USE IT OR LOSE IT

INDUSTRIAL WASTE HEAT OR NUCLEAR POWER HEAT TRANSPORTED BY TANKERS TO CITY DISTRICT HEATING SYSTEM

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TABLE OF CONTENTS

Executive Summary

Our proposed solution is to transport hot water with reliable upgraded and insulated ice-classed oil tankers (shuttle tankers) to the City of Helsinki´s district heating system. The shuttle tankers could be Finland´s National Emergency Supply Agencies ice-classed tanker fleet which could be used for 15-20 more years in this water trade after they have been out phased from the existing oil trade. The shuttle tankers will have a capacity to pump in heat to the district heating system up to 1000 MW for 3-4 hours with a temperature of 95-100°C per ship. This means that the shuttle tankers will also be used as energy batteries for the city´s district heating system. The heat input to the district heating system can therefore be optimized based on the needs. Using these reliable types of ships which have been supplying Finland with oil without any problems even during strong ice winters will this heat transport with ships be a reliable way to get CO_2-free heat delivered to Helsinki when it is needed.

Our system needs to have only one or two heat exchangers connected to the district heating system where the ships could discharge the heat in Helsinki. No land area is needed for this system nor any changes are needed to the existing district heating system. The hot water can be sourced from the close-by nuclear power plant in Loviisa or the industrial area in Kilpilahti. It will take about 5 or 7 hours with the intended shuttle tankers to bring in the heat from the above-mentioned sources and the number of shuttle tankers should be optimized based on the need of heat as well as the possible loading speed at the heat source.

The shuttle tankers will be insulated with our patented ~~insulation~~ method which will keep the hot water´s temperature almost unchanged during the voyage. The water onboard the shuttle tanker during discharging will be pumped through the heat exchanger in Helsinki to an empty tank onboard which means that the temperature of the water on board after the discharging of the heat to the district heating system will be about 40°C. At the loading place, it will be done the opposite way and the 40°C water will be pumped through the heat pump where it will be heated up to 95-100°C and pumped to an empty tank onboard. This will continue until all tanks water is heated up except one tank which is left empty. The transportations CO_2-footprint is small because the shuttle tankers propulsion machinery consumption is equal to about 1% or less of the energy they transport. The ships will be upgraded with the gas-driven main engine which could run on Liquified Biogas (LBG) and also install the modern type of sails (rotor sails) on deck to reduce the fuel consumption with about 10% to further minimize the CO_2-footprint. We could use different sized vessels but minimum 3-6 pieces of 25.000 to 100.000-ton deadweight shuttle tankers are needed to have a continuous delivery of heat between 200 to 1000 MW.

The heat sources can be direct hot water of about 120°C from a Combined Heat and Power (CHP) nuclear power plant or by using industrial heat pumps which will use about 25°C industrial cooling water or nuclear power cooling water as heat input. CHP nuclear power heat is a cost-effective way to get heat provided the heat is needed all the year-round. But in most cases, the need for district heat is seasonal which also reflects the sales price of the district heat. A combination of CHP and low-temperature waste heat using heat pump technology or heat pump technology alone is a solution for cost-effective CO_2-free heat delivery. To have possibilities to choose different heat sources as well as maximizing the profitable sale of CO_2-free heat the heat pumps should be placed on board a ship which can be moved from one heat source to another as well as moved into Helsinki during the summer period to produce cooling when the delivery of hot water is not needed.

The heat pump can be of dual-type which will run on electricity from shore and by LNG/LBG powered generators onboard the heat pump ship. By doing so can the heat pump power be optimized based on the electricity and fuel prices. When using 25°C cooling water as heat input to the heat pumps the COP will be high and therefore an economical way to produce 95-100°C hot water.

The price of the CO_2-free heat delivered to Helsinki will be around 30 €/MWh including taxes, investments, the power needed and running costs. Our system can be beneficially implemented within two years and in steps according to the City of Helsinki`s need. In addition to this economically sound heat delivery system requiring relatively small investments can the CO_2-free heat production and delivery be optimized hourly, daily, weekly and seasonally by the district heat sales prices.

Implementing this system will lead to creating direct new jobs and also lead to indirect jobs namely in the form of support services as well as industry supplying types of machinery, pumps, electric motors, compressors automatization etc. Besides, all the upgrading works on the oil tankers and heat pumps which should be done at Finnish shipyards which also will create a lot of jobs for the Finnish Market. This will even expand when exporting this system to other cities where CO_2-free heat, as well as cooling, is needed. With the heat pumps onboard ships can some of the units be used in other cities during the summer period in case the cooling need is not as high as the heating need.

Also, our sea transport solution has a zero impact (when using LBG as fuel) on natural resources, besides, it will be safe because the ships transport only water and the nuclear cooling water will be disconnected from the city district heating system which demonstrates that our solution is highly reliable and risk-free with no chance of radioactive contamination.

One of the main benefits of this system is the fact that the required heat can be obtained from different suppliers and can also be combined using different sources. This ensures the continuous supply of the needed amount of energy. The water tankers can also be used as energy storage units and this stored energy can be optimized and pumped into the city district heating system exactly when it is required. The detailed process of how the system works is explained in the below section 1.2.

Two, this low investment heat delivery project is economical since it can be stopped during the summer period when no heat is needed because CAPEX is small and most of the cost involved is OPEX related, which can be reduced to a minimum when delivery has seasonal stop according to the need of heat in Helsinki.

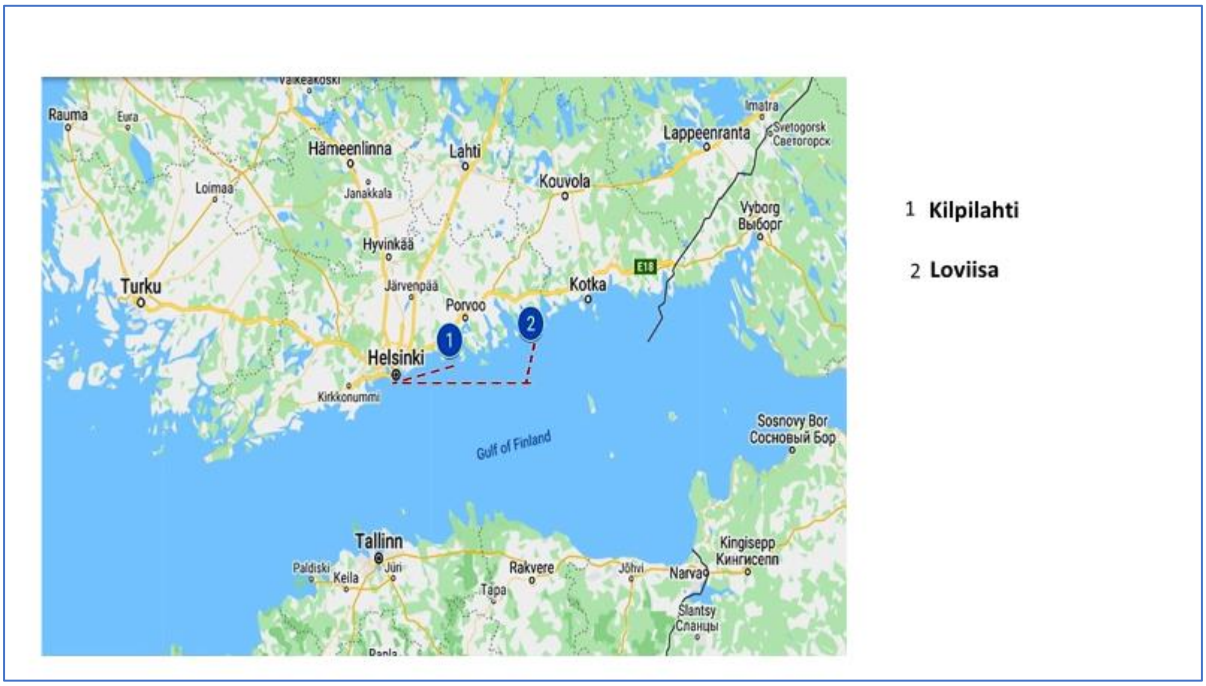

Figure 1 Sources of energy to Helsinki

1 Introduction

1.1 Purpose of this document

USE IT OR LOSE IT is an energy system being developed by this team over the last decade. It has been adapted to meet the energy requirements called for by the Helsinki Energy Challenge. In this document will we describe in detail how we will bring in cost-efficiently up to 1000 MW CO_2 heat to the City of Helsinki when it is needed.

1.2 Technology- How it Works?

The heat energy will be stored in hot water onboard the shuttle tankers. This because water is one of the best media to store heat in and it is environmentally friendly. Its heat capacity is 4.2 kJ/kg°C, which is about 4 times more than concrete´s heat capacity and it is mainly hydrogen and helium which have higher heat capacity than water per kg. It will have a temperature between 40 and 95-115°C and will always be onboard stored in the cargo tanks but pumped through the heat exchanger/heat pumps during loading and through heat exchangers during discharging.

To transport with shuttle tankers hot water of about 95-115°C without losing the energy especially during the cold season, good insulation of the tanks is needed. We have developed and patented a heat insulation system, the patented tank system which has been tested up to 200°C with a heat loss of only 68W/m2 and it can easily be adjusted to about 30W/m2 or even less. This insulation can be applied to the inside of the tanks, which gives us the possibility to convert standard oil tankers for hot water transportation. Currently, this insulation method is been used in fifteen large vessels worldwide which are fully operational, which proves it is proven technology. Therefore, standard oil tankers can be converted for this purpose without substantial investment. We will use secondhand ice-classed oil tankers which will be upgraded to this hot water trade and we call them shuttle tankers.

The shuttle tankers water cargo will be pumped through a heat exchanger or heat pump from one full tank to an empty one in a sequential manner in a continuous flow until all the tanks water on the tanker are heated up expect one tank which is left empty. In practice, it means that the ship's water goes into the heat exchanger/heat pump with about 40°C and comes out to the empty tank in 95-115°C. The shuttle tanker´s all water cargo will be heated up to 95/115°C at the heat pump ship and/or nuclear power plant. In Helsinki, this procedure will be done in the opposite way when pumping out the heat to the district heat system via a heat exchanger. The shuttle tanker will return from Helsinki to the heat pump ship and/or nuclear power plant still fully loaded but with only 40°C water. It is worth to note the water onboard is always the same. To have the transport chain with reduced or complete CO_2 free or reduced the best energy supply as LNG or LBG must be chosen for this trade in addition to the reduction of power needed for the propulsion system using wind rotating sails.

In case the hot water will be supplied from Loviisa nuclear power upgraded to CHP plant will the temperature of the available water be about 120°C and the loading of the energy will be done through the heat exchanger at the nuclear power plants vicinity.

Most probably will we use low-temperature waste heat from Kilpilahti industrial area or/and Loviisa nuclear power plant. This low-temperature waste heat will be used as a heat source for the EPV which have many heat pumps combined to be able to produce 200 MW heat continuously, to heat up the water tankers return cargo water (40°C) to about 95°C. We have here presented 200 MW sized for calculation purpose but other sizes can also be used. This 200 MW heat pump ship will have LNG/LBG driven 45 MW power plant to be able to work autonomously if shore power is not available or when the electricity price is too high. We will have up to 5 pieces of these EPV´s distributed in Kilpilahti and/or in Loviisa to be able to deliver 1000 MW heat continuously when it is needed. The EPV´s can be moved to another heat supplier if needed but the main idea is to have the possibility to use the heat pump´s also for cooling purpose in Helsinki during the summer period when the heat is not needed. The shuttle tankers will be laid up when no heat is needed to be delivered to Helsinki.

1.3 Transport from the heat source to Helsinki

The transport of the energy from the close buy Kilpilahti Industrial area or/and Loviisa nuclear power plant to Helsinki will be done with shuttle tankers.

1.3.1 Shuttle tankers

The shuttle tankers that can be used would be standard oil tankers with ice-class[1] for trading in Finnish winter conditions preferable with a loading capacity of 40-50.000 ton. To deliver 1000 MW from Kilpilahti industrial area or/and Loviisa nuclear power plant to Helsinki is as a minimum 6 (+2 back up) shuttle tankers with a capacity of above sizes needed. The sizes can vary from this, but then could the number of vessels also change. Finland´s National Emergency Supply Agency (NESA) are the owners of an ice-classed oil tanker fleet which is in extremely good condition and will be phase out from the oil trade within 1-2 years which could be suitable for this water trade. It most probably would suit NESA well to continue to be owners of such fleet which is bringing in important heat to the capital of Finland.

These oil tankers have been supplying Finland with oil without any unexpected stops for 15 years even when it has been strong winters with heavy ice conditions. The upgrading of oil tankers to be suitable for this trade is the insulation of the cargo tanks, installation of rotor sails and machinery converted to run on LNG/LBG or alternatively insert one new small size (for usage up to 10 knots speed) engine running on LNG/LBG. There are quite many ice-classed oil tankers for sale on the market worldwide. But in case secondhand ice-classed tankers are unavailable, we could upgrade non-ice classed ships to required ice class or upgrade bulker to water tankers. Since the cargo is environmentally friendly and not dangerous, technical requirements are much lower than for a normal oil tanker. This means in practice that the cost for converting bulk vessels to water tanker could also be cost-effective. We can also use big sized oil tankers loaded partly to have draft suitable to get into Helsinki.

1.3.2 Insulation

The insulation of the tanks should be done by our patented method to get cost-effective insulation, which will have a heat resistance with the heat loss of only 30-60 W/m2. It is also worth to note that the insulation material used in our solution is sourced from Finland. We believe in sourcing from the local sources and which in turn will reduce our carbon footprint. The heat loss for 46.000-ton water cargo loaded with 95-115°C will be around 1,5 MW which means for these short voyages about 10 MWh which will be heat losses of about 0,3 % of the whole cargo's energy.

[1] *Ice Class, Wikipedia [online] Available from: https://en.wikipedia.org/wiki/Ice_class [Accessed on 16th March 2020]*

1.3.3 Rotor sails

By installing several rotor sails of the new Norsepower[2] type as depicted in the below picture, we could reduce the external power needed for the propulsion of the ship by 4-10% per tower installation. Norsepower rotor sails have good track records and several well-known shipping companies as Viking Line, Maersk etc. use this fuel-saving technology. It is worth to note Norsepower is a Finnish company which was founded in 2012 and who provide rotor sails solutions, which are reliable and easy-to-operate auxiliary wind propulsion system with a proven savings record.

Figure 2: Maersk Pelikan a 110 000 ton oil tanker having two Norsepower installed on the deck.

1.3.4 LNG and LBG engines installed

Machinery onboard the secondhand oil tankers will be converted to run on LNG/LBG. Alternatively, we will insert one new small 3000 kW size gas engine with LNG/LBG as fuel. This small-sized engine will be optimized for this trade which 10 knots speed is enough. The old diesel engines will be kept as back-up and also for extra power need when weather conditions require it (ice or strong winds). This new engine will be used for the power needed in the port during discharging to avoid usage of diesel generators. We will use LNG or/and LBG as fuel. The more environmentally friendly LBG can be gradually increased by blending when more LBG is available on the market. When using 100% LBG the CO_2 emissions will be practically zero for the transport with shuttle tankers.

1.4 Heat exchangers

The heat exchangers in Helsinki will be of standard type (titanium or stainless steel). The hot water will be pumped through the heat exchangers using the vessel's cargo pumps which should have the pumping capacity up to 11.500 ton/hour to be able to pump out 1000 MW/h with a 75°C temperature difference. With lower temperature difference must we have two tankers pumping simultaneously to keep the 1000 MW delivery requirement. It will be good to have two places in Helsinki where we could discharge the heat to the district heating system when the capacity has been grown over 600 MW. This will be good also for the existing district heating system which works better if there will be an input of heat in both eastern and western part of Helsinki. The district heating systems return water of 40°C will be heated up to about 90°C. The heat exchanger will be designed exactly as per the receivers needs based on the vessel’s pumps and flowrate as well as the temperatures of the incoming and outgoing water. The heat exchangers need a temperature difference of about 10°C between the heated waters maximum temperature and the water which will give off the heat. This will reduce the amount of heat which can be given off from the cargo. This is the working principle of the heat exchangers and it has

[2] *Norsepower, Available from https://www.norsepower.com/ [Accessed on 16th March 2020]*

been taken into consideration. The heat exchangers should be placed as close as possible to the shuttle tankers berthing place for smooth connecting to it from the ship with loading arms or hoses. A similar type of heat exchanger should be placed at the vicinity of the nuclear power plant for loading the shuttle tankers in case we will get CHP heat from Loviisa.

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1.5 Energy Power Vessel (EPV)

The modular Energy Power Vessel (EPV) has been planned to have an energy output of 200 MW continuously, but as we have explained before other sized EPV can be used. Due to the modularity is it easy to increase the capacity with more EPV´s until the need for heat is sufficient. To get 200 MW output is about 45 MW electrical power needed when the COP will be about 4,5 due to our double-acting heat pump system described under section 4.5. We will use second-hand ro-ro ships where the heat pumps can be placed on the sheltered cargo area. We will arrange a shore power connection using high voltage to have an effective and not too heavy connection system. The waste cooling water which is the energy source will be connected to the heat pump ships with big hoses or loading arms. The shuttle tankers will be connected to the EPV with hoses or loading arms during loading of the heat. We will also install a 45 MW LNG/LBG driven power plant consisting of 4 pcs Wärtsilä gas-driven power plants. This engine type can be running on LNG, LBG and then later also hydrogen and ammoniac blends. Due to quite big engines must the ship be equipped with a big LNG/LBG tank. This can then be used as a bunkering station for our ships as well as ships trading on Kilpilahti running on LNG/LBG. By doing so will the LNG/LBG price be much lower than the usual truck bunkering. We can have up to three EVP´s laying side by side and then load the shuttle tankers coming in for loading heat. The EVPs can be moved to other heat sources like Loviisa or to distribute them between two places to get the optimum waste heat supply to have the best COP for the heat pumps as well as overall costs taking into consideration port costs, distances as well as the cost of shore electricity and the possibilities to get it connected.

The EVP can easily be moved to Helsinki during the summer season for producing cooling. Alternatively, the EVP can be moved to other cities if Helsinki does not need all cooling capacity. By doing this will expensive investments be used almost the whole year round and the investment costs will be equally spread over the year. This 45MW/200MW EVP running on LBG could also supply environmentally friendly electricity to the cruise ships coming to Helsinki during the summer period.

1.6 Loading of the energy

The heat will be loaded through the heat pump (low-temperature source) or a heat exchanger (CHP source) at the nuclear power plants vicinity. The shuttle tanker will pump the 40°C water through the heat pump or heat exchanger by the shuttle tanker's cargo pumps and hereby heat the cargo water to about 90-115°C. It will be pumped from one full tank to an empty tank with a constant flow. The maximum loading speed will take 4 hours with a pumping capacity of 11.500 ton/hour, which will result increasing the temperature with 75°C (i.e., water temperature is increased from 40 to 115°C) ***Please refer use it or lose it attachment page 7 for calculation***. A 200 MW EPV will have the possibility to load 200 MW/h and we have to adjust the pumping capacity and size of the shuttle tankers as per the heat requirement in Helsinki. To have a continuous flow from the EPV and/or CHP nuclear power plant the next water tanker should be ready to load immediately after the other one has full energy cargo.

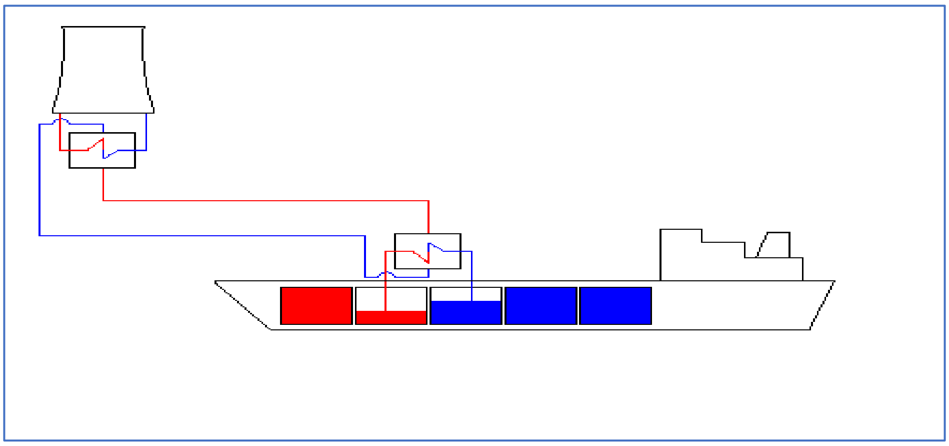

Figure 3: Concept depicting the Loading procedure at Nuclear Power plant.

1.7 Loviisa nuclear power plant

The Loviisa nuclear power plant has a license to operate until 2027-30 and they will most probably get a 20-year extension on its lifetime. The plant is owned by Fortum and the electrical power generated by these two reactors combined, is 1000 MW which will have the possibility to give out 1000 MW heat if the plant will be upgraded to CHP plant. It can be considered as a viable supplier for this project because the plant is operating 98% of the time and there are two possibilities to get heat from this plant. One possibility is modifications for CHP to get direct hot water or we use EVPs and use low-temperature cooling water (2000 MW) which is now dumped to the sea. The distance between Loviisa and Helsinki is 72 nautical miles which will take around 8 hours with a speed of average 10 knots including the manoeuvring. The fairways depth to Loviisa is 9,5 meters but can easily be increased to 11.0 meters similar to Helsinki Vuosaari fairway's depth. The entrance to Loviisa must be checked up by Traficom Administration, but according to our knowledge, we don't see any noticeable problems to increase the depth to Hästholmen where Loviisa nuclear power plant is located.
Around 500 meters outside of the nuclear power plant there is an open area where loading buoy could be placed including the loading hoses. Alternatively, the loading pier should be built. Loading from a buoy is commonly used across the oil industry. The entrance is narrow but should be enough for the tankers planned. Tugboats could be used for assistance, but it will increase the costs. The fairway is now 9.5-meter deep, but it should be possible to be increased to 11.0 meters.

1.8 Kilpilahti industrial heat

Based on the information we have received from the Neste, we could get waste heat water at 25˚C from Kilpilahti industrial area. The port of Kilpilahti is Finlands biggest port which is mainly serving Neste Oy:s oil refinery. The fairway into the port is 15-meter-deep. There is a nice place available where the EVP´s could be placed and the shuttle tankers could easily be berthed to the EVP during loading of heat even for big sized shuttle tankers. This place is not within the explosion hazardous area and it is only about 1 km from the heat source, and it will be quite easy to prepare water pipes and shore electricity to the pier in this industrial area where pipes, pump stations and cabling is already spread over the area.

1.9 Discharging of energy in Helsinki

The heat from the shuttle tankers will be discharged through the heat exchanger which is connected to the district heating systems and placed close to the pier where the shuttle tankers will be. During discharging hot water will be pumped from the vessel's tanks with 95-115°C water and returned to an empty tank. The water will return at around 40°C temperature with a constant flow from the heat exchanger. The discharging will take 4 hours with full pumping speed with a pumping capacity of about 11.500 ton/hour. The pumping speed could be optimized by adjusting the pumping speed as per the need of heat to the district heating system. We could also discharge the heat in two places in Helsinki to distribute the heat from two directions (east and west) to avoid overloading the district heating network. To have a continuous flow from the shuttle tankers to the district heating system should the next water tanker be ready to discharge immediately after the other one has discharged all the energy from the cargo. We need to carefully check which return temperature they can reach, to maximize the energy the ships can bring in. The district heating systems return temperature in the district heating will be the key for maximizing the energy the shuttle tankers can bring in. This because one of the main issues regarding the amount of energy the shuttle tankers can carry will be the cargo tanks waters temperature difference before and after the discharging.

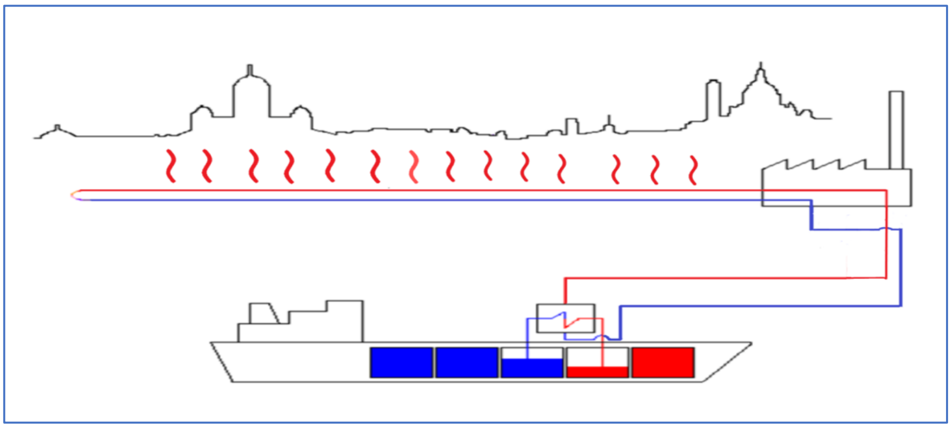

Figure 4: Concept depicting discharging of energy in Helsinki.

1.10 Benefits

The main benefits of this system are:

- A fast implementation which can be done in stages, City of Helsinki will have full control of the whole energy supply chain, making it reliable and ensuring the security of supply.
- Proven and safe technology, delivery with a reliable and proven method, cost of energy delivered to Helsinki is quite low, small investment cost, possibilities to cover more than 1000 MW need within a couple of years, the system has built-in energy battery for compensating variation in the need, possibility to provide heat when it is needed. Making it flexible.
- The main part of the system can be used for the growing need of cooling during the summer period, the EPV´s can be used as electricity providers and LNG/LBG bunker vessel for the cruise ships in Helsinki during the summer period can also work simultaneously in Kilpilahti as LNG/LBG bunker point for own and other ships,
- Possibility to phase out usage of coal fast, with low or no CO_2 footprint, recycling of oil tankers reduce further the environmental footprint,
- Can use different fuels, easy to move the whole system, can be used in other cities nationally and internationally, provide working places, tax income from people who work with this, income to the port of Helsinki which is owned by the City of Helsinki, ensure Finnish winter shipping knowledge, Finnish technology and know-how which can be a Finnish export product.

2 Climate Impact

Our solution provides the entire energy demand with the emission of CO_2 and other greenhouse gases with a significantly lower concentration than what Helsinki has today. We can further reduce to zero-emission immediately when we introduce LBG as fuel for all machinery involved. Through this solution, the Helsinki city district heating system will be mainly emission-free within a few years.

The energy required can be sourced in two different ways, either by sourcing energy from Loviisa nuclear plant low-temperature waste heat using heat pumps or High-temperature nuclear power CHP heat and the other option being utilizing low- temperature waste heat resources using heat pumps from the Kilpilahti process plant.

2.1 High-temperature CHP heat

One source is to get CO_2-free high-temperature water from Loviisa CHP nuclear power plant. By further developing Loviisa Nuclear power plant to a CHP plant, our solution will not have any CO_2-emission at all related to the processing of heat, only for the transport, which will be identical with the Kilpiahti source. Emissions will be extremely low when using LNG and can be reduced to zero when changed to LBG.

2.2 Low-temperature waste heat using heat pumps

The other heat source is the energy from available low-temperature cooling water from Kilpilahti and/or Loviisa, using heat pumps in the process.

Our system is based on the supply of 200MW heat through a modular arrangement for maximum flexibility based on heat pumps. With our optimized energy system, we have a COP (Coefficient of Performance) of 4,5. Our self-contained process vessel will supply sufficient electrical power through LNG driven generators. The EPV can produce 200MW heat using purchased electricity, LNG or LBG as energy to operate the heat pumps. Due to its modularity will there not be any difference on the CO_2-emissions per produced MWh.

The CO_2-emissions for the heat produced with heat pumps using different energy forms (***Please refer use it or lose it attachment page 8 for calculation***) are as follow:

Emission kg CO_2/MWh produced heat		
LNG	**LBG**	**Purchased electricity**
kg/MWh	kg/MWh	Kg/Mwh
85,7	**0**	**6,7**

Table 1: CO_2-emissions for the heat produced with heat pumps using different energy forms

2.3 CO_2-free energy transport

One important of this project will be the implementing of the CO2-free/reduced propulsion systems for the ships to transport energy. First, for the vessels need of external energy should be reduced by the insulation of the cargo tanks and by installing rotating sails on the deck as well as keeping low speed. We will install LNG engines on all ships which will reduce significantly the CO_2 emissions and this upgrading will make it technically possible to use LBG. To have the system completely CO_2-free the energy needed for the propulsion will be LBG implemented in steps by increasing the LBG blend to 100%.

LNG

The CO_2-emissions for the transport with the shuttle tankers running on LNG can be summarized as follow (***Please refer use it or lose it attachment page 8 for calculation***):

LNG as fuel Loviisa-Helsinki

Transported Energy (MWh)		kg CO2/MWh
2679,5	MWh dT50	8,0
3486,8	MWh dT65	6,2
4025	MWh dT75	5,3

LNG as fuel Kilpilahti-Helsinki

Transported Energy (MWh)		kg CO2/MWh
2679,5	MWh dT50	6,9
2953,2	MWh dT55	6,3
3486,8	MWh dT65	5,3

Table 2: CO_2-emissions for the transport with the shuttle tankers running on LNG

The CO_2 emissions per MWh are depending on the amount of heat delivered per shipment and correlating to the temperature difference between the heat onboard after the delivery compared to the temperatures before delivery (dT). With the heat pump system will it be realistic to use dT 50°C in our calculations but for CHP will the dT be close to 75°C. We have used 12 hours of loading and discharging time in this calculation to use the worst scenario. Loading and discharging time will improve when more EVPs are in use or if CHP is used as a heat source.

LBG

The CO_2-emissions for the transport with the shuttle tankers running on LBG can be summarized as zero CO_2-emission. Loading time or the temperature of the cargo difference before and after loading (dT) will not have any influence when using LBG as fuel for the shuttle tankers.

2.4 CO_2-emissions with different fuels used

According to the data regarding the needed heat to Helsinki city´s district heating system, we can say that for seven months there is a need for a substantial amount of heat but the rest five months the need will go down to about 200 MW. Considering this, we have calculated that this system is in use for seven months having full production and delivery during that period. We have used the emission 6,9 kg/MWh as average for the transport from Kilpilahti to Helsinki for a 50°C temperature difference of the cargo (***Please refer use it or lose it attachment page 8 and 9 for calculation***). Reason to use this is that the range is between 5,3 and 8 kg CO2 /MWh and the Kilpilahti case with 50°C water temperature difference represents a quite possible case which is within the range. We have also inserted the delivered heats price per MW for different cases when using shore electricity, LNG and LBG.

The summary table below shows that using LNG is the cheapest but also have the biggest emissions. Using purchased electricity for the heat pumps and LBG for the transport will give the best value for money which means small CO2-emission and still quite a low price for the heat delivered to Helsinki.

When using purchased electricity for heat production and LBG for transport the calculation shows that the price will be 33,8 €/MWh delivered to Helsinki and the CO_2-emissions 33 600 ton for 5 040 000 MWh which is about 90% of Helsinki Citys heat demand. With nuclear power CHP heat from Loviisa and using LBG in the transport will the price be 30 €/MWh and no CO_2-emissions. In this calculation, the parameters used have been conservative (***Please refer use it or lose it attachment page 8 for calculation***).

Project done	Heat pump installation	CHP installation	Total heating capacity	Periods in use	Energy cost at site	EPV Capex and Opex	Produced and delivered heat	EPV using electricity	EPV using LNG	EPV using LBG	Shuttle tankers using LNG	Shuttle tanker using LBG	EPV use electricity and LNG for transport	EPV use electricity and LBG for transport	LNG for EPV and transport	LBG for EPV and transport	CHP heat and LBG for transport
Year	MW		MW	Months			MWh/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year	ton CO_2/year
2023	200	0	200	7			1008000	6720	86408	0	6965.8	0	13686	6720	93373.5	0	
2024	200	0	400	7			2016000	13440	172815	0	13931.6	0	27372	13440	186747	0	0
2025	200	0	600	7			3024000	20160	259223	0	20897.3	0	41057	20160	280121	0	0
2026	0	400	1000	7			5040000	33600	432039	0	34828.9	0	68429	33600	466868	0	0
2027	0	0	1000	7			5040000	33600	432039	0	34828.9	0	68429	33600	466868	0	0
2028			1000	7			5040000	33600	432039	0	34828.9	0	68429	33600	466868	0	0
2029			1000	7			5040000	33600	432039	0	34828.9	0	68429	33600	466868	0	0
2030			1000	7			5040000	33600	432039	0	34828.9	0	68429	33600	466868	0	0
					€/MWh			€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh
Heat pump energy					2	3.7		13.5	10.8	21.5	13.5	14.6	32.7	33.8	30.1	41.8	
CHP energy					20							10.0					30.0

Table 3:CO_2-emissions with different fuels used and the cost estimation

3 Impact on Natural Resources

3.1 CHP nuclear power plant as a heat source

Upgrading a nuclear power plant to CHP, for providing a certain amount of MW as 100-120ºC water, identical to what we provide with electro power, will not have a significant impact on the natural resources. The amount of cooling water dumped into the Baltic Sea will be reduced, but at the same time, electric energy supplied to the grid from the plant will be reduced by 15-20%,[3] which then can have an indirect influence on natural resources in the substitution of that lost energy.

3.2 Industrial waste heat or nuclear power cooling water using heat pump technology.

Using industrial waste heat or cooling water from a nuclear plant and applying heat pump technology in a system designed for optimized COP, we will have a negligible impact on natural resources. Our system has a high COP (4,5), and with the low-temperature process, we will only need 20-25% electrical energy to provide the requested high-temperature energy for the district heating system. Natural resource impact in this solution will only be related to the electricity needed for the heat pumps. When LBG is used we are close to zero and for purchased electricity, it will be in an acceptable range.

3.3 Transport of the hot water with shuttle tankers.

The shuttle tankers we will use for this energy trade is second-hand oil tanker which will be out phased from oil trade. Oil tankers are not accepted for trading with major oil companies' oils when the age is exceeding 15 years. We can use such ships for a further 15 years in the safe energy/water trade and hereby save natural resources. The shuttle tankers cargo tanks will be insulated with our patented insulation system which will reduce the heat leakage to almost nil during the voyage. This will save natural resources because no heating of the water is needed during the voyage. The insulation material is made from sustainable renewable sources not containing any artificial or hazardous materials and has been installed in many vessels around the world.

The distance between Helsinki and Kilpilahti/Loviisa by sea is 54/72 nautical miles which take 5-7 hours with 10 knots speed. With such speed is the power needed for the 45-50.000 ton tankers small, only about 3 MW and the time when it is needed short due to small distance. The power needed during loading and discharging is less than 1 MW. As an average will we need 1,5-2 MW continuously per ship having 6 ships for 1000 MW heat delivery using only 9-12 MW which is about 1% of the energy these ships bring into Helsinki. This means that the impact on natural resources is the needed fuel equal to 1% of the energy delivered. We will anyway try to reduce the use of fuel for transport as well as use more environmentally friendly fuels.

[3] *Bergroth,N,[2010] Carbon-free nuclear district heating for the Helsinki area? [online], Available from https://www.powerengineeringint.com/world-regions/europe/carbon-free-nuclear-district-heating-for-the-helsinki-area/# [Accessed on 16th March 2020]*

4 Cost Impact

4.1 Main costs involved

Our costing has been based on previous internal feasibility studies undertaken during the last decade to build an understanding of viable and environmental energy input into worldwide district heating systems.

4.2 High-Temperature CHP energy from Loviisa nuclear power plant

The Loviisa nuclear power plant can, according to the owner Fortum, be upgraded to be a CHP plant enabling 1000MW energy supply to available for the city of Helsinki district heating system.[4] By doing so the electricity supply to the grid will be reduced by 16-20%. Based on preliminary discussions between our team and Fortum regarding potential feasibility for such initiative, Fortum has concluded that in principle it is possible to implement our solution within a time frame of 4 to 5 years. For obvious reasons, Fortum could not give out any price estimation for energy produced in Loviisa CHP nuclear plant.

Based on discussions and understanding rough calculations could, however, be laid out based on a summary of the investments required + reduced electricity production + profit divided with the produced heat. We have assumed that the cost of procuring heat energy from the nuclear power plant condensed water from the Loviisa CHP nuclear power plant, will be approximately 15-20 EUR/MWh, which is approximately 30-40% of the Nordic average electricity price or about 30-40% of the Helsinki district heat sales price for private consumers.

This assumption is considering that the electric power output from the nuclear power of 1000 MW will be reduced by about 200 MW in the case of full Combined Heat and Power (CHP). Also, assuming that for a CHP nuclear power plant there will be no other taxes for the heat other than VAT which will be deducted from the final sale of heat to the end-user and is therefore not considered.

Using the cooling water to heat the cities instead of heating the sea, will be a ~~big~~ significant environmental benefit for the power station. Considering the fact, that the heating of the seas soon is an environmental issue it will have cost implications for the nuclear power plants in future.[5] Some investments have to be done to get the hot CHP water loaded into the ships, these investments could affect the energy price mentioned above.

The time to heat 46.000 ton of water takes about 4 hours if we will get 1000 MW cooling water output. The 46.000 ton of water can contain 4000 MWh.

[4] *Bergroth,N,[2010] Carbon-free nuclear district heating for the Helsinki area? [online], Available from https://www.powerengineeringint.com/world-regions/europe/carbon-free-nuclear-district-heating-for-the-helsinki-area/# [Accessed on 16th March 2020]*

[5] World Nuclear organization, Cooling Nuclear Plant]s [2019], Available from: https://www.world-nuclear.org/information-library/current-and-future-generation/cooling-power-plants.aspx, [Accessed on 23rd , March 2020]

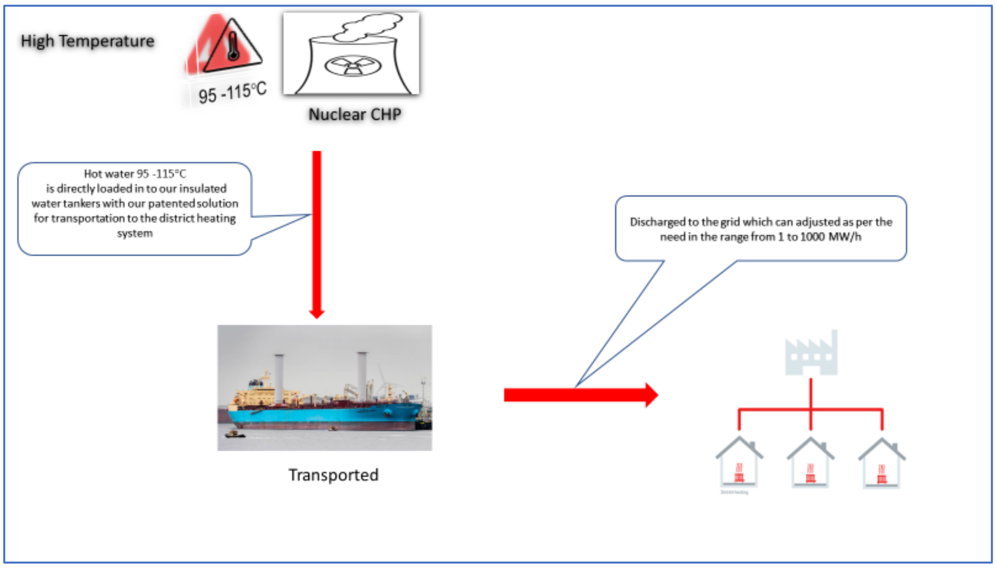

Figure 5: Depicting how our solution can be implemented-CHP

4.3 Low-temperature waste heat water from Kilpilahti and/or Loviisa nuclear power plant.

From the industry area in Kilpilahti, about 1000 MW cooling water at a temperature of about 25°C is dumped to the sea continuously. About 600 MW is from Neste Oy and the remaining 400 MW, from the other industries. From the Loviisa nuclear power plant about 2000 MW low-temperature cooling water is dumped continuously with a temperature in the same range as in Kilpilahti. This low-temperature cooling water can be used as heat for heat pumps which will heat it to a suitable temperature for district heating. The availability of cooling water from both places is high. It will be sufficient to cool it further down only 5-10°C and hereby get a quite high coefficient of performance (COP) when using to reach required district heat water temperature

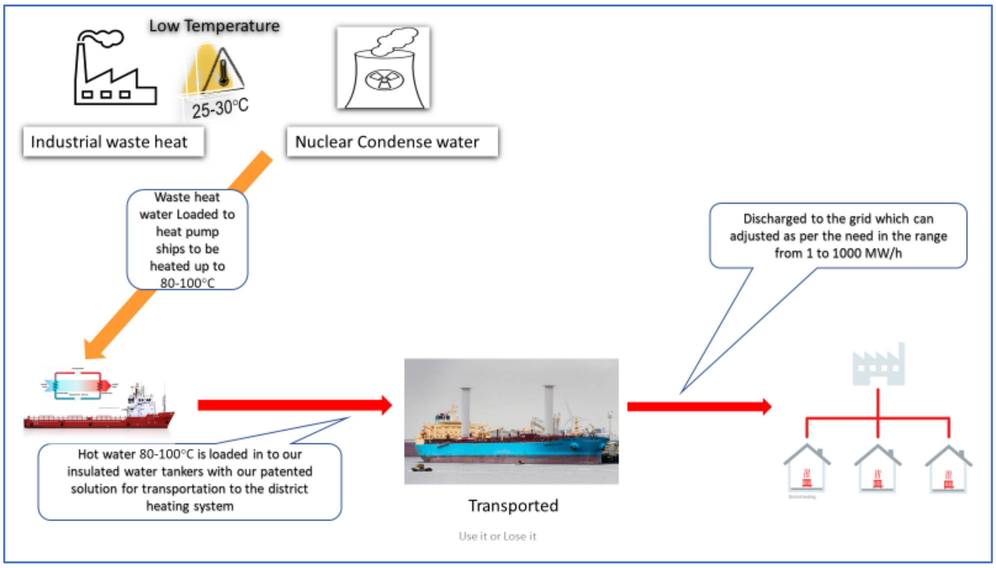

Figure 6: Depicting how our solution can be implemented low temperature waste water.

This cooling water should be available at a low cost since all of it is dumped to the sea and it would be preferable for the local environment to reduce ~~it~~ the amount of tempered water loaded to the sea. Some investments ~~are~~ will be required for piping etc. hence the price could be about 1-2 EUR/MWh. The company Port of Kilpilahti ~~is~~ owned by Neste Oy, also have additional income from each shuttle tanker call due to the port costs. The same would apply for the Loviisa nuclear power plant´s cooling water as that port would be owned by Fortum Oy, who is the owner of the nuclear plant.

4.4 Energy Power Vessel (EPV)

Several shuttle tankers will be used in the transportation of energy between source and the Helsinki District Heating System. The energy moved will be powered by spill water (as discussed) processed through heat pumps located on Energy Power Vessels (EPV). The EPV's will be self-contained vessels with sufficient onboard electric energy to power the heat pumps and other systems. The EPV will at the place of loading also act as a mooring place for the water shuttle tankers. During April/May when heat requirements drop in Helsinki and the need for cooling may increase, one or several EPVs can be moved to Helsinki providing city cooling, or the Helsinki harbour, as another example, can be served with electric energy servicing vessels in the harbour or even act as bunker vessel for LNG catering vessels calling Helsinki port. The EPVs can be brought back to Kilpilahti/Loviisa when heat requirements increase around October month or when required.

The flexibility gained from enabling the EPV's to move around will not only provide flexibility, but it will make the entire operation more economical as capacities can be optimized and costs will be low as the systems always are in operation making income or taking spill water from the at any time lowest-cost supplier. The EPV will be extremely flexible as it can take, when possible or economically, electric power from the local grid or it can deliver electric power to onboard systems using the energy available aboard. As the Helsinki city can oversee vessel in terms of how to use its potential, the city will be able to use the resources most optimally and economically, securing the stable and continuous supply of energy. The EPV's will be vessels optimized to secure sufficient power and equipment required for the operational task and the EPV will have sufficient redundancy enabling the continuous secure supply of energy. The shuttle tankers will also be optimized and being provided with enough redundancy means reducing the risk of failure in supply to a minimum.

We are planning to have modular EPV which has own power of 45 MW to produce electricity for the 200 MW heat pumps or using purchased electricity of high voltage. According to Finnish tax rules are the fuel used for electricity production tax-free, but the usage of electricity has a tax. This means that we shall pay tax for the usage of electricity for the heat pumps. This tax for electricity used for heat pumps are now in accordance with electricity class I which is around 25 €/MWh but during 2022 the heat pumps will be classified under class II to be 0,5 €/MWh. We have used this value in our calculations but added the security of supply fee giving a total tax of 0,63 €/MWh in accordance Finnish Tax Regulation. The cost of the energy for the heat pumps are the highest costs in heat production with heat pumps. We have used the purchased electricity's price 40 €/MWH as per the instructions and the transport costs of it to 20 €/MWh totally 60 €/MWh in our calculations. The fuel costs for producing electricity with our power plant onboard the EPV for LNG is the given 25 €/MWh and the LBG has been estimated to be double the LNG´s price based on discussion with Finland's major gas supplier.[6]

The investment costs for such EPV ship consists of following parts: Ship 3 M€, 47MW power plant consisting of 4 x Wärtsilä 20V31SG generator sets 33 M€, 200 MW heat pump modules 20 M€, Installation and parts 4 M€ totally around 60 M € and the expected lifetime would be 20 years. Based on the fact that it will be used as a cooling ship during the summer period can we ignore the capital expenses during the period it will not be used as a heat pump ship. The capital expenses will affect the heating price with 2,52 €/MWh (363.500 €/month / (200 MW*24*30 h/month). The running cost including maintenance for a ship standing in the port with a reduced crew will be about 6000 €/day. This will affect

[6] Sähkön ja eräiden polttoaineiden verotaulukot - vero.fi, Accessed on 22nd Jan 2021.

the heat production price with 1,25 €/MWh. This cost will only affect heat production because the ship will be used in cold production during the summer period.

The production cost of the heat is depending on which type of fuel or if we use purchased electricity from shore. The different prices including capital expenses and running costs for the usage of different fuels are shown in section 4.7. It is the most economical way to produce heat with our EPV´s is operating them with LNG followed with purchased electricity from shore and finally LBG.

4.5 Double Acting high-performance heat pump

To get as high as possible Coefficient of Performance (COP) for the heat pump, the energy supply water should be as hot as possible and the water which we will heat should be as cold as possible. We will use as input 25°C cooling water from Kilpilahti industrial area or Loviisa nuclear power plant and cool it down to 20°C. With this input water, we will heat the water onboard the water tanker from 20°C to 95°C. In Helsinki, we will heat the district heating system by cooling down the water onboard the water tankers from 95° to 40°C by pumping the hot water through a heat exchanger. The water on board the tanker on the return trip to Kilpilahti is 40°C and we will use it as input to the heat pump and cool it down to 25°C. After all the water tankers cargo except one tank is cooled from 40° to 25°C we will connect to the 25°C waste cooling water and use that as input energy. We call this double-acting since it rises the COP to 4,5 instead of 3,5 (***Please refer use it or lose it attachment page 13 for calculation***). This double-acting heat pumping makes it possible to have high COP for the heat pumps without changing anything in the existing district heating system. It requires that we have one extra empty tank in the shuttle tankers to be able to do this double-acting. The shuttle tankers have always extra empty tanks which can be used for this purpose. This can be handled by using some of the ballast tanks in case cargo tanks can´t be used..

4.6 Cost of heat transport to Helsinki

Our calculations have been done for a 56 (Kilpilahti) and 72 (Loviisa) nautical miles (nm) one-way voyage including return trip with a tanker doing average 10 knots as well as manoeuvring time. One tanker with a loading capacity of 46000 ton can do one full trip in 1 day and therefore six pieces of this sized tankers would be needed to be able to deliver 1000 MW heat energy continuously into Helsinki. In practice, it will be more reliable to have one or two extra tankers to be sure that smooth delivery of 1000 MW can be handled. In our calculation all port dues known as per today for Helsinki has been taken into consideration and has been spread out for the whole year, assuming 200 voyages per year.

At the nuclear power plant, the loading will be done from a private berth and therefore no port costs in Loviisa are needed, but 7 000 Eur/voyage as port costs in Kilpilahti is considered here for calculation purpose. In this calculation, an increase of 10% power which is cost-free and CO_2-free for the shuttle tankers has been considered, based on the usage of Norsepower Rotor Sails instead of reduction of fuel consumption. We have used a calculated time charter cost of 12.000 €/day for the shuttle tankers. This cost includes investment (purchase price + upgrading cost with a lifetime of 15 years), crew, maintenance, insurance, management costs as well as laid up period during the summer period.

The fuel costs are calculated with LNG and LBG. We have used LNG´s price given in the instructions to the finalists and the LBG has been estimated to be double the LNG´s price based on discussion with Finland's major gas supplier. Due to the fact that we have short voyages will the speed not affect the actual travel time. Therefore, can the speed be 10 knots and for such speed will a small engine of only 3000 kW be used. Besides, we will get about 10% more power from the rotor sails. Due to this, the fuel consumption per voyage and also the cost per MWh will be small. In case more power is needed for a short period when for example ice conditions the diesel engines will be used. This extra diesel power onboard will be used so seldom that it has been neglected in our calculations.In the table under section 4.7 is the costs shown in a table also for the transport part. We have used the temperature difference of 50°C before and after the heat has been pumped into the Helsinki district heat system as a base for voyages transporting heat from EPV´s. For transporting CHP heat from Loviisa has the cargo difference temperature of 65°C been used. In all cases ha a slow discharging and loading of 12 hours each been used. This to have all calculations on the conservative side (***Please refer use it or lose it attachment page 9,10,11 and 12 for calculation***).

4.7 Heat energy´s delivered cost

The total cost of the energy delivered to Helsinki´s district heating system has been calculated based on the explanations above in chapter 4 and summarized below. The most beneficial way would be to use LNG in all steps but based on the emissions described in section 2 will it most probably be more vice to use purchased electricity for the heat production onboard EPVs and use LBG for the shuttle tankers. This will give a price of 33,8 €/MWh. In case our assumption that it will be possible to purchase high-temperature CHP heat from Loviisa nuclear power plant will the price be 30 €/MWh. But according to Fortum which are the owners of the nuclear plant will it take about 5 years from the decision to get the nuclear plant updated to CHP and therefore could a combination of low and high-temperature sources be a good way of arranging CO_2-free heat to Helsinki

	Energy cost at source	EPV CAPEX and operational costs	EPV using electricity	EPV using LNG	EPV using LBG	Shuttle tankers using LNG	Shuttle tanker using LBG	EPV use electricity, LNG for transport	EPV use electricity, LBG for transport	LNG for EPV and transport	LBG for EPV and transport	CHP heat, LBG for transport
	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh	€/MWh
Low temp waste heat	**2**	**3.7**	**13.5**	**10.8**	**21.5**	**13.5**	**14.6**	**32.7**	**33.8**	**30.1**	**41.8**	
High temp CHP heat	**20**						**10.0**					**30.0**

Table 4 Delivered heat energy cost calculations.

5 Implementation Schedule

We would suggest that the implementation schedule will be moderate with a speed of 200 MW/year starting from 2023. This is to be able to test and improve the solution during the 5-year implementation phase. This moderate implementation schedule will also keep the prices for the ships, machinery, equipment, work etc. slightly lower than the precursor to compensate the 2% inflation and therefore are the price kept unchanged for the heat pump ships and water tankers. The implementation plan will be as follow in case we choose to get all delivery from waste heat using heat pumps:

Year	No of heat pumps ships	Capacity MW	No of Transport ships	Heat delivery GWh/year
2023	1	200	3	1,008
2024	2	400	3+1	2,016
2025	3	600	4+1	3,024
2026	4	800	5+2	4,032
2027	5	1000	6+2	5,04
2028	5	1000	6+2	5,04
2029	5	1000	6+2	5,04
2030	5	1000	6+2	5,04

Table 5:Implementation plan

We could also combine the waste heat using heat pumps with 400-500 MW CHP heat from Loviisa (install the CHP on one of the 500 MW plants only) which will further reduce the CO_2 emissions and price, as well as providing multiple heat sources. This could also increase the capacity over 1000 MW to be able to deliver CO_2 free heat also during the peak periods and perhaps to the surrounding cities. This will not change much the above-mentioned implementation schedule because the owner of the nuclear power plant Fortum estimates (based on our initial discussion) that it will take about 5 years to implement CHP system to Loviisa nuclear power plant starting from the decision until it is done. Loviisa nuclear power plant´s low temperature cooling water with heat pumps could be used to have several heat suppliers and to improve the heat pumps COP when we are getting closer to the maximum amount of low-temperature heat available.
The detailed analysis of the risk factors has been done for the proposed solution. We have considered the most relevant risks that can have a significant impact on the implementation schedule of our proposed solution and also the key stakeholders have been identified. ***Refer Appendix:1 and 2 under USE IT OR LOSE IT attachment for the key implementation of schedule risks identified and mitigation plan and for the list of key stakeholders.***

Firstly, entering into contracts with the suppliers for the delivery of energy for a given period is a critical factor. The major risk factors which could be associated with securing these contracts which could have an impact on the schedule will be:
● Not able to secure a contract with the energy suppliers
● Poor definition of the scope and objectives of projects in the business case resulting in the omission of cost during project costing.

The second factor being Government Tax Policy on electricity when used to produce district heat, the electricity taxes and network fees will have an impact on the production cost.[7]

The third key factor being the procuring the tankers for transport, which can also impact the schedule along with securing port/loading facilities and access for pick up as well as delivery.

[7] Energy Taxation, Avialable from heating-system-in-helsinki.pdf (Accessed on 12th Jan 2021)

6 Implementation Feasibility

Implementation of our plan is assumed to be technologically, financially, administratively, culturally and ethically feasible as such. This because the technology is proven and available, the cost is low, no need to change the legislation, no permits needed as well as the shipping is a known and accepted method to transport goods in an environmentally friendly way. Finland´s import and export is mainly going with ships without any stops even during the worst ice winters or stormy weathers. Therefore, we can say that using ice-classed oil tankers as shuttle tankers is a reliable and proven way to transport energy to Helsinki.

We have the knowledge to implement this plan and experienced personnel for the ships are available in Finland. Heat pump technology is a proven technology with a manufacturer in Finland. Shipyards which can do the needed upgrading of the ships is available in Finland. The needed new LNG machinery and power plants are manufactured also in Finland. The Finnish state-owned gas delivery company informed that LBG is available for this project when it is needed. Kilplahti port has a place close to the heat sources where the EPVs can be placed where the depth is enough also for the shuttle tankers to manoeuvre. Loviisa nuclear plant is also close to the sea where a berth easily can be built. The fairway to Loviisa should be dredged deeper but the depth is already enough for quite big shuttle tankers. The fairways to Helsinki are enough and berthing places available quite close to the city´s district heating. In the Helsinki area there not need for any changes in the existing district heating system except for the installation of the heat exchanger where the energy will be discharged to the district heating system. No space needed in Helsinki and no permits or other complicated and difficult decision are needed for this project.

Based on the preliminary analysis, currently, an enormous amount of heat energy is flushed out to the sea impacting the environment. With our solution, we will be able to harness this energy and bring it in vast amounts safely and reliably to Helsinki using the minimum amount of energy for transporting it. Therefore, we believe that our solution has the following advantages and can be easily implemented:

Climate impact
- zero or small greenhouse gas emissions from the delivered energy

Impact on natural resources
- the delivered energy has no impact on natural resources.

Cost impact
- the price of the delivered energy to Helsinki is about 50% lower than the current sales price.

Implementation schedule
- 1000 MW or more CO2-free energy supply to Helsinki can easily be implemented in steps of 200 MW per year from the day of the contract being awarded

Implementation feasibility
- ethical, financially viable, no need for a big investment, no legal hurdles, and easy to administer and operate. It can be easily replicated and can be used in other cities in Finland and worldwide.

Reliability and security of supply
- The minimum risk with multiple continuous sources of energy for decades to come. Multiple EPVs having back-up autonomous power plant. Several ice-classed shuttle tankers with some extra used for energy battery and to ensure reliable supply as a back-up. All the shuttle tankers and EPVs will be operated and certified based on the ISPS code which is the International security code as well as the ISM code which controls safety and reliability.

Capacity
- From the two close-by sources Kilpilahti and Loviisa are 3000 MW low-temperature heat available. Can completely stop the dependency of all CO_2-emission in heat production.

7 Reliability and Security of Supply.

Nuclear Power plants and Industrial areas generate a large amount of waste heat which is valuable and a reliable source for District Heating. Waste heat/spill water represents unused green energy which is not utilized to a large extent today. Our proposed solution utilizes these resources and will play a major role in the Helsinki decarbonizing program for the city district heating system. The proposed solution is flexible and with a small CO_2 footprint providing heating (and cooling when required), reliably and stably. We have identified two key sources which can provide the energy needed for the Helsinki district heating using our solution.

Kilpilahti, Neste Oy: low-temperature waste heat water

Based on the information we have received from the state-owned oil company Neste, we could get waste heat hot water at 25°C from Kilpilahti area. Kilpilahti has been continuously operating without any breaks, all maintenance issues are usually carried out in July making Kilpilahti a reliable supplier for Helsinki district heating needs.

Figure 7: Google maps depicting Neste seawater pools where the waste heat water can be harnessed, info source: Neste.

Loviisa, Fortum Oy

The required hot water can be acquired from the Nuclear Power plants in two forms, one, being low-temperature cooling water and other being high temperature from nuclear plant CHP. Based on the information we have received from Fortum from our initial discussion It is also possible to upgrade both Loviisa nuclear power plants reactors or only one of them to CHP, which could then provide up to 120°C hot water Fortum estimated that it will take about 5 years to get it done after the decision has been made. Loviisa nuclear plant is one of the most reliable plants which has been operating about 97% of its time and the maintenance stops are always planned to be done during the summer period.

The ships which will be used are ice-class, which are suitable for any severe weather conditions including heavy ice conditions and we will have six ships and two back up units to meet the demand.

We have added the following important key factors which make our system reliable and secure

- We are using 5 EPVs each equipped with 200MW heat pumps for generating 1000MW energy.
- Energy can be harvested from any spilled water energy source or in a combination with possible energy provided by CHP system which might be installed in Loviisa.

- Each EPV will be self-contained in terms of electrical power which offers flexibility in variations between fuel types and electrical power depending on availability and cost for the same.
- Heat energy from the source can easily be connected to the EPVs process system.
- The shuttle tankers in this trade will all be ice-classed vessels suitable to negotiate any severe weather condition or heavy ice condition

The detailed analysis of the risk factors has been done for the proposed solution. We have considered the most relevant risks that can have a significant impact on the reliability and security of supply of our proposed solution. ***Please refer Appendix 3 Risk analysis of Reliability and Security of Supply and Mitigation plan. in the Use it or Lose it Attachment.***

We consider the sourcing of suppliers as a major risk, to mitigate this risk we have tried to adopt flexible supplier sourcing which will provide reliable alternatives in case of capacity constraint or hazardous disruption. In our case both the sources of supply are well established and have a good track record in terms of safe and secure operations.

We contemplate heavy ice conditions as a major risk, for reliable operations even during harsh winters, in the first place, we will be operating using Ice class-vessels however as a backup plan, if the need arises, it is worth to mention that Finland has the best ice breakers fleet in the world, which will assist the operations to run smoothly, making it most reliable solution.

Figure 8: Icebreaker Polaris going out from Helsinki with coal burned power plant in the background

We have also considered the ice breakers going on strike, to mitigate this we will use our best-in-class shuttle tankers which have highest ice class 1A Super which has extremely powerful engines to act as our ice breakers (refer the below picture), which eliminates the dependency on state-owned ice breakers.

Picture 9: Double acting Ice breaking shuttle tanker in action.

We have also considered that the crew on our vessels might be going on strike, to mitigate this we will follow social labour laws and regulations. Agreements reached beforehand with all the unions involved will be securing that our crew will not be allowed to go on strike, as this operation will be considered as critical services.

To counter the supply capacity risk, we have adopted early supplier involvement (ESI). With this approach, the supplier's capacity and production flexibility be known beforehand, leading to a better supplier selection. (Our calculations are based on this method which has lead to accurate calculations) This early adaptation also benefits the suppliers in that they can improve planning with better forecast information.

We do not foresee any operational disruptions due to political instability or natural disasters, however, our mitigation plan involves sourcing waste heat water from suppliers within Finland and the transportation is done using the ice-classed shuttle tankers with our tested and patented insulation solution. It is also worth to note our solution is flexible and can be moved to any place anytime in case there are any policy changes due to political factors.

The shuttle tankers and the EPV´s will be operated and certified in accordance with the ISPS Code and ISM code. The ISPS code is the International Ship and Port Facility Security code which is the proven system on how to operate the ships and harbours in a safe and secured way. The ISM code is the International Safety Management code which is a management tool to manage the ships safely and reliably. When operating under these mandatory codes the operation will be safe, secure and reliable because it covers all operations onboard the ships and in the port. The port areas where we will load and discharge heat are highly controlled under the ISPS code to prevent and avoid possible threats. It is also mandatory for the ports to be ISPS certified.

We have also considered the Environmental risk since there is an increased public awareness of environmental degradation. Our mitigation plan is to communicate our process clearly to all the stakeholders involved demonstrating our environmentally friendly solution. Financial risks are also considered, Our mitigation plan follow robust procedures in calculating the costs, including the exchange rate, tax and financial strength of the partners with whom we will be planning to work. The financial health of the partners with whom we will work with is carefully studied and understood to eliminate any vulnerability associated with supply chain disruptions.

In a nutshell, the Helsinki District Heating will be not prone to any outside political influence nor threats since the energy suppliers are based out of Finland and Finnish Government has a major stake which can influence the operations of these suppliers, thus making this very reliable and secure.

8 Capacity

Our proposed solution can have a significant impact on the cessation of coal-fired heat production in the city of Helsinki. As depicted in the below graph with our solution we can provide continuously 1000 MW heat power (highlighted in orange) during the peak season and reduce the supply during the non-peak season. The heat load through one year (2016), which is depicted in the below graph. Our modular system can supply 1000MW carbon-free energy on a continuous basis, covering the orange area of the graph, and it can be balanced through the year when energy demand is lower in a linear way

The graph shows that our solution could cover most of the city´s needs except for January month where an additional 1000 MW peak power is needed. For all need of power over 1000 MW Helen can use the existing natural gas CHP, biomass plant, heat pumps and peak boilers also, Our system can if/when required, temporarily provide additional energy like 1000MW for 4 hours or 500 MW for 8 hours, using 2 shuttle tankers simultaneously at the Helsinki point of discharge.

When our solution is compared with the actual Helsinki district heating power data 2016 (the blue curve), it is quite evident that our solution can contribute significantly to achieving Helsinki city's goal of carbon neutrality by 2030.

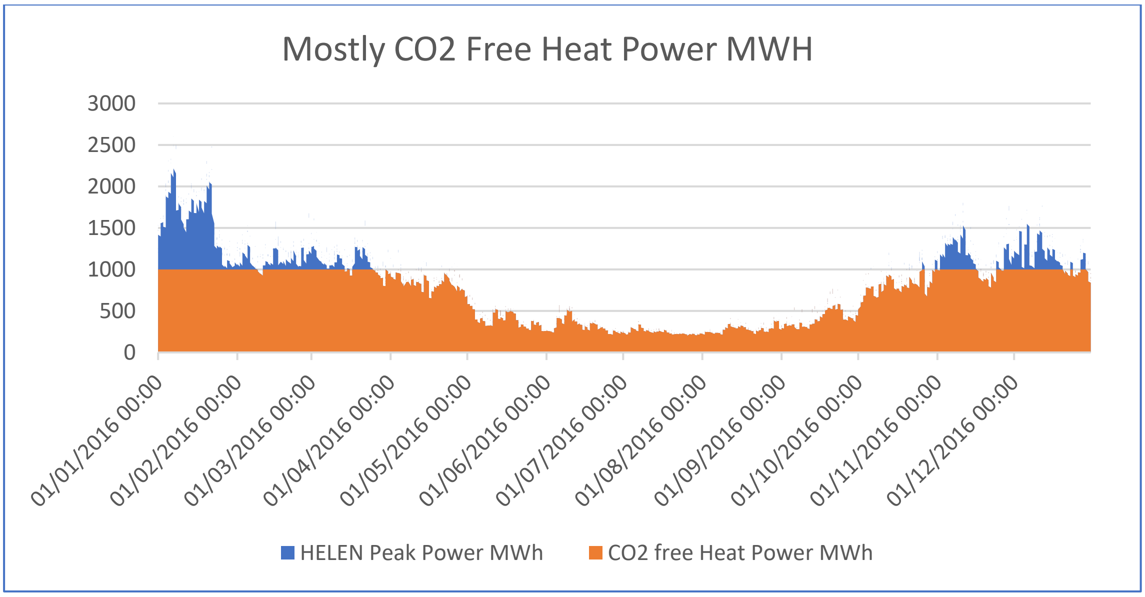

Figure 10 Actual Helsinki District heating power data[8] in comparison with our proposed solution (highlighted in orange)

[8] https://www.helen.fi/helen-oy/vastuullisuus/ajankohtaista/avoindata