Rammaáætlun, 2014). The third phase and the review of the master plan should further strengthen the scientific assessment methodology and the independence of the steering committee. It is important to develop some cost-benefit analysis process which gives appropriate consideration to all dimensions of power development (environment, tourism, social and regional development, project profitability). The power lines should also be integrated in the reviewed master plan.

6.2. Environmental impact assessment and permitting

The plan does not replace the need for full environmental impact assessment. The Orkustofnun is responsible for licensing new power plants (over MW 1 of capacity) and transmission lines. A licence can be granted only if the plant or infrastructure is in accordance with the relevant master plan for the area, and has undergone EIA (if required). The authority has to take EIA results into consideration in granting the licence. It can place conditions on power development licences to ensure that the use of the renewable energy resources is efficient from a macroeconomic and environmental perspective. The draft licence is made available to the public, which has four weeks for comments.

To facilitate energy plant and infrastructure development and respond to public concerns over the environment, Iceland has improved its EIA procedures. In particular, the decision point was shifted to local level, though municipalities must take into account the opinion of the NPA (Chapter 2). The design of power plants and aluminium smelters has been changed, sometimes significantly, following EIAs (OECD, 2006). Before EIA, generators need to undertake a number of investigation and consultation stages to, for example, gain permission for exploratory site investigations and drilling (in the case of geothermal development). Oil and gas exploration are also subject to licensing and to SEA (Box 4.5).

Box 4.5. **Oil exploration and development**

Iceland imports all fossil fuels and has no domestic oil refineries. However, two areas on its continental shelf are thought to have potential for commercial accumulations of oil and gas: Dreki, 200-400 km north-east of Iceland, and Gammur on the northern insular shelf. In early 2013, the government issued exploration licences for the Dreki area, which is in deep waters (between 800 and 2000 metres) and therefore technically challenging to explore and develop.

Exploration and production are regulated by the 2001 Hydrocarbons Act, which prescribes that “exploitation shall take into consideration environmental aspects” but does not include specific provisions for environmental protection. Since the adoption of the SEA Act in 2006, oil exploration and development plans have been subject to SEA. Licences for the Dreki area followed the positive outcome of the SEA. No SEA has yet been made of the Gammur area.

The development of this resource, if it proves technically and economically feasible, would bring Iceland additional revenue through royalties. Without development of indigenous refining capability, it would not in itself materially affect Iceland’s oil security and therefore would only be a source of additional government revenue.

As initial exploratory work has only just begun, development (if it occurs) is likely to be many years away. Furthermore, any such development is likely to be controversial and opposed by significant portions of the community on environmental grounds due to the risks of deep sea oil drilling and development.

Some generators claim that these preliminary regulatory steps, when considered along with the EIA process, are too complex and time consuming, as they require multiple consultations, often with the same agencies or groups (e.g. municipalities, MII, MENR, EAI, NPA and other stakeholders). Similarly, they claim that EIA and permitting procedures duplicate each other and lead time is too long. For example, the authorisation process for new transmission lines can take from two to four years (MII, 2012). The EAI has no mandatory deadline for processing the application (Chapter 2).

7. Improving efficiency of final energy use

7.1. Energy efficiency in the residential sector

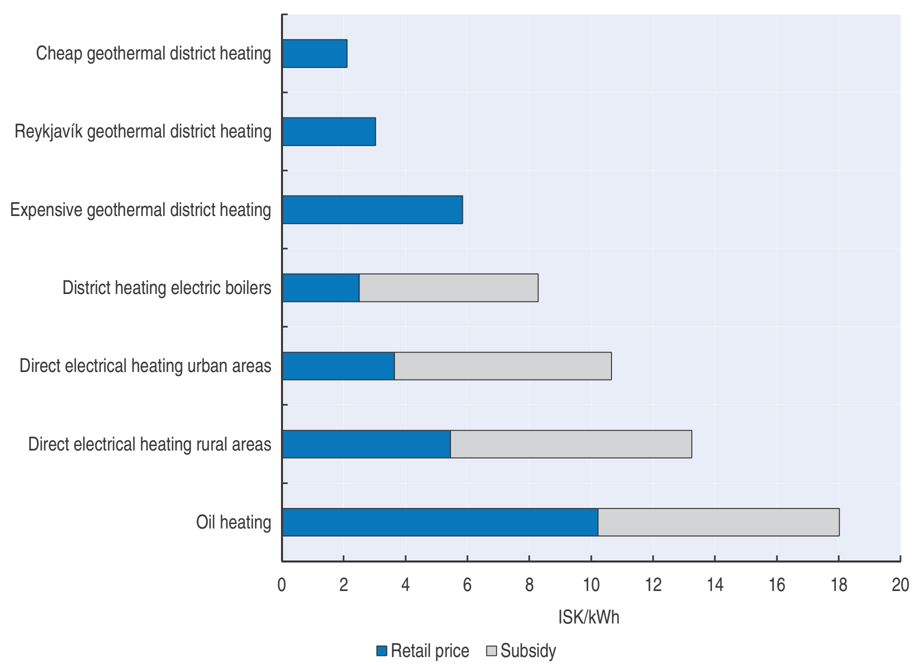
Iceland has implemented, or is implementing, the EU Regulation (EC) No. 106/2008 on energy efficiency labelling for office equipment, the eco-design directive (2009/125/EC) and the energy labelling directive (2010/30/EU) (MII, 2012). It requested derogations on the directives on energy performance of buildings (2010/31/EU) and on energy end-use efficiency and energy services (2006/32/EC), citing the special features of the country’s energy supply as grounds. The Icelandic authorities have maintained that implementing these directives would be insufficiently beneficial for consumers and the environment, given the abundant, low-priced renewable energy (IEA, 2013).

Energy efficiency requirements for new buildings and renovations in the Icelandic building code have been changed repeatedly in the last years. They now include, among other things, standards on ventilation and airtightness. Despite being less stringent than elsewhere, the code is believed to require more energy efficiency than cost minimisation would determine optimal (IEA, 2013). Partly as a result, the level of building insulation is generally lower than in other Nordic countries. Open window ventilation is still common in new buildings, with no restrictions on design.[13] There is little private economic benefit from improved insulation in existing houses because it is generally cheaper to heat houses than to insulate them to the level employed in other Nordic countries.

As a result, consumption of heat in residential buildings grew by 12.5% between 2000 and 2011, although it stabilised after 2007 because of the economic crisis. Encouraging building energy efficiency, via stricter building standards and information campaigns, would help keep downward pressure on overall energy demand. This would help save geothermal reservoirs for future generations, as some reservoirs may have limited capacity (Section 6).

Around 10% of the population cannot use geothermal space heating, depending largely on electric heating. For these people there is a more obvious economic benefit in improving home insulation, installing heat pumps, etc. Electric and oil home heating in communities lacking geothermal water is subsidised so that affected homeowners effectively pay a similar price to those using geothermal heating, as Figure 4.9 shows.

Figure 4.9. **Energy prices for residential heating in mid-2013**



Source: Orkustofnun (2013), *Energy Statistics* (database).

StatLink http://dx.doi.org/10.1787/888933087895

In 2011, this subsidy amounted to ISK 1.14 billion. A similar subsidy is provided to greenhouse farmers; it amounted to about ISK 0.22 billion per year in 2011-13. Iceland also applies reduced VAT (7%, compared to the standard 25.5%) to sales of hot water, electricity and oil used for space heating and swimming pools, and heating oil is exempt from the general excise duty on energy products and the carbon tax (European Commission, 2011). These subsidies can decrease interest in searching for new geothermal resources and thus work against the transition to geothermal space heating. Subsidised electricity prices also reduce incentives to improve energy efficiency. Phasing out the subsidies could benefit the environment, although the impact on overall energy use and emissions of GHGs and air pollutants is likely to be small in the short term.

The MII also subsidises switching from fossil-fuel or electric heating to heat pumps when geothermal district heating is unavailable, providing lump-sum grants determined by the cost and estimated energy savings. In addition, it subsidises insulation and connections to district heating when available, as well as construction of district heating systems. The government gives grants to various projects with emphasis on finding usable geothermal water for heating in areas where resources have not yet been found.

The Energy Agency provides information on energy, creates educational materials for schools and consumers, and helps small and medium-sized companies and municipalities plan strategies to improve energy efficiency. Online calculators allow homeowners to calculate the possible energy savings, energy costs and payback time for investments. Reykjavík Energy also offers information and education on energy use and ways to reduce it (IEA, 2013).

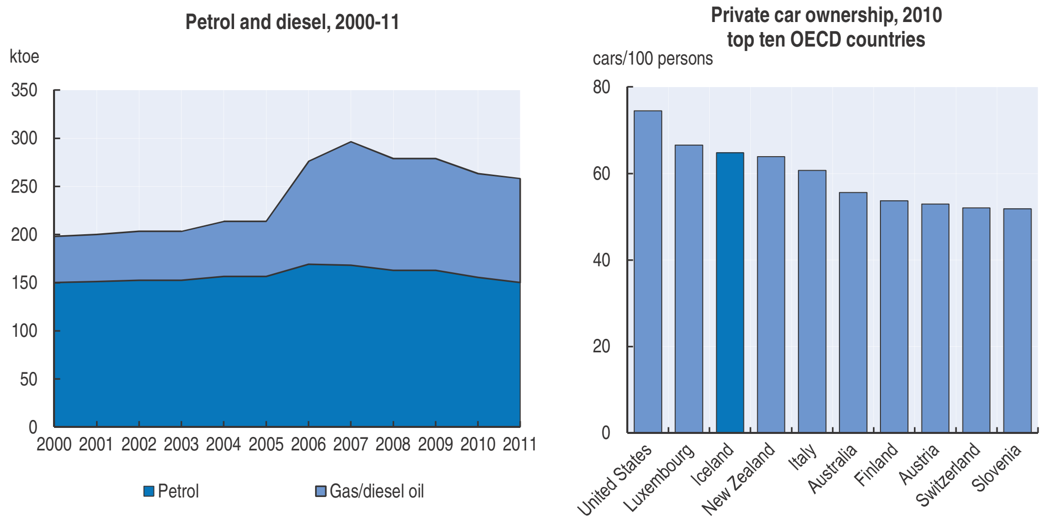
7.2. Reducing fossil fuel use in transport

Road transport

Road is the dominant transport mode in Iceland. There is no rail network because the country's geographic characteristics and sparse population have made investment in railways economically unsustainable (Ministry for the Environment, 2010). Iceland has one of the highest levels of private car ownership in the OECD, as Figure 4.10 shows. Road transport accounts for more than 95% of energy use and GHG emissions in domestic transport. Energy use for transport has grown by 32% since 2000, with a sharp rise in diesel consumption since 2005. That year a special tax on diesel vehicles was replaced by an excise duty on diesel fuel, stimulating diesel vehicle sales (Speck et al., 2006). Fuel consumption started to decline due to the economic crisis, króna depreciation and higher fuel prices. GHG emissions followed the same pattern (Figure 4.6).

With such high per capita vehicle ownership and limited transport alternatives, improved urban public transport networks in major municipalities and vehicle efficiency could deliver significant energy savings in the sector. The government and the Reykjavík municipality have introduced environmental requirements in vehicle procurement policy and undertaken an investment plan to expand the public transport network in the capital region, with an annual budget of ISK 1 billion between 2013 and 2022. The capital's government has also invested in expanding the bicycle network. Transport emissions could be reduced by strengthening co-ordination among municipalities in the Reykjavík area in urban planning and infrastructure development, to reduce urban sprawl and commuting in private motor vehicles (OECD, 2013a).

Figure 4.10. **Road fuel consumption and private car ownership**



Source: IEA (2013), *IEA World Energy Statistics and Balances* (database); OECD (2014), *OECD Environment Statistics* (database).

StatLink http://dx.doi.org/10.1787/888933087914

Vehicle taxes to improve fuel efficiency in the fleet

Average CO_2 emissions from new cars sold in 2009-11 came to 168 grammes of CO_2/km (Harding, 2014), well above the EU average of 140.5 g CO_2/km (EEA, 2013). This is partly because sport utility vehicles (SUVs) are needed to drive in many parts of the country for most of the year. As Chapter 3 notes, in 2011 the government amended vehicle taxation and linked it to CO_2 emissions to encourage the purchase of more fuel- and carbon-efficient cars. However, rental car companies, which account for a large share of the fleet, benefit from reduced vehicle taxes, which encourages them to buy high-emission vehicles (Chapter 3). CO_2-differentiated taxation has had a significant impact on consumer choice in other Nordic countries. In Finland and Denmark, changing tax systems to reflect CO_2 emissions helped reduce average emissions from new cars by 8% in the year following the reform. Similarly, in Norway, the share of cars emitting less than 120 g CO_2/km in new cars sold doubled after the introduction of a tax deduction for such vehicles (IEA, 2013).

Renewable transport fuels

Iceland has encouraged the use of alternative fuels in its vehicle fleet. In its national renewable energy action plan (Section 4.2), the MII aims to raise renewables use in transport to 23.7 ktoe by 2020 from less than 1 ktoe in 2010. The increase will mostly take the form of biogas and vegetable oil (75%). Biodiesel (internally produced) is expected to contribute some 15% and renewable electricity the remaining 10% (MII, 2012). A public-private committee, EcoEnergy, was established by the government in 2010 to develop a policy for promoting use of renewables in transport.

Use of biogas from landfills for transport commenced in 2007. This is the only renewable transport fuel used, representing less than 0.5% of energy use in the sector, a share comparable to that in Denmark but considerably lower than in other Nordic countries, such as Norway (4%) and Sweden (8%). Among the reasons for the slow development are lack of supporting infrastructure and a relatively slow pace of vehicle fleet renewal since the economic crisis (MII, 2012). Recent legislation obliges fuel distributors to guarantee that at least 3.5% of fuels sold for transport are of renewable origin by 2015, rising to 5% by 2016. Fuels must comply with sustainability criteria.

Given Iceland's scarcity of biomass, however, large-scale biofuel deployment using current technology (which relies on large quantities of animal or vegetal material) is unlikely to be feasible and cost-effective. A demonstration project is under way in Akureyri in northern Iceland, where waste vegetable oil and animal fat are used as biodiesel in local public transport. Subsidies are available for the conversion of motor vehicles to use methane from waste landfills and a number of conversions have been undertaken. Use of methane is promoted through favourable taxation on the fuel and vehicles (Chapter 3). However, because methane is available only around the capital, many owners of subsidised methane-powered vehicles use standard petroleum products, defeating the environmental purpose of the subsidy.

Electric vehicles

Iceland is an ideal location for widespread electric vehicle (EV) deployment: it has comparatively cheap electricity that is 100% renewable, reliable nationwide transmission and distribution systems, high imported fuel prices and generally short commutes. As most Icelanders live within a short distance of Reykjavík, the use of EVs, which are best suited for city driving, could make a significant difference to transport emissions. Analyses indicate that expanding the EV fleet is technically feasible with little additional investment in power infrastructure and generation capacity (Box 4.6). This is a medium-term strategy, which depends on more economic EVs coming on the mass market.

Box 4.6. **Impact of electric vehicles on the power system**

Analysis by Reykjavík Energy indicates that the power system could cope with a major shift to EVs. The analysis estimates that 50 000 EVs could be charged within the company's distribution area by 2030 (i.e. up to 15% of the forecast national fleet). While the system would need reinforcement, in some areas it could meet the additional distribution needs of an all-EV fleet. The annual power generation required to service 50 000 EVs would be 112 GWh, or less than 10% of the company's production in 2010, and just 0.56% of the forecast total Icelandic production for 2030. If the cars were charged cyclically, 60 MW of additional capacity would be needed in the Reykjavík Energy system, i.e. a minor addition to the 2011 capacity of 2 668 MW and well within the expansion capacity envisaged in the master plan (Section 6). If charging took place in off-peak hours, no further power plants would be needed. Even if the whole fleet went electric by 2030, annual demand would be about 750 GWh, not quite 4% of the power generation forecast for 2030. According to the national transmission system operator, a fully electric car stock would not require any changes in the transmission network.

Source: IEA (2013), *Nordic Energy Technology Perspective.*

A few companies have formed the Icelandic Electric Vehicle Association to promote the use of EVs. Projects launched to promote EVs include a partnership between the Landsvirkjun and Icelandic New Energy to test EV performance (Landsvirkjun, 2012b). EV deployment is still in its infancy, with some 30 EVs in Iceland in 2013. Icelanders appear reluctant to switch to EVs because of the high upfront cost, lack of charging stations, higher electricity requirement in cold weather and the fact that most EVs on the market are small cars unsuited to frequently difficult driving conditions (Kelly, 2013). A complete charging solution would mean sufficient charging stations to meet public demand. This may not be too great a challenge, as around 75% of the population lives within 60 km of Reykjavík. Financing infrastructure development for EVs in the aftermath of the crisis remains an issue (MII, 2012).

In 2012, Iceland introduced a two-year VAT exemption for electric and hydrogen-powered vehicles (Chapter 3). This should bring electric SUVs closer to price parity with their fossil fuel counterparts. SUVs make up 35% of new car sales in Iceland, where they are popular for recreational driving in the interior. This tax change is a step in helping establish more widespread EV use, and could be combined with higher taxes on high CO_2-emission vehicles. A comparison of energy consumption in electric and standard vehicles at current energy prices indicates that the energy cost per kilometre of EV use in Iceland is about 80% below that of an energy-efficient fossil-fuel car.[14] Estimates indicate that for a consumer driving the average distance per year, lower energy costs would completely offset the higher EV price in six to seven years (IEA, 2013).[15]

Aviation and shipping

Due to its isolation from the rest of Europe, Iceland relies almost entirely on aviation for international passenger transport and on sea shipping for freight haulage to Europe and North America. The number of passengers travelling through Keflavík International Airport grew by 63% between 2000 and 2012.

In 2011, GHG emissions linked to international aviation accounted for two-thirds of emissions from international bunkers and sea shipping for the remaining third. As a comparison, international aviation emissions amounted to about half the emissions from domestic road transport and 20 times those from domestic flights.[16] They grew rapidly to 2007, after which the economic crisis damped Icelanders' air travel abroad, along with emissions, which in 2011 were only 3.5% above their 2000 level (EAI, 2013). More recently, energy consumption and emissions from international aviation have been rising again. Energy use in the sector is forecast to grow by some 60% between 2011 to 2020, not least because of growth in tourism (MII, 2012) (Chapter 5).

Aviation is used also for longer-distance domestic travel. Domestic aviation and shipping account for less than 5% of energy use and GHG emissions from the transport sector. Energy use in domestic aviation declined by 33% in 2000-11 and GHG emissions by 27%, partly as a result of the crisis. Energy and emission trends in domestic navigation do not show a clear pattern.

The key policy measure to tackle fuel use and GHG emissions in aviation is Iceland's participation in the EU ETS. The carbon tax on aviation fuel was lifted after emissions from intra-European aviation were included in the trading system (Chapter 3). A tax on air passengers, at rates varying with flight distance, was unsuccessfully proposed to the Parliament in 2011. With aviation emissions included in the EU ETS, there is little case for introducing such a tax from a GHG mitigation perspective.

Shipping and aviation are the most difficult sectors to decarbonise. Aside from efficiency gains and the use of biofuels, breakthrough technologies are needed to overcome the barriers that limit the share of biofuels: cost, availability and concerns about sustainability. Co-operation with other countries would be necessary in order, for example, to build infrastructure for refuelling (IEA, 2013).

7.3. Improving fuel efficiency of the fishing industry

Fishing accounts for 8% of final energy consumption. Fuel use in this sector decreased by 3% between 2000 and 2011, reflecting a reduction in fishing and improved efficiency of vessels and processes. A 30% drop in the number of fishers and vessels between 2000 and 2009 contributed to a decrease in fishing capacity through an improved fisheries management system based on transferable quotas (Chapter 3). The government did not provide any subsidy or decommissioning programme (OECD, 2013b).[17]

Rising oil prices in the 2000s led Icelandic fishing firms to focus increasingly on fuel efficiency and fuel switch. There was a substantial renewal of the fishing fleet with more fuel-efficient vessels. Energy-saving devices based on information technology have been developed through experimental projects supported by the government. In addition, the Marine Research Institute has set up an energy-saving system in the research vessel Árni Fridriksson, and the Ministry of Justice has agreed to install such a system in the Coast Guard's newest cruiser. Another measure involves equipping harbours with land-based electricity, which would allow engines and independent internal power sources to be switched off in harbour. There was no use of land-based electricity and heat in 2000; in 2010, this accounted for about 21% of energy used in the fishing industry for powering vessels in harbours (of which geothermal represented 60%). This measure is expected to reduce emissions by some 16 000 tonnes of CO_2 per year (Ministry for the Environment, 2010).

The MENR estimates that the fishing industry can contribute considerably to reductions in energy use and GHG emissions. Emissions from fishmeal factories could be almost eliminated by using electricity rather than burning fuel. Similarly, emissions of the fishing fleet could be reduced by 75% through increased use of biofuels and energy saving measures. Considerable costs would be involved in such a transformation, especially in securing reliable electricity for fishmeal plants, which would call for significant investment in power plants and infrastructure (OECD, 2011).

Renewables-based fuels for fishing are being researched. The Maritime Administration and other agencies have been working on pilot projects aimed at developing biofuels to power ships. The uptake of biofuels in fishing depends on many factors, including oil prices. Icelandic New Energy, in co-operation with foreign partners, as well as the European Union and the Icelandic government, is working on a project aimed at determining the economic and technological feasibility of using hydrogen as an energy carrier for fishing vessels. The results of this project could apply to the transport sector as well.

The fishing sector faces a carbon price in Iceland. Fishmeal factories, which are energy intensive, are covered by the EU ETS. Unlike many other OECD countries, Iceland imposes a carbon tax on fuel used to power vessels. Higher oil prices have led vessel owners to replace standard fuel with less refined oil, thus increasing emissions. Iceland should look into the effects of fuel prices and taxation on substitutability between fuels and the effect on fuel use and GHG emissions (OECD, 2011).

Notes

1. Industrial use of geothermal heat includes a seaweed processing plant at Reykhólar in western Iceland, using about 250 TJ per year for drying; and a plant commercially producing liquid CO_2 that has operated at Haeðarendi in the south-west since 1986.
2. Iceland is authorised to emit an additional 1.6 Mt of CO_2 eq per year from new heavy industry units (mainly aluminium smelters) established after 1990, if the units meet conditions set by Decision 14/CP.7 on using renewables and best available technology.
3. The production technology in all aluminium plants is based on prebaked anode cells. The main energy source is electricity. Industrial process CO_2 emissions are mainly due to the anodes that are consumed during electrolysis (EAI, 2013).
4. The Hellisheiði plant is located about 30 km from Reykjavík. Operated by Reykjavík Energy, a publicly owned utility company, it generates electricity almost entirely for aluminium production at the Grundartangi smelter. A 90 MW expansion is planned near Hverahlíð, south of the Hellisheiði plant, to generate energy for a smelter in Helguvík, near Keflavík International Airport.
5. Recent examples include settlements in 2012 between Australia's government and the Bell Bay and Point Henry smelter operators and in August 2013 between Rio Tinto and the New Zealand government.
6. The MENR leads the committee, which includes representatives from the Prime Minister's Office, the MII, the Ministry of the Interior, the Ministry of Finance and Economic Affairs, and the Association of Local Authorities.
7. These industries can emit an additional 1.6 Mt CO_2 eq per year.
8. Perfluorocarbons (PFCs) from aluminium production are now covered by the EU ETS, in addition to the related CO_2 emissions.
9. The environmental impacts of hydropower development considered in developing the plan included loss of vegetation, habitats and organic soil due to reservoir submergence. For geothermal development, they included visual landscape and wilderness intrusion of infrastructure, noise pollution, reduction of some surface manifestations of geothermal activity (e.g. drying up of springs) and land subsidence. The environmental impact of each potential project was assessed and ranked using multi-criteria analysis (Thórhallsdóttir, 2007a).
10. Phase 1 (1999-2003) concluded with a preliminary assessment due to limited availability of scientific evidence and data. The expert groups and steering committee continued with the analysis during Phase 2 (2004-10), and concluded with suggestions for a categorisation of possible power plant developments.
11. There were four working groups: 1) nature, environment and cultural heritage; 2) recreation, fishing, hunting and agriculture; 3) social and economic impact and regional development; and 4) economic aspects.
12. In the first half of 2013, production fell at the Hellisheiði power plant by around 30 MW, representing a decline of over 2% of annual energy production. This decline is expected to be permanent and could increase if field pressure continues to decline (Hansen, 2013; Hávarðsson, 2013).
13. Many Icelanders even open windows instead of turning down the heat when the inside temperature is too high (IEA, 2013).
14. In 2010, EV energy use averaged about 150 watt hours per kilometre (Wh/km), or 195 Wh/km in bad weather. At the 2012 electricity price, the energy cost of using an EV in Iceland was USD 0.0183/km. At the 2012 fossil fuel price of around USD 1.93/L, owners of diesel and petrol vehicles using 5 L/100 km had an energy cost of USD 0.0966/km (IEA, 2013).
15. Assuming a 6.36% interest rate and similar maintenance costs and fixed energy prices for electric and standard vehicles (IEA, 2013).
16. As almost all international flights depart and arrive from Keflavík, oil products sold to the Keflavík airport are reported as being for international use. However, domestic flights sometimes depart from Keflavík and some international flights from Reykjavík airport. The EAI is developing a methodology to calculate the fuel split between international and domestic aviation now that Iceland is part of the EU ETS for aviation (EAI, 2013).
17. Decommissioning programmes are government programmes to purchase vessels, permits, licences and other entitlements from participants in the fishing sector.

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