Oil Products Used in Greenland

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Preface

This report is a product of the participation in the course Arctic Technology at the Technical University of Denmark. The course is divided into three parts. The first part included lectures about essential knowledge regarding arctic: nature (climate, geology, permafrost, flora- and fauna), culture (living conditions in arctic, history), buildings and infrastructure, energy supply (power supply, hydro power, energy from waste biomass, solar energy), environmental technology (waste treatment and reuse, oil pollution and handling, air pollution). The second part consisted of the fieldwork in Sisimiut, the second largest town in Greenland, in the period from 4th till 22nd of August 2009. The last part included lab tests of the fuel samples that were brought from Greenland and writing this report.

I would like to thank PhD student Janne Fritt-Rasmussen, postdoctoral Gunvor Marie Kirkelund and the laboratory technician Caroline Burger, for guidance during the project.

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1 Introduction

Greenland is the largest island on Earth, located in the northern hemisphere. From Cape Farewell in the south to the world's northernmost landmass, Odak Island, there is a distance of 2,670 kilometers. Measured across, the island stretches 1,050 kilometers at its widest point. Out of Greenland's 2,175,600 square kilometers area, only about fifteen percent is free of ice; the rest is covered by the world's second-largest ice sheet: the inland ice (approximately 2 millions square kilometers). The coastline of Greenland is almost 40.000 km long, so it is comparable to the length of the Equator.

Greenland has an arctic climate. That means that the average temperature in the summer never exceeds 10°C and there is permafrost, so only the top layers of soil thaw in the summer. That also means that the country has little rainfall and no forests - only a little brush and bushes as tall as a man can grow in south Greenland. The size of the country causes the weather in Greenland to vary widely. In Greenland sudden changes in weather are common. Precipitation is mostly snow. The north part of the island and most of the interior characterizes true an arctic climate, with the temperature only rising above freezing for brief periods in the summer. During the winter, temperatures range from - 5°C to - 30°C and in the summer from 4°C to 15°C. In the southern part and the innermost parts of the long fjords, the temperature can, however, rise up to more than 20° C in June, July or August. The air is generally very dry in Greenland and that is why temperatures do not feel as cold as in Europe .The summer period runs from June all the way into September.

Figure 1: Map of Greenland [1]

Several systems of sea currents meet in Greenlandic waters. They influence the temperature and salt content of the sea, and thus the occurrence of marine organisms. The sea currents also determine the spread of the sea ice. Because of the sea ice, the areas from Qeqertarsuup Tunua (Disko Bay) north, as well as the east coast can only be navigated for a few months in the summer. Excluding West Greenland from Paamiut (Frederikshlb) to Sisimiut (Holsteinsborg), there is what is known as the open water area, where the fjords and waters near the coast freeze only occasionally in the winter.

On 1st of January 2009 Greenland's population was 56,194, of whom 47,000 live in towns with the remainder living in small settlements up and down the east and, in particular, the west coast. Greenland's capital, Nuuk, has approximately 15,000 inhabitants. The second largest town is Sisimiut with 5,458, followed by Ilulissat (4,528) and Qaqortoq (3,304). Usually, in Greenlandic settlements live between 50-500 inhabitants.

Fishing and hunting continues to be a dominating sectors in Greenlandic economy. Currently, fish and seafood production is the primary export industry - more than 90% of all exports are derived from fish products, including prawns and Greenland halibut. Greenland is home to one of the most modern fleets of fishing vessels in the world today and has a large industry exporting high quality seafood products to markets all over the world.

The fishing industry is the largest consumers of petroleum products. That is why consumption of the energy and fuels is strictly connected to the fishing industry. In these days it is quite common that the fishing activity is moving to different areas, which means that the fuels supply needs to move as well.

The quite hard climate condition, population as well as location and distances between towns and settlements causes that supply energy for Greenlandic society becoming huge challenge. As it is shown in the Figure 2 energy sources in Greenland are based on the oil products. The dependence on petroleum products import is so extremely high, that any disturbances in supply chain could be dangerous not only for single household, but for the whole society. In the worst-case scenario this strong correlation may entail that the society will stop functioning; without fuels supply there is lack of heat , lack of electricity and the transport is unrealizable.

In the next sections, the report is focusing on overview of the main oil products used in Greenland, determining their properties and the amounts used. The process distribution and storage will be presented as well.

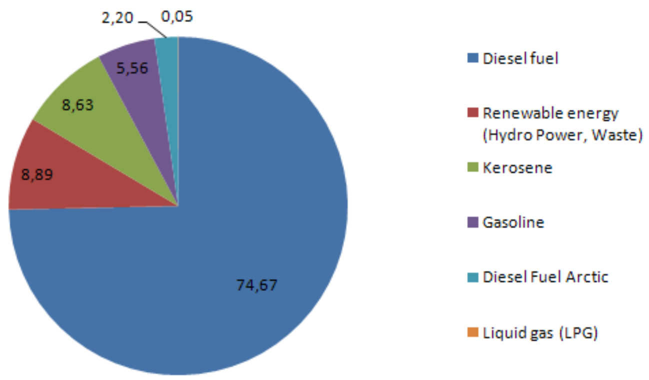

Figure 2: Energy Consumption in Greenland, 2007 [2]

2 Consumption of oil products

As it was mentioned in the previous section, Greenland's production of energy is strongly dependent on the oil products import (diesel fuel, gasoline, kerosene). Even though the renewable energy production has been started since the 1990s, it still represents only about 8-9% of the total energy production. The main green energy produced is hydro energy.

Let's have a look at the statistics. Greenland's total energy consumption was 9,663 TJ in 2007, and this poses 6.5% more compared to 2003, when the energy consumption was 9070 TJ. Since 1997, energy consumption increased by 12.4%. During the same period (2003-2007) consumption of renewable energy increased by 33% (see Table 1). In 2007 consumption of all crude oil based fuels decreased besides gasoline. The majority of energy comes from imports of diesel oil, kerosene and gasoline. Diesel oil is the most common used fuel, and it is used to produce electricity and heat for heating in households, institutions, business and industry, fishing, watercraft and land transportation. Kerosene is used for heating in households and in air transportation as a jet fuel. Consumption of kerosene has been increasing since 2003, and in 2007 kerosene posed 8.6% of the total energy consumption. Gasoline is used as a fuel in land transport (cars, motorbikes etc.), fishing trawlers and other watercraft. Consumption of gasoline has risen steadily since 1996. In 2007, 537 TJ gasoline was used, which corresponds to 17.63 million liter.

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Total consumption	8596	8093	8305	9430	8808	8277	9070	9296	9372	9660	9663
Diesel fuel	7119	6445	6643	7739	7141	6594	7429	7110	7174	7275	7215
Renewable	554	580	617	616	567	654	647	780	798	784	859
Kerosene	434	529	505	523	533	468	405	719	727	839	834
Gasoline	384	424	447	463	479	479	504	487	504	533	537
Diesel Fuel Arctic	*	*	*	*	*	*	*	194	163	223	213
Liquid gas (LPG)	12	12	7	7	7	7	6	7	6	5	5
Coal, briquette	0	0	1	1	1	0	–	–	–	–	–
Waste	93	103	85	81	80	75	79	*	*	*	*

Table 1: Energy consumption in TJ; – no data, * combined data for DFA with diesel fuel and waste with renewable energy [3, 4]

2.1 Dependence on fossil fuels

In 1990 Greenland was entirely dependent on imported fossil fuels. That is why for recent years energy planning has been focused on reducing the dependence on fossil fuels. The use of renewable energy in a larger scale could make Greenland less dependent on imported fossil fuels, and less vulnerable to fluctuating oil prices on international markets or supply failure. In 1992 incineration plant was established thanks to which the dependence on fossil fuels decreased only slightly to 99%. The first breakthrough in development of renewable energy in Greenland was the launch of hydropower plant in Buksefjorden in 1994. In connection to this event, reduction of its dependence on oil reached level of 91%, and it has been oscillating between 91 -92% with a slight upward trend till now. In 2007 the dependence on fossil fuels sources was 91.1%. Energy production from renewable sources has been increasing since 1992, nevertheless this increase has been balancing due to the sustained increase in consumption of fossil fuels. The total imports of liquid fuels are shown in Table 2 .

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Arctic Gas Oil	147,9	146,8	74,1	98,6	88,5	134,6	80,8
Automotive Gas Oil -20	5,9	37	91,4	90,1	87,2	79,5	124,1
Automotive Gas Oil -5	28,2	19,5	11,6	18,3	13,6	18,4	-
Diesel Fuel Arctic	6,6	4,5	5,5	5,5	5	4,3	6,1
Total Diesel Fuels	**188,5**	**207,8**	**182,6**	**212,6**	**194,2**	**236,8**	**211**
Jet A-1(Kerosene)	22,4	23	23	20,6	15,9	24,8	26,7
Gasoline	12,8	14,3	15,2	18,6	13,8	14	14,6
Total	**223,8**	**245**	**220,9**	**251,7**	**224**	**275,5**	**252,3**

Table 2: Imports of liquid fuels, mil.liters [4]

3 Distribution and storage of oil products

In these days mainly KNI Polaroil is responsible for supplying Greenland in oil products according to the service contract with Home Rule Government, which constituted approximately 70% of all KNI Polaroil business and is not profitable, which means that incomes cover only maintains and eventual investments. Polaroil is an independent company in KNI Group, whose tasks are to provide, transport, store, distribute and sell environmentally compatible liquid fuels (diesel fuel, gasoline and kerosene) during the year in whole Greenland and keep stable, lowest prices. The other technical related products are purchased, stored and sold at a commercial basis. Polaroil operates a total of 70 stations distributed in 17 towns (total capacity $216.695m^3$), 5 import plants (in Qaqortoq, Faeringehavn, Nuuk, Sisimiut and Kangerlussuaq) and 53 settlement installations (capacity $19.980m^3$), and also, apart from those, in all towns and settlements there are storage facilities for lubricating oils and gas. In total, Polaroil maintains 455 tanks with capacity approximately 280 millions liters. The local distribution of liquid fuels in the towns take place first of all through self-owned organization and then through local sellers according to agreements with them. In the settlements it is done by KNI's sale department, Pilersuisoq. The total consumption of liquid fuels was 250.2 millions liters in 2007 [2]. The prices of liquid fuels in Greenland do not include taxes (Figure 3) and the market prices are the same everywhere in Greenland. It is worth to mention that Polaroil does not receive any profits from Greenland Home Rule Government.

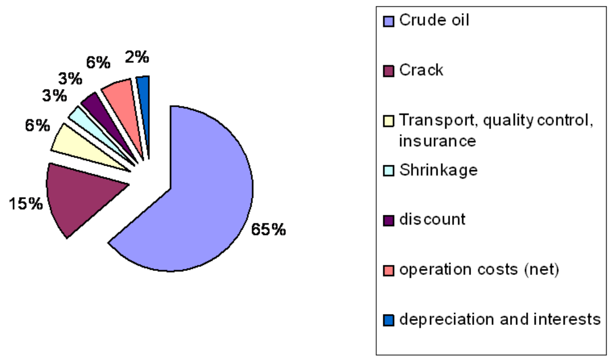

Figure 3: Pricing elements [2]

The other important issue is the fact that the products which are delivered to Greenland, are not standard products. For example, the diesel fuel is a special product with high cold characteristics. Storage, treatment and transport of fuels in arctic regions requires a high safety factor - and environmental rules. Polaroil has built up the expertise in those fields for many years through collaboration with international suppliers and shipping companies. Characteristics of all imported oil products has been adapted to international environmental provisions as well as to the special application and to storage conditions in Greenland. Thus, the sulphur contents has been reduced essentially in the last years and Polaroil imports exclusively unleaded gasoline. In order to ensure that the oil products constantly comply with the necessary demands and specifications, Polaroil has developed a quality security system. Imported oil products are subjected to running quality assurance and controls which are fitting to each product. Polaroil has carried out an extensive development and modernization of all tank installations in the last years, and it is still in progress. The work has been organized on partnership basis, where all partners (building owner, advisers, contractors) are involved in the community at all levels. The reason of this is to secure the supplies in the best possible way and to improve the safety for the staff and the environment and furthermore to ensure that all the improvements in the tanks installations are maintained.

3.1 Oil products in Sisimiut

In Sismiut, Polaroil has one of the largest Fuel Storage Depot (FSD) and import facility in Greenland. The FSD is located (red color in the picture) at the periphery of the town, around 1km from the harbor (green color in the picture). Tanks farm included 12 tanks. Capacity of each is presented in the Table 3. Total capacity of the FSD is 26.343 millions liters.

Figure 4: Location of the Fuel Storage Depot in Sismiut

During the fieldwork the tanks in FSD were inspected. The inspection was based on the organoleptic methods and interviews with workers. In general, all tanks are in good condition. No leakages or unseals have been noticed , but on some of the tanks there could be seen stone chip damages on the welds and some corrosion spots (see Figure 6 and 7). But those defects typically occur during exploitation of tanks and cannot be source of any hazards or pollution. It is worth to notice that every five years all tanks are renovated by external company from Denmark, and once per year the tanks are cleaned. The other minor repairs are done by Polaroil's workers. It can be confirmed that all other procedures regarding the safety of service and environment protection are at high level. As the most of the tanks were built around 40 years ago, Polaroil has decided to replace the whole tank installation in Sisimiut - and this process is going to start in 2010.

In Sisimiut, the distribution chain of the fuels has very simple structure. On the top there is a tanker which transports the fuels from Preem refinery in Sweden. Then the fuels are pumped to the biggest tanks (no. 6-12 and 20). From the biggest tanks, fuels are pumped down into the smallest tanks (no. 13-16). From there, fuel goes into the fuel

Figure 5: Fuel Storage Depot in Sisimiut

Tank no.	Max. capacity, liters	Year of construction	Type of fuel
6	2,483,597	1966	Diesel fuel
7	2,470,379	1967	Diesel fuel
8	4,971,365	1971	Diesel fuel
9	492,108	1967	Jet A-1
10	490,729	1967	Gasoline
11	247,927	1967	Jet A-1
12	249,136	1967	Gasoline
13	16,150	1968	Gasoline
14	16,150	1968	Diesel fuel
15	16,150	1968	Diesel fuel
16	8,868	1968	Jet A-1
20	14,881,153	1981	Diesel fuel

Table 3: Capacity of the Fuels Storage Depot in Sisimiut

Figure 6: Corrosion on the tanks

Figure 7: Stone chip damage on the tanks

tracks, Figure 8. Currently in Sisimut there are 5 fuels trucks, three of which belong to the "Sisimut Oile" A/S company. This company is responsible for distribution of fuels to filling stations and private households. In Sismiut there are three main filing stations. Two of them are located in the harbor. One of those two is intended mainly for cruise ships and larger watercrafts. The other supplies cars, motorbikes and small ships and boats. The last one is located next to the fire station (see picture), and has only one diesel self-service petrol pump with non-cash payment system. All of the petrol pumps are hidden in metal housings in case of high level of snow (Figure 8).

Figure 8: Distribution chain in Sisimiut. Tanker Orasila. "Small tanks". Fuel track, "Sismiut Oile" A/S. Filling staion.

After the visit in fuel storage depot in Sismiut two improvements could be recommended. The first one is Automatic Measurement System. This system may help workers with measurements of quantity of fuels in the tanks. Currently the level of fuels, even in the largest tank, is controlled by hand measurements or reading the indicators . In the past, an automatic measurement system was installed but after a year of exploitation it failed (Figure 9).

The other improvement could be Vapor Recovery Unit (VRU) technology. After consulting with the representative of Polaroil in Manitsoq, the following conclusion was made regarding the possibility of installing VRU. Basically, it is possible to install VRU in Greenland, but it is very expensive and the gasoline vapor due the low temperatures in the Arctic does not constitute such a big problem. But, it should not be forgotten that VRU is a huge advantages not only for recovering gasoline vapor but as well for crude oil vapour.

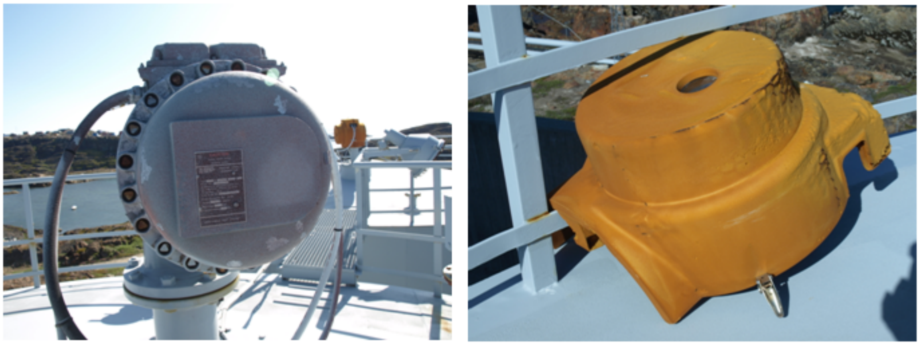

Figure 9: Broken Level Measurement System

According to GEUS (Geological Survey of Denmark and Greenland) [5]: "[In Greenland] total area of sedimentary basins with petroleum prospectively exceeds 350,000km^2. Total seismic data base approximately 110,000km^2, but coverage uneven. Only 6 offshore wells and 1 onshore well drilled, all in West Greenland. Large areas still untested". Currently, Greenland is considered as a country with huge potential of exploring crude oil. And this is the another reason of presenting closer the VRU technology.

3.2 Vapour Recovery Unit [6]

There are three main reasons why gasoline vapours are recovered. The most important is the reduction of the emission of environmentally hazardous substances. The others are reduction of the risks of explosion in the distribution chain and storage of gasoline, and reduction of the significant losses of valuable energy resources. Gasoline is a volatile liquid that vaporizes very easily when in contact with the atmosphere. Vaporization stops when the air/gas mixture reaches the saturation point, which depends on the temperature, the composition of gasoline and the surrounding pressure. For the gasoline to vaporize at the right time upon injection into the combustion engine, the vapour pressure must be adjusted to the temperature of the surroundings. An arctic climate requires the gasoline to have a higher vapour pressure than that of a tropic climate, to enable it to vaporize at the lower temperature. On the other hand, a gasoline suitable for arctic climate will cause trouble in a tropical climate, vaporizing before injection into the combustion engine and creating vapour pockets in the fuel supply. Thus, gasoline types differ according to place of use. The vapour pressure of the gasoline is adjusted by changing the blending proportions of the different hydrocarbons in the mixture. In cold climates more hydrocarbons with a high vapour pressure, like butane and propane, are added to gasoline than in gasoline used in warmer climates. As a result, gasoline with an RVP (Reid Vapor Pressure measure of the volatility) of 70-90 kPaA is used in colder climates and gasoline with an RVP of 55-70 kPaA is used in warmer climates.

A significant loss of gasoline vapours occur during transfer. The vapours escape to the atmosphere when a gasoline product is transferred from one storage tank to another or from a storage tank to the mobile distribution, due to the displacement of the vapour mass in the tank being filled. Vapours also escape to the atmosphere by "breathing" - it happens during temperature expansion of the liquid from storage tanks. It is worth to remember that gasoline is explosive in a 1-7% mixture with atmospheric air. That is why caution is required in the distribution and handling of gasoline to ensure that there is no present ignition source of the vapours in the area. On the other hand, the distribution of gasoline requires great caution, especially during the loading of tankers and ships, during the filling of underground storage tanks on service stations and vehicles.

Figure 10: An example of VRU installation [6]

The vapour of gasoline contributes to the ground-level ozone production and has harmful effects on human, animal and plant life. Gasoline also contains numerous substances that constitute a health hazard to people employed in the gasoline distribution. An example is benzene, a component of gasoline, proved to cause cancer. Benzene is also present in gasoline vapours and thus constitutes a serious health threat to the surroundings.

Generally, the recovery of gasoline vapour has a great economic potential. Saturated gasoline vapour at 0°C contains approximately 0.6kg gasoline per cubic meter, which is equal to 1 liter of recovered gasoline. At 25°C, cubic meter of the saturated vapour contains approximately 2 liters of gasoline. Under normal circumstances, a gasoline terminal will have an average recovery potential of approximately 1500 liters of gasoline for every 1000 cubic meters transferred. For example, in 2008 Polar Oil transferred around $15720m^3$ [2] of gasoline in Sismiut import plant, and if normal circumstances will be assumed, only in 2008 it was possible to recover 23500 liters of gasoline. Of course the value of the recovered gasoline varies according to whether the recovered product is taxed or not . As in Greenland the fuel prices are not taxed (Figure 3) and weather condition are less favorable, return of the costs investment for VRU technology is longer then in e.g. Western Europe where there is the practice to refund tax on the recovered product, so the product is not subjected to double taxation.

One of the most common and generally recognized processes for recovery of gasoline vapours is Carbon Vacuum-regenerated Adsorption Process (CVA). It is very simple and highly efficient. It is also the most economical process, with installation and operating costs consuming less than 0.1 kWh per liter of recovered gasoline. So how does the process look in details? At first gasoline vapour is collected from the emission source and then is passed through one of two beds filled with activated carbon. The hydrocarbons molecules are adsorbed on the surface of the carbon, and the air is vented to the atmosphere. Before the carbon filter reaches saturation, the flow of gasoline vapour is shifted to the clean filter, and the first carbon bed is regenerated by means of vacuum. The highly concentrated stream of gasoline vapour is routed through a counter flow of fresh gasoline, which absorbs the hydrocarbon components. The gasoline is continuously recycled to the storage tank.

3.3 Handling fuels in Greenlandic Airports: Sisimiut and Kangerlussuaq

All fuels to be used in aviation require careful handling. Negligence in the receipt, storage and handling of fuel or an error in fuelling can endanger an aircraft and the lives of all on board. Thus it is essential that the correct grade and quantity of fuel is supplied and that it is in a condition that fits the use in aircraft.

In Sismiut Airport there is no storage facilities for aviation fuel. The fuel is stored in a tank truck (Mercedes Actros 1831), and filling of airplanes and helicopters takes place directly from the tank truck (Figure 11). Currently only Jet A-1 fuel is available for aircrafts. The aviation fuel comes from FSD in Sisimut. One or two times per day airport tank truck goes to the FSD, where it is refilled. The tank truck contains two tanks each with 1000 liters capacity. After filling each tank, a sample of approximately 1 liter of Jet A-1 is taken from the truck tanks. After 10 minutes the worker of FSD and the driver of the truck check the transparency and measure the temperature and volume to estimated density of the Jest A-1 by using Aviation Fuel Density Calculator (see Figure 13). The fuel density should not vary by more than 0.003 kg/liter (when measured at 15°C) from the value quoted on the delivery note. Additionally, every day at the airport, Jet A-1 is checked twice for presence of water. The installation for checking the water content is very simple: it contains syringe and water detector (see pictures). The sample of the fuel is suck inside the syringe, and if the sample contains high water concentration, then water detector which is placed on the syringe inlet changes color from light yellow to green (Figure 12).

There is no special issues regarding handling Jet A-1 at Sismiut Airport. During winter time tank truck stays in a heating garage and goes out only to fill an aircraft or to load fuel in FSD. The one of special requirements for Jet A-1 in the Arctic is to keep the electrical conductivity high enough for use in aviation. Therefore Polaroil requires at least a value of 300 pS/m when the fuel is loaded in Swedish refinery. It is due the fact that big loss of conductivity can occur by transport and storage at low temperatures. The conductivity is one of the most important index of aviation fuels. The ability of a fuel to dissipate charge that has been generated during pumping and filtering operations is controlled by its electrical conductivity, which depends upon its content of ion species. If the conductivity is sufficiently high, charges dissipate fast enough to prevent their accumulation and dangerously high potentials in a receiving tank are avoided [7]. That is why the antistatic additives are used in the fuel to prevent the accumulation of static electrical charges in the fuel: they are capable of causing explosions in storage tanks, aircraft tanks, pumps, etc. On the other hand "the fuel conductivity cannot be increased above a certain limit (300-600

Figure 11: Handling of fuel at the Sisimiut Airport

Figure 12: Water detector

Figure 13: Density measurement of Jet A-1

pS/m), since extremely high conductivities would have an adverse effect on the accuracy of the readings of capacitance-type fuel gases installed in storage tanks and aircraft tanks" [8] Before the loading in Sweden, all properties of the Jet A-1 are checked and proved by quality certificate. Example of a Jet A-1 fuel certificate from Sisimut Airport can be found in Appendix A. During the fieldwork, short visit in Kangerlussuaq Airport was paid as well. Kangerlussuaq Airport is the largest civil airport in Greenland. That is why handling of the aviation fuel is organized in a much different way, compared to Sisimut Airport. At the Kangerlussuaq airport two kinds of aviation fuels are available, i.e. Avgas 100LL and Jet A-1, with Avgas 100LL sold in very small quantities. Norwegian Statoil supplies and distributes fuels in the airport. All oil products are refined in Bergen, Norway. Aviation fuel after import from Norway is transported from Kangerlussuaq harbor through around 11 km long pipelines to three large storages tanks outside the airport. Each tank has a capacity of $8000m^3$ (see Figure14). Storage of Jet A-1 in non-heated tanks with large capacity for long time causes decrease of conductivity. Thus, fuel is pumped from large tanks to smaller ones through a sort of "mixing station" (see Figure 14). The aim of the "mixing station" is to blend Jet A-1 fuel with anti-static additive Stadis 450, thanks to which conductivity can reach required level (minimum is 60 pS/m). Stadis 450 is a static dissipator, comprised of dinonylnapthalene sulfonic acid and other organic solvents, and according to its Material Safety Data Sheet, it contains two "trade secret" ingredients (Appendix B). According to the recommendations for the dosing of Stadis 450, initial injection should be done as close as possible to the airport, preferably into storage directly upstream of a dedicated supply route to the airport. At the Kangerlussuaq airport injection of the Stadis 450 is done on the way of fuel from large tanks to the small tanks which are located at the airport. Only one small tank can be filled at the same time in case of over-dosing or unresponsive Jet A-1 fuel. After filling one of the small tanks, conductivity is measured (see Figure14). Conductivity is usually close to the lower limit, because the dosage amount is around 3-5mg per liter of fuel. Due to this low dosage amount overdosing can occur very easily. From the small tanks, with capacity 2 x $100m^3$ and 2 x $50m^3$, fuel goes through the filters and then is loaded to one of the three tank trucks and later to the aircrafts. The fuel installation included separately filling station for Avgas 110LL.

Figure 14: Handling of fuel at the Kangerlussuaq Airport

As it could be noticed, the two different ways of keeping suitable values of conductivity in aviation fuel were presented. Commonly antistatic additive is injected into Jet A-1 in refineries. The advantages of this route are that refineries are often well equipped to inject additives and for some supply chains no further dosing is required. However, this is not necessarily the best practice because transport modes from the refinery (such as multiproduct vessels and pipelines) can cause significant and unpredictable loss of conductivity. But for Polaroil it is more convenient to purchase an aviation fuel with upper values of the conductivity then build the installations for mixing antistatic additive with the aviation fuel. Especially because Polaroil supplies small local airports which are spread around Greenland.

In conclusion, after inspection in Sisimiut nad Kangerlussuaq airports, it can be confirmed without any doubts that storage and distribution of aviation fuel entirely fulfill international safety and environmental standards.

4 Properties and composition of the fuels in Greenland

As it could be easily seen in the Figure 2, 75% of all energy consumption in Greenland comes from used diesel fuel. So why diesel fuel is so widespread in Greenland? The main reason is that the diesel engines consume less fuel than a gasoline engine performing the same work, due to the engine's higher temperature of combustion and greater expansion ratio. Gasoline engines are typically 25% efficient, while diesel engines can convert over 30% of the fuel energy into mechanical energy. The other important reason is that gas oil is denser and contains about 15% more energy by volume. This is important because volume of fuel, in addition to mass, is an important consideration in mobile applications. No vehicle has an unlimited volume available for fuel storage. Moreover, diesel engines have several other advantages over internal combustion engines, which are listed below, e.g:

- They can deliver much more rated power than a gasoline engines and have high reliability and easy adaptation to humid environments, due to lack of high tension electrical ignition system.
- The life of a diesel engine is generally about twice as long as that of a petrol engine due to the increased strength of parts used, and also because diesel fuel has better lubrication properties than gasoline.
- Handling of diesel fuel is considered safer than gasoline in many applications because it does not release a large amount of flammable vapour. The low Reid Vapor Pressure (RVP) of diesel fuels is desirable especially in marine, where the accumulation of explosive fuel-air mixtures is a big hazard.

4.1 Cold characteristics of diesel fuel

Common use of diesel oil to produce electricity and heat, and propel in fishing industry, watercraft and land transportation cause that the diesel fuel has to be resistant in the arctic weather conditions. So, what kind of problem could appear? All diesel fuels contains wax. It is considered an important diesel fuel component because of its high Cetane Number (CN-characterizes ability to self-ignition and proper combustion process; equivalent to the octane number for gasoline). Normally the wax is a liquid in the fuel, however, when diesel fuel gets cold enough the wax starts to crystallize. If the temperature is sufficiently low, enough crystals will from to block the fuel filter and the engine can stop through fuel starvation. That is why diesel fuel used in the arctic need to have special properties to avoid such a problem, unlike gasoline, which have freezing points much below even the most severe winter ambient. The most important properties which characterize ability of a diesel fuel to function in the arctic conditions, especially in the winter time, are Cloud Point (CP) temperature and Cold Filter Plugging Point (CFPP).

CP is the temperature below which wax in diesel fuel begins to form a cloudy appearance. The presence of solidified waxes thickens the oil and clogs, as it was mentioned above, fuel filters and injectors in engines. The wax also accumulates on cold surfaces (e.g. pipeline or heat exchanger) and forms an emulsion with water. Therefore, cloud point indicates the tendency of the diesel fuel to plug filters or small orifices at cold operating temperatures [11].

CFPP is the highest temperature, at which a given volume of fuel fails to pass through a standardized filtration device in a specified time when cooled under certain conditions. This test gives an estimate for the lowest temperature that a fuel will give trouble free flow in a fuel systems. The high value of the cold filter plugging point means that clog up vehicle engines is more easily [11].

There are three main ways of improving CFPP/CP properties. The first way is the production of diesel oil with less concentrations of wax, with simultaneous dropping of centane number and lubricant properties. The second way is adding special additives, so called cold flow improver or Middle Distillate Flow Improver - MDFI. This additives, made of polymers and copolymers of methyl acrylates, help to modify the wax structure (size and shape) as it builds up during cooling and keep wax crystals small, so they can pass through the pores of fuel filters and whole route to the injector pump.

Currently Polaroil sells two kinds of diesel fuel: Automotive Motor Gasoil -8/-20 (MGO) and Arctic Gasoil -22/-27 (AGO), the first number describes CP value and the other CFPP value. Before 2009 in Greenland there were available other types of diesel fuels e.g. Motorgasoil (CFPP -5) and Arctic Fuel Diesel (CFPP -47). The difference between previous types and current types was the CFPP/CP values, the other properties were similar. It is worth to notice, that centane number for MGO and AGO, according to product specifications (Figure 1516) is equal to 47. On the other hand European Standards (EN 590:2009) require at least value of 51 for cetane number. It means that diesel fuel which is sold in Greenland besides cool flow additives contains less concentration of waxes compared to the European diesel fuels.

4.2 Properties and composition of the fuels

The main properties of the fuels which Polaroil sells in this days, are presented in the Tables:15,1617 (aviation fuels are shown in the Appendix A:

One of the aims of the fieldwork was to take samples of fuels witch are used in Greenland and check composition by using Gas Chromatography(GC). GS is one of the most common techniques used for separating hydrocarbons for identification by other techniques. In some cases, GC can also be used for identification, if the model compounds exist or are known. GC uses volatility as the primary property for separation. The first step is to convert the oil components into vapor, which is passed through a packed column along with an inert carrier gas, such as nitrogen or helium, to elute them. The carrier gas helps these components to travel through the column to a detector, which generates signals to be recorded on a chromatogram. During the laboratory test, flame ionization detector was used (FID). In this kind of detectors, the column effluent is mixed with hydrogen and air and ignited. The organic material such as hydrocarbons produces, among other species, ions and electrons,which create signals. The signals are collected and display as graph [11].

Product Specification: GREENLANDIC AUTOMOTIVE GASOIL -8/-20

Property	Limit Min	Limit Max	Unit	Ref. Method	Com.
Appearance at 20°C	clear and bright		-	Visual inspection	
Appearance at 20°C		2	rating	ASTM D 4176-04	1
Ash content		0.010	% m/m	EN ISO 6245:2002	
Carbon residue (on 10% dist res)		0.15	% m/m	EN ISO 10370:1995	
Cetane index	45.0		-	EN ISO 4264:1996	
Cetane number	47.0		-	EN ISO 5165:1998	
Cloud point		-8	°C	EN 23015:1994	
Cold Filter Plugging Point		-20	°C	EN 116:1997/AC:1999	
Colour (ASTM scale)		2.0	-	ISO 2049:1996	
Conductivity	150		pS/m	ISO 6297:1997	
Cu strip corrosion (3h at 50°C)	class 1		rating	EN ISO 2160:1998	
Density at 15°C	820.0	860.0	kg/m3	EN ISO 12185:96/C1:01	
Dist: Temp. at 65% V/V rec.	250.0		°C	EN ISO 3405:2000	
Dist: Temp. at 85% V/V rec.		350.0	°C	EN ISO 3405:2000	
Dist: Temp. at 95% V/V rec.		385.0	°C	EN ISO 3405:2000	
Dist:Recovery	98.0		% V/V	EN ISO 3405:2000	2
Dist:Residue		2.0	% V/V	EN ISO 3405:2000	2
Flash point	61.0		°C	EN ISO 2719:2002	
Lubricity (WSD 1,4) at 60°C		460	µm	EN ISO 12156-1:2000	
Odour	normal		-	PRR 0009:1999	
Oxidation stability		15	g/m³	EN ISO 12205:1996	
Sediment content (Extraction method)		0.05	% m/m	EN ISO 3735:1999	
Sulphur content		0.20	% m/m	EN ISO 8754:2003	
Total Acid number		0.30	mg KOH/g	ISO 6619:1988	
Total contamination		24	mg/kg	EN 12662:1998	
Viscosity at 40°C	2.000	4.000	mm2/s	EN ISO 3104:96/AC:99	
Water content		175	mg/kg	EN ISO 12937:2000	

Comments:
1. If not clear and bright, appearance max 2 is accepted. Reference method ASTM D 4176, procedure 2.
2. Dist. recovery or dist. residue to be reported on CQ.

Figure 15: Properties of MGO[2]

Product Specification: GREENLANDIC ARCTIC GASOIL -22/-27

Property	Limit Min	Limit Max	Unit	Ref. Method	Com.
Appearance at 20°C	clear and bright		-	Visual inspection	
Appearance at 20°C		2	rating	ASTM D 4176-04	1
Ash content		0.010	% m/m	EN ISO 6245:2002	
Carbon residue (on 10% dist res)		0.15	% m/m	EN ISO 10370:1995	
Cetane index	45.0		-	EN ISO 4264:1996	
Cetane number	47.0		-	EN ISO 5165:1998	
Cloud point		-22	°C	EN 23015:1994	
Cold Filter Plugging Point		-27	°C	EN 116:1997/AC:1999	
Colour (ASTM scale)		1.5	-	ISO 2049:1996	
Conductivity	150		pS/m	ISO 6297:1997	
Cu strip corrosion (3h at 50°C)	class 1		rating	EN ISO 2160:1998	
Density at 15°C	810.0	840.0	kg/m3	EN ISO 12185:96/C1:01	
Dist: Temp. at 10% V/V rec.	180.0	230.0	°C	EN ISO 3405:2000	
Dist: Temp. at 95% V/V rec.		340.0	°C	EN ISO 3405:2000	
Flash point	61.0		°C	EN ISO 2719:2002	
Lubricity (WSD 1,4) at 60°C		460	µm	EN ISO 12156-1:2000	
Odour	normal		-	PRR 0009:1999	
Oxidation stability		15	g/m³	EN ISO 12205:1996	
Sediment content (Extraction method)		0.05	% m/m	EN ISO 3735:1999	
Sulphur content		10	mg/kg	EN ISO 20884:2004	
Total Acid number		0.30	mg KOH/g	ISO 6619:1988	
Total contamination		24	mg/kg	EN 12662:1998	
Viscosity at 40°C	1.500	3.000	mm2/s	EN ISO 3104:96/AC:99	
Water content		175	mg/kg	EN ISO 12937:2000	

Comments:
1. If not clear and bright, appearance max 2 is accepted. Reference method ASTM D 4176, procedure 2.

Figure 16: Propreties of AGO [2]

Product Specification: GREENLANDIC UNLEADED GASOLINE M95

Property	Limit Min	Limit Max	Unit	Ref. Method	Com.
Appearance at 20°C	clear and bright		-	Visual inspection	
Benzene content		1.0	% V/V	EN 238:1996/A1:2003	
Colour	undyed		-	Visual inspection	
Conductivity	300		pS/m	ISO 6297:1997	
Cu strip corrosion (3h at 50°C)	class 1		rating	EN ISO 2160:1998	
Density at 15°C	725.0	780.0	kg/m3	EN ISO 12185:96/C1:01	
Dist: Evaporated at 70°C	20.0	45.0	% V/V	EN ISO 3405:2000	
Dist: Evaporated at 100°C	46.0	70.0	% V/V	EN ISO 3405:2000	
Dist: Evaporated at 150°C	75.0		% V/V	EN ISO 3405:2000	
Dist: Evaporated at 180°C	85.0		% V/V	EN ISO 3405:2000	
Dist:FBP		215.0	°C	EN ISO 3405:2000	
Dist:Residue		2.0	% V/V	EN ISO 3405:2000	
Gum content (solvent washed)		5	mg/100ml	EN ISO 6246:1997	
Lead content		5	mg/l	EN 237:2004	
Octane number, RON	95.0		-	EN ISO 5164:2005	
Octane number, MON	85.0		-	EN ISO 5163:2005	
Oxidation stability	360		minutes	EN ISO 7536:1996	
Oxyg: MTBE content		0.5	% V/V	EN 13132:2000	1
Sulphur content		10	mg/kg	EN ISO 20884:2004	
Vapour Lock Index, VLI		1250	-	Calculated	
Vapour Pressure (DVPE)	65.0	100.0	kPa	EN 13016-1:2000	

Comments:
1. MTBE or other oxygenates may not be added.

Figure 17: Properties of gasoline [2]

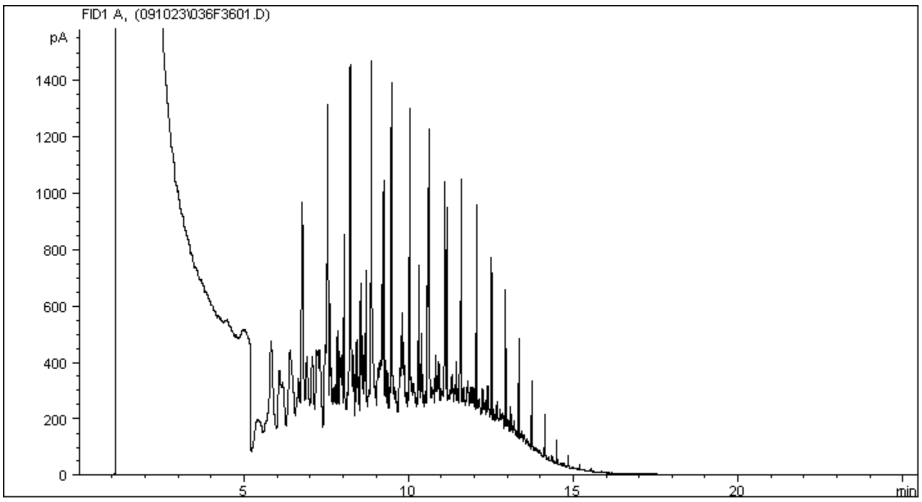

Figure 18: GS analysis of MGO from FSD, Sisimut

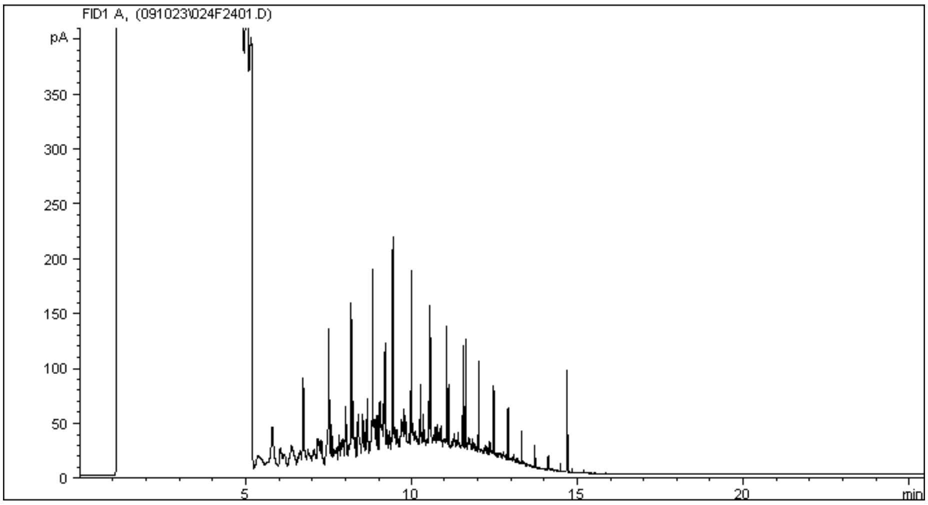

Figure 19: GS analysis of AGO from FSD, Sisimiut

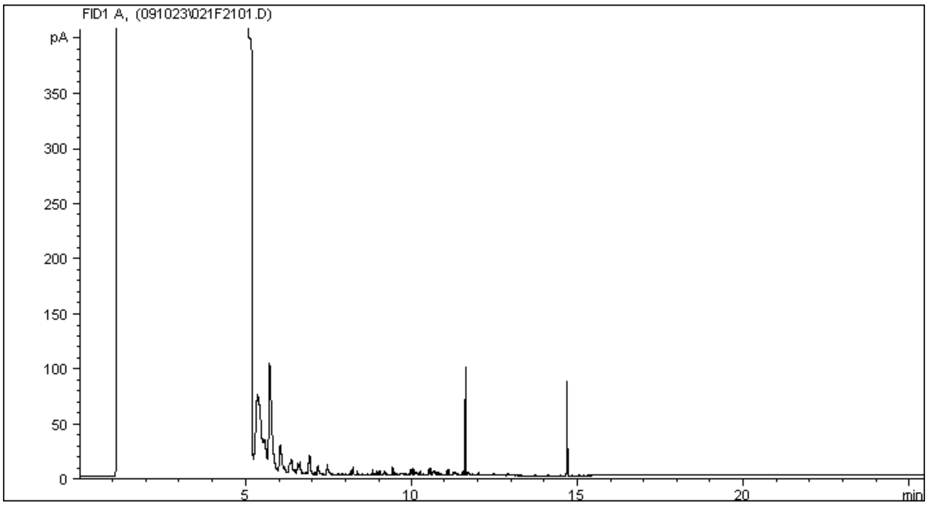

Figure 20: GS analysis of gasoline from FSD, Sisimiut

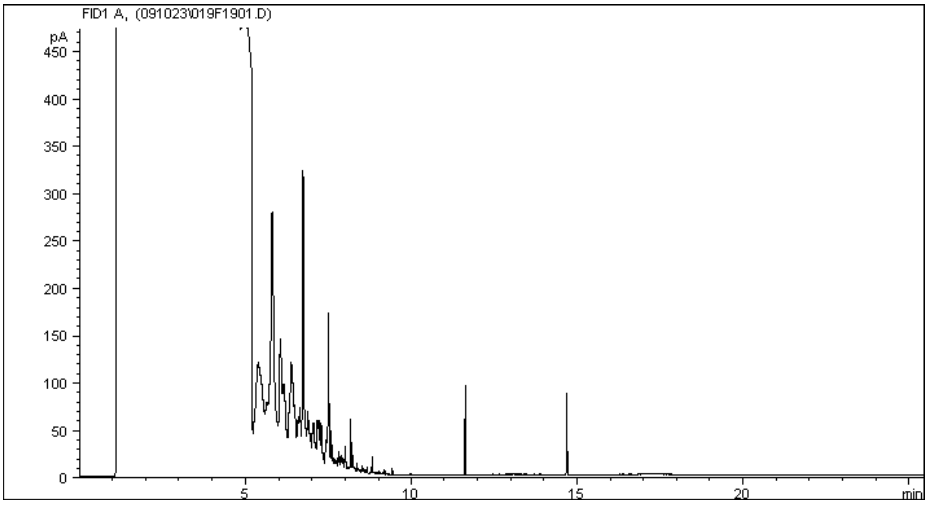

Figure 21: GS analysis of Jet A-1 from Sisimiut Airport

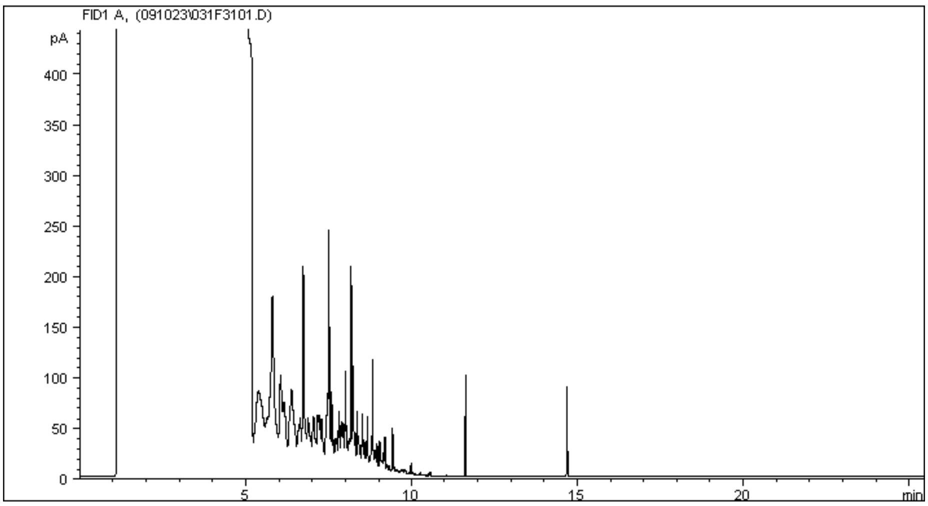

Figure 22: GS analysis of Jet A-1 form Kangerlussuaq Airport

5 “Green alternative”for fossil fuels and energy production in Greenland

The strong dependence on import of fossil fuels, causes Greenland to become increasingly focused on developing the renewable sources of energy. Hydro power is the main and also the most promising renewable source in Greenland, with potential of approximatly 800,000 GW/h per year. More than 15 large potential sites for hydroelectric power stations for both consumer and industrial purposes have been pinpointed, comprising a total potential of 13,000 GW/h per year. Thus, the international aluminum industry is currently investigating the investment potential of Greenland in this area. The most attractive places for industrial hydro power are located along the western edge of Greenland's Ice Cap, between 62 and 68 degrees north. In this part of the island the vast interior reservoir contain energy potential around 600-2500 GW/ h per year each. The highly attractive reservoirs are: Tasersiaq, Imarsuup Isua, Soendre Isortup Isua and Tasersuup Isua (Figure 23)[9].

Figure 23: Location of attractive reservoirs [9]

The first hydro power plant was inaugurated in Buksefjorden near Nuuk in 1993, one year before launch of the incineration plant in Qaqortoq. Consumption of renewable energy has generally been increasing since 1992. But on the other hand, consumption of fossil fuels was increasing approximately at the same pace as production of renewable energy, in the parallel time. In 2007, renewable energy production was 859 TJ, which corresponded to 8.89% of total energy consumption. Hydro power was 89.1% of the total production from renewable sources(Table 4). Total heat production from the incineration plants was 87 TJ, which constituted 10.9% of total renewable energy production and almost 1% of total energy. Other renewable energy sources represent a very small share in total energy consumption, but they may have influence in isolated settlements or households. The minority sources of ”green energy” are mini-wind turbines, solar energy and burning of fish oil. The statistics for these sources are not available currently.

As it is known, most of the fossil fuels are used for production of electricity, heating, and transportation. Let's look what kind of possibilities there are in order to reduce consumption of fossil fuels.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total consumption	8392	8596	8093	8305	9430	8808	8277	9070	9296	9372	9660	9663
Total renew. en.	697	647	683	702	697	647	729	726	780	798	784	859
Hydro power	594	554	580	617	616	567	654	647	780	798	784	859
Waste	103	93	103	85	81	80	75	79	89	87	–	–

Table 4: Renewable energy consumption in TJ [3, 4]

At first we shall consider transportation. Infrastructure is very poor. Total length of Greenland's road is just around 100 km. Majority of the public road network is located in the capital city, Nuuk. Roads are built up only in the towns. There are no roads between towns. An exception are dirt roads connecting sheep farms in South Greenland. Transportation of passengers and freight takes place with ships or aircrafts. Actually, in the transportation area there are no large possibilities of replacement of even reduction of use of fossil fuels in near future.

5.1 Electricity and heat production in Greenland

Let's focus on the areas where consumption of oil products is large, i.e. electricity and heat production. The main company which is responsible for production of electricity and heat is Nukissiorfiit. Nukissiorfiit means "where energy is generated." Nukissiorfiit is one of Greenland's largest companies, and its main task is to produce and distribute electricity, water and heat to the society. This is handled by 14 local branches that are responsible for 17 towns and 54 settlements (excluding Kangerlussuaq, Narsarsuaq and Ivittuut). Nukissiorfiit's vision is to develop sources of energy that are environmentally friendly in the best and less expensive possible manner for society, and to reduce dependency on oil products. The other major task is to keep electricity and heat supply safe, especially that Nukissiorfiit's serve as building blocks. Nukissiorfiit employs approximately 400 people[10].

Roughly half of the energy that Nukissiorfiit produces comes from hydroelectric plants. Today, Nukissiorfiit operates three hydroelectric facilities that supply four towns - Nuuk, Tasiilaq, Qaqortoq and Narsaq - with clean, green energy. A fourth hydroelectric plant is under construction in Sisimiut and will be ready for production in the year 2010. There are also ongoing efforts to build a number of additional hydroelectric facilities in the country. In fall 2009, the Home Rule Goverment will decide if it is possible to build a hydro power plant north from Ilulissat (the third town in Greenland).The rest of the energy Nukissiorfiit is producing is produced using imported diesel fuel. Especially the smaller towns and settlements are dependent on diesel based energy supply, and many of them do not have the possibility to establish hydro power facilities or other types of renewable energy in larger scale. Furthermore, diesel fuel energy production is also used as backup in the towns that are supplied from hydro power these days. Besides the significant emissions from use of diesel fuel, the dependency of imported oil products is a challenge for Greenlandic society in near future, especially that in long term the crude oil will be scarce and expensive. The first symptom of future problems was the considerable rise of crude oil price in 2008, which resulted in an increase of the diesel fuel price in Greenland and thus increased energy costs for the customers. Nukissiorfiit does not concentrate only at development of hydro power sources, but it tries to go a bit forward. That is why in 2009, in cooperation with H_2 Logic A/S, Nukissiorfiit has started an exciting project, called H_2KT, in order to enable increase the use of renewable energy in Greenland. The aim of H_2KT project is to establish a hydrogen and fuel cell plant in Nuuk and get the first experience in use of new technologies and opportunities for storing renewable energy. Storage is needed to balance the seasonal fluctuations in energy consumption and to make possible distribution of energy into towns and settlements without local potential for production of green energy. That is why H_2KT project will be investigating opportunities of using hydrogen as a fuel. The idea is to use surplus of electricity from the hydro power station at Buksefjord (Nuuk) to split water into hydrogen and store it. In the periods when energy consumption is higher, usually during winter time, the stored hydrogen is converted to electricity and heat in a fuel cell power plant. In future the hydrogen could be distributed to towns and settlements where it is not possible to produce renewable energy. Production of hydrogen and fuel cells technology may replace completely use of oil products in energy production and transportation, and even export of hydrogen may also be possible in the future [10].

Figure 24: Visualization of the fuel cell plant in Nuuk [10]

5.2 Electricity and heat production in Sismiut

Production of electricity in Sismiut is based on two diesel generator power plants. Currently, only one of them is in use, and the other is treated as a backup plant in case of failure of the first one. The main power plant is located close to the harbor and consists of three diesel generators, i.e.

- 2 x Burmeister & Wain , type 9S35P , 3300 kW each, 600 rpm
- 1 x Catepilar, type 3516 HD 1860 kW ,1500 rpm

The backup power plant consists of following diesel generators:

- 2 x Burmeister & Wain, type 26 MTB-40 , 900 kW ,600 rpm
- 1 x Catepilar, type 3516 HD 1860 kW ,1500 rpm

Supply of the district heating in Sisimiut comes from surplus heat from electricity production, surplus heat from the incineration plant (owned by the municipality) and from following heating stations:

Heating station 1:

- 2 x Danstoker oil boilers, 925 kW each.
- 1 x Danstoker oil boiler, 1200 kW.

Heating station 2:

- 2 x Heto oil boilers, 600 kW each.
- 2 x Heto oil boilers, 750 kW each.

All the boilers in heating station 2 will be soon replaced by:

- 2 x electric boilers, 600 kW each.
- 2x new oil boilers, 1000 kW each.

This replacement is done in order to commission the power plant to neighborhood of Sismiut.
Heating station 3:

- 2 x Danstoker oil boilers, at about 825 kW each.
- 1 x Danstoker oil boiler, at about 600 kW.

Heating station 4:

- 2 xTasso oil boilers, at about 750 kW each.

The surplus heat from the electric power plant comes from 3 flue gas boilers:

- 2 x DDS flue gas boilers, at about 1500 kW.
- 1 x Danstoker flue gas boiler, at 989 kW.

Figure 25: Fasilities of power plant

For production of electricity and heat, Nukissiorfiit uses two different types of diesel fuel which is delivered by Polaroil. There are Automotive Motor Gasoil (MGO) -8/-20 and Arctic Gasoil -22/-27 AGO. The MGO fuel is used in the towns south of Ilulissat during summertime and AGO in the winter time. Nuuk, Narsaq and Qaqortoq, however, (that all are situated south of Ilulissat) uses AGO the whole year around, because these towns have hydro power plants as their main source of energy. That is why, use of diesel fuel for heat and electricity production is marginal. And there is no need to empty the tanks during the summer season. All towns and settlements north of Ilulissat (including Ilulissat) uses AGO for the whole year. The differences and properties of MGO and AGO were mentioned in the section 4. As long as diesel fuel has good resistance against low temperature, there is no other particular problems with production of heat and electricity in Greenland, even during winter time. Nuissiorfiit poses a plenty of extra capacity in all serve towns and settlements, to continue production when the cold and dark winter comes and supply with fuels is impossible. However, one thing causes that energy production in Greenland is a bit more challenging compared to other countries. Greenland has many small communities spread out over area size of Western Europe and lack of road connection between towns and settlements. Hence, it is necessary to have production plants and full backup in all towns. This causes that energy supply is very expensive. On the other hand backup is however crucial, if one plant/machine will break down, it is impossible to get energy from another town, and of course delivery of new machines/parts takes a lot of time. Especially when one takes into account that Greenland is so isolated and some harbours are inaccessible for up to 11 months a year because of ice cover. Good planning and being at least one step in before of every possible accident is very crucial.

5.3 Sismiut hydropower plant

The construction of Sisimiut hydro power plant started in the summer of 2007. Icelandic company Istak is responsible for design and construction of the plant, including supply of all equipment such as turbines, sluice gates, electrical equipment, pylons and high voltage lines. The building costs are about 500 million Dkk. The water from the large lake Taserssuaq will

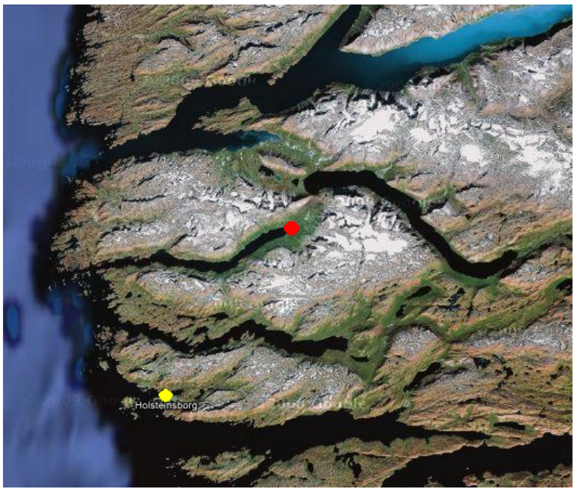

Figure 26: Location of hydro power plant

be used to supply power station, which is located at the end of the Kangerluarsuk Ungalleg fiord (in Danish "2. fjorden", in English "the 2nd fjord"), north from Sisimiut (see map, ref). The water from the lake will be running in the pipes through a 4.7 km long blasted tunnel. The two water turbines have been placed in an underground cavern at the end of the fjord. The elevation difference between the lake and the fiord is about 80 meters. The water from the turbines will be passing into the fjord below sea level. Near the entrance to the power station, a building has been built in which there will be accommodation facilities for service personnel, as well as an equipment store-room and a workshop. Between the plant and Sisimiut, pylons with 27 km long high voltage line (60 kV) are erected. At the end of the high voltage line at Sisimiut, a transfromer station has been built (building next to the road to the airport) for connecting the plant to the town's electrical system. The powerplant have two 7.5 MW turbines each, and it will be able to produce 58.000 MWh electricity per year. This amount will be enough to provide electricity to the whole town for many years. The power plant is going to work whole year around, except periods when it will be closed for inspection.

The plant is expected to be commissioned at the beginning of 2010, and with the power output of 15 MW, it will be the second largest hydro power plant on the island , after Buksefjorden plant (45 MW). The next big hydro power plant that Nukissiorfiit is planning to build till 2014, is placed outside Ilulissat with capacity of 22.5 MW. Main technical data of Sisimut Hydropower Plant:

- Turbines: 2 x 7.5 MW, Francis
- Production capacity: 58 GWh/year
- Area for water uptake: 862 km?
- Precipitation, Tasersuaq: About 340 million $m\hat{3}$/year
- Dam: There is no dam
- Maximal elevation difference: 78,6 m
- Fed & pressure tunnels: 4.680 m
- Tunnels in all: 5.130 m
- Transmission line: 60 kV, 82 pylons, 27.4 km

When the hydro power plant starts production, the diesel generation plants will become backup plants. In 2008, Nuissiorfiit used about 6.5 million liters of diesel fuel for electricity and heat production in Sismiut, which now will be replaced with green energy from the water in the lake Tasersuaq. With these days fuel price, it will be possible to save around 28 million Dkk per year, and of course gain a large environmental benefit.

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Appendix

A Certificates of aviation fuels

STATOIL

Statoil A/S
Teknisk Service
Borgmester Christiansensgade 50
2450 København SV
Tlf. +45 33 42 40 10

Statoil A/S
Laboratoriet
Raffinaderiet
DK-4400 Kalundborg
Tlf. +45 59 57 45 00

REPORT: Jet A1 Periodic Test Compare.

Analyse rapport nr.: 090006

101C/Order nr.: **Rekvirent:** Fly **Kunde:** Statoil A/S, Postbox 1003, 3910 Kangerlussuaq, Grønland **Att.:** Ivan Hansen	**Received date: 20-01-2009** **Drawn date** 13-01-2009 **Tank no:** 1 T,M,B **Product recived:** 01-08-2007 **Quantity at present:** 4993 m^3

Nr	Property	Test meth.	Checklist limits	Previous Test data	Present Test data	Accept diff.
01	Report no.			080111	090006	-
02	Apperance	Visual	C&B	B&C	B&C	-
03	IBP °C	D 86	Report	152,2	149,3	8
04	10 % Recov °C	D 86	205,0 max	163,7	164,5	8
05	50 % Recov °C	D 86	Report	184,6	185,2	8
06	90 % Recov °C	D 86	Report	230,7	232,4	8
07	FBP °C	D 86	300,0 max	257,4	257,0	8
08	Flash point °C	IP-170	38,0 min	40,5	40,0	3
09	Density at 15 °C kg/m	D 4052	775,0-840,0	806,2	806,7	3,0
10	Cu Corrosion, 2 hr/100 °C	D 130	1 max	1a	1a	max
11	Ex.gum mg/100 ml	D 381	7 max	<1	<1	3
12	Elek.conductivity pS/m at °C	D 2624	50min600max	60 @ 22	100@22	Limit
13	Water Sep. Mod. MSEP	D 3948	>=70	86	86	Limit

This product meets the latest issue of Aviation Fuel Quality Requirements for Jointly Operated Systems (Joint Fuelling). System Check List for Jet A1) and complies with the latst issue for DEF STAN 91/91.

Kommentar:

Batch Recertification approved by Lola P[illegible]

Date 20-01-2009

APPROVED
STATOIL A/S
LABORATORY
KALUNDBORG

Satisfactory for Use in Aircraft

[illegible] RESULTS HAVE BEEN COMPARED WITH THE LAST PREVIOUS ANALYSIS MADE ON THE FUEL, AND NO SIGNS OF CONTAMINATION HAVE BEEN FOUND

STATOIL

Statoil A/S
Teknisk Service
Borgmester Christiansensgade 50
2450 København SV
Tlf. +45 33 42 40 10

Statoil A/S
Laboratoriet
Raffinaderiet
DK-4400 Kalundborg
Tlf. +45 59 57 45 00

REPORT: AVGAS 100LL Periodic Test Compare.

Analyse rapport nr.: 090057

101C/Order nr.: **Rekvirent:** Fly **Kunde:** Statoil A/S Postbox 1003 3910 Kangerlussuaq Grønland **Att.:** Ivan Hansen	**Received date: 29-04-2009** **Drawn date** 20-04-09 **Tank no:** 110 T, M, B **Product recived:** 27-10-08 **Quantity at present:** 39 m^3

Nr	Property	Test meth.	Checklist limits	Previous Test data	Present Test data	Accept diff.
01	Report no.			080153	090057	-
02	Apperance	Visual	C&B	B&C	B&C	-
03	Colour	Visual	Blue	Blue	Blue	
04	Knock rating	D 2700	99,5 min	104,8	105	3
05	TEL content g Pb/l	ASTM D	0,56 max	0,54	0,54	0,05
06	IBP °C	3341	Report	34,1	34,8	8
07	10 % Evap °C	D 86	75,0 max	61,9	62,8	8
08	40 % Recov °C	D 86	75,0 min	96,0	96,3	8
09	50 % Recov °C	D 86	105,0	102,7	102,9	8
10	90 % Recov °C	D 86	135,0 max	122,3	121,9	8
11	FBP °C	D 86	170,0 max	152,2	151,9	8
12	Sum of 10+50%evp	D 86	135,0 min	164,6	165,7	8
13	Recovery % vol	D 86	97 min	97,3	98,0	8
14	Residue	D 86	1,5 max	1,5	0,8	
15	Loss % vol	D 86	1,5 max	0,9	1,2	
16	RVP	D 86	38,0-49,0	46,2	46,0	4,5
17	Density at 15°C kg/m3	D 323	Report	708,2	708,2	3.0
18	Cu Corrosion, 2 hr/100 °C	D 1298	1 max	1a	1a	max
19	Ex.gum mg/100 ml	D 130	3,0 max	<1	2	3
		D 381				

This product meets the latest issue of the Avgas 100 LL specification DEF STAN 91/90.

Kommentar:

Batch Recertification approved by Lo[illegible]

Date 01-05-2009

APPROVED
STATOIL A/S
LABORATORY
KALUNDBORG

Satisfactory for Use in Aircraft.

ABOVE TEST RESULTS HAVE BEEN COMPARED WITH THE LAST PREVIOUS ANALYSIS MADE ON THE FUEL, AND NO SIGNS OF CONTAMINATION HAVE BEEN FOUND

STATOIL

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Teknisk Service
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2450 København SV
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Laboratoriet
Raffinaderiet
DK-4400 Kalundborg
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REPORT: Jet A1 Recertifikation Analyse

Analyse rapport nr.: 070119

101C/Order nr.: Rekvirent: Fly Kunde: Statoil A/S Postbox 1003 3910 Kangerlussuaq Grønland Att.: Ivan Hansen Loading port.: Mongstad Tank/batch no: 200701174 Vessel: Future	Received date: 16-08-2007 Drawn date 03082007 Tank no: 1 t,m,b Quantity before: Tom m^3 Quantity received: 7523856 m^3 Quantity after: 7523856 m^3

Nr	Property	Test meth.	Checklist limits	Previous recert.	Cert. of analyse	Present Recert.	Acce pt diff.
01	Report no.			TOM	SM 384600	070119	-
02	Apperance	Visual	C&B		B&C	B&C	-
03	IBP °C	D 86	Report		150,8	149,5	8
04	10 % Recov °C	D 86	205,0 max		163,9	164,6	8
05	50 % Recov °C	D 86	Report		185,2	184,6	8
06	90 % Recov °C	D 86	Report		232,1	231,9	8
07	FBP °C	D 86	300,0 max		257,8	256,7	8
08	Residue % vol	D 86	1,5 max		1,0	0,8	-
09	Loss % vol	D 86	1,5 max		0,8	1,0	-
10	Flash point °C	IP-170	38,0 min		42,5	42,0	3
11	Density at 15°C kg/m3	D 4052	775.0-840.0		806,5	806,8	3.0
12	Freezing Point	D 2386	-47,0 max.		-60,4	-61,7	3.0
13	Cu Corr, 2 hr/100 °C	D 130	1 max		1a	1a	max
14	Ex.gum mg/100 ml	D 381	7 max		<1	<1	3
15	Elek.conductiv pS/m °C	D 2624	50min600max		374@19	150@25	Limit

This product meets the latest issue of Aviation Fuel Quality Requirements for Jointly Operated Systems (Joint Fuelling). System Check List for Jet A1) and complies with the latest issue for DEF STAN 91/91.

Kommentar:

Batch Recertification approved by Lola Petersen

Date 19-08-2007

APPROVED
STATOIL A/S
LABORATORY
KALUNDBORG

Satisfactory for Use in Aircraft.

ABOVE TEST RESULTS HAVE BEEN COMPARED WITH THE LAST PREVIOUS ANALYSIS MADE TO THE FUEL AND NO SIGNS OF CONTAMINATION HAVE BEEN FOUND.

B Material Safety Data Sheet, Stadis 450

SAFETY DATA SHEET
STADIS (R) 450

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND COMPANY/UNDERTAKING

PRODUCT NAME:	STADIS (R) 450
PART No.:	*PSST450
IN-HOUSE No.:	Petroleum Specialties
APPLICATIONS:	Antistatic additive for use in distillate fuels.
SUPPLIER:	The Associated Octel Company Limited PO Box 17 Ellesmere Port Cheshire CH65 4HF ENGLAND Tel: +44 (0)151-355-3611 Fax: +44 (0)151-356-2349
CONTACT PERSON:	CHINA: +86 10 6800 1019 ENGLAND: +44 (0)151-355-3611 FRANCE: +33 (0)2.32.64.35.35 GERMANY: +49 (0)2325-9800 ITALY: +39 02 93 30 94 1 SINGAPORE: +65 6336 6286 SOUTH AFRICA: +27 21 701 5340 / 5906 SWEDEN: +46 54 67 0450
EMERGENCY TELEPHONES:	(24 hour): +44 (0)151 355 3611

2. COMPOSITION/INFORMATION ON INGREDIENTS

NAME CAS No.:	EINECS Nr.:	CLASSIFICATION	CONTENT
TOLUENE 108-88-3	203-625-9	Xn ,F R-11, 38, 48/20, 63, 65, 67 Rep3	30-60 %
SOLVENT NAPHTHA (PETROLEUM), HEAVY AROMATIC 64742-94-5	265-198-5	Xn ,N R-51/53, 65, 66, 67	10-30 %
DINONYLNAPHTHYLSULPHONIC ACID 25322-17-2	246-841-9	Xn R-22, 36/38	10-30 %
TRADE SECRET POLYMER CONTAINING SULPHUR		- Not classified.	10-30 %
TRADE SECRET POLYMER CONTAINING NITROGEN		- Not classified.	5-10 %
PROPAN-2-OL 67-63-0	200-661-7	Xi ,F R-11, 36, 67	1-5 %
NAPHTHALENE 91-20-3	202-049-5	Xn ,N R-22, 40, 50/53 Carc3	1-5 %