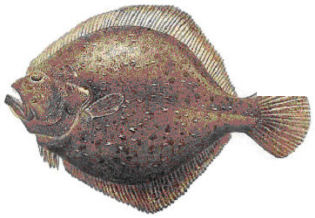
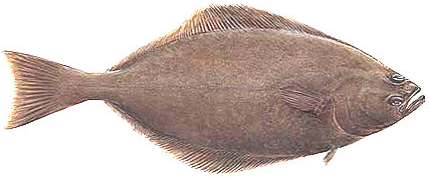
Fish farming in Husavik – Iceland

~Arctic charr – Tilapia – Atlantic halibut – Turbot~

FRUMKVÖÐLASETUR NORÐURLANDS

ATVINNUÞRÓUNARFÉLAG ÞINGEYINGA HF.





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Abstract

Key words: Iceland, Húsavíkurbær municipality, fish farming, Arctic charr, Turbot, Tilapia and Atlantic halibut

Iceland is located in the North Atlantic Ocean. Húsavíkurbær municipality is located in the northeast part of Iceland, more specificly on the east cost of Skjálfandaflói (Skjalfandi bay) in the county of Thingeyjarsysla. Húsavíkurbær has abundant water resource potential in form of geothermal water, cold water and warm cooling water (23°C) from the electrical power plant located just south of the inhabited area of Húsavíkurbær. Because of those abundant water resources Húsavíkurbær has been considered as an ideal place for fish farming. The main species that have been mentioned in that context are arctic charr, tilapia, turbot and Atlantic halibut.

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1 Introduction

Húsavík, a small town on the north-east part of Iceland has been considered a good place for fish farming. It is mainly because the area holds huge resources of cold and geothermal water and there is a plentiful of cooling water from the new electrical power plant located just south of Húsavík. The temperature of the cooling water is around 23°C. In this report demands and characteristics of water availability in Húsavík are discussed as well as other important issues pertaining to fish farming i.e.the availability of land, environment affairs and support services. Finally, four species considered to be viable for cultivation under the conditions found in Húsavík will be discussed. These species are Arctic charr, Tilapia, Turbot and Atlantic halibut. This report is particularly made to inform investors in the fish farming sector who are interested in Húsavík's potential for fish farming.

This project is a collaboration between The Development Agency for the Region Thingeyjarsýsla, Incubator Centre of the University of Akureyri, Húsavík Academic Centre and Hólar College. Hlifar Karlsson (now managing director of Rifós fish farming) introduced the idea to the institutions above in the beginning of the year 2004 after having studied fish-farming at Hólar College. Hlifar started the project by collecting base information about water resourches in Husavik Area. The author of this report, Ásmundur Gíslason (BSc Honors in fisheries science) followed on Hlifars work and wrote this report the summer 2004. The sponsors of the project are Húsavík Energy, Impra Innovation Centre, GPG fish processing and Fiskiðjusamlag Húsavíkur (a deep-rooted fish processing company in Húsavík).

2 Iceland - overview

In this chapter the Icelandic economy and governmental issues are discussed as well as the various occupations and education offered in Iceland is briefly introduced. Information about the town of Husavik is provided at the end of the chapter.

2.1 Iceland

Iceland is located in the North Atlantic Ocean. By air it takes about 3 hours to go from the major cities in Europe and 5-6 hours from the East Coast of the United States. Shipping distances are 3-4 days to Europe and 7-8 days to eastern North America. Iceland´s location in the mid-Atlantic makes the country an ideal base for companies with business in both continents.[1]

Figure 1. Iceland[2]

[1] Doing Business in Iceland, 3rd edition 2004.
[2] http://www.lmi.is/landmaelingar.nsf/pages/vefkort.html

Iceland is roughly 103.000 square kilometers or 40.000 square miles.[3] The country´s population is 290.490 (1st of December 2003).[4] Reykjavik is the capital with population of 113.387 and the greater Reykjavik area population is 181.746.[5] Population density per square kilometer is 2,8 which makes Iceland the least populated country in Europe and the seventh in the world. Most of the people in Iceland are of Norwegian descent with some admixture of Celtic blood. The mean annual temperature in Reykjavik, is -0,5°C in January and 10,6 in July. In Akureyri, the main northern town, the temperature is -2,2 in January and 10,5 in July.[6]

2.1.1 Language

Iceland's written and spoken language is Icelandic, a Nordic language. Danish and English are the two mandatory languages taught in schools. Literacy in Iceland is the highest in the world, 99,9 %. [7] English is widely spoken language in Iceland.

2.1.2 Religion

The state church of Iceland is Evangelical Lutheran Church, which 86,6% of the population belong to. Lutheran free churches have 4,2% of the population and others have 9,2%.[8]

2.1.3 Education

In Iceland there is a mandatory school (primary school) from 6 – 16 years of age. There are 192 schools for compulsory education and 42 educating

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[3] http://www.afe.is/
[4] http://www.hagstofa.is/template25.asp?pageid=219&nid=267&highlight=íbúafjöldi
[5] http://www.hagstofa.is/template_lb_frameset.asp?PageID=311&intPXCatID=61&ifrmsrc=/temp/mannfjoldi/sveitarfelog.asp
[6] Doing Business in Iceland, 3rd edition 2004.
[7] http://www.afe.is/
[8] http://www.afe.is/

students who have finished the mandatory education.. There are 8 universities and colleges.[9]

Primary school education for children aged 6 – 16 is free of charge. Normally the school year is from the beginning of September to the end of May or about 9 months. The main subjects in primary school are Icelandic (grammar and literature), Mathematics, History, Danish, English, Social Studies, Science, Handicraft, Sports and music. At the conclusion of 10th grade students undergo standardized tests in Icelandic and Mathematics for overall evaluation and comparison. When primary school is over students can go to higher secondary comprehensive schools, it's not compulsory and students must pay for their textbooks but tuition is free of charge. This level of education takes between one and four years and is divided into numerous courses of study, both theoretical and practical. The theoretical studies conclude with a General Certificate which is a necessary prerequisite for entering university. The practical part usually concludes with a Journeyman's Certificate.[10]

There are nine universities in Iceland:[11]

- The University of Iceland (www.hi.is)
- The University of Akureyri (www.unak.is)
- Reykjavik University (www.ru.is)
- Iceland University of Education (www.khi.is)
- Technical University of Iceland (www.thi.is)
- Bifrost School of Business (www.bifrost.is)
- Hólar College (www.holar.is)
- Iceland Academy of the Arts (www.lhi.is)
- Hvanneyri College of Agriculture (www.hvanneyri.is)

[9] http://www.afe.is/
[10] http://www.iceland.org/polisube.html
[11] http://www.ask.hi.is/page/haskolaraislandi

The Faculty of Natural Resource Science at the University of Akureyri has a special department of Aquaculture where a three year BS program in aquaculture science is offered.

Holar College is a development, educational and research institution run by the Ministry of Agriculture. It has three departments, Department of Aquaculture, Department of Rural Tourism and International Center for Icelandic Horses.[12] The department of Aquaculture is a leading research center in aquaculture and since 1993 designated as the center for Arctic charr research in Iceland.[13]

For further information about Hólar College see:
http://www.holar.is/enfis.htm and http://www.holar.is/rannsfisk.htm

In addition there are numerous institutions in Iceland that are defined as non-university institutions but offer a range of education at a university level.

2.1.3.1 Educational level

The educational level for Iceland and all the Nordic countries is among the highest in the world. Demand for education on university level has increased significantly in the Nordic countries during past years.[14]

2.1.4 Government

Iceland is a parliamentary democratic republic. The President is the head of state. He is elected for a term of four years at a time. The Prime Minister is the top the government. The parliament is elected for a term of four years. The parliament consists of 63 members, elected by proportional representation. Since the establishment of the Republic in 1944, no party has secured a parliamentary majority and there for coalition governments have always been ruling. Elections were held in May 2003, the centre-right

[12] http://www.ask.hi.is/page/haskolaraislandi
[13] http://www.holar.is/enfis.htm
[14] http://formennska.forsaetisraduneyti.is/Aaetlun/Menntir_og_visindi/

coalition of the Independence Party (IP) and the Progressive Party (PP) continued in office for a third term. The Prime Minister is the leader of the PP and the Foreign Minister is the leader of IP. All the twelve ministers are members of the parliament.[15]

2.1.5 International Organizations

Iceland is a founding member of the European Economic Area (EEA) which allows tariff-free movement of labor, capital, goods and services. Companies from any of the other member countries of the EEA or OECD have the same rights to operate in Iceland as any registered Icelandic company. It just needs the same permits and registration as an Icelandic-domiciled company. There is free movement of labor between EEA countries.[16] Iceland is a member of many international organizations. It is a member of the United Nations and its agencies, Council of Europe, EFTA, NATO, WTO and the Nordic Council.[17]

2.1.6 Workforce

The total workforce in Iceland on the 1st of December 2003 was 167.300 individuals. The overall participation rate was 84,3%. The participation rate was 87,6% for males and 81% for females. In recent term unemployment has been averaging 2-4%. Iceland has the youngest population in the world, with 24% of its population aged 15 or below and 12% aged 65 or above.[18]

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[15] Doing Business in Iceland, 3rd edition 2004.
[16] Doing Business in Iceland, 3rd edition 2004.
[17] http://www.afe.is/
[18] Doing Business in Iceland, 3rd edition 2004.

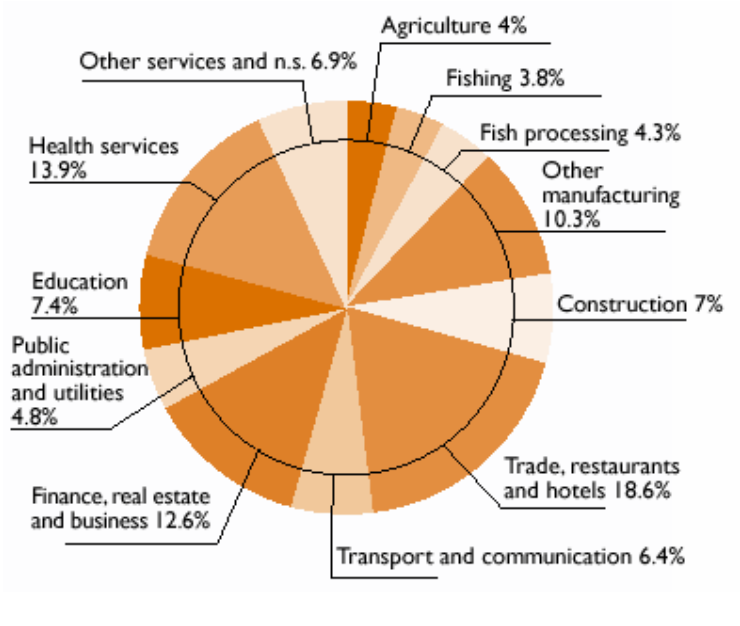

Figure 2. Employment by sectors in 2001[19]

More than 85% of employees in Iceland belong to unions where the Icelandic Federation of Labour (ASÍ) is the largest. Many other unions are operating e.g. Municipal Employees (BSRB) and Association of Academics (BHM). The labor unions are non-political and decentralized. A written contract of employment must be made for every employee engaged for a term longer than one month. When an employee is hired, a trial period from one to three months is common, but in higher-level jobs up to six months. International comparison shows that wages and wage-cost in Iceland are very competitive relative to most Western countries. The working week is in most cases 40 hours over 5 days, but some professions have 37,5 - 39,5 hours per week. Shift-work rate are an extra 33% on top of the daytime rate, but for weekend or public holiday work this rate is 45%. It may be up to 80% depending on the contract of employment. Every employee has 11 hours continuous rest period guaranteed during each 24 hour period. The rest period may be shortened to 8 hours in certain circumstances. During sickness or after accidents at work employees get paid wages which correspond to 2 working days, which is the minimum rights. This right gets greater the longer the

[19] Labour Market in Iceland 2002.

employee has worked for the employer. The minimum vacation period is 24 working days and the right to vacation depends upon the length of the wage-earner's service during the last 12 months. Vacation is calculated as two paid vacation days per month of work. Unemployment benefit is ISK 79.767 (USD 1.121) a month plus ISK 147 (2,07) per day for each child under 18 years old. Unemployment benefits are there for not related to the previous salary.[20]

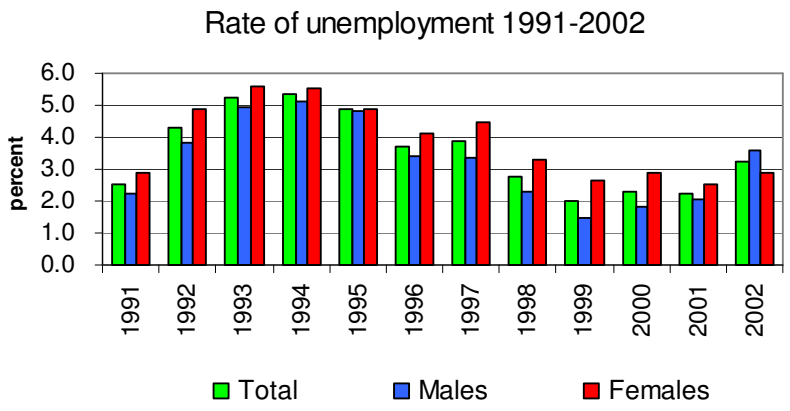

Figure 3. Unemployment in Iceland 1991-2002[21]

Movement of labor between Iceland and other EEA/EU countries is free and the minimum wages in Iceland for 40 hours a week, is ISK 93.000.[22]

2.1.7 Taxation

The main taxation form in Iceland is indirect taxes or about 52% of the total tax burden. The total tax burden, in the year 2002, as a percentage of GDP (Gross Domestic Product) was 37,8% and is estimated to be 39,3% for the year 2003. The Icelandic tax system is relatively simple compared to other

[20] Doing Business in Iceland, 3rd edition 2004.
[21] Ottó B. Ottósson 2004.
[22] Ottó B. Ottósson 2004.

countries. The tax system has been simplified and tax rates reduced in the last few years.[23]

2.1.7.1 Direct taxes

The national income tax rate on individuals is 25,75% and the municipal tax rate may vary from 11,24% to 13,03% (average 12,83%). That makes a total income tax rate on individuals of 38,58%. A tax deduction of ISK 27.469 (USD 386) is available every month, meaning that monthly income up to 71,270 (USD 1002) is tax-free. The tax is paid as the income is earned. Spouse's tax deduction may be transferred to the other spouse if not fully used. Capital income earned by individuals e.g. interests and dividends are taxed at a flat rate of 10%. Business income of individual is taxed as a ordinary income of the business owner and expenses are deductible to the extent required to obtain, secure and maintain business income.[24]

2.1.7.2 Indirect taxes

Value-added tax (VAT) of 24,5% is levied on any sale of goods, services or power with various exceptions. Exemptions are e.g. the following:

- All export sales
- Banking and the operation of other financial institutions and sales of bonds
- Insurance service
- Schools and other educational institutions

There is also a 14% VAT levied on other goods and services, e.g. sales of books, hotels and other accommodation and more. All individuals, corporations, state, municipal and individuals that sell or grant any kind of taxable goods or services in Iceland are assessable for VAT. The VAT assessment period is two months and the tax is due within 35 days from end of each period. All foreign enterprises shall be registered through an

[23] Doing Business in Iceland, 3rd edition 2004.
[24] Doing Business in Iceland, 3rd edition 2004.

Icelandic resident representative that is jointly responsible for payment of VAT.[25]

Other taxes are e.g. property tax which is levied on land and property. The tax is paid to the municipal authorities and varies between municipalities and also in regard to use. Production or consumption of pollutants is not specially taxed in Iceland.[26]

2.1.7.3 Corporate taxes

Tax rate for limited liability companies is 18%. Registered partnerships for tax purposes with unlimited liability pay 26% income tax. For individuals with business income the tax rate is 25,75% or 29,75% depending upon which bracket their income enter. All capital gains are added to other taxable income and taxed at the regular corporate rate. Interest income is defined as regular income and therefore included in taxable income of companies. Dividends that company receives from shares it owns in another company are not taxed in the hands of the recipient company. Anyway a withholding tax of 10% is withheld at the source for dividend payments both to individuals and corporations, and as regards corporations it is considered a prepayment for regular income tax payable after assessment.[27]

2.1.8 Icelandic economy

The Icelandic economy has been opened more and more during the past few decades and companies and individuals are not as restricted in their transactions with foreign companies and individuals as they were. Banks and companies owned by the government have been privatized and government intervention has declined. Nevertheless, the government share of GDP has raised from 21,5% in 1993 to 23,6% in 2002.[28]

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[25] Doing Business in Iceland, 3rd edition 2004.
[26] Doing Business in Iceland, 3rd edition 2004.
[27] Doing Business in Iceland, 3rd edition 2004.
[28] Ottó B. Ottósson 2004.

2.1.8.1 Currency

The krona (ISK) is the official currency of Iceland. One krona equals 100 aurar but today aurar are not commonly used and the Central Bank has announced that it will withdraw the existing stock of aurar coins from circulation. The krona has more or less been floating freely in the context of an inflation targeting framework, since March 2001. The krona's exchange rate is determined on the interbank market for foreign exchange.[29]

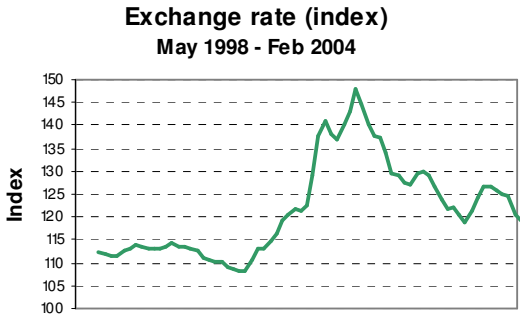

Figure 4. Icelandic krona, exchange rate (index)[30]

The exchange rate of the krona is measured against a basket of the 18 main trading partners, currencies. The weight of each currency is based on each country's share in trade of goods and services.[31] The ISK exchange rate against USD, GBP and EUR can be seen in appendix.

2.1.8.2 Economic growth

The estimated economic growth in Iceland for the year 2002 was -0,5%, after positive growth for the previous seven years.[32] The economic growth is expected to be 2% in 2003, 3% in 2004 and 4,25% in 2005. Iceland was ranked among the seven most prosperous nations in the world with a GDP

[29] Doing Business in Iceland, 3rd edition 2004.
[30] Ottó B. Ottósson 2004.
[31] Doing Business in Iceland, 3rd edition 2004.
[32] Ottó B. Ottósson 2004.

per capita of USD 26.700 in 2001.[33] Inflation for 1998-2003 and an inflation forecast is shown in figure 5. Average change in inflation from previous year is shown in figure 6.

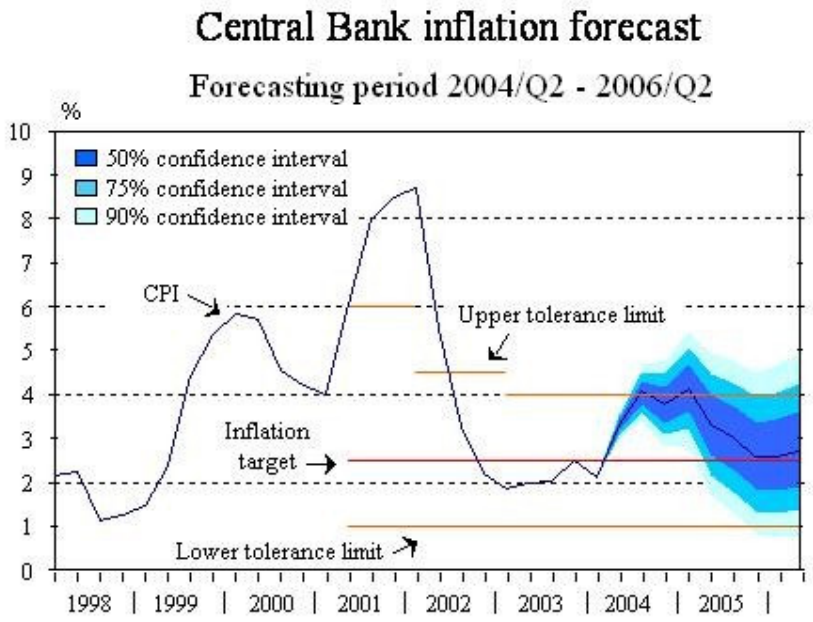

Figure 5. Inflation forecast from May 2004[34]

[33] Doing Business in Iceland, 3rd edition 2004.
[34] http://www.sedlabanki.is/template4.asp?pageid=200

Figure 6. Average change in inflation from previous year (%)[35]

2.1.8.3 Economic structure

The Icelandic economy depends significantly on the fisheries sector and fore the year 2002 it accounted for 12,4% of the GDP. Other significant sectors are manufacturing, industries, construction and utilities (19,8%) and various private and public services (44%). Public ownership has decreased with systematic privatization, but health, education and social welfare are driven by the public sector. Fish and fish products accounted for 62,9% of merchandise export in 2002 and for 41,7% of total export (merchandise and service receipts). The total value for fish and fish products in 2002 was ISK 128.592 billion. In 2001 export of aluminium was 282.000 tons to the value of ISK 38,58 billion (FOB), which accounted for 18,9% of the merchandise export. A new 320.000 ton aluminum plant is being built and therefore export of aluminum will weigh much more in the future.[36,37]

[35] Ottó B. Ottósson 2004.
[36] Ottó B. Ottósson 2004.
[37] Doing Business in Iceland, 3rd edition 2004.

Table 1. Economic sectors by percentage of GDP in 2002[38]

Economic sector	%
Agriculture	1,5
Fishing and fishprocessing	12,4
Aluminium and ferrosilicon processing	1,3
Manufacturing, other	8,5
Electricity and water supply	3,5
Construction	7,8
Commerce, hotels and restaurants	13,5
Transport, storage and communication	7,5
Other private services	22,9
Producers of government services	21,1
	100

2.1.9 Financial sector

The Icelandic financial system is based to a large extent on EU directives and the government has reduced their intervention in financial markets. Financial institution (non-bank) who covers e.g. stock broking and other financial services have grown in number past few years. The Central Bank of Iceland is a independent institution and its main objective is to ensuring price stability, as defined by an inflation target of 2,5%. The bank also monitors financial stability and administrates Iceland's foreign exchange reserves. The Central Bank is both the fiscal agent for the government and the borrowing agent for the Republic of Iceland in international capital markets. In Iceland there are four commercial banks. Three of them are listed on the Icelandic Stock Exchange but the fourth is owned by over 20 local savings banks. Today Icelandic banks offer a full range of financial services both to individuals and businesses. Iceland's commercial banks have extensive links to foreign banks for corporate lending. The State Housing Fund is the main source of mortgage finance for private housing. Interest rates in Iceland are

[38] Doing Business in Iceland, 3rd edition 2004.

determined by market forces. The Central Bank has adopted a formal inflation target that may influence the interest rates when trying to be reached.[39] In figure 7 yields on a few government bonds is shown. It can be seen that expectations of inflation clearly illustrates its yield. Yields on 90 day treasury bills were 5.09% 4th of July 2003, 8.40% on 4th of July 2002 and 11.17% 4th of July 2001.[40]

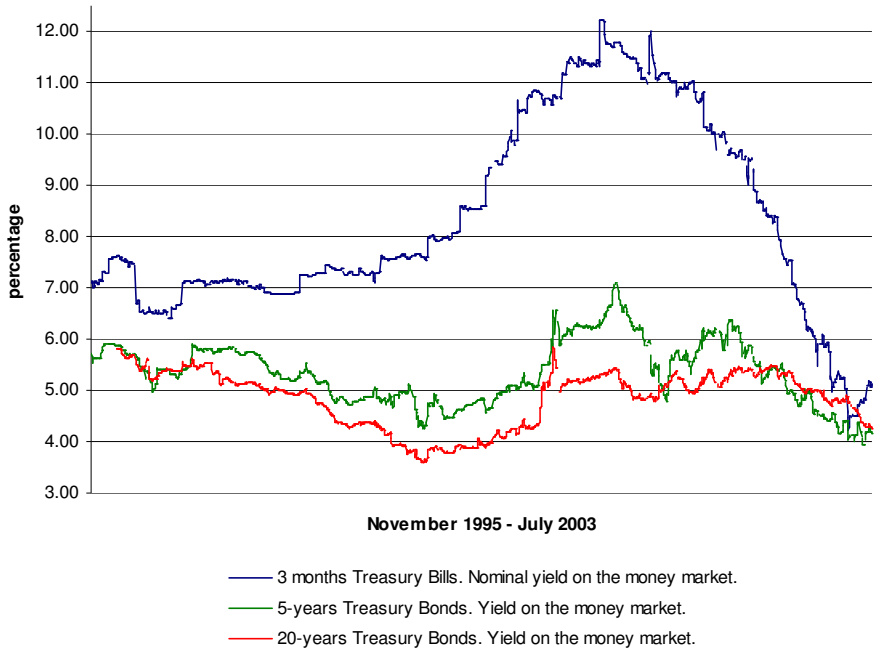

Figure 7. Yields on a few papers[41]

The Icelandic Stock Exchange (ICEX) was established in 1985 and it is the official trading floor for stocks and bonds. At the end of 2003 there were 42 companies listed on the Icelandic Stock Exchange and in the beginning of 2004 there were 18 members. Members are the Central Bank, all commercial banks, security houses and some savings banks. Only licensed brokers handles trading on Icelandic Stock Exchange. In the year 2003 the trading

[39] Doing Business in Iceland, 3rd edition 2004.
[40] Ottó B. Ottósson 2004.
[41] Ottó B. Ottósson 2004.

amounted to ISK 1.577 billion (USD 22.16 billion) and had increased by 39% compared to the previous year.[42]

Foreign companies have traditionally raised their funds in international finance markets. However, Icelandic finance companies offer a broad range of services such as export guaranties, medium and long term loan and a full array of other financial services.[43]

2.1.10 Foreign trade

Iceland must maintain a high level of import to supply consumer needs. Therefore Iceland must also maintain high level of export to finance the import. Capital goods, consumer goods and food and beverages are the main import items. In 2002 European Economic Area countries accounted for 75,1% of all Iceland's exports and 60,5% of imports. Fish and fish products account for some 63% of Iceland's total export and for 41% of its foreign currency earnings. Services account for 32% of foreign currency earnings, thereof tourism 12%.

2.1.11 Energy

Iceland has abundant energy potential in the form of geothermal energy and hydropower. Energy consumption per capita in Iceland is among the highest in the world. About 87% of all housing in the country is heated with geothermal energy; the remainder being heated mainly with electricity. Most of the country's electricity (83%) is generated using hydropower; the remainder being based on geothermal power. Only 10-15% of the technically feasible hydropower, and only a fraction of the geothermal potential available for electricity production, has been harnessed.[44]

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[42] Doing Business in Iceland, 3rd edition 2004.
[43] Doing Business in Iceland, 3rd edition 2004.
[44] http://www.os.is/

2.2 Húsavík

The Húsavíkurbær is a community of 2.500 residents. The municipality consists of Húsavík town on the peninsula Tjornes and further south to the agricultural area Reykjahverfi.[45]

The Húsavíkurbær is located in the northeast part of Iceland, more specificly on the east cost of Skjálfandaflói (Skjalfandi bay) belonging to the region Thingeyjarsysla.

Figure 8. Húsavík

Figure 9. Location of Húsavík[46]

[45] http://www.husavik.is/page.asp?id=546

Akureyri, the main northern town, is in a driving distance of 91 km (57 miles) from Húsavík and the capital Reykjavik is in 480 km (298 miles) distance.[47]

2.2.1 Occupations

Fishing and fish processing are the main industries in Húsavík, along with meat processing. All milk processing was moved to Akureyri in 2002 which was a relapse for the Húsavík economy. Public and private services, agriculture in Reykjahverfi and tourism are also important sectors for Húsavík's economy. Tourism in Húsavík has been growing rapidly for the past few years, mostly in relation to the whale watching tours on Skjalfandafloi (Skjalfandi bay) from Húsavík. The whale watching industry in the area has grown so significantly that Húsavík is now known as The Whale Watching Capital of Europe.

Húsavík is the centre of merchandise and services in Thingeyjarsysla. A few convenience stores, computer store, pharmacy and clothes stores are there among others. Public services, such as health service and the Husavik High School, create many jobs for the inhabitants.[48,49]

2.2.2 Education and educational level

There are two nursery schools in Húsavík where children can go to when they have reached 1 year of age. Waiting list for nursery school is short. Borgarholsskoli is the mandatory school in Húsavík for children from 6-16 years of age. The 420 children attending Borgarholsskoli are offered lunch every day and they have the possibility of staying at the school for after hours activity (daycare). The higher secondary school in Húsavík is Framhaldsskolinn a Húsavík (FSH) or the Húsavík High School. In FSH there are 150 students and the school offers four study programs, which lead

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[46] Ragnar Jóhannsson 2001.
[47] http://www.vegagerdin.is/vefur2.nsf/pages/vvl_husavik.html
[48] http://www.husavik.is/page.asp?id=546
[49] Byggðarlög í sókn og vörn 2001.

to a General Certificate which is a prerequisite for entering university. The school also offers study for the theoretical part of practical studies e.g. for those wanting to become electricians. High ratio of students who have graduated with the General Certificate have gone on to undergraduate study at universities and many of them either came back to Húsavík or are interested in coming back if employment opportunities come about. The closeness of the University of Akureyri (see chapter 2.1.3) has brought people in Húsavík new opportunities and some students even travel on daily basis between Akureyri and Húsavík. The conservatoire of Húsavík, or the Husavik Music School, is in close cooperation with both Borgarholsskoli and the nursery schools. There are about 300 students studying at the conservatoire or about 12% of the inhabitants of Húsavík.[50]

The Húsavík Academic Centre (HAC) is a newly founded university- and research centre, located in midtown of Húsavík. It serves as a study and service centre for university students living in the area of Thingeyjarsýsla as well as an academic research centre, focusing on interdisciplinary researches in the area around Húsavík.[51]

For further information see: http://www.hac.is/

[50] Byggðarlög í sókn og vörn 2001.
[51] http://www.hac.is/page.asp?Id=553

3 Water resources

Water resources around Húsavík are discussed in this chapter, both geothermal- and cold resources. The amount of available water, its cost and chemical content is mentioned along with other things related to the region´s water resources.

3.1 Cold water resources

In June 1992 the National Energy Authority carried out a study of wellsprings in Húsavík and its surroundings. The reason for this study was that in Húsavík was a group of innovative people who were wondering if water export would be a profitable business. The areas that were studied are Reyðará river, Bakká river north of Húsavík, the Húsavík's water supply and Þorvaldsstaðaá south of Húsavík. Wellspring water from the bedrock flows up on those areas. That water is rainwater that has fallen in the Iceland's plateau east of Húsavík and strained through leaky stratums to the wellsprings.[52]

3.1.1 Reyðarár wellsprings (Reyðarárlindir)

Reyðarár wellsprings originate up in the fells close to the mountain Krubbur east of Húsavík. The river Reyðará runs to sea north of Húsavík. The wellsprings are 200 m above sea level and a rivulet runs from the wellsprings to the river. In June 1991 the water's temperature was 3°C, the flow rate was around 20 l/s and its conductivity was 92 µS. Some smaller wellsprings are also in that area and the total water flow from the area is estimated around 100 l/s, former measurements showed flow rate of 60-250 l/s. The wellsprings can for sure supply around 50 l/s in normal conditions. Environmental condition is good and it should be easy to pipe the

[52] Árni Hjartarson 1991, bls. 1.

wellsprings into one waterhole. Pollution hazard is considered to be negligible.[53]

3.1.2 The river Bakkaá

Bakkaá rivers origination is just north of the mountain Húsavíkurfjall. The rivers wellsprings are 200 m above sea level. The rivers temperature was 2,4°C when measurements were made, its flow rate was around 70 l/s and its conductivity was 100 µS. The wellsprings on at this area are a little diffused. Former measurements showed that rivers flow rate can fall to around 40 l/s and therefore a 30 l/s is estimated to be the certain water supply from the river. Environmental condition is good and it should be easy to pipe the wellsprings into one waterhole.[54]

3.1.3 Húsavík's water supply

Húsavík's water supply is around 100 m above sea level. The water flows up from gaps on the bedrock. The flow of the wellsprings is 250-300 l/s, but temperature and conductivity varies from 4,0-6,0°C and 115-140 µS. The heat and the conductivity are highest on the east part of the area but lowest on the west part. Around 100 l/s of water are considered available from the area, without what is needed for the water supply. The Húsavík's water supply is considered one of the best in Iceland, pumping is not needed, the water does not have to be piped a long way and pollution hazards are considered to be negligible. At the lake Botnsvatn, east of the water supply, are two wellsprings. One is at the east end of the lake, its flow is around 100 l/s and the temperature is 2,6-3,0°C. The other is located north-west of the lake, its flow is considered to be around 100 l/s. The river that runs from lake Botnsvatn has a flow of around 200 l/s.[55]

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[53] Árni Hjartarson 1991, bls. 1.
[54] Árni Hjartarson 1991, bls. 1.
[55] Árni Hjartarson 1991, bls. 1-2.

3.1.4 The river Thorvaldsstaðaá

The river Thorvaldsstaðaá originates in deep ravine south of Húsavík. Two wellsprings are located in the ravine. One is 180 m above sea level and its flow is around 80-100 l/s. The other is 80 m above sea level and its flow is around 50-100 l/s. The wellsprings have the same temperature and conductivity or 2,7°C and 90 µS. Two other wellsprings are located on each side of the river. The wellspring on the west side has flow of 4 l/s and temperature of 2,8°C. The wellspring on the east side has flow of 5 l/s and temperature of 3,2°C. The river Thorvaldsstaðaá has the total flow of 180-200 l/s and it is considered easy to harness. The flow can increase significantly in the spring time because of swelling.[56]

3.1.5 Chemical content[57]

The water from the wellsprings mentioned above was chemically analyzed at the National Energy Authority laboratories. The samples were analyzed in the same manner as regular drinking water.

Table 2. Chemical content of cold water resources

Location		Reyðarár wellsprings	Bakkaá river	The Húsavik's water supply	Þorvalds-staðaá, upper wellsprings	Þorvalds-staðaá, lower wellsprings
Date		11.6.1991	11.6.1991	11.6.1991	11.6.1991	4.9.1990
Temperature °C		3,0	2,4	5,4	2,7	2,7
pH/°C		7,97 / 22,90	9,10 / 21,50	8,40 / 21,40	8,63 / 22,00	8,22 / 12,00
Silicon (SiO_2)	ppm	14,09	13,20	16,67	18,12	18,80
Sodium (Na)	"	8,38	11,49	14,13	8,68	7,36
Potassium (K)	"	0,34	0,06	0,50	0,85	0,82
Calcium (Ca)	"	4,01	5,52	5,46	3,72	3,96
Magnesium (Mg)	"	1,63	0,63	1,73	2,00	2,09
Carbonate (CO_2)	"	18,80	19,70	23,20	18,30	18,70
Sulfate (SO_4)	"	2	2,39	2,94	1,9	2,04
Hydrogen sulfide(H_2S)	"	< 0,03	< 0,03	< 0,03	< 0,03	
Chloride (Cl)	"	10,35	10,20	14,57	9,37	9,67
Fluorine (F)	"	0,032	0,039	0,062	0,060	0,059
Nitrate (NO_3)	"	-	-	0,047	0,023	-
Bromine (Br)	"	0,035	0,037	0,054	0,032	0,032
Soluble matter	"	45,90	48,70	57,90	49,10	46,30
Conductivity (µS)		92,0	100,0	120,0	90,0	90,0

[56] Árni Hjartarson 1991, bls. 2.
[57] Árni Hjartarson 1991, bls. 2-3.

The chemical content of the water illustrates North-Icelandic wellspring water very well. The water has flowed through the bedrock with a little adoption of soluble matters. The water has also warmed up a little because of geothermal heating. The content of soluble matter in the water is far under international sanitary standards.

3.1.6 Delivery of cold water

All the wellsprings mentioned above can easily provide water up to 100 l/s each. The water does not have to be pumped nor is any drilling necessary.[58]

3.1.7 Cost

The charge for cold water from the Húsavík water supply according to the price list is 12,75 kr/m^3. Large quantity users where cold and/or hot water is a direct production factor can purchase the water for 25% of the price or for 3,19 kr/m^3.[59] In particular incidents the water can be purchased with more discounts.[60]

Further information can be seen on Húsavík Energy web-site: http://www.oh.is/default.asp

3.1.8 Quality

Virtually all freshwater in Iceland is unrivalled when it comes to purity and low levels of contaminants. Water is an ample resource in Iceland and in most cases much cheaper than anywhere else in Europe.

3.2 Geothermal resources

There are three geothermal areas close to Húsavík. At Hveravellir in Reykjahverfi (located approximately 20 km south of Húsavík) geothermal water has been utilized for the heating of greenhouses for a long time. About

[58] Árni Hjartarson 1991, bls. 3.
[59] http://www.oh.is/pricelist.asp?tID=7
[60] Hreinn Hjartarson, viðtal 2004.

25 km south-east of Húsavík is another geothermal area called Þeistareykir. Researches imply that the water temperature there is above 250°C. And finally, the third geothermal area is located in Húsavík.[61]

3.2.1 Geothermal resources at Húsavík

West of Laugardalur valley in the north part of Húsavík, water flows up from gaps by the sea. Hot water flows up from two gaps south of Húsavíkurhöfði (Cape Húsavík). Water also flows up in the littoral by Húsavík (28°C) and by Traðargerði (14°C) about one kilometer east of Laugardalur. Between 1961-1966 five bores where drilled in the Laugardalur area and at Húsavíkurhöfði. The bores names are HU-01, HU-02, HU-03, HU-04 and HU-05 and their location can be seen in figure 10.[62]

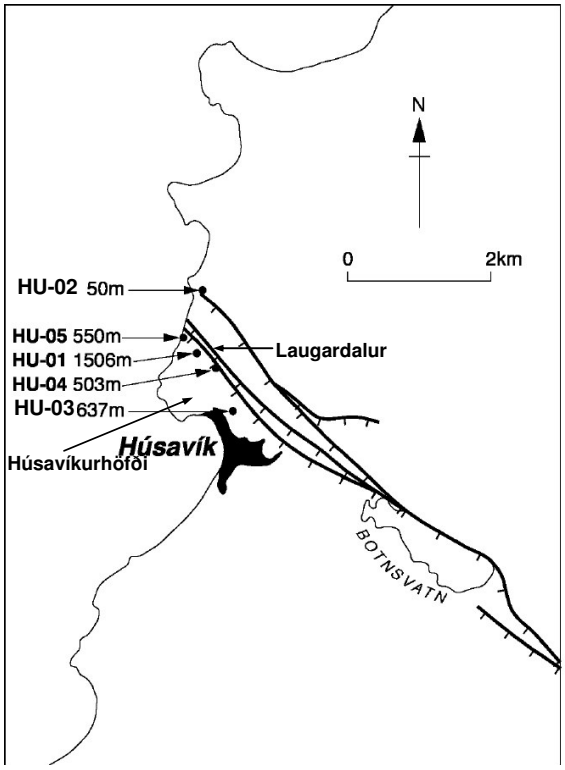

Figure 10. Location and depth of hot water bores at Húsavík[63,64]

[61] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
[62] Jens Tómasson o.fl. 1969.
[63] http://www.smsites.org/frontpage.html
[64] Jens Tómasson o.fl. 1969.

Few pumping tests were made for the bores. Bore HU-1, HU-4 and HU-5 all lie close to each other, those bores can provide around 12 l/s of water with temperature of 87°C. Although the bores lie close to each other (Figure 10) interconnection between them is not considered to occur because the chemical content of the water from these bores are rather different. Bore HU-3 can provide around 7 l/s of water with temperature of 43°C.[65] No information was found about pumping tests for bore HU-2. Other information related to the bores can be seen in table 3.

Table 3. Geothermal bores in Húsavík[66]

Bore	Year drilled	Depth (m)	Water level (m)	Max. temperature (°C)
HU-1	1961-1964	1.506	25,2	105,6
HU-2	1961	50	8,0	-
HU-3	1961-1964	637	17,0	46,0
HU-4	1964	503	17,2	81,0
HU-5	1964-1966	550	40,0	74,0

The amount of soluble matter is different or between 500-4000 ppm. The matter in the greatest abundance is Chloride (Cl), 300-2000 ppm.[67] The water from the bores was too salty to be used for house heating.[68] In table 4 the chemical content for water from all the bores, except bore HU-2, is shown. The measurements were made in 1966-1968.

[65] Jens Tómasson o.fl. 1969.
[66] Jens Tómasson o.fl. 1969.
[67] Jens Tómasson o.fl. 1969.
[68] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf

Table 4. Chemical content of hot water in Húsavík[69]

		HU-1	HU-3	HU-4	HU-5
Date		8.7.1968	14.11.1966	17.8.1966	19.8.1966
Temp. (°C)		94	45	79	72
pH		8,8	8,5	7,9	8,0
Conductivity (Ohm)		-	-	$2,65 \times 10^{-3}$	$3,0 \times 10^{-3}$
Soluble matter	**ppm**	3243,0	973,6	1412,0	2000,0
Silicon (SiO_2)	**"**	86,4	33,6	62,0	50,0
Sulfate (SO_4)	**"**	80,2	17,0	24,7	41,0
Chloride (Cl)	**"**	1735,0	482,0	704,0	872,0
Fluorine (F)	**"**	0,3	0,1	0,4	0,4
Calcium (Ca)	**"**	252,0	44,8	45,0	76,0
Magnesium (MG)	**"**	0,3	0,1	1,5	2,4
Sodium (Na)	**"**	1110,0	300,0	412,0	492,0
Potassium (K)	**"**	31,4	8,9	10,3	11,4

3.2.2 Hveravellir

Geothermal water from Hveravellir is used for house heating in Húsavík. The utilization of geothermal water from Hveravellir has been monitored since Húsavík's geothermal water supply was established in 1970. The average utilization of geothermal water from Hveravellir is 80-85 l/s of water with temperature of 100-128°C. The area is considered to be able to provide at least 190 l/s of geothermal water form the existing bores.[70] The throughput of the bores can be seen in table 5.

Table 5. Throughput for bores H1, H10 and H16 in Hveravellir[71]

Bore	Flow (l/s)	Temperature (°C)
H1	26	128
H10	61	124
H16	8	115
H1 and H10	87	125
H1, H10 and H16	95	124

[69] Jens Tómasson o.fl. 1969.
[70] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
[71] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf

3.2.3 Theistareykir

Theistareykir is a geothermal area located on Reykjaheiði about 25 km south of Húsavík. Theistareykir is a flatland about 300 m above sea level, although some surface heat can be found higher up, or in Bæjarfjall mountain (530 m above sea level) and in Ketilfjall (500 m above sea level). The most promising area in terms of utilization is north of Bæjarfjall. That geothermal area is about 11 km^2. Solfataras can be found at Theistareykir but no geysers.[72] At Theistareykir there are more than 1000 l/s of water with temperature of 25°C.[73]

3.2.4 Cost

The cost of geothermal water from Husvik Energy according to the price list is 69,97 kr/m^3. Large quantity users where hot water is a direct production factor can purchase the water for 25% of the price or for 17,49 kr/m^3.[74] In particular incidents the water can be purchased with more discounts.[75]

Further information can be seen on Húsavík Energy web-site: http://www.oh.is/default.asp

3.3 "Warm" cooling water from Húsavík Energy

In the year 1998 a new bore for geothermal water was drilled at Hveravellir, bore H10. The bore throughput is 60 l/s of water with temperature of 124°C. That same year a preparation for restoration of the old asbestos-cement pipe from Hveravellir to Húsavík was started. The geothermal water from Hveravellir is hot enough to both use it for house heating and industrial purpose. Therefore it was decided to aim for multiple or cascade use of the geothermal water in connection with the restoration of the pipe. Prior to this, the water was cooled down to 100°C. According to the multiple or cascade

[72] http://www.os.is/jardhiti/theistareykir.htm
[73] Ragnar Jóhannsson 2001.
[74] http://www.oh.is/pricelist.asp?tID=7
[75] Hreinn Hjartarson, viðtal 2004.

use of the geothermal water, cooling the water was discontinued and it instead piped to the geothermal electrical power plant in Húsavík. The power plant is located at an industrial area about 2 km south of the inhabited area of Húsavík.[76]

Figure 11. The electrical power plant[77]

According to the maximum flow in 2001 (95 l/s) the water's temperature decreases by 3°C, down to 121°C, during the transportation from Hveravellir to the electrical power plant. This high temperature made it possible to utilize the water for applications such as electricity production or for example some type of industry requiring hot steam.. When the water temperature has fallen down to 80°C it enters the distribution system and is distributed to the costumer.. The water is cooled down to 80°C in the electrical power plant and at the same time electricity production takes place. The electrical power plant produces 1,7 MW and it is the only electrical power plant in the world that produces electricity by this production method.[78]

[76] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
[77] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
[78] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf

3.3.1 The cooling water

The water that is used for cooling the geothermal water is taken from the Húsavík water supply. The water is, in most cases, led directly to the power plant's condenser. The cooling process requires 190 l/s of water with temperature of 4°C. The transport capacity of the pipes from the Húsavík water supply is 200 l/s, with the potential of additional 80 l/s being transported from the river Thorvaldsstaðaá if necessary for the electricity production to take place. While cooling the geothermal water in the condenser the cold water warms up to 23°C.[79]

This cooling water is considered to have great potentials when it comes to fish farming, both for direct use and as a heating medium in heat exchangers. Today the cooling water is led to a drainage system where it unifies excess production of 80°C water, usually 20-60 l/s. Around 1 km south of the electrical power plant is a man-made lagoon which the water is led to through a DN400 polypropylene pipe. The output from the pipe is around 400 meters away from the electrical power plant. Through that output around 40 l/s of cooling water are led to an arctic charr farming company located in Haukamýri just west of the power plant. The temperature of that water is a little bit higher than of the cooling water or around 30-35°C.[80,81]

The tropical fish, Tilapia, has been mentioned as an optimal farming species for these conditions. Dr. Ragnar Jóhannsson, a former specialist at IceTec, conducted a pilot-study of the profitability of Tilapia farming where the cooling water was a key-factor. The study was based on 6.000 tons production, but it was recommended that experimental plant whould be built to determine factors like growth rate and to check out if the production equipment operates like expected.[82] Other species that have been mentioned as optimal farming species for these conditions are turbot (*Scopthalmus*

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[79] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
[80] Hreinn Hjartarson, viðtal 2004.
[81] http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
[82] Ragnar Jóhannsson 2001

maximus), Atlantic halibut (*Hippoglossus hippoglossus*) and arctic charr (*salvelinus alpinus*).

Further information about the electrical power plant and the cooling water:

http://www.oh.is/skjol/kynningarefni/islenskar/oh_fjolnyting_jardhita.pdf
http://www.oh.is/skjol/kynningarefni/english/multiple_use_of_geothermal_energy_in_husavik.pdf

3.3.2 Chemical content

The cooling water is, as mentioned earlier, taken from the Húsavík water supply. The chemical content is shown in table 2 in chapter 3.1.5.

3.3.3 Distances

The electrical power plant is located in an industrial area. Distances within that area are therefore in most cases short, or less than 4-6 km.

3.3.4 Cost

The price for the cooling water is the same as for water from the Húsavík water supply or 12,75 kr/m^3 and 3,19 kr/m^3 for large quantity users where the water is a direct production factor. It should also be mentioned that if all the amount of the cooling water is used for fish farming a considerable discount would possibly be granted.[83]

3.4 Summary

It can be assumed that around 560 l/s of cold water are available in Húsavík from the wellsprings that have been mentioned. It is believed that each of the wellsprings mentioned can be quite easily piped into waterholes. The chemical content of the cold water is typical for North-Icelandic wellspring water and the water's content of soluble matter is far under international sanitary standards.

[83] Hreinn Hjartarson, viðtal 2004.

In the north part of Húsavík five geothermal water bores were drilled in 1961-1966. Bore HU-1, HU-4 and HU-5 all lie close to each other, and those bores can provide around 12 l/s of water with temperature of 87°C. Bore HU-3 can provide around 7 l/s of water with temperature of 43°C. The water from the bores was rather saline. Húsavík Energy utilizes geothermal water from Hveravellir to heat all the houses in Húsavík. Utilization of geothermal water from Hveravellir has been around 80-85 l/s of water with temperature of 100-128°C. The area is nevertheless considered to be able to provide 190 l/s of geothermal water. Geothermal water from Theistareykir is not yet utilized in Húsavík. The area is considered to be able to provide around 1000 l/s of water with temperature of 25°C.

The electrical power plant located just south of the inhabited area of Húsavík uses 190 l/s of water with temperature of 4°C as cooling medium for cooling geothermal water in its condenser. The water is taken from the Húsavík water supply and its temperature is around 23°C after the cooling process. The cooling water has great potentials when considering fish farming..

4 Seawater

The sea in Skjálfandi bay, its temperature and salinity, will be discussed in this chapter. The sea bores that have been drilled in the Húsavík area are also mentioned.

4.1 Skjálfandi bay

Skjálfandi bay is 10 km wide at the bottom and around 51 km wide between Gjögurtá and Tjörnnestá (figure 12). Skjálfandi bay is approximately 25 km long and the maximum depth is around 220 m.

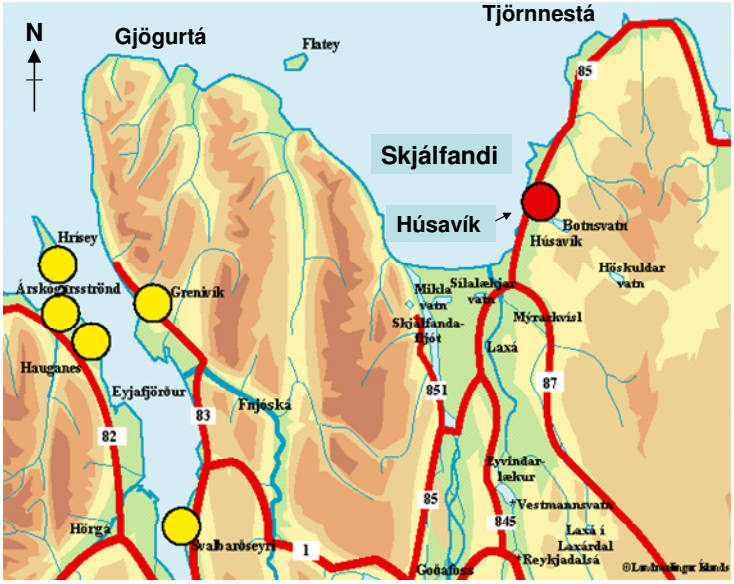

Figure 12. Skjálfandi

4.1.1 Temperature

In the year 1988-1990 the Marine Research Institute measured the sea temperature in Skjálfandi bay. The temperature was measured every two hours and the mean for all the measurements from midnight to midnight was calculated which gave one average value for every 24 hours.[84]

[84] http://www.hafro.is/Sjora/

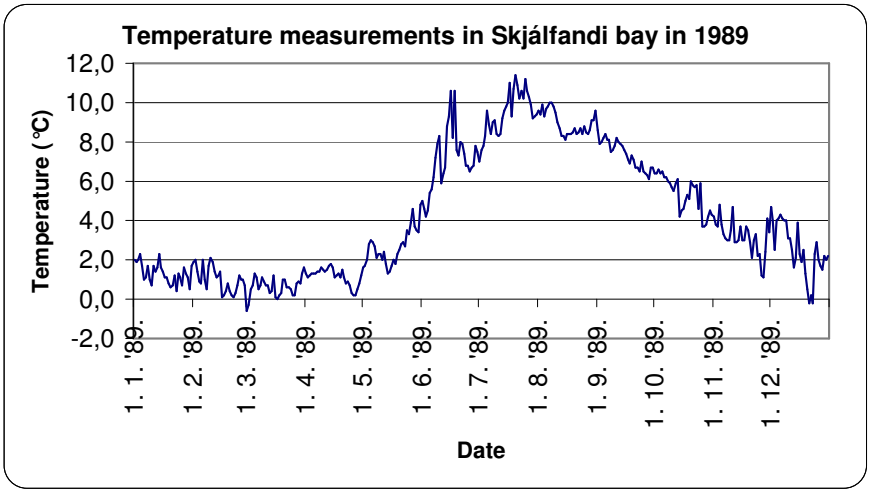

Figure 13. Temperature measurements in Skálfandi bay in 1989[85]

The highest value was in July 11,4°C but the lowest value was in March -0,6°C. The annual mean temperature was 4,24°C.

4.1.2 Salinity

Two large rivers meet the ocean in Skjálfandi bay. On the west side at the bottom of the bay falls Skjálfandafljót, with its average flow of 95 m^3/s. On the east side at the bottom of the bay falls Laxá í Aðaldal and its average flow is 60 m^3/s.[86]

In the year 1994 the Marine Research Institute measured freshwater impact on the sea salinity in the springtime. The research was carried out for the National Energy Authority and the National Power Company and the results were reported and published in 2002. The salinity at the surface (1-3 m depth) was measured and the thickness of the freshwater was calculated together with other things. Four research expeditions were carried out. SO-2/94 was carried out 20th – 21st of April 1994, SO-3/94 was carried out 10th – 13th of May 1994, B-8/94 was carried out 26th – 27th of May 1994 and SO-

[85] http://www.hafro.is/Sjora/
[86] http://www.lmi.is/landmaelingar.nsf/pages/Landfraedilegarupplysingar.html

4/94 was carried out 12th – 14th of June 1994.[87] Main results are shown in table 6.

Table 6. Salinity at the surface and calculated thickness of freshwater in Skjálfandi bay[88]

Expedition		Salinity at the surface (‰)	Calculated thickness of freswater (m)
SO-2/94	20.-21. April 1994	33 - 34	-
SO-3/94	10.-13. May 1994	30 - 31	0,8
B-8/94	26.-27. May 1994	25	2,0 - 3,0
SO-4/94	12.-14. June 1994	28	1,0 - 2,0

It can be seen that salinity at the surface decreases significantly for expedition B-8/94 and SO-4/94. The reason for this is probably that the average total flow of freshwater from land reaches its peak when these measurements are made. Another important factor is the wind and how the wind impacts the mixing of the sea and the freshwater. The sea in Skjálfandi bay changes from being cold, relatively even in salinity and mixed from the surface to the bottom to being stratified and there is a considerable impact of the freshwater.[89]

4.2 Sea bore at Haukamýri[90]

A sea bore (HSH-1) was drilled in Haukamýri about 1 km south of Húsavík town. The aim was to find out if there was a potentiality of getting seawater from sea bore on the east cost of Skjálfandi bay.

[87] Jón Ólafsson o.fl. 2002.
[88] Jón Ólafsson o.fl. 2002.
[89] Jón Ólafsson o.fl. 2002.
[90] Guðmundur Ó. Friðleifsson o.fl. 1988.

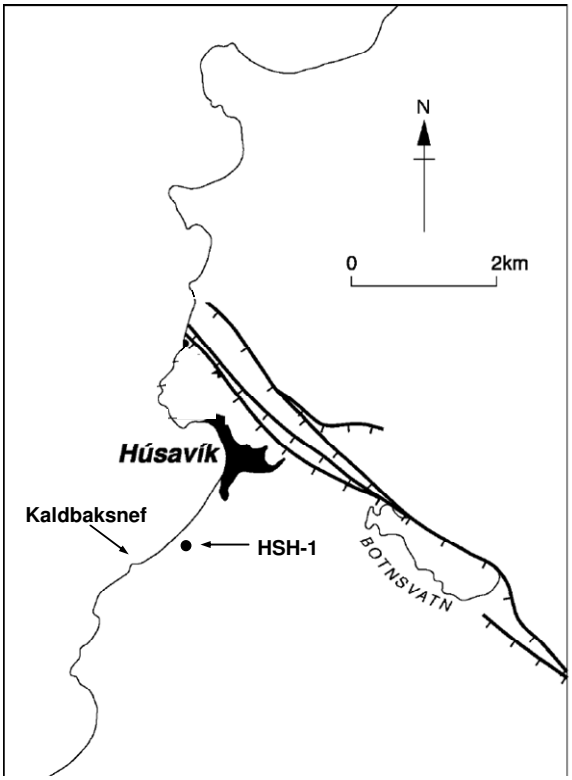

Figure 14. Location of the sea bore HSH-1 at Haukamýri

The bore HSH-1 is 12 m above sea level and its depth is 71 m. Fresh water level was reached on 14 m depth and it came down to 35 m. The water level of the bore was 12-13 m. Sea water with high salinity was reached on 40 m depth and on 57 m depth fully saline sea water was reached with temperature of 4°C and flow rate of 25 l/s. Measurements that were carried out later showed that the salinity decreased at the bottom of the hole, that implies that the thickness of the sea water layer is not so much or about 20 – 50 m. Pumping test showed that ground water and/or sea can unimpeded flow down to the bore's fountain. The bore's characteristics for utilization are considered as "good" compared to fresh water resources or other sea bores. Although it is important to drill another bore with flow of 40 – 50 l/s to better determine the possibilities of utilization . As can be seen in table 7 the salinity is only about 26,7 ‰ which is about 75% of regular seawater salinity. This is caused by the mixing of sea water with fresh water.

Table 7. Chemical content of seawater from sea bore, HSH-1

		HSH-1	"Standard" sea
Temperature (°C)		4,4	-
pH/°C		8,9/15	8,0/25
Silicon (SiO_2)	**mg/kg**	9,5	2,9
Sodium (Na)	"	8172	10760
Potassium (K)	"	328	387
Calcium (Ca)	"	401	413
Magnesium (Mg)	"	1020	1294
Iron (Fe)	"	0,1	0,003
Manganese (Mn)	"	0,05	0,0004
Carbonate (CO_2)	"	88	103
Sulfate (SO_4)	"	1987	2712
Hydrogen sulfide (H_2S)	"	< 0,03	-
Chloride (Cl)	"	14788	19353
Fluorine (F)	"	0,53	1,3
Soluble matter	"	28770	-
Oxygen (O_2)	"	5	-
Salinity (‰)		26,7	35

On the region from Kaldbaksnef to Húsavík (about 600 meters) a several hundred liters per second of seawater is considered to be available from 5-10 bores.

4.3 Other sea bores[91]

In November 1994 three sea bores were drilled for Mr. Olafur Sigurdsson, a ship owner in Húsavík. The bores are located at the harbor area at Húsavík. Alvarr Inc. Engineering Service drilled the bores. Chemical content of water from the bores is not known.

[91] Alvarr, Friðfinnur K. Daníelsson, Borskýrslur fyrir holur nr. 1, 2 og 3 1994.

4.3.1 Bore 1

The bore is located at Beinabakki in Húsavík. The structure of the bore's stratums is shown in table 8.

Table 8. Stratums for bore 1

Depth	Stratums
0 - 2 m	Filling, gravel
2 - 9 m	Loess, soft
9 - 23 m	Loess, soft
23 - 24 m	Water leak
24 - 32 m	Soft soil
32 - 33 m	Clay and gravel, probably seabed

The bore's flow is about 2 l/s with reduction in water level of 0,4 m. The bore is 33 m deep and the water temperature was 17°C.

4.3.2 Bore 2

The bore is located at the harbour area in Húsavík close to the fish processing company Uggi sf., exact location is not known. The structure of the bore's stratums is shown in table 9.

Table 9. Stratums for bore 2

Depth	Stratums
0 - 5 m	Filling and sand
5 - 26 m	Sediment
26 - 27 m	Lava
27 - 30 m	Volume of the bore increases

The bore's flow is about 1,1 l/s with reduction in water level of 0,2 m and 2,2 l/s with reduction in water level of 0,5 m. The water temperature was about 8°C and the depth of the hole is 30 m. Afterwards a pumping test for the bore showed that it could easily give 12-13 l/s.

4.3.3 Bore 3

The bore is located at the harbour area in Húsavík close to the fish processing company Uggi sf., exact location is not known. The structure of the bore's stratums is shown in table 10.

Table 10. Stratums for bore 3

Depth	Stratums
0 - 4,5 m	Concrete, filling and sand
4,5 - 27 m	Soft sediment
27 - 36 m	Pillow lava

Water came out on about 7 m depth and it increase by depth. The water temperature was around 8°C, the depth of the bore is 36 m but the flow rate is not known.

4.4 Summary

Temperature measurements were made in Skjálfandi bay in 1989. The temperature got highest in July 11,4°C and got lowest in March -0,6°C. The annual mean temperature was 4,24°C.

Great amount of bore seawater is considered to be available in the region from Kaldbaksnef to Húsavík and the seawater bore HSH-1 is located in that area. The bore's flow rate was 25 l/s and the temperature was 4°C on 57 m depth which is close to the annual average temperature in Skjálfandi bay. The bore's characteristics for utilization are considered as good as any fresh water resources or other sea bores.

There are also other seawater bores located in Húsavík but the flow rate of those bores is much lower than for bore HSH-1 and those bores are much less known.

5 The farming

This chapter covers general factors related to fish farming such as authorizations, effluent regulations etc.

5.1 Land for fish farming in Húsavík[92]

The area where the electrical power plant is located is prearranged for industrial purposes. This location can also serve as a great place for fish farming.

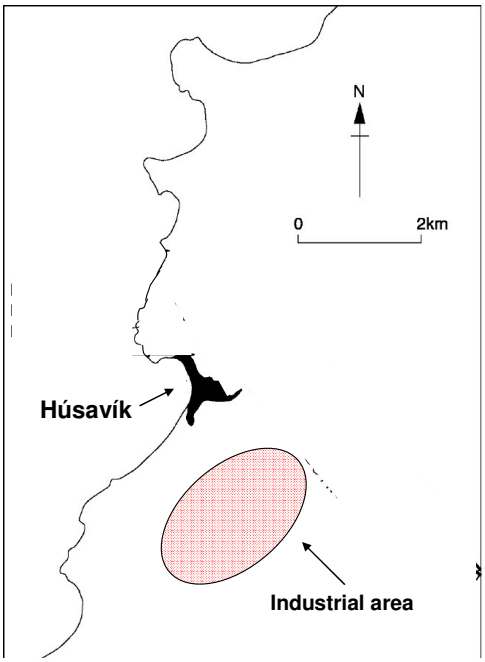

Figure 15. Industrial area south of the inhabited area of Húsavík

The area north of the inhabited area of Húsavík is prearranged as an area for major industrial operation.

[92] Gaukur Hjartarson 2004.

5.2 Effluent

Maximum disposal of polluted compounds to the receptor are as follows:[93]

- Phosphorus compounds: 7 kg per ton produced.
- Nitrogen compounds: 60 kg per ton produced.
- If sufficient researches shows that the receptor can stand more disposal of those compounds these limits can be increased.

Where the effluent is piped in river or lake the following is required:[94]

- The maximum variation in temperature caused by the effluent is 2°C.
- The minimum oxygen saturation is 70% and may not be lower than 6 mg O_2/l and must be over 9 mg O_2/l for 50% of the time.
- pH must be 6-9 and the maximum change caused by the effluent is 0,5.
- Ammonia (NH_3) must be less than 0,025 mg/l.
- The Biological Oxygen Demand (BOD) may not be more than 4 mg O_2/l (which equals COD: 20 mg O_2/l).
- Hypochlorous acid (HOCl): maximum 0,004 mg/l.
- Oil slick may never occur in the receptor.
- The maximum increase of plankton caused by the effluent is 2 mg/l.

At the effluent's outlet there may not be any sediments, precipitations, accumulated bacteria or fungus, oil or foam, garbage or matter that can cause bad smell, colour or turbidity.[95]

[93] http://www.hollver.is/mengun/Leyfi/fiskeldi/silfurstjarnan.pdf
[94] http://www.holar.is/~eldisbondi/node66.html
[95] http://www.hollver.is/mengun/Leyfi/fiskeldi/silfurstjarnan.pdf

5.3 Authorizations

The application for operation license must be sent both to The Environmental and Food Agency of Iceland and to The National Planning Agency of Iceland which forwards the application to other institution for evaluation.[96]

5.3.1 Operation license I (Starfsleyfi)

"The operation license is a written license paid out by the Environmental and Food Agency of Iceland (Umhverfisstofnun). The operation licenses states the applicant's right to operation as long as he fulfil all provisions stated by laws and regulations."[97]

The Environmental and Food Agency of Iceland (Umhverfisstofnun) pays out operation license for operation that can cause pollution, stated by laws nr 7/1998. The minister for the environment pays out regulations about general provisions such as location, pollution protection, supervision, water and seawater usage as receptors for effluent and researches. Operation license is required for farming on seawater and freshwater species where production is more than 200 tons per year and the effluent's receptor is the sea or where production is more than 20 tons per year and the effluent's receptor is freshwater. The Environmental and Food Agency of Iceland publishes publicly the content of the operation license. Written remarks on the operation license can be made within 8 weeks from the publication. Within 4 weeks after the deadline for making some remarks has expired The Environmental and Food Agency of Iceland must deicide whether the operating licence will be granted or not.[98]

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[96] http://www.holar.is/~eldisbondi/node70.html#SECTION00410210000000000000
[97] http://www.reglugerd.is/interpro/dkm/WebGuard.nsf/0/c35ea433a174643100256a080032f77a?OpenDocument
[98] http://www.althingi.is/altext/stjt/1998.007.html

5.3.2 Operation licence II (Rekstrarleyfi)

An operation licence paid out by the Directorate of Freshwater Fisheries is required for all fish farming. The directorate evaluates ecological factors and disease connected factors that possibly could be related to the farming. If the available data does not give sufficient information for this evaluation the directorate can require further information on different factors e.g. if the farming increases the risk of fish-diseases distribution. The applicant must pay all cost of such researches. The application shall state e.g. who owns the intended fish farming, what special knowledge the applicant have, the size of the farming, production volume, farming species and farming methods. Information such as land-, water- and seawater usage, financing plan, operation plan and statements of other licenses required by laws must also be enclosed. If the application and all documents are sufficient the operation license is paid out for five years.[99]

Further information: http://www.althingi.is/lagas/nuna/1970076.html

5.3.3 Environmental impact assessment

Environmental impact assessment (EIA) legislation in Iceland is built upon EU-directives on the matter. Whether fish-farming is subject to an EIA in Iceland depends on the projects nature, size and location on a case-by-case basis. For all intensive fish farming, where the annual production is 200 tonnes or more and waste water empties into the ocean or where annual production is 20 tonnes or more and waste water empties into freshwater the developer shall notify the Planning Agency. The Planning Agency seeks the opinion of the granters of consent, the developer and other parties and make a decision on whether the project is subject to EIA. The Planning Agency's decision can be appealed to the Ministry for the Environment.

[99] http://www.althingi.is/lagas/nuna/1970076.html

5.3.4 The application for operation licence

The application must consist of the following:[100]

- Exact information about farming methods, equipment and the reason for the placement of the culture. Also information about possible environmental impact.
- Description and layout of the structure.
- Arrangement of buildings, services, security affairs, layout of facilities and other things must be described.
- An assessment of environmental impact caused of building process and other accomplishment related to the establishment.
- Evaluated quantity of excreta and how it will distribute and eliminate in the receptor.
- Pollution burden must be evaluated and in addion a model of the changes of pollution condition caused by the operation must be made.
- Impact on ground water, rivers and lakes must be evaluated.
- Impact on organisms at the area which the culture will be located and at pacified areas nearby.

5.4 Surveillance

According to laws no. 786/1999, all fish farming must undergo regular surveillance by the Environmental and Food Agency of Iceland.[101]

The supervisor of the farming must attend surveillance of the farming. The supervisor must catalogue all the major factors of the production e.g. number and weight of fish and changes of those components in relation to sales, movements and mortality. Also all use of feed and water. The supervisor shall catalogue all use of dangerous or harmful substances (chemicals) and pharmaceuticals. The supervisor shall catalogue all the main factors related

[100] http://www.holar.is/~eldisbondi/node71.html
[101] http://www.reglugerd.is/interpro/dkm/WebGuard.nsf/0/5c2ec03861bfb1bd00256a080032fe80?OpenDocument

to operation of recirculation and solid filters e.g. stoppage caused by cleaning or due to other factors. All difficulties shall be announced to the Environmental and Food Agency of Iceland. Information about draining of waste must also be catalogued, e.g. the date of draining, the volume of waste and where the waste was rejected.[102]

Every two year, samples for measuring phosphorus, nitrogen and COD are taken from the in- and outlet of the clarifying equipment, from the receptor and from waste. Plankton shall be measured every year. These measurements are accomplished by the authorities.[103]

5.5 Support services

5.5.1 Fish processing

Fish processing has been one of the main industries in Húsavík for decades and in fact for centuries. Knowledge of fish processing is therefore significant in Húsavík.

Fiskiðjusamlag Húsavíkur (a deep-rooted fish processing company in Húsavík) was established in 1947. The company mainly processes cod and haddock and on annual basis it processes around 4.000 tons of raw material.[104]

5.5.2 Transportations

Transportations are one of the most important things for a production company who needs to send its production to the costumer. Transportations will be discussed in this section.

[102] http://www.hollver.is/mengun/Leyfi/fiskeldi/silfurstjarnan.pdf
[103] http://www.hollver.is/mengun/Leyfi/fiskeldi/silfurstjarnan.pdf
[104] Ingóflur Hjaltalín 2004.

5.5.2.1 Land based transportation

Between Húsavík and the capital Reykjavik and between Húsavík and Akureyri the main northern town, all roads are paved. Overall the road system in Iceland is mostly paved.

There are two main transportation companies in Iceland that do land-based transportation . Those are Flytjandi and Landflutningar. Both companies offer daily (except weekends) transportation between Húsavík and Reykjavik. Both companies also offer transportation twice a day between (except weekends) Húsavík and Akureyri. The transportation between Húsavík and Reykjavik takes about 6 hours and between Húsavík and Reykjavik about one hour.[105]

For further information on land-based transportation see:http://www.landflutningar.is/ and http://www.flytjandi.is

5.5.2.2 Air transportation

About 8 km south of Húsavík is Adaldals-airport. The airport has not been operated for several years or since scheduled flight was discontinued because of difficulties in flight-operation.[106]

Akureyri holds an airport that serves the town and its neighbouring community. There are about 8 scheduled flights between Akureyri and Reykjavik each day and there are also scheduled flights to other towns such as Isafjordur og Egilsstadir.[107]

By air it takes about 3 hours to go to Iceland from the major cities in Europe and 5-6 hours from the East Coast of the United States.[108] Keflavik International Airport is the main international airport in Iceland, located in

[105] Information about land based transportation.
[106] Byggðarlög í sókn og vörn 2001.
[107] http://www.caa.is/Forsida/Flugvellir/Akureyri/view.aspx?.
[108] Doing Business in Iceland, 3rd edition 2004.

Keflavik about 50 km south of Reykjavik. Export through Keflavikairport has increased significantly as can be seen in figure 16.

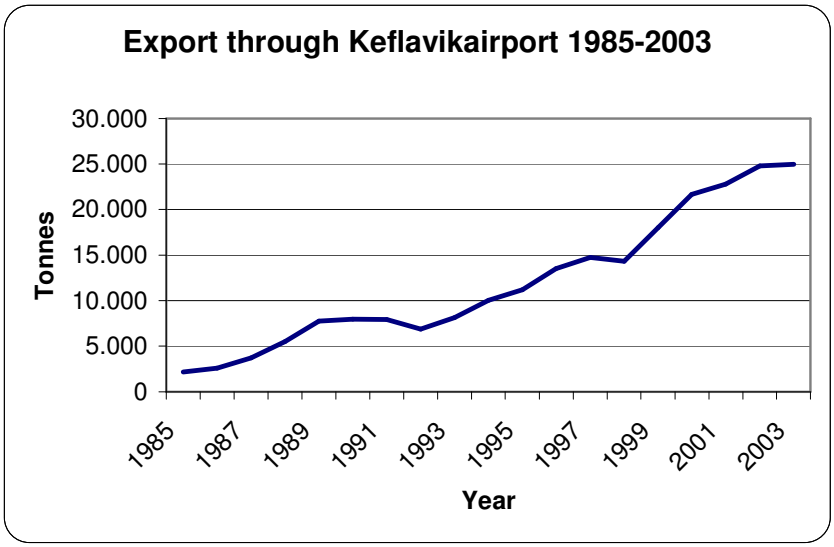

Figure 16. Export through Keflavikairport 1985-2003[109]

Exportation of fresh fish fillets, by air, from Iceland have increased significantly since it first started late in the eighties. In the year 1998 the exportation was around 9.500 tonnes (ISK 4,2 billion), in the year 2000 the exportation was around 12.000 tonnes (ISK 6 billion) and in 2002 the exportation was 14.000 tons at the value of ISK 9 billion. Iceland's main markets for fresh fish fillets are Britain, USA, France, Belgium and Germany. Cod, haddock and redfish are the main species.[110] Icelandair-Cargo, Bluebird and Islandsflug are the main cargo-airlines that serve the fish industry.

For further information on exportation by air see:

http://www.islandsflug.is/islandsflug/english/
http://www.icelandaircargo.is/main/view.jsp?branch=3515061
http://www.blafugl.is/

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[109] http://www.keflavikairport.com/traffic_2.html
[110] Statistics Iceland 1998-2002.

5.5.2.3 Sea transportation

As mentioned before, shipping distances are 3-4 days to Europe and 7-8 days to eastern North America.[111]

Costal transportation is carried out once a week to 11 coastal towns around Iceland by Eimskip. Time schedule can be seen on:
http://www.eimskip.is/SiglingaAaetlun.aspx?catID=42

Eimskip and Samskip are the main sea transportation companies in Iceland.

Samskip offers weekly transportations for import and export from/to the following cities in Europe: Immingham, Aarhus, Rotterdam, Cuxhaven, Varberg and Moss. Samskip offers transportation for import and export once every two weeks from/to the following cities in North-America: Argentia, Shelburne, Boston/Everett and Philadelphia. Samskip also offers weekly transportation for import from the following cities: New York, Norfolk, Montreal, Charleston, Boston, Miami, Halifax, Houston, Long Beach, Oakland, Seattle and Rotterdam.[112]
For further information, see:
http://www.samskip.is/media/siglingaaetlun//Schedule0404.pdf and
http://www.samskip.is

Eimskip offers weekly transportation to and from the following cities in Europe: Torshavn, Rotterdam, Hamburg, Aarhus, Gothenburg, Fredrikstad and Immingham. Eimskip also offers transportation to and from the following cities in America once every two weeks: Argentia, Shelburne, Boston/Everett, Philadelphia and Newport News[113]

For further information, see:
http://www.eimskip.is/SiglingaAaetlun.aspx?catID=42 and
http://www.eimskip.is

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[111] Doing Business in Iceland, 3rd edition 2004.
[112] http://www.samskip.is/media/siglingaaetlun//Schedule0404.pdf
[113] http://www.eimskip.is/SiglingaAaetlun.aspx?catID=42

5.5.3 Other services

All general veterinarian and sanitary services are available in Húsavík. All mechanical, electric and various other types of service that pertain to industry are also available in Húsavík. As mentioned before, Akureyri the main northern town, is in 91 km (57 miles) distance form Húsavík where diverse services are available.

6 Farming species

In this chapter four species that are considered to be viable for cultivation under the conditions in Húsavík will be discussed. These species are Arctic charr, Tilapia, Turbot and Atlantic halibut. The background for cultivation of Arctic charr in Iceland is quite good and experimental cultivation of Atlantic halibut and turbot is now being conducted. Tilapia has not been cultivated in Iceland so far but a great interest has been shown and preliminary business plan for evaluating the competitiveness of producing 7.000 metric tons of tilapia in Húsavík using Recirculation Aquaculture System (RAS) has been made.

6.1 Arctic Charr

The arctic charr (*Salvelinus alpinus*) is quite long and rakish fish with thick torso. The snout is pointed and the jaws are equiadstant. The main difference between the arctic charr and other salmonidaes is that the head is smaller, the teeth are smaller and the scale is smaller. Its back is usually sable, the sides silvery and the underbelly light. When gets on for the spawning season the arctic charr gets more sable on the back, the underbelly gets red and fins gets sable with white stripe.[114]

Figure 17. Arctic Charr[115]

The arctic charr can only be found in the northern hemisphere e.g. in Iceland, Greenland, Svalbard (Spitzbergen), in Scandinavia, Russia, Britain and on

[114] Karl Gunnarsson o.fl. 1998, bls. 148.
[115] http://www.islandsvefurinn.is/wildlifepage.asp?ID=107

the north coast of North-America. It can also be found in countries in Europe close to the Alps and in the north part of Asia.[116]

6.1.1 Arctic charr cultivation

The potentiality for cultivate arctic charr under Icelandic conditions are considered to be good in many ways. The arctic charr withstands low temperature and can moreover acquire a great growth rate at low temperature. The arctic charr also withstands much more density than many other species and moreover it has a higher growth rate when the density is e.g. 50 kg/m^3 than if it is 15 kg/m^3. It is also able to cultivate the arctic charr at density of 150 kg/m^3 without growth reduction, provided that accrual of waste doesn't occur and oxygen demand is enough.[117] The optimal temperature for arctic charr cultivation is considered to be 12-16°C.[118] For arctic charr juveniles the daily growth rate can be 4-6% in optimal conditions.[119] Overall the average growth rate is estimated 0,55% and for 1 kg increasing in weight about 1,1 kg of feed is needed.[120] The arctic charr poorly withstands salinity of 35 ‰, but cultivation of arctic charr in water with salinity of 5-10 ‰ has positive impact on the growth rate compared to arctic charr cultivated in fresh water. Cultivation of arctic charr weighing more than 200 g, in water with the salinity of 23-26 ‰ and temperature higher than 6°C has been successful.[121]

6.1.1.1 Researches on arctic charr in Iceland

Holar agricultural college has taken an active role in aquaculture research in recent years and has since 1993 been a centre for research on arctic charr in

[116] http://www.holar.is/~eldisbondi/node8.html
[117] http://www.holar.is/~eldisbondi/node5.html
[118] http://www.holar.is/~eldisbondi/node86.html
[119] http://www.holar.is/~eldisbondi/node87.html
[120] Ragnar Jóhannsson 2004.
[121] http://www.holar.is/~eldisbondi/node99.html

Iceland. The college works on many research projects in arctic charr cultivation, for example:[122]

- Development of sustainable aquaculture of arctic charr
- New stocks for arctic charr aquaculture
- Breeding program for arctic charr
- Development of methods to control growth and sexual maturation in arctic charr
- Development of standards for organic production of arctic charr

For further information on this subject, see:
http://www.holar.is/rannsfisk.htm and http://www.holar.is/enfis.htm

6.1.2 Cultivation in Iceland

There are several fish farming companies in Iceland cultivating arctic charr.

Silungur ehf is one of the biggest producers of arctic charr in the world with annual production of around 1.000 tons. The company is located in Vogar on the southwest coast of Iceland. Silungur ehf uses brackish water from bores at the temperature of 6°C.[123]

Silfurstjarnan is a fish farming company located in Öxarfjörður around 100 km northeast of Húsavík. Silfurstjarnan was established in 1988 as a land based salmon production company. Today Silfurstjarnan has cut down the salmon production and is now giving more effort to salmon juvenile production. Other species cultivated at Silfurstjarnan are arctic charr, turbot and experimental cultivation of Atlantic halibut. The company also cultivated rainbow trout but packed it up recently. Silfurstjarnan produced around 400 tons of arctic charr in 2003.[124]

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[122] http://www.holar.is/rannsfisk.htm
[123] http://www.silungur.is
[124] Benedikt Kristjánsson 2004.

Fiskeldið Haukamýri is an arctic charr farming company located in Haukamýri about 1 km south of the inhabited area of Húsavík. In the year 2003 the company produced around 70 tons of arctic charr. As mentioned in chapter 3.3.1 the company utilizes around 40 l/s of the "warm" cooling water from the electrical power plant for the cultivation.

Figure 18. Fiskeldið Haukamýri

6.1.3 Production

According to FAO (Food and Agriculture Organization of the United Nations) the countries stated in table 11 are the biggest producer of arctic charr on global scale.

Table 11. Production of Arctic charr in selected countries 1990-2002 (tons/year)[125]

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Iceland	69	217	321	340	388	471	541	644	731	888	927	1.318	1.479
France	0	15	60	60	60	60	90	90	39	39	36	36	0
Ireland	0	0	0	0	0	0	0	0	50	56	63	35	< 0.5
U.S.A	0	0	0	0	0	0	0	0	0	0	65	75	44
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	42
United Kingd.	0	0	0	0	0	0	0	0	0	3	< 0.5	4	7
Austria	0	0	0	0	0	0	0	0	2	4	2	< 0.5	1
Total	69	232	381	400	448	531	631	734	822	990	1.093	1.468	1.573

Iceland cultivates most of arctic charr in Europe. Norway and Sweden are also cultivating arctic charr but their production volume is much less than Iceland's. Canada also cultivates arctic charr and their estimated annual production is around 400 tons. Estimated annual production of arctic charr on a global scale is 1.800-1.900 tons.[126]

6.1.4 Markets and prices

The main markets for cultivated arctic charr are in Europe and on the northeast cost of America. Iceland, Norway and Sweden are also important markets for arctic charr. The markets in Europe and America are considered to increase in near future.[127]

Table 12. Arctic charr price per kg in selected countries[128]

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Iceland ($/kg)	4,85	6,90	6,90	5,47	5,50	5,00	5,50	5,50	5,50	5,00	5,00	4,90	5,00
France ($/kg)	-	3,20	3,50	3,50	3,50	3,50	3,20	3,20	3,50	3,50	3,03	2,93	-
Ireland ($/kg)	-	-	-	-	-	-	-	-	4,27	4,27	4,00	5,62	-
U.S.A ($/kg)	-	-	-	-	-	-	-	-	-	-	4,43	4,40	4,95
Denmark ($/kg)	-	-	-	-	-	-	-	-	-	-	-	-	3,5
Utd. Kingd. (&/kg)	-	-	-	-	-	-	-	-	-	4	-	4	4
Austria ($/kg)	-	-	-	-	-	-	-	-	3,25	5,175	6	-	6

[125] FAO, Fishstat plus 2004.
[126] http://www.holar.is/~eldisbondi/node36.html
[127] http://www.holar.is/~eldisbondi/node36.html
[128] FAO, Fishstat plus 2004.

6.2 Tilapia

Tilapia is of the Cichlidae family. It is a fresh water fish native to the Middle East and Africa.[129] Tilapia is generally 4 to 18 inches in length and weighs anywhere from 170 grams to around 2,2 kg. It thrives in saline, brackish or fresh water and range in color from golden red, pale red, white, grey, grey-blue, dark-blue to black.[130]

Figure 19. Tilapia

6.2.1 Tilapia cultivation

Nile tilapia (*Oreochromis niloticus)* is one of three tilapia species with recognized aquaculture potential, the other are blue tilapia (*O.aureus*) and Mozambique tilapia (*O. mossambica).* Nile tilapia is the most commonly used tilapia species in fish farming.[131] Compared to other tilapia species the Nile tilapia (hereafter named tilapia) is least tolerant of cold water conditions. The maximum cultivation temperature is 29°C and the lower lethal temperature is 11°C. Tilapia growth is quite fast and it takes on average about 6-8 months to reach market size. The growth can be broken into three distinct phases, which are exponential or accelerating phase, linear phase and decelerating or plateau phase.[132]

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[129] Ragnar Jóhannsson 2001.
[130] http://sarasota.extension.ufl.edu/FCS/FlaFoodFare/Tilapia.htm
[131] http://www.fishfarming.com/
[132] Ragnar Jóhannsson 2001.

Table 13. Expected average final weights for different culture periods and initial weights of tilapia[133]

Length of growing season (weeks)	Expected average final weight for male population (g)		
	30 g	60 g	100 g
12	200	270	350
16	250	340	440
20	310	410	520
24	370	480	600
28	420	550	690

In Latin America tilapia is mainly reared in traditional pond culture, it is the cheapest way and also considered to be one of the best. Tilapia is also cultivated in tanks which involves considerably greater expensive to construct but offers much greater control.[134]

6.2.1.1 Cultivation in Iceland

Tilapia culture in Iceland has not been operated so far but a great interest has been paid to it and preliminary business plan for evaluating the competitiveness of producing 7.000 metric tons of tilapia in Húsavík using Recirculation Aquaculture System (RAS) has been made. The business plan is based on using the "warm" cooling water mentioned in chapter 3.3. Traditional pond cultivation of tilapia can not compete against the farming described in the business plan due to the muddy flavour from algae.

For further information on the tilapia project in Húsavík contact Mr. Ragnar Jóhannson in +354-530-8673 or ragnar@rf.is

6.2.2 Production

Production of tilapia on global scale has increased significantly or from 360.000 in 1989 to about 970.000 tons in 1998. In 1998 Nile tilapia was the

[133] http://aquanic.org/publicat/usda_rac/efs/srac/281fs.pdf
[134] http://www.fishfarming.com/

main tilapia species produced, which accounts for about 75% of the total production. Mozambique tilapia is the second largest or about 20% of the total production in 1998.[135] The total tilapia production was 1.265.800 in the year 2000.[136]

Table 14. Production of Nile Tilapia in 1994-2002 (tons/year)[137]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002
China	236.101	315.053	394.745	486.538	526.984	562.879	629.795	672.307	706.996
Egypt	25.214	21.969	27.854	30.416	52.755	103.988	157.425	152.515	167.735
Philippines	74.427	70.036	68.102	78.494	60.655	69.788	77.642	89.507	104.352
Thailand	59.397	76.054	90.416	91.112	73.427	76.460	82.363	98.250	100.478
Indonesia	17.626	21.317	25.668	28.084	26.807	31.217	40.836	50.876	60.437
Lao People's Dem. Rep.	1.400	1.610	2.000	9.514	9.549	13.662	18.928	22.499	26.872
Costa Rica	0	0	0	0	5.252	6.338	7.700	8.000	12.490
Others	11.335	13.526	14.867	14.392	17.277	24.615	33.196	32.973	37.695
Total	425.500	519.565	623.652	738.550	772.706	888.947	1.047.885	1.126.927	1.217.055

China is by far the biggest single producer of tilapia in the world as can be seen in table 14. Other big producers are Egypt, Thailand, Philippines and Indonesia.

6.2.3 Markets and prices

The biggest importing country of tilapia is USA. The import has increased significantly or from 3.400 tons in 1992 to 58.000 tons in 2001. The import of fillets has grown very much in recent years where fresh fillets are mainly imported from Costa Rica, Honduras and Ecuador and frozen fillets from Indonesia and China. The market for fillets has increased by approximately 30% since 1992 and the estimated market for fillets in USA in 2005 will then

[135] Ragnar Jóhannsson 2001.
[136] http://www.fishfarming.com/
[137] FAO, Fishstat plus 2004.

be 36.000 tons.[138] Tilapia is the third most imported aquaculture product to the USA (56.300 tons in 2001).[139]

Price for fresh fillets was around 5 $/kg in 1992, raised to around 5,6 $/kg in 1996, fell to around 4,8 $/kg in 1998 and raised to around 6 $/kg in 2000-2002. Price for frozen fillets was around 3,2 $/kg in 1992, fell to around 2,8 $/kg in 1994, raised to around 4,5 $/kg in 1998-2000 and fell to around 4 $/kg in 2000-2002.[140]

Table 15. Tilapia price per kg in selected countries (whole fish)[141]

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002
Taiwan ($/kg)	1,10	1,33	1,42	1,09	0,91	0,98	1,36	1,09	0,95
Brazil ($/kg)	-	3,50	3,50	3,40	3,30	3,30	3,30	3,20	3,20
Colombia ($/kg)	2,84	3,30	3,47	3,30	3,20	3,10	3,10	3,00	3,00
Malaysia ($/kg)	2,02	2,33	1,98	1,67	2,57	1,24	1,32	1,25	1,09
Philippines ($/kg)	2,13	1,76	1,89	1,72	1,23	1,26	1,12	0,97	0,96
U.S.A ($/kg)	2,76	3,31	3,31	3,86	3,31	3,31	3,31	3,31	2,20

6.3 Turbot

Turbot (*Scopthalmus maximus*) is a flat fish which can reach the length of 100 cm and the weight of 25 kg, though it rarely gets longer than 60-70 cm. The turbot is caught in the Mediterranean Sea in the south to the coast of Norway in the north and the main catching countries are Norway, Denmark, Germany, Netherlands, Belgium, Britain and Spain. Turbot is a very rare species around Iceland and the annual catch is usually less than 100 pieces. The annual world catch in 1988-1995 was around 10.000 tons.[142]

[138] Ragnar Jóhannsson 2001.
[139] http://www.fishfarming.com/
[140] Ragnar Jóhannsson 2001.
[141] FAO, Fishstat plus 2004.
[142] Agnar Steinarsson o.fl. 2000.

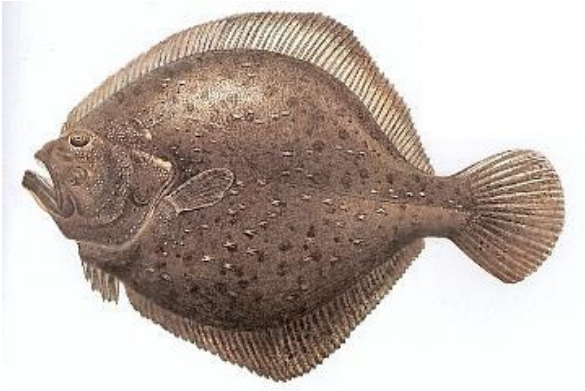

Figure 20. Turbot

6.3.1 Turbot cultivation

Turbot cultivation began slowly in Europe in 1980's but the production increased significantly from 1984-1995 and in the year 2002 the production was around 5.000 tons. The optimal temperature for turbot cultivation is 13-18°C and its cultivation takes 2-3 years. Usually the turbot is marketed at the size of 0,5-3,0 kg but the most common size is 1,5 kg. Turbot is both cultivated in mariculture and in brackish water.[143, 144]

Turbot juveniles are around 2-3 mm long and weigh around 0,5 mg, which is quite small compared to juveniles of other flat fish. The juveniles are primarily fed with rotifer and Artemia. The survival is usually only around 10-20% after the primary feeding period is over, and at that time the juveniles are ready for sale at the size of 10 grams.[145] Annually there are produced around 4 millions turbot juveniles in the world. France, Spain, Denmark, Norway and Britain, in this order, are the main producers of turbot juveniles in the world.[146]

In Spain the turbot is cultivated in seawater which is pumped directly from the sea. In Spain it takes around 30 months for turbot to grow from 5 grams up to 2 kg. In Norway where warm waste water is used in turbot culture it

[143] Agnar Steinarsson o.fl. 2000.
[144] FAO, Fishstat plus 2004.
[145] http://www.imr.no/__data/page/4257/Oppdrett_av_piggvar.pdf
[146] Agnar Steinarsson o.fl. 2000.

takes around 20 months for turbot to reach the same weight. The ability to control the temperature perfectly as well as being able to delay the maturity by using lights is considered to increase Norway's competitiveness against Spain and other countries that cultivate turbot in warm sea water.[147]

6.3.1.1 Cultivation in Iceland

In the year 1992 the Marine Research Institute (MRI) of Iceland started to collect turbot juveniles in collaboration with fishermen in Iceland. Juvenile experimental production has been carried out by the MRI for several years and in 1995 MRI managed to produce 20 turbot juveniles. In 1999 the juvenile production was around 10.000 pieces. Those turbot juveniles have been sold onwards to fish farming companies in Iceland for experimental cultivation.[148]

Silfurstjarnan, a fish farming company mentioned in chapter 6.1.2, started its land based turbot cultivation late in the year 2000 when 5.000 turbot juveniles at the size of 2 grams were obtained from the MRI. In the year 2001 the company also bought 5.000 juveniles and in the year 2002 and 2003 the company bought 50.000 juveniles and plans to buy the same amount in the year 2004. In the year 2003 Silfurstjarnan produced around 10 tons of turbot and in the future it plans to produce around 100 tons annually.[149]

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[147] http://www.imr.no/Dokumenter/publikasjoner/Havbrrapp_kap2_3.pdf
[148] Agnar Steinarsson o.fl. 2000.
[149] Benedikt Kristjánsson 2004.

Figure 21. Silfurstjarnan. Left, one of the turbot houses. Right, inside one of the turbot house.

The turbot is cultivated indoor in 1 m deep tanks. Shelf system which often is used in halibut cultivation can not be used in turbot cultivation because the turbot simply doesn't lie on the shelves. Therefore the tanks are only 1 m deep. The maximum cultivation density is around 50-80 kg/m^2 but density of 100 kg/m^2 does not seem to reduce the growth rate nor cause any other problems. The cultivation temperature is around 20°C for the juveniles but around 14°C for the larger ones, the salinity is around 22-25 ‰. To reach the accurate temperature for the cultivation a blend of seawater and geothermal water is made, therefore the salinity depends on how much geothermal water must be used to reach the optimal temperature. The salinity of the cultivation water is usually higher in the summer time because the seawater's temperature is higher at that time and therefore less geothermal water is needed to reach the optimal temperature.[150]

[150] Benedikt Kristjánsson 2004.

Figure 22. Silfurstjarnan. Left, turbot juveniles. Right, market size turbot.

The market size of the turbot is around 2 kg and on average it takes two years for the turbot to reach that size. For juveniles the daily growth rate is up to 2,5% but around 0,5% for 1 kg turbot. The turbot cultivated at Silfurstjarnan needs 1,25 kg of feed for 1 kg increasing in weight, the feed is a special turbot and halibut feed bought from LAXÁ (http://www.laxa.is/main/nidur/adal/english/Welcome.html). Most of the turbot produced at Silfurstjarnan has been sold to USA, Britain, Germany and to restaurants in Iceland.[151]

6.3.2 Production

According to FAO (Food and Agriculture Organization of the United Nations), Spain and France cultivates most of Turbot in Europe.[152] The production can be seen in table 16.

[151] Benedikt Kristjánsson 2004.
[152] FAO, Fishstat plus 2004.

Table 16. Production of turbot in Europe 1990-2002 (tons/year)[153]

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Spain	640	825	1.622	1.539	1.810	2.174	2.189	1.800	1.969	2.849	3.378	3.636	3.847
France	15	100	100	150	550	694	225	980	900	868	908	702	728
Portugal	0	0	0	0	35	82	102	196	188	378	380	343	386
United Kingd.	0	0	0	0	0	0	0	0	0	0	107	120	45
Ireland	0	0	3	4	3	15	30	0	5	8	12	28	50
Iceland	0	0	0	0	0	0	0	0	0	0	0	27	9
Germany	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0	0	< 0.5	0	0	0	2
Netherlands	0	0	0	0	0	12	25	25	25	0	0	0	0
Malta	0	0	0	0	1	1	< 0.5	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	3
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	1
Total	656	925	1.725	1.693	2.399	2.978	2.571	3.001	3.087	4.103	4.785	4.856	5.071

The turbot production in Spain and France covers around 85% of the world production. Compared to other cultivated species such as sea bass and sea bream the growth in the production is quite slow. The main reason for that is considered to be that sea bass and sea bream are cultivated in sea-cages but turbot is cultivated onshore (land based farming) and the establishment- and operation cost is much higher for the onshore cultivation.[154]

6.3.3 Markets and prices

In 1991-1994 the price for turbot, in Spain, decreased because of increasing in production. (table 17). In 1995 the price decreased by 25% because of 40% production increase.

Table 17. Turbot, average price (FOB) in Spain[155]

	0,5 - 1,0 kg	1,0 - 2,0 kg	> 2,0 kg
Year	$/kg	$/kg	$/kg
1991	13,8	15,6	17,1
1992	11,8	11,8	14,9
1993	9,6	8,8	12,1
1994	9,6	9,0	11,8

[153] FAO, Fishstat plus 2004.
[154] Agnar Steinarsson o.fl. 2000.
[155] Agnar Steinarsson o.fl. 2000.

Table 18. Turbot price (FOB) in Spain and French[156, 157]

Country	1996	1997	1998	1999	2000
Spain (€/kg)	8,2	8,33	8,71	8,4	7,81
France (€/kg)	8,3	8,77	9,42	8,48	-

Now it seems that the price has reached equilibrium. It isn't easy to make price-forecast for turbot, though the price is likely to follow the prices for other species cultured in Mediterranean countries such as sea-bass and sea-bream. The production of sea-bass and sea bream has increased 15 times and the price has fallen from 13-14 €/kg to 6-7 €/kg. It is nevertheless highly unlikely that the onshore-production of turbot ever reaches the same amount as the sea cage-production of sea-bass and sea-bream. The price is not expected to fall as much as the price for sea-bass and sea-bream because the production cost for turbot is much higher since it is cultured onshore. Market for turbot in Iceland is considered to be less than 10 tons a year.[158]

6.4 Atlantic Halibut

Atlantic halibut (*Hippoglossus hippoglossus*) is a long and thick bony fish. It has quite big head and mouth but the teeth are rather small and sharp. The lower jaw is protrusive and its eyes are rather small situated on its right side. The halibut's right side is sable, dark green, grey or brown and its left side is white. Halibut is the biggest of the flatfish and also among the biggest bony fish. Its length can be more than four meters and its weight more than 200 kg. The halibut can be found widely e.g. in the North-Atlantic, Arctic Sea, Barentssea, the North Sea and by the British Isles. The halibut lives in the ocean around Iceland, Faroe Island and Greenland. The main halibut fishing grounds around Iceland are south, southwest and west of the island.[159]

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[156] http://feap.info/production/countries/spain/spainprices_en.asp
[157] http://feap.info/production/countries/france/franprices_en.asp
[158] Agnar Steinarsson o.fl. 2000.
[159] Karl Gunnarsson o.fl. 1998, bls. 226.

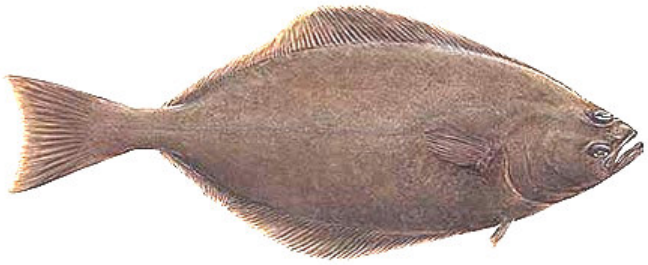

Figure 23. Atlantic halibut[160]

6.4.1 Atlantic halibut cultivation

The potentials for cultivating Atlantic halibut have been studied in United Kingdom, Canada and in Norway and these studies indicate that Atlantic halibut cultivation will become technically and commercially viable.[161]

The optimal temperature for Atlantic halibut decreases by increasing size. Juveniles can poorly withstand temperature lower than 5°C. Larger halibut can withstand lower temperature than the smaller ones and the low temperature does not affect their growth rate as much as it does for the smaller ones. Halibut under 100 gram gains the most growth if the temperature is above 12°C. The optimal temperature for larger halibut is 10-12°C, but is can also reach acceptable growth at 8°C.[162]

The maximum density for cultivated halibut can be seen in table 19.

Table 19. The maximum density for cultivated halibut[163]

Size	"Density" (kg/m^2)
10 g	1 - 2
100 g	8
500 g	11
1000 g	20
3000 g	80

[160] http://www.islandsvefurinn.is/wildlifepage.asp?ID=119
[161] http://www.aquamedia.org/Production/Species/flatfish/halibut_en.asp?SpeciesID=34
[162] http://kveitemanualen.imr.no/Vekst.htm
[163] Tómas Árnason 2004.

6.4.1.1 Cultivation in Iceland[164, 165, 166, 167]

Fiskey in Eyjafjordur, around 100 km west of Húsavík is a fish farming company that specializes in Atlantic halibut juvenile production. The company also produces marketable fish in its grow-out station in Thorlakshofn in south-Iceland.

Fiskey has been the largest individual producer of Atlantic halibut juveniles in the world since 1998. A large part of the juvenile production is sold onwards to foreign grow out stations and the Fiskey also utilizes the juveniles for its own cultivation in Thorlakshofn.

Table 20. The juveniles production of Fiskey[168]

Year	Numer (thous.)	Estimated world market ratio
1998	220	31%
1999	290	45%
2000	300	45%
2001	340	35%
2002	400	37%
2003	750	55%

In 2004 Fiskey plans to produce about 700-900 thousand juveniles.

In Thorlakshofn about 50 km south of the capital Reykjavik is Fiskey's grow-out station located. The juveniles are transferred from Hjalteyri in Eyjafjordur to Thorlakshofn after approximately 6 months from spawning, weighing 5-10 grams. The fish is initially kept in indoor tanks but when they have reached a certain size they are moved to tanks outside. The outside tanks are covered in order to protect the halibut from the sunlight because it is at a risk of sunburn. The halibut is cultivated in very pure bore seawater at the temperature of 7°C with the possibility to increase the seawater

[164] http://www.fiskey.is/feeding.php
[165] http://www.fiskey.is/marketable.php
[166] Tómas Árnason 2004.
[167] Benedikt Kristjánsson 2004.
[168] http://www.fiskey.is/feeding.php

temperature by using geothermal water as heating medium. On a global scale Fiskey's estimated share in production of cultivated halibut for the past few years has been around 10%. In 1999 the production was 13 tons, increasing to 140 tons in 2003 and the company aims to increase its production in Thorlakshofn in the coming years to 350-400 tons in 2007.

Table 21. Fiskey's production segmentation and price in Britain[169]

Weight (kg)	Ratio of total production	Price (ISK/kg)
1 - 3	20%	620
3 - 5	40%	850
5+	40%	1000

Fiskey's main markets are in North-Europe and USA and the halibut is mainly sold whole and gutted.

For further information on Fiskey, see: http://www.fiskey.is/indexen.php

Silfurstjarnan a fish farming company which was mentioned in chapter 6.3.1.1 and started experimental Atlantic halibut cultivation late in the year 2002 when they obtained 5.000 halibut juveniles at the size of 5-10 grams. Today these juveniles, from the year 2002, are on average 3 kg and are cultivated at temperature of 14°C with salinity around 22-25 ‰, just the same way as for the turbot. In 2004 Silfurstjarnan plans to obtain 50.000 juveniles and therefore put more effort in the Atlantic halibut cultivation.

[169] Tómas Árnason 2004.

Figure 24. Silfurstjarnan, halibut cultivation

The halibut is cultivated in outdoor tanks covered with net (seine-net) which has not been very successful because the halibut tends to sunburn and also can growth of algae be very significant especially when weather is sunny. For 1 kg increase in weight about 1,25 of feed is needed and the same feed is used for the halibut and the turbot.

Table 22. Daily growth-rate of halibut at Silfurstjarnan[170]

Fish size	Daily growth-rate
200 g	1,1%
500 g	0,8%
1000 g	0,7%
1700 g	0,6%

Atlantic halibut cultivation at Silfurstjarnan is on initial stage and therefore the company has not been selling its production to foreign markets. The market-size of the halibut from Silfurstjarnan has been 2-3 kg.

[170] Benedikt Kristjánsson 2004.

6.4.2 Production

According to FAO Iceland and United Kingdom are the main producers of Atlantic halibut in the world.

Table 23. Production of Atlantic halibut in 1990-2002 (tons/year)[171]

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Iceland	0	0	0	0	0	0	0	2	8	13	34	93	120
United Kingd.	0	0	0	0	0	0	0	0	0	4	1	80	187
Total	0	0	0	0	0	0	0	2	8	17	35	173	307

It can be seen that the production isn't much but the production will continue to increase if production plans will succeeds.

6.4.3 Markets and prices

The price and demand for Atlantic halibut is greatly related to the size of the product. Demand for halibut at the size of 1-3 kg is not much, the price is rather low and the yield after filleting is bad. Halibut at the size of 1-3 kg are thin and are therefore in direct competition to other flatfish. Halibut at the size of 5-7 kg are much more valuable, the yield after filleting is much better and it is much thicker and meatier. Halibut of that size is mainly purchased by restaurants. Demand for halibut bigger than 7 kg is vast and it can easily be marketed at a very high price. Each 7 kg halibut yields four 1,1 kg fillets.[172] Demand for halibut in Europe is high and the only species that outsells it is turbot.[173]

In January 1999 it was predicted that future price for cultivated Atlantic halibut would be around £5 - £6 for a 3-4 kg fish. If this forecast is compared

[171] FAO, Fishstat plus 2004.
[172] http://www.seafood.no/eff/effnews.nsf/viewluSpeeches/38B95A6B6B382BA4C1256D8900404009/$FILE/trondheimaqua.pdf
[173] Tómas Árnason 2004.

to the price information in table 24 it can be seen that the forecast is not that preposterous.[174]

Table 24. Atlantic halibut price per kg in selected countries[175]

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Iceland ($/kg)	0	0	0	0	0	0	0	10	10	9,5	9	8,5	8,5
Utd. Kingd. ($/kg)	0	0	0	0	0	0	0	0	0	9,5	9,5	9	9

[174] http://www.aquamedia.org/Production/Species/flatfish/halibut_en.asp?SpeciesID=34
[175] FAO, Fishstat plus 2004.

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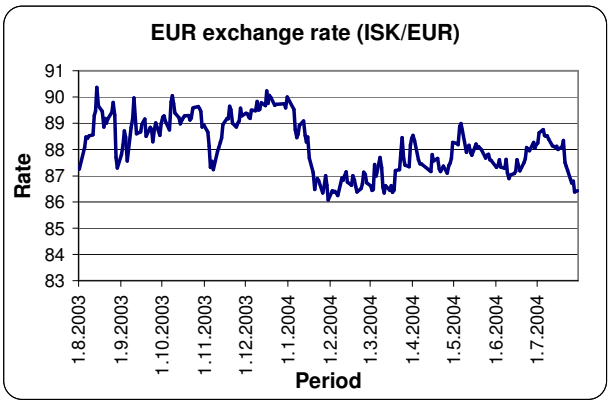
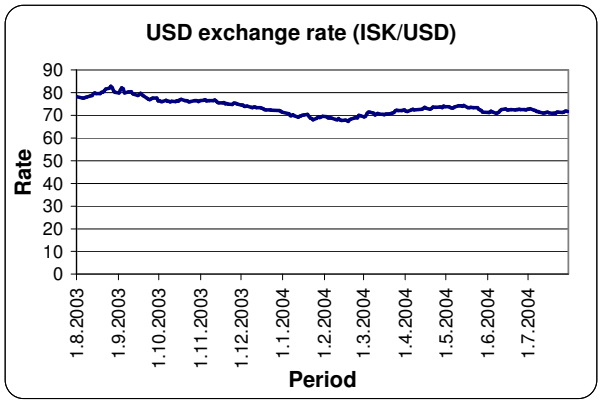
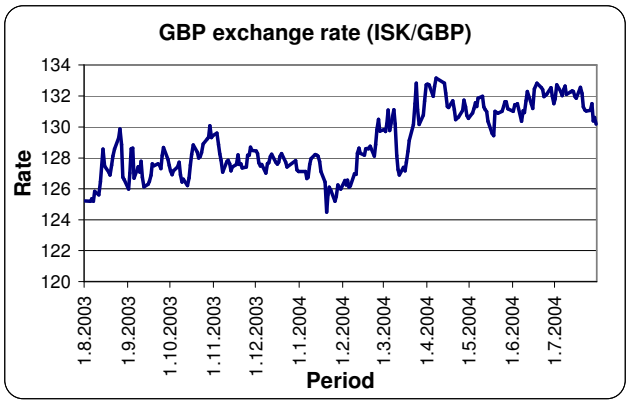
Appendix

Currency exchange rates[176]







[176] http://www.kbbanki.is/default.aspx?pageid=282