Vard Marine Inc.

CANADIAN ARCTIC GREYWATER REPORT: ESTIMATES, FORECASTS, AND TREATMENT TECHNOLOGIES

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WWF Canada

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SUMMARY OF REVISIONS

Rev	Date	Description	Prepared by	Checked by
0	08 May 18	PRELIMINARY DRAFT FOR CUSTOMER REVIEW	MT	AK
1	10 May 18	PRELIMINARY DRAFT FOR CUSTOMER REVIEW – EDITORIAL CHANGES AND FORECAST UPDATES	MT	AK
2	29 May 18	FINAL REPORT INCORPORATING CUSTOMER COMMENTS	AB	MT

EXECUTIVE SUMMARY

The Arctic Waters Pollution Prevention Act (AWPPA) prohibits the discharge of any "waste" into Arctic waters. The Arctic Shipping Safety and Pollution Prevention Regulations (ASSPPR) do address permissible sewage (black water) discharge but they do not mention grey water. There is also no process for approval of discrete grey water treatment systems as these are not allowed for under the regulations, and Transport Canada does not currently approve or certify any greywater treatment system for use in the Canadian Arctic.

In 2015, VARD Marine Inc, conducted a report for Transport Canada titled "Projections for ship-generated waste travelling though the Canadian Arctic". This report used 2013 ship traffic data to develop shipborne waste generation rate estimates for 2013 as well as projected estimates.

This updated study builds on the greywater analysis from the 2015 report by analyzing shipping data for the Canadian Arctic in 2016 and presents both a baseline for waste travelling through the region in 2016 and projections for the quantities, types and locations (routes) of greywater in the Canadian Arctic in 2025 and 2035. This study also provides a summary of greywater treatment options available in the marine industry today, as well as a review of system costs, gaps in the current understanding of greywater carriage in the Canadian Arctic, and recommendations for future development of the latter.

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LIST OF ACRONYMS

AOPS	Arctic Offshore Patrol Ship
ASSPPR	Arctic Shipping Safety Pollution Prevention Regulations
AWPPA	Arctic Waters Pollution Prevention Act
AWPPR	Arctic Waters Pollution Prevention Regulations
CCG	Canadian Coast Guard
DWT	Deadweight Tonnes
GT	Gross Tonnage
IMO	International Maritime Organization
KW	Kilowatts
LOA	Length Overall
MARPOL	International Convention for the Prevention of Pollution from Ships
NORDREG	Northern Canada Vessel Traffic Services Zone
NSPS	National Shipbuilding Procurement Strategy
TC	Transport Canada
CSA	Canada Shipping Act
CCGS	Canadian Coast Guard Ship
USCG	United States Coast Guard

1 INTRODUCTION

Vessel traffic in the Arctic is increasing, with resource development and tourism in particular experiencing growth. As sea ice continues to disappear in the Arctic even more opportunities for the development of the marine sector will present themselves. WWF Canada (WWF) are interested in the environmental impact of this growth, and have been researching the impact of grey water (water from sinks, showers, laundry facilities, galleys, etc.) on ships and the greywater discharge regulations that ships must follow.

The Arctic Waters Pollution Prevention Act (AWPPA) prohibits the discharge of any “waste” into Arctic waters; waste being any substance that will have a deleterious effect on the water column. The Arctic Shipping Safety and Pollution Prevention Regulations (ASSPPR) do address permissible sewage (black water) discharge but they do not mention grey water. This puts the onus on the operator to prove that grey water does not include any deleterious waste as defined above, which is extremely difficult. There is also no process for approval of any form of grey water treatment systems as these are not allowed for under the regulations.

These regulations require that most operators process and discharge greywater before entering a zero-discharge region. However, remaining in the Arctic for an extended period would require the vessels to have very large holding tank systems, Transport Canada to certify a treatment system, or for the operator to ignore the regulations and discharge regardless. At this moment Transport Canada does not approve or certify any Greywater Treatment system for use in the Canadian Arctic.

In 2015, VARD Marine Inc, conducted a report for Transport Canada titled “Projections for ship-generated waste travelling though the Canadian Arctic”. This report used 2013 ship traffic data to develop shipborne waste generation rate estimates for 2013 as well as projected estimates.

Building on the 2015 report, this updated study analyzes shipping data for the Canadian Arctic and presents both a baseline scenario in 2016 data for waste travelling through the region and projections for the quantities, types and locations (routes) of greywater in the Canadian Arctic in 2025 and 2035. This study also provides a summary of greywater treatment options available in the marine industry today.

2 BASELINE PROFILE FOR ARCTIC SHIPPING

Currently, the largest driver of ship traffic in the Canadian Arctic is consumer demand in most of the communities in Nunavut, the Northwest Territories, and Northern Quebec, which rely on ships to provide articles which in the rest of Canada are more likely to be supplied by rail or truck.

The next largest drivers are tourism traffic, including cruise ships and expedition vessels, and traffic supporting the mineral extraction sector. Tourism traffic has increased somewhat in the last 5 years, including a successful Northwest Passage transit by a large cruise ship in 2016. The cruise sector also includes several subsectors, with very large vessels to handle mass market demands and “boutique” ships that market unique experiences at much higher price points. Mineral extraction traffic has significantly in the last few years, with a step change in traffic in 2016 due to the growth of operations at the Baffinland Mary River site which exported over 2.7 Million MT of ore during the 2016 season.

Before 2016 another major component of shipping through the Arctic was trade (predominantly grain exports) through the Port of Churchill which is located south of the Arctic (as defined in the Arctic Waters Pollution Prevention Act and the IMO Polar Code) but relies on routes through Hudson Bay and Hudson Strait to access ports in Europe and elsewhere. This port has been closed from August 2016, with zero trade and trade ship traffic going to the port. However, there is some potential for Cruise vessels to travel to the port and attached town of Churchill, Manitoba. Additionally, with the construction of the rebuilt rail line, the port may re-open for trade.

Certain other activities, by their very nature, rely wholly on marine assets of various types. Government icebreaking operations, training voyages, and sovereignty exercises take place every season in the Arctic. Large scale commercial fishing makes use of large factory ships which can stay at sea for weeks if needed. Limited oil and gas exploration activity also continues in the Arctic.

The data used in this report is based on satellite AIS data for the Canadian Arctic in 2016 provided by ExactEarth. This data offers high resolution position and time data for vessels, but is also subject to various quality issues for vessel particulars. The data has been extensively processed and corrected, as well as correlated with 2016 NORDREG vessel data, and provides a complete list of all known ship voyages in Canadian Arctic waters occurring in the baseline year 2016. The scope of the dataset is limited to those voyages which enter the NORDREG zone and/or certain regions of the Mackenzie River[1].

[1] The Northern portion of the Mackenzie River flows through Shipping Safety Control Zone 12 and falls under NORDREG. Vessels entering Zone 12 at any point in their voyage will generally file a NORDREG report regardless of tonnage.

2.1 VESSEL INFORMATION

The following table provides an overview of traffic in the Canadian Arctic in 2016. Note that for the purposes of this report, a "voyage" is the AIS based track for a given vessel from the time it enters the NORDREG zone to the time it leaves.

Table 1: Activity by Vessel Type in the Canadian Arctic, 2016

Vessel Type	Total Voyages	Total Distance (km)	Total Days	Unique Vessels
Passenger Vessel	16	156,046	197	12
Fishing Vessel	114	339,018	1,586	26
Coast Guard Icebreaker	18	184,495	479	10
General Cargo	29	270,973	615	15
Bulk Carrier	49	204,370	530	26
Tug	40	98,252	928	19
Cruise Ship	1	17,328	12	1
Tanker	17	104,061	396	9
Military Vessel	4	34,901	63	2
Factory Ship	8	28,632	105	1
Chemical Tanker	3	26,964	108	1
Sailing Ship	26	79,221	259	13
Trawler	2	28,005	60	2
Coast Guard Tender	3	11,870	111	1
Research Vessel	2	19,574	25	2
Yacht	9	43,509	93	4
Adventurer	3	3,934	21	1
Totals	**344**	**1,615,151**	**5,589**	**145**

Note that the various passenger vessel types are not always reported consistently. In general, an adventurer or yacht refers to a small motor vessel with fewer than 10 persons on board. A "passenger vessel" covers a range of vessel sizes and accommodation loads, ranging from small boutique vessels with 20 persons on board, to small cruise ship style expedition vessels, the largest of which in 2016 in the Canadian Arctic was the Le Boreal with approximately 400 persons on board. Cruise Ship refers to a large, conventional cruise ship such as the Crystal Serenity, which may have over 1000 persons on board.

2.2 VOYAGE INFORMATION

The project is based on a complete list of all known ship voyages in Canadian Arctic waters occurring in the baseline year 2016. The scope of the dataset is limited to those voyages which enter the NORDREG zone and/or certain regions of the Mackenzie River. Note that only the portion of the voyage occurring within the NORDREG zone has been used for the purposes of calculating the particulars of each voyage such as distance, time, etc.

The data is divided at the top level into industry sectors:

1. Fisheries
2. Mining and minerals extraction, including resupply and construction at industrial sites
3. Sealift/Community Resupply
4. Bulk shipping – specifically a limited number of voyages made by bulk carriers passing through the Arctic but not stopping at mining facilities
5. Government operations – primarily Canadian Coast Guard, also military and research
6. Tourism traffic, including commercial operations and adventurer expeditions
7. Research, not including oil and gas exploration or government operations
8. Other traffic – in 2016 this includes oil and gas surveys, non-government support/escort operations, and other unclassified traffic.

Each voyage is associated with a discrete vessel record, and by extension the particulars for that vessel. As a result, it is possible to present and evaluate the voyages based on a variety of data types other than associated industry, such as vessel type or other means of categorization, waste stream factors, and temporal data.

The following table provide an overview of activity in each industry sector in the Canadian Arctic for the baseline year 2016, with distances and days referring only to the portion of the voyage within NORDREG limits:

Table 2: Activity by Industry in the Canadian Arctic, 2016

Industry Sector	Total Voyages	Total Distance (km)	Total Days	Unique Vessels
Sealift and community resupply	75	462,418	1,679	34
Fishing vessels (all types)	124	395,655	1,752	29
Tourism and adventurers	55	300,038	582	31
Government vessels, primarily Coast Guard	26	231,374	654	15
Mining bulk shipping and support	53	220,633	714	29
Research vessels including oil and gas	2	19,574	25	2
Bulk shipping (not in support of mining)	2	19,169	16	2
Others, including local tug support	11	4,521	179	9

Note that under NORDREG, only vessels of 300gt or more, vessels towing a combined tonnage of 500gt or more, or vessels carrying or towing as cargo pollutants or dangerous goods are required to file reports. The satellite AIS data used for this report captures every vessel in the region with an active AIS transponder.

As a result, this report captures all significant traffic in the Canadian Arctic. A small number of local vessel sailings, such as small recreational craft, may not be captured, however it is assumed that all voyages with a significant duration, distance, and resulting potential for the generation of waste in 2016 have been included.

The following figure shows the distribution of traffic within the NORDREG zone in 2016.

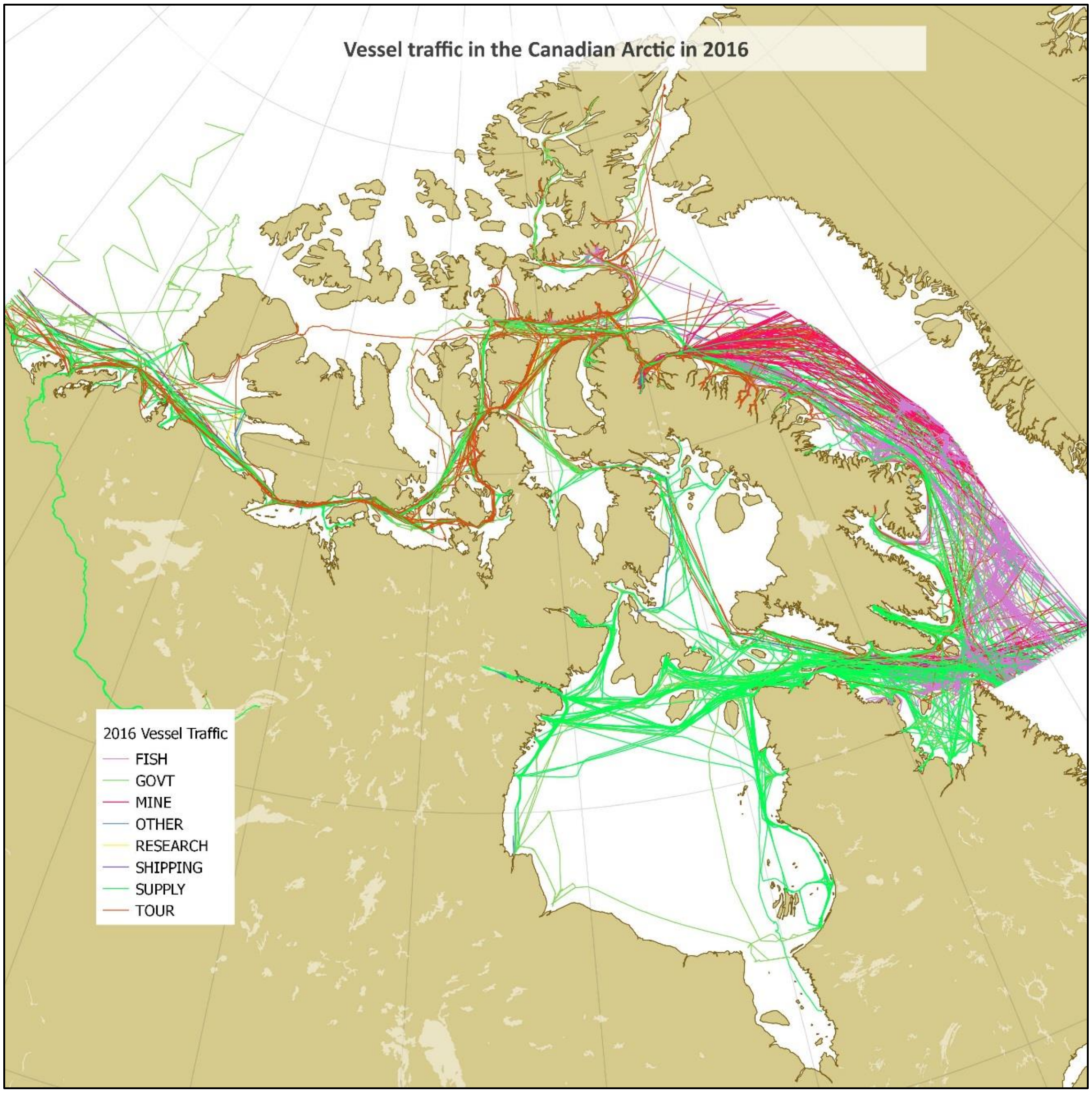

Figure 1: All Individual Ship Voyages Inside NORDREG Zone, 2016

2.3 VOYAGES IN INDUSTRY SECTORS

2.3.1 FISHERIES

Fishing vessel activity in the Canadian Arctic is limited to vessels fishing offshore in designated NAFO[2] fishing areas, as well as vessels transiting to and from Labrador, Greenland, and Pangnirtung. Additionally, some vessels operated by Northern Canadian interests will visit smaller communities to change crews. Fishing in Northern regions is demanding on vessels, and as a result most are larger ice classed trawlers.

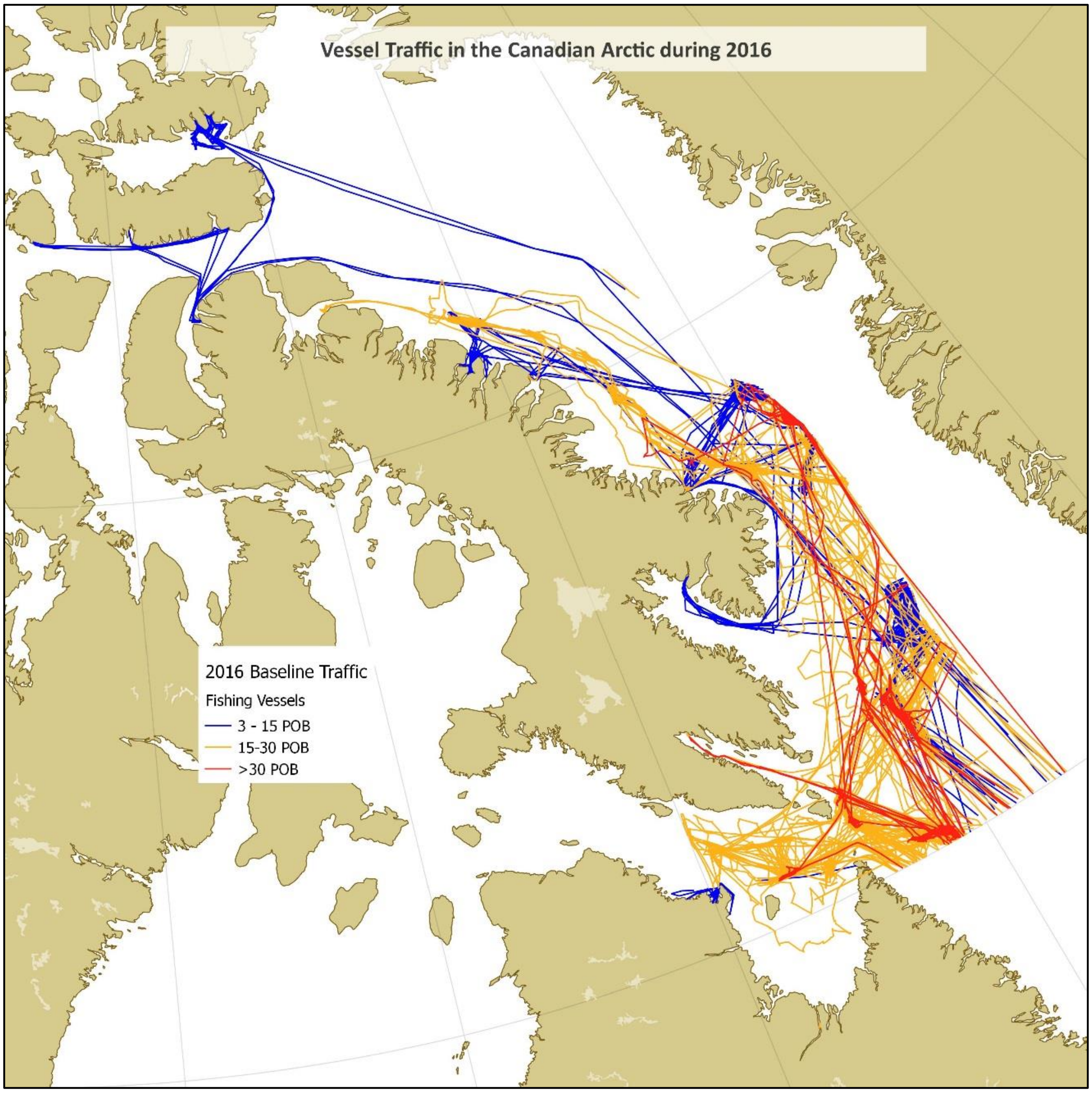

Figure 2: All Individual Fisheries Voyages in the Canadian Arctic, 2016

[2] The Northwest Atlantic Fisheries Organization (NAFO) regulates fishing of most species in the Northwest Atlantic. NAFO mandate, regulated areas, etc.: http://www.nafo.int/fisheries/frames/fishery.html

2.3.2 MINING AND MINERALS EXTRACTION

The mining sector included 3 areas of activity in 2016. The Raglan mine exports iron ore from Deception Bay Eastbound out of the NORDREG zone. The Agnico Eagle gold mine at Baker Lake does not export any product by sea, but does receive supplies and equipment by tug and barge, or by tanker or general cargo vessels with the supplies being transferred to barges. The Baffinland Mary River iron ore mine exported approximately 2.7 million MT of iron ore via bulk carrier in 2016, and receives operational supplies of fuel and provisions via sealift.

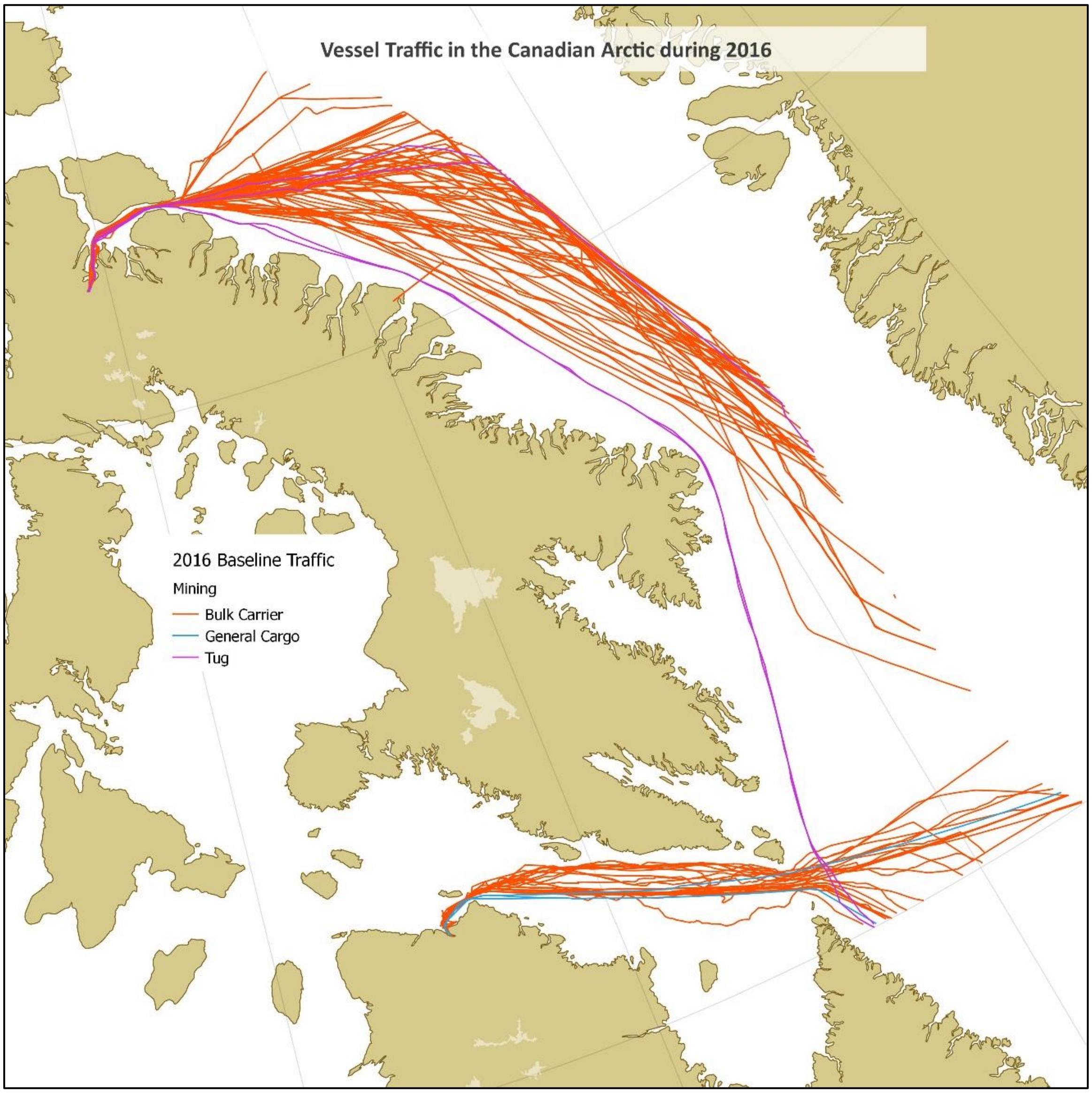

Figure 3: All Individual Mining Industry Voyages in the Canadian Arctic, 2016

2.3.3 SEALIFT

Most Northern communities are entirely dependent of cargo vessel deliveries for resupply, fuel, construction, and equipment. Resupply services are provided by a variety of vessel types, including general cargo vessels, tankers, and tug and barge.

The Beaufort Sea and Western Arctic are almost exclusively supplied by Tug and barge, with the vessels remaining in the region year-round. The general cargo vessels, tugs, and tankers that serve the Eastern Arctic return to southern regions when the season closes.

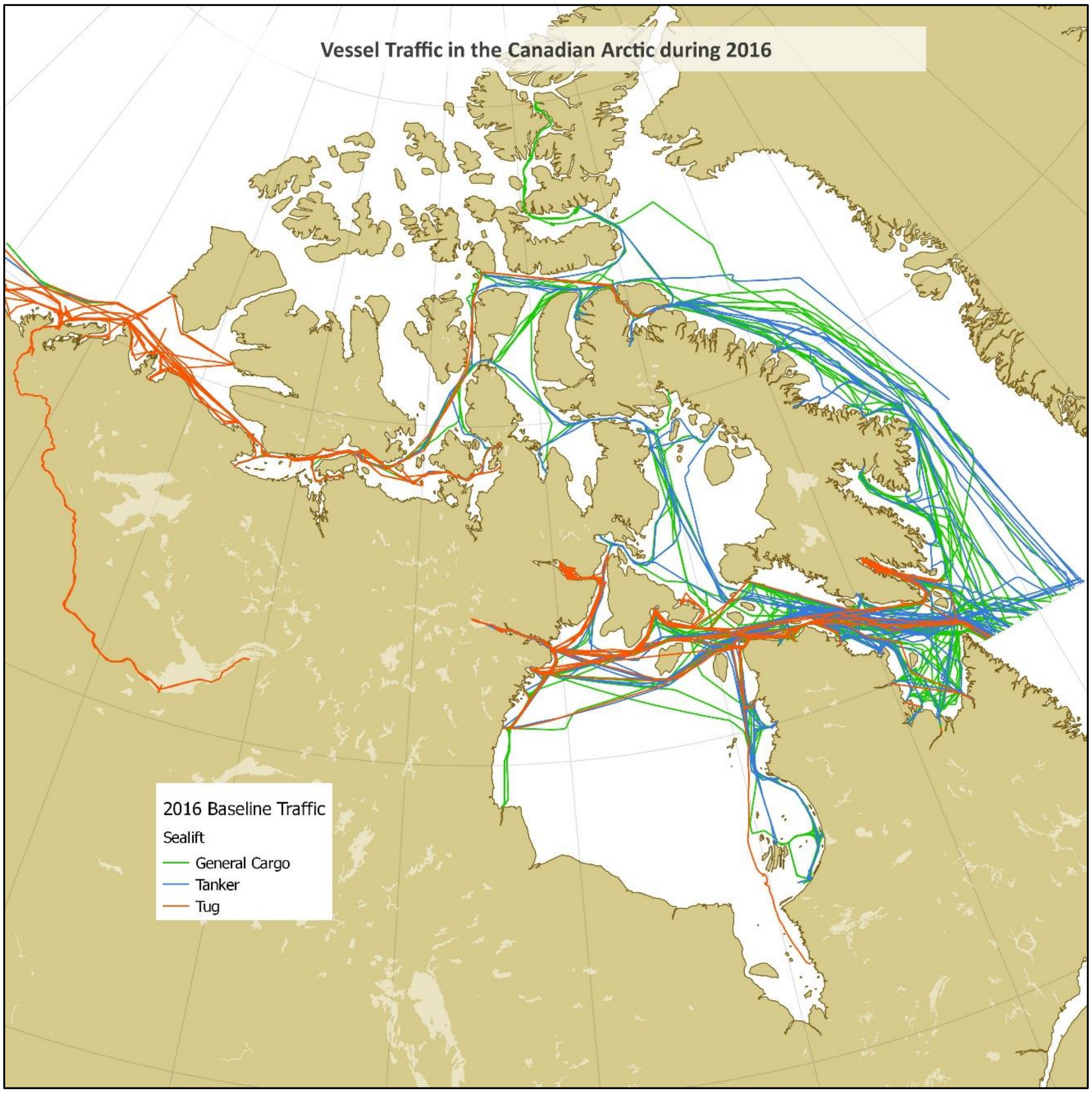

Figure 4: All Individual Sealift Voyages in the Canadian Arctic, 2016

2.3.4 BULK TRADE

The port of Churchill in Hudson's Bay has previously seen bulk carrier traffic for approximately 3.5 months of the year as (generally) foreign flagged bulk carriers arrive empty and carry grain from the port overseas. The port had closed for all operations in August 2016. A limited about of bulk trade (specifically, bulk carriers not stopping at Arctic mines) occurred in 2016 within the NORDREG zone.

2.3.5 GOVERNMENT

Most government activity in the Canadian Arctic is the operation of icebreakers in support of navigation support and escort, icebreaking operations, research, and patrol/sovereignty exercises. Additionally, smaller Coast Guard tenders operate seasonally on the Mackenzie River. Smaller research vessels and warships occasionally enter the NORDREG zone, but account for a negligible percentage of the overall sector traffic.

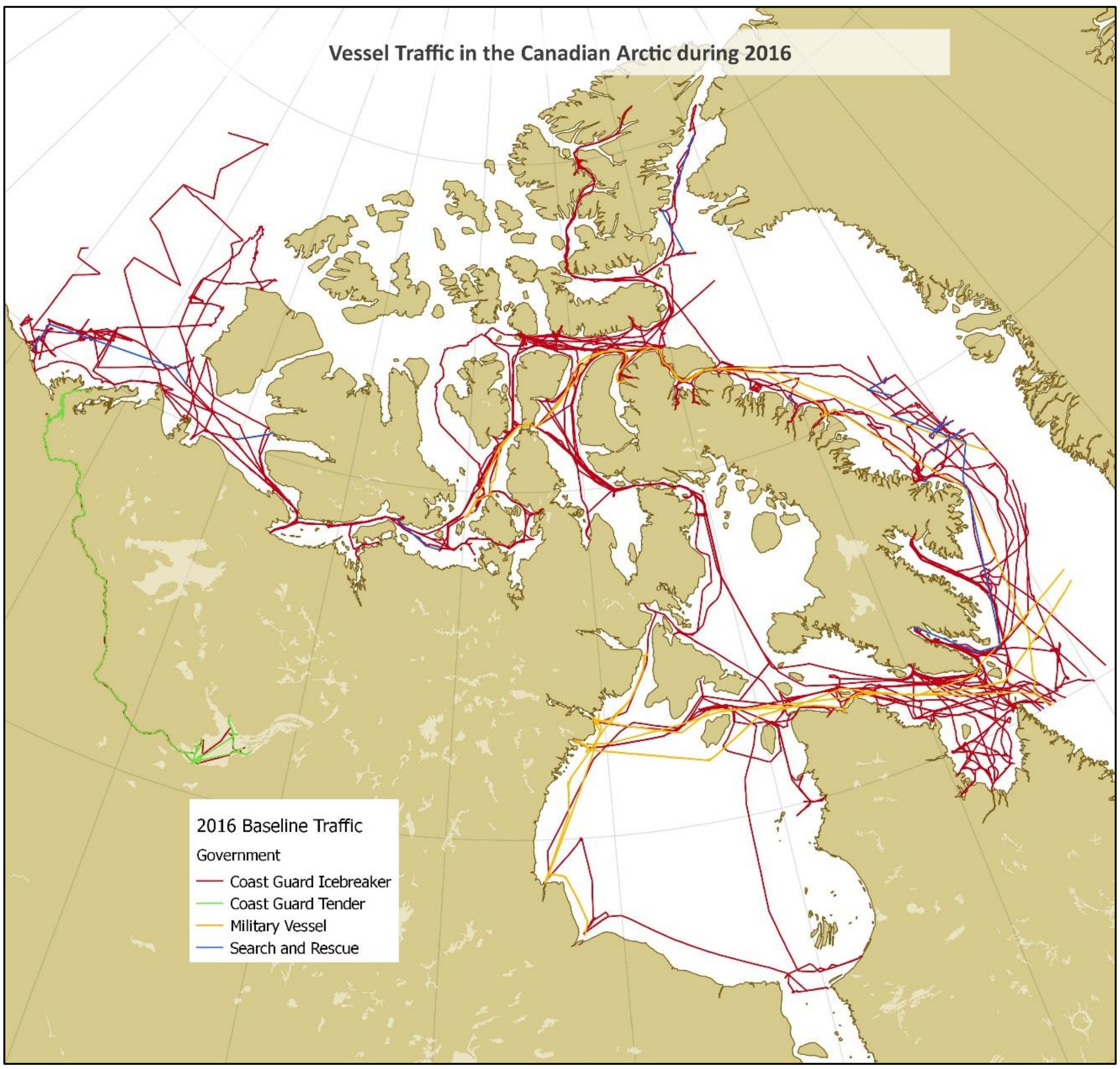

Figure 5: All Individual Government Operation Voyages in the Canadian Arctic, 2016

2.3.6 RESEARCH

This category includes vessels with a variety of sizes and capabilities, ranging from icebreaking vessels to converted trawlers with little or no ice strength. These vessels will typically remain in the Arctic for relatively lengthy periods of time to perform their research, and will have complements including crew and scientists.

2.3.7 TOURISM

The tourist trade in the Canadian Arctic is a mix of vessel sizes and types. Larger vessels include cruise ships carrying hundreds of passengers – these are typically found cruising inlets and coastal regions near Eastern Baffin Island, however in 2016 the Crystal Serenity, a 1000 passenger Cruise ship, completed a full transit of the Northwest Passage stopping at several communities and excursions along the way. Mid-size vessels include larger commercial research and utility vessels converted for expeditions as well as yachts. The sector also includes a variety of small “adventurer” vessels such as small motor craft, sailboats, and even rowboats. All vessels in this sector have historically reported to NORDREG regardless of tonnage for safety reasons.

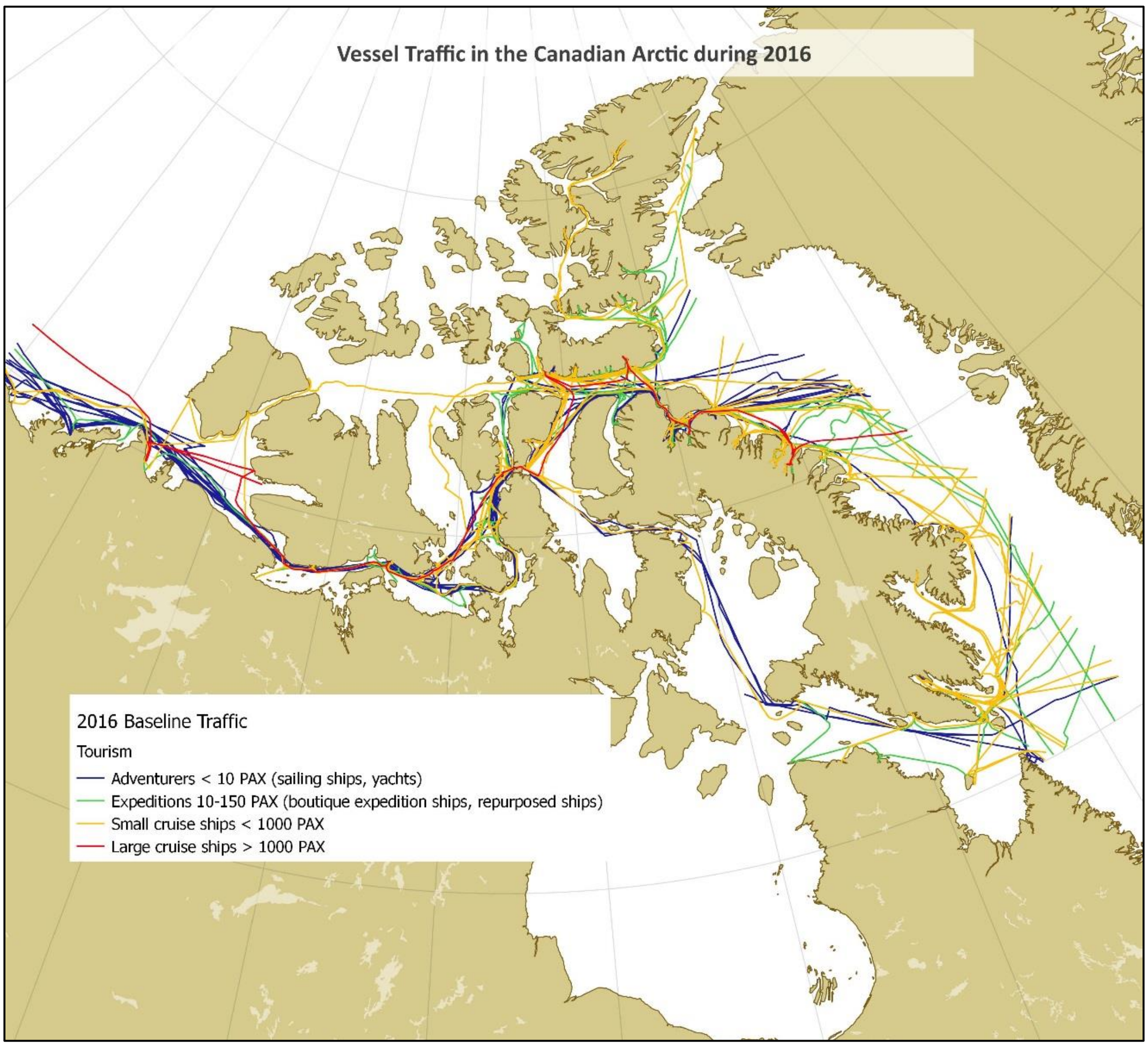

Figure 6: All Individual Tourism Industry Voyages in the Canadian Arctic, 2016

2.3.8 OTHER

There are other vessels which report to NORDREG but do not fit into any of the previous categories. Examples include vessels under tow for refit or layup, vessels providing bunkering and support to other vessels, tugs operating around Tuktoyaktuk and managing barges in the Mackenzie River, and heavy lift or other specialized vessels.

Oil and Gas Exploration is also included in this category. Due to the low level of industry activity this category is limited to a handful of seismic survey vessels for the baseline year. Should exploration resume in a meaningful way in the Beaufort Sea this category should be treated separately as traffic would expand to include offshore drilling rigs, offshore supply vessels, anchor handlers, and other support craft.

3 GREYWATER WASTE

3.1 OVERVIEW

Greywater includes waste water from sinks baths, showers, laundry and galleys. It is important to recognize that greywater is not a MARPOL waste stream, and is therefore only regulated by local regimes.

Generation rates estimates are averages for the relevant vessel type in more global operations. As a result, they may differ from the actual rates for vessels used in the Arctic. For example, operating in ice may result in higher overall engine loading or may require additional crew, or expedition style cruises (which are by their nature “luxury” voyages) may require higher hotel loads, and greater use of passenger services per passenger than typical of a conventional cruise ship.

Certain other conditions present in the Canadian Arctic are also not expected to affect waste generation rates. Common issues for Arctic navigation are cold weather and ice accumulation on decks and machinery spaces. While these can affect some aspects of vessels operation (for example, the emptying bilge and ballast tanks, relating to MARPOL Annex I waste streams), this report assumes that they do not have a significant effect on the waste generation rate for greywater.

3.2 GREYWATER GENERATION RATE ESTIMATION

The waste generation metrics for greywater from the 2009 EPA study used in the Vard 2015 Study[3] have been used to develop the estimates in this report. These rates These rates are:

- Cruise Ships: 253.6 L per day per person
- Cargo Vessels: 125.0 L per day per person

The cruise ship value is applied to all passenger vessels, and the cargo ship value was applied to all other vessel types. Per the previous study, no relation was found between the per person generation rate of greywater and the number of people on board.

The conditions found in the Arctic would not likely influence the greywater generation rate, as this amount is based on ship type and the number of persons on board. A better estimate of the actual generation rate based on ship type would improve accuracy. For example, fishing and smaller vessels may not have the laundry, shower and galley facilities that larger commercial ships have.

[3] VARD Marine Inc, “Projections for ship-generated waste travelling though the Canadian Arctic” 2015

3.3 DETAILED GREYWATER WASTE ESTIMATES

This section provides estimates greywater by applying the estimating procedures described in Section 3.2 to the vessel and voyage data described in Sections 2.1 and 2.3. These estimates are for the baseline 2016 data, and for the basis for the forecasts in section 5.

The quantity of waste generated per km travelled is derived based on the characteristics of the vessel, and the time it spent travelling its total distance within the NORDREG zone. This allows the calculation of the total amount of waste generated inside the NORDREG zone, as well as presentation of the distribution of intensity of waste generation inside the NORDREG zone on a grid or heatmap. This approach is useful for evaluating which regions are subject to more or less vessel traffic and greywater generation, regardless of the capacity or potential inbound carried quantities of waste.

The following table provides a summary of the quantities greywater generated within the NORDREG zone in 2016.

Table 3: Greywater generated within the Canadian Arctic, 2016

Vessel Type	Greywater (L)
Passenger Vessel	11,622,319
Fishing Vessel	5,771,964
Coast Guard Icebreaker	3,743,490
General Cargo	2,439,094
Bulk Carrier	3,474,563
Tug	1,623,021
Cruise Ship	1,541,667
Tanker	1,270,625
Military Vessel	676,057
Factory Ship	328,385
Chemical Tanker	228,703
Sailing Ship	204,505
Trawler	165,938
Coast Guard Tender	139,219
Research Vessel	109,833
Yacht	76,583
Adventurer	15,781
Others	6,547
Totals	**33,438,293**

The following figure shows the distribution of waste generation for grey water in the Canadian Arctic. More intensely coloured regions represent larger quantities of total waste generated within the bounds of the region.

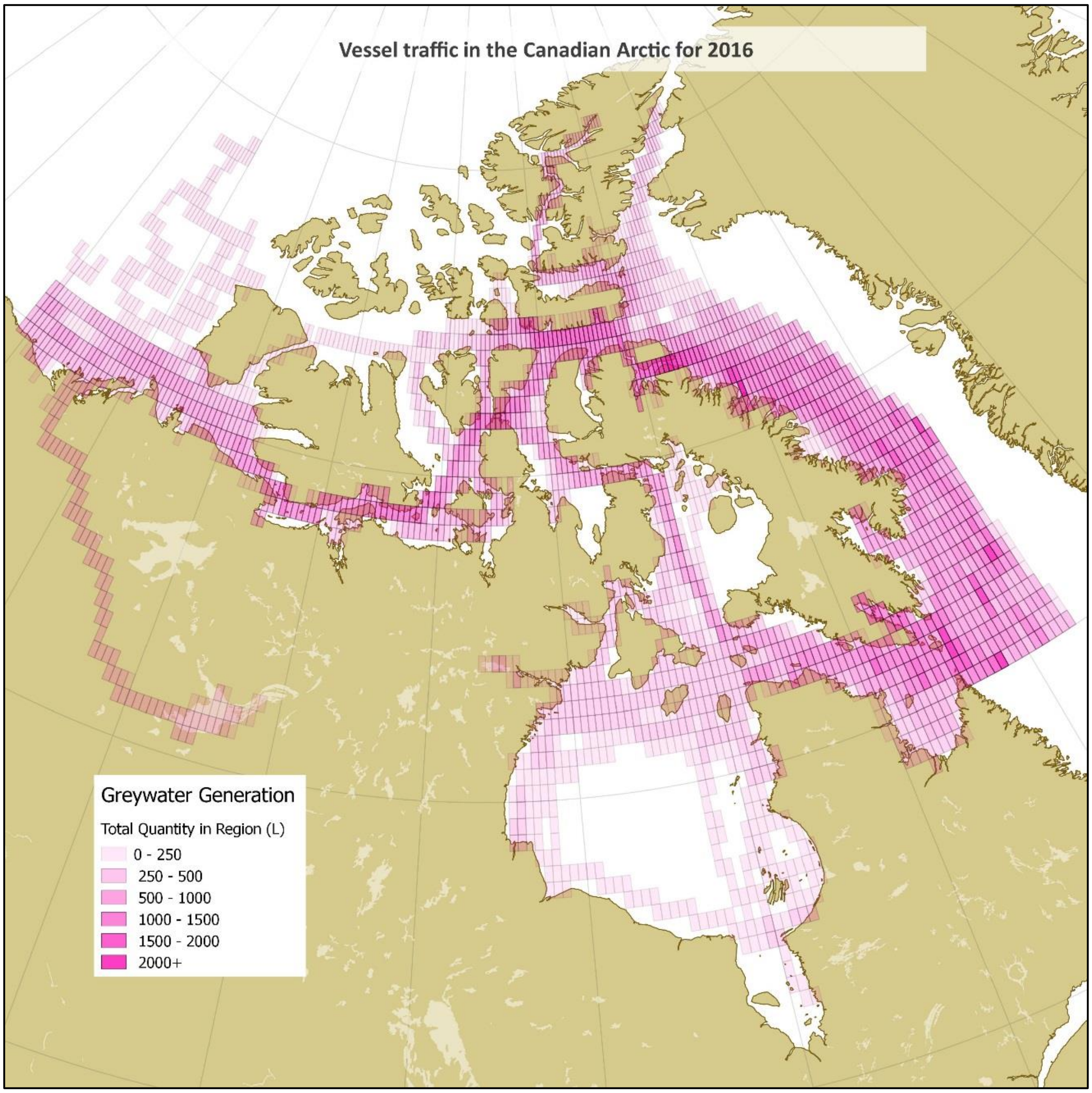

Figure 7: Total Litres of Generated Grey Water (All Vessel Types, 2016)

In this type of heatmap the greywater generation values represent the total amount of waste generated during the vessel's time in the NORDREG zone, distributed evenly along the route the vessels sailed. The calculations do not account for quantity of waste on board at time of zone entry, nor do they estimate quantities on board at discrete times during the voyage.

In this type of heatmap the Canadian Arctic has been divided into regions measuring 0.5 decimal degrees x 0.5 decimal degrees. The total amount of greywater generated within each region is then calculated:

1. First, the total quantity of grey water generated by each vessel inside NORDREG is calculated using the waste estimation procedures described in Section 3.2.
2. The total amounts from (1) are divided by the total distance sailed by the vessel within NORDREG, deriving a ratio of *quantity of greywater generated per km sailed*.
3. The distanced sailed by each vessel within each region is calculated.
4. The distance sailed by each vessel within each individual region from (3) is then multiplied by the waste generation ratio from (2), to obtain the total quantity of greywater generated by each vessel in the region.
5. The vessel totals from (4) are summed to produce the total overall quantity of greywater generated within the region.

3.4 VALIDATION OF WASTE ESTIMATING PROCEDURES

In the previous 2015 Vard study the validation task consisted of a literature review of published research into waste generation on ships, and a comparison of any available metrics or empirical data found to the values generated by the estimating procedures used in the project.

Informal discussions were held with various industry contacts in the commercial shipping and tourism sectors as part of the previous study. These contacts were unable to provide additional insight into generation rates as they are not an aspect of operations which is closely tracked.

Vessels are designed with marine systems capacities which meet all the requirements (class society notations, MARPOL, etc.) for their crew and passenger loads. The ship owners are concerned with regulatory compliance, and will discharge waste in a compliant manner as and when required - the specific waste generation rates which feed into the ship's marine systems are essentially irrelevant to their day-to-day operations.

Much of the information found during the previous 2015 Vard study's validation task is from the 2009 EPA study referenced in this report. The following sections provide additional references which were also used by the previous 2015 Vard study for validation.

3.4.1 HELCOM OVERVIEW 2014 – BALTIC SEA SEWAGE PORT RECEPTION FACILITIES

The HELCOM Overview 2014 Baltic Sea Sewage Port Reception Facilities report provides information on the status of sewage port reception facilities (PRFs) and their use in the Baltic Sea area in 2014, with a focus on international cruise traffic.

The report incorporates estimates for sewage (defined as black water and grey water only for this report) which are comparable to the generation rate for cargo ships from the Vessel Literature Review used by this project. The generation rates for cruise ships are considerably lower than those suggested by the sources in the Vessel Literature Review, primarily due to the relatively shorter average cruise durations for the Baltic Sea.

Table 4: Comparison of HELCOM Overview Generation Rates to Project Estimated Rates

Rate Type	Volume	Units	Volume	Units
Overnight ferries between Helsinki and Stockholm in the Baltic Sea	0.1	m^3/person/day	100	L/person/day
Average from HELCOM-CLIA survey	0.17	m^3/person/day	170	L/person/day
Port of Copenhagen maximum	0.13	m^3/person/day	130	L/person/day
Project cruise ship generation rate (black water and grey water)	**-**	**-**	**285.4**	**L/person/day**
Project cargo ship generation rate (black water and grey water)	**-**	**-**	**156.8**	**L/person/day**

The report addresses the large variation in sewage generation amounts as follows:

"Due to the large variation of such sewage production estimations this report does not include ready calculated figures of discharge needs in m^3/hour. Instead, the estimations are presented as a value which gives the reader estimated total discharge need in volume per time unit, if multiplied with a sewage generation estimation of choice such as those listed above."

The report also provides detailed outflow estimates in m^3/hour for 33 European ports based on survey responses.

3.4.2 ESTIMATED NUTRIENT LOAD FROM WASTE WATERS ORIGINATING FROM SHIPS IN THE BALTIC SEA AREA (VTT 2007)

The 2007 VTT report *Estimated Nutrient Load From Waste Waters Originating From Ships In The Baltic Sea Area* is referenced by the report in 3.4.1 above, and provides some additional estimations for sewage and grey water generation rates.

The purpose of this study was to estimate the nutrient load from waste waters originating from ships in the Baltic Sea area. The study also includes information about regional maritime traffic, waste water management, and legislation. The nutrient load originating from pleasure craft was not included in the study.

The study includes estimates of the amount of waste water generated in L/person as a function of the voyage time in hours. It also gives various estimates of sewage and grey water generation rates from different sources, though these are apparently dependent on the type of sewage system on board. The wastewater generation values provided by the report suggest that generation rates increase as voyage durations increase due to the requirement for additional passenger services. The peak rates were estimated to be in excess of 100L/person/day for longer voyages with basic amenities, which is relatively consistent with this project's estimate of 125L/person/day.

4 FORECAST SCENARIOS

This section provides forecasts of marine activity in the Canadian Arctic in 2025 and 2035. Forecasts for each industry sector have been prepared and the sections below outline the basis for each forecast and the main drivers at work in the industry sector. Each sector of the marine industry is influenced by a somewhat different set of factors.

The key factor for both mining and hydrocarbon development is the world price of the commodity, and forecasts/expectations of how the pricing may evolve in the medium-term future. The development of any of these resources is capital-intensive and evolves over timelines of many years, making them somewhat resilient to economic and environmental factors.

For both offshore and onshore development, it is recognized that there must be buy-in by the local communities, and that projects have to offer significant benefits to the local community. Mining projects are also subjected to increased scrutiny and regulation. For the Baffinland/Mary River project the Nunavut Impact Review Board led a lengthy consultation process which resulted in 184 recommendations for measures to be taken during the development and production phases, many of which were related to the shipping component of the project. Local groups continue to work with the developers, and continue to raise new issues for mitigation.

Fishing in Canada's North is highly regulated with the rights to operate being licensed to a small number of operators, all of whom operate under strict quotas. There may also be societal influencers where communities wish to see more local value added to a fishery, either by giving preference to certain fishing fleets or by establishing processing and distribution channels.

Resupply traffic volumes are driven mainly by the growth of the communities involved, both in terms of population and wealth. In some cases, there may be step changes; for example, where a port facility is built or (for mainland communities) if alternative road links to the South are established. The cost of transportation is a significant component of the cost of goods in the North, and many communities are supplied exclusively by a small number of ship visits each season.

Tourism is highly dependent on the health of the economy. Northern tourism over the last decade has grown and shrunk in line with general trends, and can be expected to do so in the future. Climate change may also be a significant factor, as it affects the ability of operators to plan voyages such as transits of the Northwest Passage by ships with limited ice capability. Many regulatory factors, such as reporting requirements and access permits at multiple levels of government can also have a significant influence on tourism traffic levels.

Government operations are typically driven based on the availability of resources. The operations of smaller vessels and tenders are typically scheduled well in advance, while larger icebreakers availability and the extent to which they travel in a season varies depending on research missions, patrol missions, and emergency search and rescue and ice management calls, as well as the availability of the vessels themselves due to damage, refit, and operational and budgetary constraints.

4.1 FORECAST OVERVIEW

The 2025 and 2035 forecasts are based on scaling the quantities of greywater generated in 2016 directly as a function of waste generation rate and increased traffic volume, if applicable. The resulting forecasts are presented as tables which list the metrics for change in each industry at each forecast date. These are applied to waste generation estimates as follows:

1. The Canadian Arctic is divided into a grid, and the distance travelled by each vessel within each grid cell is measured.
2. Using the estimating procedures described in Section 3.2 the quantity of grey water generated along this distance is calculated. The available data does not provide sufficient data to discern precisely how much time was required to travel any given portion of a voyage, so these calculations simplify the estimate to assume a constant average speed throughout the voyage.
3. Each voyage has a different distance based QTY/km generation rate based on the length of its voyage, the total time between arrival and departure from the NORDREG zone, and the time-based waste generation metrics from Section 3.3.
4. The total distance in each grid cell is scaled as required based on overall industry sector traffic changes.
5. Additional voyages are digitized as necessary, such as forecast traffic to and from Churchill if the port re-opens. These voyages have been processed discretely from the rest of the data and integrated to the main data set after processing.

4.2 TOURISM SECTOR OVERVIEW AND FORECASTS

There are a variety of tourism operations throughout the Canadian Arctic, and it is reasonable to expect the industry to grow throughout the forecast timeline. This forecast makes the following assumptions:

1. Low fuel prices will encourage cruise operators of large vessels to consider adding more voyages to regions for which they already have itineraries.
2. The perception of more accessible conditions in the Northwest Passage will encourage more operators to attempt sailings of its entire length with large cruise ships.
3. The forecast considers smaller adventurer voyages discretely from larger cruise ships. The assumption is that growth in this sub-sector will be moderate. The appetite for adventure expeditions is already met by the current activities in the region, however several operators are currently building or planning new expedition vessels. This forecast assumes that new ships and effective marketing should be able to drive new or repeat customers to the region, resulting in growth for the sector.

Additionally, this report assumes that cruises such as the Crystal Serenity in 2016 will in turn encourage similar voyages in following years:

1. By 2025, additional complete transits of the Northwest Passage by large commercial cruise ships will be scheduled as another new company tests the feasibility and market appetite for the itinerary. Crystal Lines will add another cruise to its calendar to meet demand. This number will increase in 2035 as multiple operators establish a safety record and successfully market their itineraries to a wide customer base.
2. The success of the above commercial efforts will encourage growth in the boutique and expedition cruise sector.

The following table lists the forecast metrics used for this sector:

Table 5: Tourism Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
Baseline 2016	Successful Northwest Passage transit by the Crystal Serenity, with more voyages planned.
2025	Increase of 20% overall traffic density for entire sector vs 2016, due to marketing of new vessels and itineraries.
	Increase from one to 3 voyages by large cruise ships over the 2016 baseline originating West of NORDREG, and transiting through the Beaufort, the entire Northwest Passage, and out of NORDREG through either the Hudson Strait or around the Northern coast of Baffin Island towards Europe.
2035	Increase of 35% overall traffic density for entire sector vs 2016, as new vessels and itineraries become established and drive demand.
	Increase from one to 6 voyages by large cruise ships following the same route as 2025 forecast.

4.3 MINING SECTOR OVERVIEW AND FORECASTS

Almost all mining traffic in the Canadian Arctic is currently related to operations at the Raglan and Nunavik mine sites which ship ore from Deception Bay, the Baffinland Mary River mine, which ships ore from Milne Inlet in the north of Baffin Island, and supply traffic to the Agnico Meadowbank gold mine at Baker Lake.

The medium to long-term projections for Mary River suggest a significant increase in traffic. In 2016 the Mary River facility exported approximately 2.7MT of iron ore via bulk carrier as shown in the baseline traffic data. Through 2017 this amount increased to approximately 4.0MT. Currently, Baffinland are projecting a future capacity increase to approximately 12.0MT through the construction of a second dock as production increases.

The following assumptions are also used in preparing the forecast for the mining sector:

3. The Agnico Eagle gold mine at Baker Lake will cease production by 2020, however the deposit at Amaruq 50km away will be online at that time[4], leading to an approximately equivalent level of traffic through the forecast period.
4. Nunavik mine Nickel ore exports will be limited to trans-Atlantic shipping only
5. The production cap of 1.3M tonnes per year at Raglan[5] remains in place.

The following table lists the forecast metrics used for this sector:

Table 6: Mining Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
Baseline 2016	2016 Baseline traffic includes ore shipments from Milne Inlet and Deception Bay, as well as support traffic through Baker Lake.
2025	Mary River bulk carrier traffic increases to match increased mine output of approximately 6.0MT from the same single pier in Milne Inlet as 2016. Moving from 2.7MT to 6.0MT will require an increase of approximately 220% of traffic.
	Nunavik mine traffic increased by 50% compared to 2016
2035	Raglan mine closes
	Nunavik mine traffic increased by 50% compared to 2016, returning traffic levels in and out of Deception Bay to approximately 2016 levels.
	Mary River bulk carrier traffic is increased to match planned 12.0MT/year peak mine output, accommodated by a second loading pier in Milne Inlet. This represents a 445% increase over 2016 traffic levels.

[4] "Studies are ongoing to reduce the potential production gap between the end of the mine life at Meadowbank and the start of operations at Amaruq in 2019" https://www.agnicoeagle.com/English/operations-and-development-projects/operations/meadowbank/default.aspx

[5] http://www.mineraglan.ca/en/about-us/raglan-mine/Pages/default.aspx

4.4 SEALIFT / COMMUNITY RESUPPLY SECTOR OVERVIEW AND FORECASTS

The level of sealift traffic in the Canadian Arctic is expected to experience modest growth from 2016 levels through 2025 and 2035. This occurs for three main reasons:

- Larger communities (such as Cambridge Bay, Rankin Inlet, Iqaluit) will continue to see modest population growth and may require additional sealift services as population grows and supporting infrastructure is expanded and/or modernized.
- Smaller communities may lose some population, but their infrastructure (housing, municipal facilities, airport facilities) will remain operational and continue to drive demand.
- Remote communities are already resupplied by a very limited number of ship visits each season, and cannot see a reduction in service without being effectively cut off.

Sealift industry representatives have suggested that the business case for adding additional services to remote communities experiencing population growth is challenging – the additional revenue more ship visits would provide is typically outweighed by the more significant capital cost of chartering or acquiring additional vessels, as well as fuel costs and crew availability. The sector's ability to grow their services to meet demand increases is currently very limited – many of the main operators in the region are already at capacity.

However, increasing populations in certain communities will likely demand additional resupply voyages regardless of the ideal scenarios for the vessel operators. The resupply sector will eventually have to add voyages to certain communities, or an outside solution will need to be found. This forecast considers the most likely result of this scenario to be modest increases in sealift activity, such as an additional sealift sailing to the most rapidly growing communities each season.

Iqaluit is developing a deepwater port, currently planned to enter service in time for the 2021 sealift season. There is a possibility that availability of this type of facility could drive additional traffic to the region, however the primary goals for the project are to eliminate the risk and time delays associated with traditional "barge to beach" sealift operations in favour of an alongside unloading process, and to allow different vessels to visit Iqaluit, potentially lowering costs to the community for goods.

The following table lists the forecast metrics used for this sector:

Table 7: Sealift Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
Baseline 2016	Sealift traffic has been consistent since before 2013, with fluctuations in number of voyages generally driven by ice conditions and therefore when the season opens, rather than by changes in demand.
2025	A conservative 10% increase in traffic to align sealift volume with expected overall population growth.
	2 additional voyages directly to Iqaluit (one for fuel, one for goods) compared to the baseline year made possible by the new deepwater port facilities.

2035	A conservative 20% increase in traffic to align sealift volume with expected overall population growth.
	4 additional voyages directly to Iqaluit (one for fuel, three for goods) compared to the baseline year made possible by the new deepwater port facilities.

4.5 BULK TRADE OVERVIEW AND FORECASTS

Growth of shipping traffic out of Churchill is expected to be zero in the near term due to the Port of Churchill ceasing operations. The port was closed on August 2016. The rail line suffered damage in early 2017 and has not re-opened.

As of May 2018 there have been efforts by a coalition of indigenous groups and private interests to purchase the rail line in an effort to restore service to the community of Churchill. This forecast assumes that the rail line will be repaired by 2020 to meet the needs of Churchill residents, and that once rail service is restored the opportunity for the port to reopen and export grain from the Canadian Prairies will present itself. Based on this, the forecasts assume that the port will reopen by 2035. This forecast assumes that the port would not be ready by 2025 because the rail line will take time to repair, and connections to the line as well as new agreements with domestic agriculture and foreign buyers will need to be reestablished.

The following table lists the forecast metrics used for this sector:

Table 8: Commercial Shipping (Churchill) Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
2016 Baseline	Limited bulk shipments in the Canadian Arctic, primarily proof of concept shipments of ore through the Northwest Passage.
2025	A marginal increase in bulk shipments through the Northwest Passage as additional companies complete their own proof of concept voyages in competition with Nordic Bulkers. Forecast is for the number of voyages to move from 2 (in 2016) to 4 in 2025.
2035	No increase forecasted in general bulk traffic, however the Port of Churchill returns to previous steady state operational levels from circa 2013.

Figure 8: Baseline and Bulk Shipping Traffic, Individual Voyages, 2016 and 2035, showing renewed traffic to and from Churchill

4.6 FISHERIES SECTOR OVERVIEW AND FORECASTS

Fisheries in the Canadian Arctic are limited to Northwest Atlantic Fisheries Organization (NAFO) areas 0A and 0B. In addition to fishing operations in these areas, fishing vessel voyages also include trips to and from the areas, typically to Greenland or the Canadian East coast, as well as limited voyages to Iqaluit and Pangnirtung. Traffic in this sector is purely seasonal, generally taking place from June to November. The sector's traffic is mostly larger factory ships with capacities exceeding 500t of catch, and mid-size trawlers with capacities of 150-250t.

Some voyages will sail further into the Arctic; this is entirely for changing crews at northern communities and taking on supplies. There is no commercial fishing in the high Arctic, and the International moratorium signed in late 2017 prohibits commercial fishing in the region until at least 2034

This forecast assumes that the fleet's current capacity to fish to quota will remain in place, and that quota increases will be marginal enough that significant additional investment in the fleet will not be necessary.

The following table lists the forecast metrics used for this sector:

Table 9: Fisheries Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
2025	Increase of 10% overall traffic vs. 2016 to account for a notional increase in quota (resulting in additional trips to the fishing grounds)
2035	Increase of 20% overall traffic vs. 2016 to account for a second notional increase in quota since the baseline year (resulting in additional trips to the fishing grounds)

4.7 GOVERNMENT OPERATIONS OVERVIEW AND FORECASTS

Most government activity inside the Canadian Arctic consists of icebreaking, support, and occasional SAR duties. Estimating the changes to traffic volumes is dependent on 3 main factors:

6. Replacement of aging icebreakers with refit or newly built vessels, including the new polar icebreaker.
7. The fleet of smaller tenders and research vessels will remain relatively unchanged, as most vessels remain in service, or be replaced in kind thereby not significantly changing the size and makeup of this portion of the fleet.
8. By 2025 the Arctic Offshore Patrol ship (AOPS) program should have operational vessels, which are notionally intended for Arctic patrol, supported by an operations base at Nanisivik.

Items (1) and (3) above are part of the current National Ship Procurement Strategy (NSPS) under which the federal government intends to completely renew the Canadian fleet. Current targets include the construction of a large polar icebreaker, between 4 and 6 small ice-capable offshore patrol ships, and a variety of smaller Coast Guard vessels. The true dates at which these vessels will enter into service are entirely unknown, however at least one AOPS should be in service within 10 years, and the polar icebreaker could potentially be in service by 2035.

The following table lists the forecast metrics used for this sector:

Table 10: Government Operations Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
2025	An additional 2 voyages compared to 2016 into Nanisivik and an additional voyage compared to 2016 on a route which mimics 2016 CCG icebreaker voyages will be made by a single new AOPS vessel.
2035	Voyages currently made by CCG heavy icebreakers will be increased by 20% to account for the enhanced capability of new vessels which will be in service by this time. The effect on greywater generation rates has not been estimated however, due to unknowns regarding crew size and ship efficiency.
	An additional 4 voyages compared to 2016 into Nanisivik and an additional voyage compared to 2016 on a route which mimics 2013 CCG icebreaker voyages will be made by two different AOPS vessels.

4.8 RESEARCH OPERATIONS OVERVIEW AND FORECASTS

Non-government research operations take place infrequently in the Canadian Arctic, and this report assumes that no significant changes will occur.

The following table lists the forecast metrics used for this sector:

Table 11: Research Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
2025	No increase forecasted.
2035	No increase forecasted.

4.9 OTHER OPERATIONS

Most of the activities categorized as “other” are related to non-Arctic activities such as towing, escort, and transiting to a winter layup or maintenance site. These are unlikely to change in a measurable or predictable way as they are mostly outside the scope of activities driving Arctic growth.

Development of oil and gas leases in the Eastern Arctic is unlikely to be a consideration until beyond the forecast window. While there is some renewed interest in exploration around Alaska and in the Beaufort Sea this forecast assumes that no significant investment in infrastructure and its accompanying marine traffic will arrive until beyond 2035.

The following table lists the forecast metrics used for this sector:

Table 12: Other Activities Forecast Metrics

Forecast	Specific Metrics Applied to Traffic Density and/or Distribution
2025	No increase forecasted.
2035	No increase forecasted.

5 WASTE FORECASTS

The forecast results were developed by applying the metrics described in Section 3.2 to each industry sector. All projected increases in traffic were included scaling the 2016 estimates for greywater generation to the forecast increases as a percentage. Some exceptions have been made for forecasts for specific traffic patterns within a given industry, such as renewed traffic to and from Churchill, or large cruise ships though the Northwest Passage. This traffic is modelled discretely and integrated into the overall dataset.

The following tables provides an overview of the results for total waste generated within NORDREG.

Table 13: Forecast Grey Water Generated within NORDREG Boundary

Industry Sector	2016 Total (L)	2025 Forecast (L)	2035 Forecast (L)
Sealift	5,177,505	5,713,318	6,249,131
Fisheries	6,266,286	6,892,915	7,519,544
Tourism	13,460,855	20,778,026	27,422,155
Government Operations	4,558,849	4,558,849	4,558,849
Mining	2,680,427	8,036,289	11,168,617
Research	109,833	109,833	109,833
Bulk Shipping	1,066,375	2,132,750	3,169,750
Other	118,161	118,161	118,161
Total	**33,438,293**	**48,340,142**	**60,316,040**

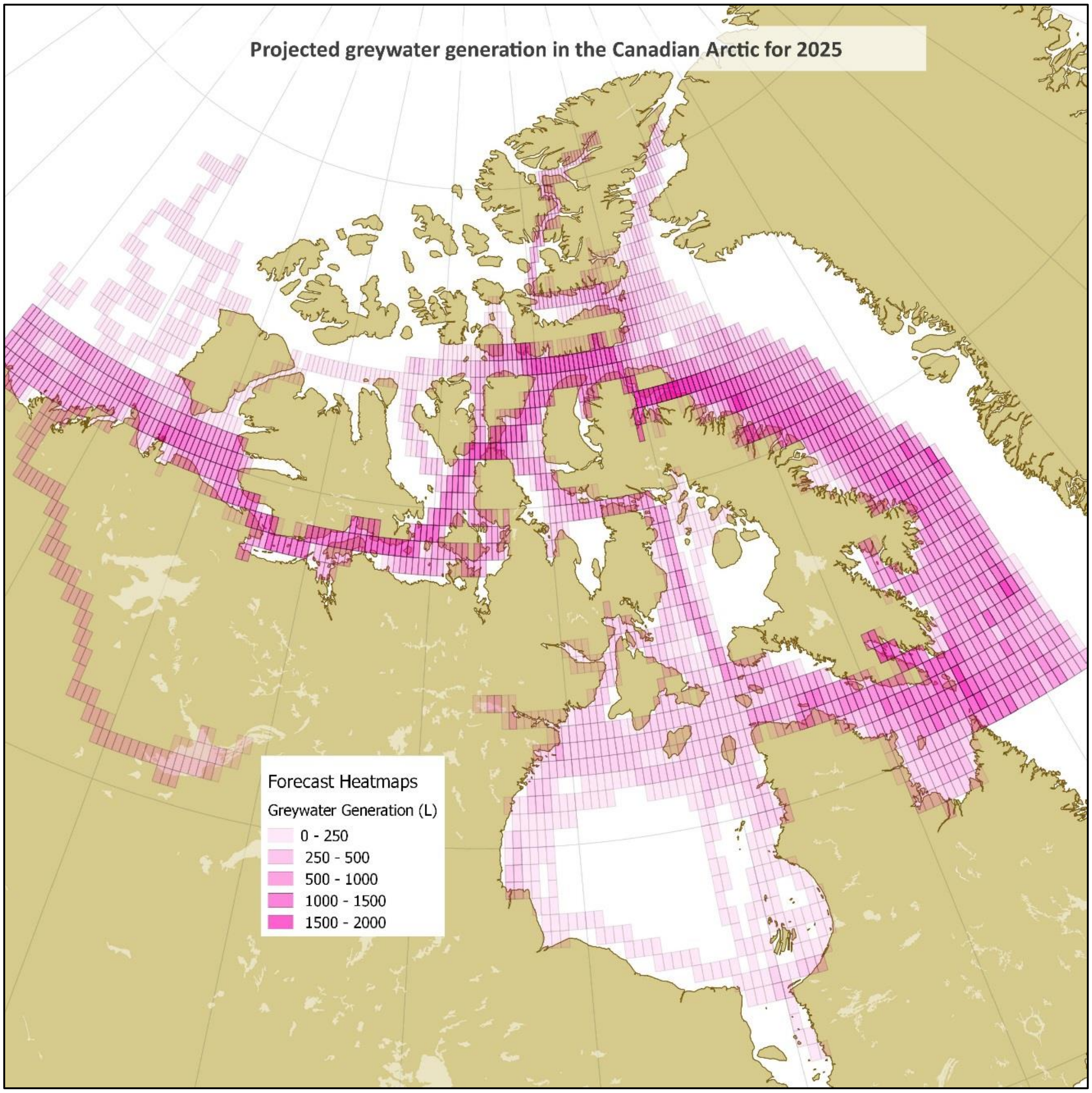

Figure 9: Forecast Generation Density of Grey Water, 2025

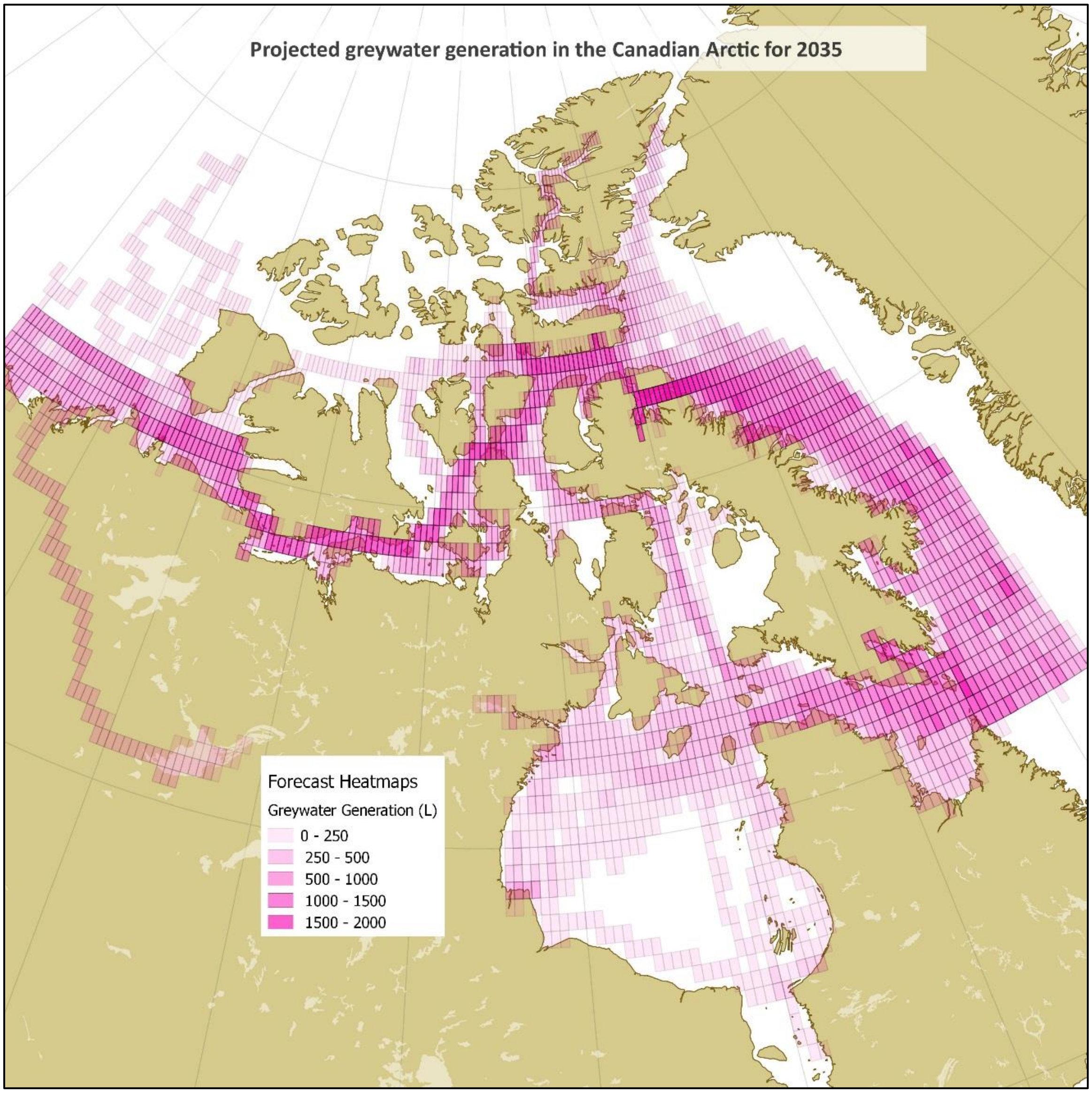

Figure 10: Forecast Generation Density of Grey Water, 2035

6 DISCUSSION AND CONCLUSIONS

6.1 2016 KEY CONTRIBUTORS

Fishing vessels are the largest contributor to overall "human" derived waste streams. This is due to the vessels of the fishing fleet making significantly more voyages than any other type of vessel in the region, and spending over twice as long in the region by number of days than any other type of vessel. Sealift vessels and tourist vessels are the next largest contributors in terms of greywater generated over a large region of the Arctic.

6.2 GAPS IN SCIENCE AND MONITORING

Greywater treatment is relatively well understood in terms of both how to treat greywater and how much will be produced under any given circumstances. Monitoring of greywater treatment and regulatory compliance in the Canadian Arctic is however non-existent. The most significant gaps to consider in the short term are:

- More information is needed on whether efforts are being made to reduce the use of chemical inputs which are potentially incompatible with biological treatment plants.
- More information is needed on how vessel operators for larger passenger vessels are handling greywater. Larger vessels are unlikely to have sufficient carrying capacity to not treat and discharge greywater, so what systems are being used and what standards the operators are working to should be explored.
- More information is needed on how Canada plans to monitor and enforce greywater discharge regulations.

6.3 2035 FORECAST CONTRIBUTORS

Mining exports from the Baffinland Mary River project are expected to cause a considerable increase in vessel traffic along the North of Baffin Island which will lead to a significant increase in greywater generation i0n the region.

Passenger vessel traffic will increase by a small number of trips, however the large number of persons on board for those trips made by cruise ships these trips will result in a massive increase in greywater generation, especially in the Northwest Passage.

6.4 AREAS OF RISK

There are risks associated with greywater discharge for all categories of vessel in the Canadian Arctic. The following are some key risks:

1. Large passenger vessels: A sailing of the Northwest Passage by a large cruise ship (~1000 passengers) is estimated to take approximately 24-28 days assuming a route which leaves from Northern Alaska, and exits the Arctic via the Hudson Strait. At even conservative waste generation rates this is still a significant amount of greywater. The carrying capacity of conventional cruise ships may not be sufficient for a voyage of this length.

2. Fishing Vessels: Factory ships will stay at sea for weeks rather than days, and some will have crews of over 20 persons. In many cases the rate at which greywater is generated will exceed the onboard capacity to carry the waste.

6.5 RECOMMENDATIONS

This report makes the following recommendations:

- Research should be encouraged into alternatives to chemical cleaning agents which could reduce the effectiveness of biological treatment plants.
- Inquiries should be made to a variety of vessel operators to determine how they are treating greywater today. What kind of treatment plants do they use, how much can they carry, and if (and how) they are monitoring discharged greywater to determine the effectiveness of their treatment system.
- Dialogue should be pursued with Canada to help create a properly developed plan to monitor and enforce greywater discharge regulations.

7 OVERVIEW OF GREY WATER TREATEMENT SYSTEMS

7.1 GREYWATER REGULATION IN THE CANADIAN ARCTIC

The Arctic Waters Pollution Prevention Act (AWPPA) prohibits the discharge of any "waste" into Arctic waters; waste being any substance that will have a deleterious effect on the water column:

"waste means

- **(a)** any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water to an extent that is detrimental to their use by man or by any animal, fish or plant that is useful to man, and
- **(b)** any water that contains a substance in such a quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water to the extent described in paragraph (a),"

This strict prohibition can be modified by regulations. The ASSPPR do address permissible sewage (black water) discharge but do not mention grey water. This puts the onus on the operator to prove that grey water does not include any deleterious waste as defined above, which is extremely difficult. There is also no process for approval of any form of grey water treatment systems as these are not allowed for under the regulations.

The new ASSPPR are in this regard no change from the previous Arctic Shipping Pollution Prevention Regulations (ASPPR). It has been generally known that while grey water discharge is in theory prohibited, in practice it has not been monitored or enforced due to the lack of any practical alternatives. In 1972, when the ASPPR were introduced, there were also no environmentally friendly sewage treatment systems and so untreated sewage discharge was allowed while treated discharge was prohibited. Modern technology has solved this problem, as reflected in the Polar Code and in the new ASSPPR. Combined back and grey water treatment systems do also now exist, as discussed in Section 7. However, as IMO does not currently regulate grey water it was not covered under the Polar Code, and Canada has missed the opportunity to deal with the gap.

These regulations require that most operators process and discharge greywater before entering a zero-discharge region. However, remaining in the Arctic for an extended period would require the vessels to have very large holding tank systems, Transport Canada to certify a treatment system, or for the operator to ignore the regulations and discharge regardless.

At this moment Transport Canada does not approve or certify any Greywater Treatment system for use in the Canadian Arctic.

7.2 GREYWATER TREATMENT OPTIONS

Grey water can be treated using an onboard water treatment plant. There are two approaches to treating the waste water generated onboard. Treating the grey water separately, or treating the black and grey water together. Combined systems are the only option that is widely marketed for larger vessels. Discrete greywater treatment systems do exist, but are primarily marketed for smaller vessels and yachts rather than commercial ships.

7.3 COMBINED SYSTEMS

These Grey and Black Water treatment plants are typically Membrane Bioreactor (MBR) systems, which treat the grey water by screening the grey water through filters, separating the treated water through membranes, and generating a fine surplus of activated sludge as the waste product. The leftover sludge would then be stored in the vessel's sludge tank before being eventually pumped ashore.

The Membrane Bioreactor (MBR) grey water treatment systems provide the vessel operator and owners with minimal operating costs, low chemical usages, smallest footprint, low purchase costs, and simple operation.

Other types of Greywater treatment systems use biological treatments, physical filtration, electrolytic processes, and UV sterilization to treat the greywater.

Rochem's Rochem LPRO and Rochem Bio-Filt systems treat greywater through two different concentration sources. The LPRO system handles the waste water generated from laundry and accommodations, while the Bio-Filt system treats the waste water from the galley and sewage. The Bio-Filt system uses screens to remove fibers and hairs, reverse osmosis membranes, and UV disinfection to reduce pathogens. The LPRO system uses screens to remove course solids, bioreactors to oxidize the waste, filtration membranes to remove particulate matter, UV disinfection to reduce pathogens.

Other available greywater treatment systems such as the Zenon ZeeWeed MBR and Scanship AWP (Advanced Wastedwater Purification) treat greywater though the use of aerobic biological oxidation and ultrafiltration, and UV disinfection. The below table is a quick summary of various Greywater treatment systems available, along with info on each system's type, what it treats, and compliance.

Table 14: Overview of Different Types of Greywater Treatment Systems

Make	Model	Type	Application	Compliant
ROCHEM	BIO-FILT	Membrane Bio Reactor	Grey & Black	IMO MEPC 159(55) by DNV
HEADWORKS BIO	CLEAN-SEA	Membrane Bio Reactor	Grey & Black	IMO MEPC 159(55) by DNV
DENORA	OMNIPURE Series 64	Electrolytic Process	Grey & Black	IMO MEPC 227(64) by Bureau Veritas
ACO	MARIPUR NF	Membrane Bio Reactor	Grey & Black	IMO MEPC 227(64) by Bureau Veritas
EVAC	ECOOCEAN	Electrolytic Process	Grey & Black	IMO MEPC 227(64), 159(55) by Bureau Veritas
EVAC	MBR	Membrane Bio Reactor	Grey & Black	IMO MEPC 227(64), 159(55) by Bureau Veritas
WARTSILA	HAMWORTHY SUPER TRIDENT	Membrane Bio Reactor	Grey & Black	IMO MEPC 227(64)
RWO	CLEANSEWAGE	Membrane Bio Reactor	Grey & Black	IMO MEPC 227(64)
DVZ SERVICES	BIOMASTER XS SERIES	Membrane Bio Reactor	Grey & Black	IMO MEPC 227(64), 159(55) by Bureau Veritas
HAMANN AG	HL-CONT Plus Series	Membrane Bio Reactor	Grey & Black	IMO MEPC 227(64)

Figure 11: Wartsila Hamworthy MBR System Overview for Black & Grey Water Treatment

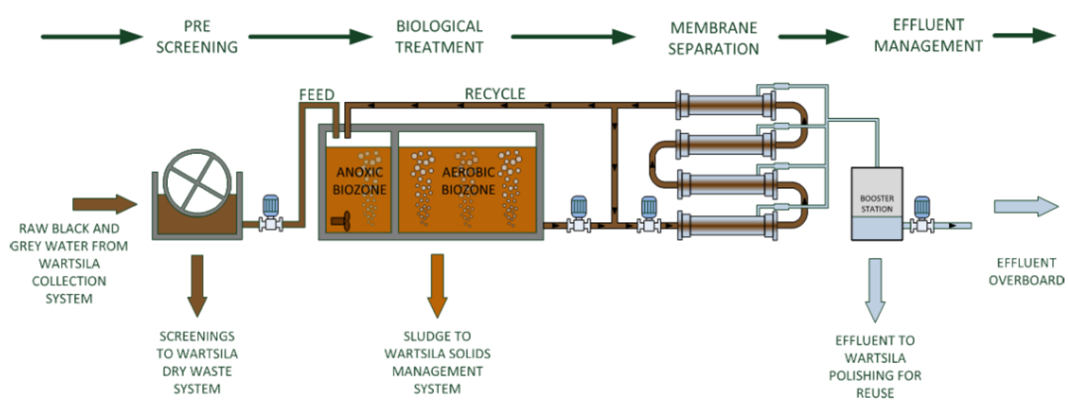

Figure 12: Wartsila Hamworthy MBR System Diagram

Figure 13: EVAC EcoOcean Sewage Treatment System

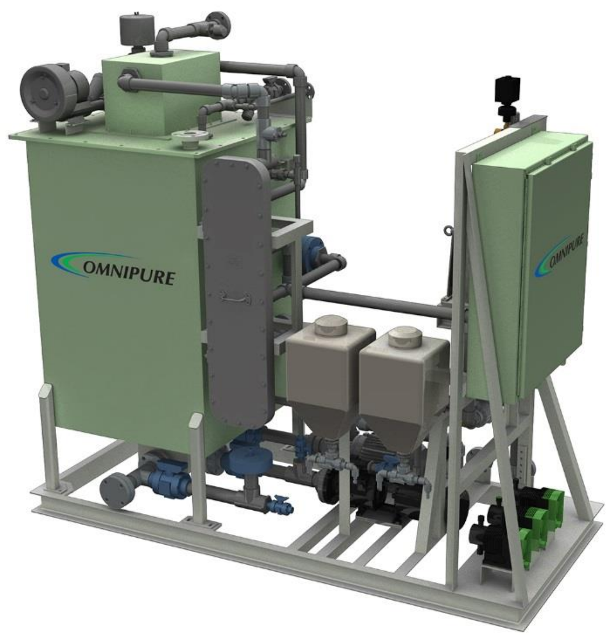

Figure 14: DENORA OMNIOURE Series 64 Sewage Treatment System

Figure 15: ROCHEM BIO-FILT (MBR) System

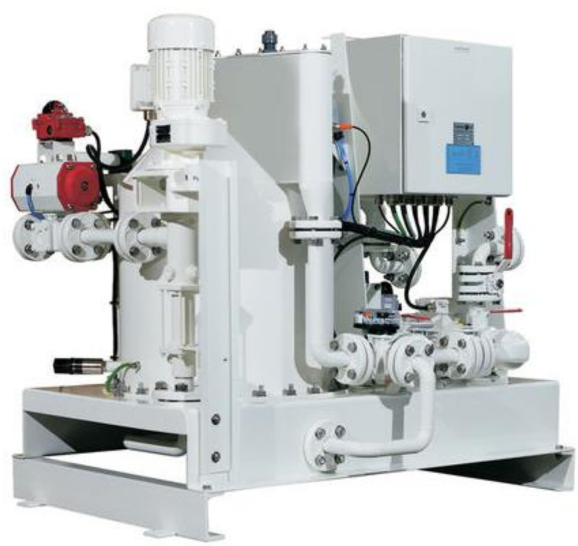

Figure 16: HAMMAN AG HL-CONT Plus Series Sewage Treatment System

The HAMANN AG HL-CONT system can be configured for capacities between 16 and 1422 persons on board, depending on the calculated L/Day rate. (See below)

HL-CONT	Capacity [litre/day]	Persons onboard calculated with 135 l / day	Persons onboard calculated with 180 l / day	Size WxLxH [m]	Empty Weight [kg]	Electrical Consumption	Vent Connection
0125	3.000	22	16	0.8 x 0.9 x 0.9	165	2.1 kW	½"
025	6.000	44	33	0.9 x 1.2 x 0.9	312	2.3 kW	1"
05	12.000	88	66	1.0 x 1.3 x 1.4	691	2.6 kW	1"
10	24.000	177	133	1.2 x 1.6 x 1.8	880	3.5 kW	1"
20	48.000	355	266	1.6 x 2.1 x 2.1	1600	5.2 kW	1"
40	96.000	711	533	2.3 x 2.5 x 2.3	2234	8.5 kW	1"
80	192.000	1422	1066	2.1 x 4.7 x 2.8	4700	15.0 kW	2"

Figure 17: HAMMAN AG HL-CONT Plus Series Specifications

7.4 ISSUES WITH COMBINED SYSTEMS

The main issue with combined treatment systems is their dependence on bio-filtration or bio-treatment of incoming greywater. If the waste stream is contaminated at source by harsh chemicals such as bleaches, sanitizers, or even some personal hygiene products there is a risk that too high a concentration of these chemicals can impact the bio treatment organisms in the system and reduce or entirely disrupt its effectiveness.

Part of any greywater management plan should include best practices for reducing harmful inputs to the system. Harsh chemicals not only jeopardize the effectiveness of many treatment systems, but constitute a pollution risk themselves, and in many cases are more difficult to fully eliminate from the waste stream than biological matter.

7.5 COMBINED SYSTEMS COSTS

The following is a rough guide for the systems costs for combined black and greywater treatment systems. These are rough quotes provided from Hamann AG, and should not be used outside of this report. The actual costs for the treatment systems will vary greatly based on specific requirements for the vessel and the environment.

The Persons On Board (POD) numbers are calculated using the L/day numbers found in Section 3.2.

Table 15: Hamann AG Combined Systems Costs Estimates

Model	L/Day	Cruise POD	Cargo POD	Cost (EUR)	Cost (CAD)
HL-CONT Plus 0125	12,000	47	96	€22,740	$34,337
HL-CONT Plus 025	6,000	24	48	€32,700	$49,377
HL-CONT Plus 05	12,000	47	96	€75,350	$113,779
HL-CONT Plus 10	24,000	95	192	€80,350	$121,329
HL-CONT Plus 20	48,000	189	384	€141,850	$214,194

HL-CONT Plus 40	96,000	379	768	€235,600	$355,756
HL-CONT Plus 80	192,000	757	1536	€298,700	$451,037

* Note: Prices listed above are from 2014.

Unofficial pricing for systems from other manufacturers suggests that the pricing for the Hamann AG systems is of the same order of magnitude as other manufacturer's offerings. 2014 pricing from EVaC included a system rated for 36 persons at a cost of $91,000.

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