Tidal Sector Service Barge/Drydock Feasibility Study

For

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EXECUTIVE SUMMARY

Lengkeek Vessel Engineering and project partner Gardner Pinfold, along with mentoring partners DP Energy, Green Marine, and RJ MacIsaac Construction, have been tasked by the Offshore Energy Research Association to conduct a feasibility study for a shared multi-use service barge/drydock for the tidal sector. The study includes two main tasks, where Task 1 involves the development of the design parameters and attributes of a marine asset that best serves the tidal industry, and Task 2 involves the development of ownership scenarios and a financial model for the asset. Ultimately, the study determines if there is economic justification to proceed with the design and construction of such a vessel to help promote and progress tidal energy projects in Nova Scotia.

The study draws its data, information, and knowledge from stakeholders in the tidal industry including developers, technology providers, and marine service providers, as well as from marine industry stakeholders. Twenty face-to-face and telephone interviews were conducted using a templated interview questionnaire to delve into the stakeholder's experiences, observations, and beliefs regarding optimum marine assets, ownership, and costs. The information and data received from the stakeholders was compiled and analysed to determine common needs and develop a picture of the most useful asset for the industry, who should own the asset, and what charter rate could be expected for the asset. A financial model was then developed to help determine the feasibility of bringing such an asset into the industry.

It was determined that the ideal asset for large tidal technology is a catamaran barge with the capability of lifting equipment weighing approximately 300 tonnes at a reach of approximately 18m. The principal particulars of a barge suitable for this lifting capacity were found to be similar to those of the existing heavy lift barge Scotia Tide, hence it was determined that modification of the existing barge is a viable option and should be considered in the feasibility study. It was determined that the lifting mechanism for both a purpose-built barge and a modified Scotia Tide is a large A-frame capable of lifting the largest of the common components of the various technologies from the quayside. This functionality addresses the common desire to use nearby ports that do not have the infrastructure to support handling of the larger components, and to avoid the expensive chartering of large heavy ships and construction vessels. Concept designs were developed for both the newbuild barge option and the modified Scotia Tide option. It was further determined that small tidal technology does not require a heavy lift asset and a smaller asset such as a MultiCat is optimal, however the availability of a new or modified heavy lift asset having multimodal functionality could bring operating efficiencies to the small tidal stakeholders.

The financial model is based on an assumed level of tidal development activity that requires the support of a heavy lift barge. The analysis shows it will be challenging to attract private sector investment without a capital subsidy for the options considered. Several financial risk factors are also identified.

A discussion is included related to possible ownership models.

TABLE OF CONTENTS

List of Tables

1 INTRODUCTION

Lengkeek Vessel Engineering and project partner Gardner Pinfold, along with mentoring partners DP Energy, Green Marine, and RJ MacIsaac Construction, have been tasked by the Offshore Energy Research Association to conduct a feasibility study for a shared multi-use service barge/drydock, or marine 'asset', for the tidal sector. The study addresses the feasibility of employing a generic, shared use, multimodal turbine transport, deployment and retrieval asset for the tidal energy industry. The study investigates the operational requirements of tidal developers, operators, and service providers. These requirements are then analyzed to determine optimal design concepts for the asset as well as determining the types of supporting assets required by the industry. The study also addresses design and construction options, ownership options, and the associated costs and risks associated with each option. Ultimately, the study determines if there is economic justification to proceed with the design and construction of such a vessel to help promote and progress tidal energy projects in Nova Scotia.

Important Note - the liquidation of OpenHydro occurred during the preparation of this study. This unfortunate event changes information contained within the study related to stakeholders, berth holders, Scotia Tide modification concepts, usage and ownership. Since the analyses and conclusions of the study were already developed it was decided not to rework the study at such a late date, but rather to consider a revision of the findings should they be taken further.

1.1 BACKGROUND

The potential of tidal energy as a renewable resource worldwide is estimated at 3,000,000 MW [1]. The potential within the entire Bay of Fundy is estimated at 50,000 MW, with the Minas Passage estimated at 7,000 MW [2]. To manage this huge potential of renewable energy and to support the sustainable growth of the tidal sector, the Province of Nova Scotia introduced its Marine Renewable-energy Act in April 2015. The goals of the legislation are to protect the environment, respect community and local needs, and ensure that Nova Scotians benefit from development of marine renewable energy. The Act defines how the sector will grow in a safe, viable, and sustainable manner from its current demonstration phase to the commercial development phase. The Act applies to two Areas of Marine Renewable Energy Priority (AMRAPs), being the Bay of Fundy and the Bras d'Or Lake. Within these priority areas, there are smaller areas for project development known as 'Marine Renewable Electricity Areas' or MREAs, which are identified as being the best locations to develop marine renewable energy projects. There are four MREAs identified now: FORCE sight, Digby Gut, Grand Passage, and Petit Passage.

Some economic benefits of tidal energy have already been realized in Nova Scotia with the development of the FORCE site, the initial deployment of OpenHydro/Nova Scotia Power's test project in 2010, the construction and deployment of the FORCE FAST platforms, installation of FORCE subsea cables, and construction of turbines and a heavy lift barge for Cape Sharp Tidal. Additionally, two research projects were announced under a memorandum of understanding signed between the government, Offshore Energy Research Association and Innovate UK. These projects will help governments, industry and researchers better understand the effect tidal technology has on the marine environment, and the impact of the marine environment on that technology.

The Nova Scotia government's Marine Renewable Energy Strategy committed to approving up to 300 megawatts (MW) of in-stream tidal energy. In the coming years deployments are intended by developers, including DP Energy (Atlantis Operations Canada and Halagonia Tidal Energy), Black Rock Tidal Power, Minas Tidal LP and Big Moon Power. Nova Scotia is hence well positioned to become a global leader in the development of commercialized tidal energy, a much-needed source of carbon free renewable energy.

1.2 PURPOSE

The tidal industry is in its infancy and consequently there is a wide range of technology currently under development for extracting tidal energy. The technology was categorized in the 2011 Marine Renewable Energy Infrastructure Assessment [4] as small and large, where small tidal technology is defined as a single device with a rated capacity of up to 500kW and large tidal technology is defined as a single device with a rated capacity of greater than 500kW. Within both the small and large tidal technology categories there are many different marine asset requirements for deploying, retrieving, and connecting the equipment. There are also different ownership scenarios for the marine assets required to support the different technologies, given that some technologies require either large multipurpose lift vessels or large bespoke assets, while other technologies only require smaller workboats. There is also a difference in the requirements for an industry that is the demonstration and development phase versus an industry that is in the production phase using proven technology deployed as an array of devices.

The two main types of technology are subsea and floating/semi-submersible, and each type has considerably different requirements for deploying, retrieving, and maintaining the associated equipment. Subsea technology involves cable connected turbines on the seabed that are positioned either with structural subsea bases that are anchored or ballasted to the sea floor or subsea piles that are driven or screwed into the sea floor. Floating/semi-submersible technology involves floating or semi-submersible platforms with one or more turbines affixed to the platform and cable connected, with the platform moored to the sea floor with ballasted moorings or driven or screwed seabed anchors. Another variant of floating technology involves a keel driven vessel tethered to an onshore generating unit.

Within each type of technology being demonstrated or intended to be demonstrated in Nova Scotia there are several different equipment designs. The subsea technology currently being considered for deployment in Nova Scotia includes turbines by OpenHydro and Andritz Hammerfest. Openhydro uses a 16m diameter turbine with power generated by circumferentially mounted rotors having an open center. The turbine is mounted to a large steel subsea base using pillars on the base and collars on the sides of the turbine (eg. pintle and gudgeon). The subsea base is a heavy steel framework of pipe with a triangular base, that is filled with concrete for ballasting. The assembly including concrete ballast weighs in the order of 1100t (turbine 270t, SSB & TCC 450t, ballast 380t). Andritz uses a subsea mounted turbine with 18m rotors and a length of 12m, weighing 190t; a steel subsea base weighing 170t and ballast weighing in the order of 400t per foot (the base has 3 feet). The turbine and subsea base are designed so that the turbine can be deployed and recovered without lifting the base, and the base and ballast can be deployed as separate units, so that smaller marine assets can be used. The entire assembly, with ballast, can be deployed and retrieved if a large enough asset is employed.

The floating and semi-submersible technology currently being considered for deployment in Nova Scotia includes platforms by Scotrenewables, Sustainable Marine Energy (SME), and Tocardo. The Scotrenewables SR2000 monohull platform is the largest at 64m in length, weighing 500t, and carrying two turbines producing 1 MW each. The SME PLAT-I tri-hull platform is smaller at 32m in length, 27m in breadth, weighing 93t, and carrying 4 Schottel turbines for a total power of 280kW. The Tocardo UFS is a semi-submersible platform having most of its structure below the surface, a width of approximately 36m, depth of 18m, weight of 230t, and carrying 4 or 5 Tocardo T2 turbines for a power of 1MW to 1.5MW. All the floating/semi-submersible technology can be towed to/from the site for deployment, recovery and maintenance, and all can lift or partially lift their turbines for maintenance.

Big Moon Power uses another type of floating technology that does not utilize turbines but rather uses a fixed shore mounted generator affixed to a moving platform. The moving platform is a 60m pontoon barge with a winged keel affixed to the underside. The keel and barge are driven by the tidal flow and energy is produced by a tether line turning the shore-based generator. The system includes a subsea turning sheave affixed to a gravity anchor, and both will be initially deployed by floating out and sinking on-site. The subsea sheave is the only item that requires to be retrieved by a marine asset for maintenance purposes. The barge can be towed to/from the site for deployment and maintenance.

Marine asset solutions for demonstration and development phases differ considerably from production phases. During the demonstration phase the wide range of technology used and the periodic need for marine assets favours a multi use asset that can be chartered as required. During the production phase there will be an array of the same devices deployed by each developer, and the frequent need to maintain this array favours a bespoke marine asset dedicated to that device and developer.

Ownership models for the marine asset differ by technology and again by phase of the project. This is already demonstrated in Nova Scotia's tidal industry where the developer with the heaviest and largest technology has already committed to constructing their own bespoke heavy lift barge 'Scotia Tide' so as not to be reliant on chartered vessels for deploying ad recovering their turbines. Scotia Tide is underutilized during the current demonstration phase, but when OpenHydro reaches the production phase they envision requiring two such barges to manage their turbine array.

The purpose of this study is to determine the feasibility of designing and building a generic, shared use, multimodal turbine transport, deployment and retrieval vessel that can be utilized by some or all of the tidal developers now, during the demonstration phase.

1.3 Methodology

The study is divided into two major tasks with Task 1 being the determination of the main requirements and desired characteristics of the marine asset, and Task 2 being the determination of ownership options. Both tasks require the collection of information and data from industry stakeholders both in Nova Scotia and abroad, including developers, technology providers, marine service providers, and other interested marine groups. The Nova Scotia based stakeholders were of course the priority for gathering information regarding the best marine asset to be employed in the region, so it was important to include all of the berth holders at FORCE and other MREA sites, FORCE itself, the technology providers that are currently slated to deploy their equipment in Nova Scotia, and marine service providers that have already been involved or are positioned to be involved in the local tidal industry. Equally important was the collection of information from parties that have had tidal industry experience elsewhere, such as Scotland and France, where the industry is slightly more developed and where there is greater experience amongst the same categories of stakeholders.

It was determined that the best way to obtain the information and data required for the study was to conduct face to face interviews where possible, and otherwise telephone or video conference interviews. A questionnaire was developed by the project team that sought responses to questions related to both Tasks 1 and 2. For Task 1 in order to define the physical requirements of the asset questions were asked regarding the weights and dimensions of the equipment and technology being used, including the anchoring method for the technology. Previous experience and current intentions regarding assets used or envisioned for loading out at the dock, transiting to the site, and deployment/retrieval/maintenance was questioned. Locations of dock loadout and maintenance sites were also questioned, again based on previous experience and current intentions. Lastly the Task 1 questions included a discussion regarding the most desired and required design features for a marine asset. For Task 2 the discussion opened around the question of who should own the asset and whether a shared asset would be feasible. Questions were asked in order to facilitate the financial analysis including: charter rates experienced; durations required at dock loadout, transit, and on-site; and the frequency of such operations, both experienced and envisioned. Not all the questions could be addressed by all the parties interviewed, and some questions and topics were of greater interest to certain groups and hence solicited lengthier discussions and responses.

All the responses were compiled in a master spreadsheet for analysis. Responses for each question were assessed and analysed amongst each group of stakeholders, and then assessed and analysed across all groups, with key commonalities and key discrepancies highlighted, and with a key factor considered, that being the categories of small vs. large technology. The analysis of marine asset requirements, Task 1, focused on the weight and dimensions of the technology involved, as this is a key driver for the determination of the asset's principal particulars and its concept design. The analysis also considered key design features that were identified by respondents, relating to multi-function/multi modal, port versatility, towing/station keeping, etc. The result of the analysis was a variety of concept design options for large tidal technology, ranked in order of most useful/most desirable. The concepts derived included type of asset, principal parameters, lifting equipment, lifting capacity, and special features. Concept 3D models were prepared to visually demonstrate the concept.

The analysis of ownership models, Task 2, followed the same approach of collating information from the master spreadsheet. A financial model was developed based on information provided regarding charter rates, durations and frequency of use.

The financial model is based on the two barge scenarios. There are many variables to account for in the financial analysis, a Base Case provides an attempt to offer as straight forward an analysis as possible. The key assumptions behind the Base Case are noted throughout. To start assessing the financial implications associated with the barge scenarios, an estimate of the total potential annual demand for barge services has been made and is based on a plausible development scenario as per the Marine Renewable Energy Strategy and the utilization of the FORCE site. The project mentors provided guidance on the number of days a single barge might be commissioned annually based on the development scenario presented. In addition, mentor's advice combined with interview data have suggested a range of per day charge out rates that could be expected for a barge of the technical specifications defined under the barge scenarios. Based on their estimates, two financial scenarios are presented for day charge out rates of $30,000 and $50,000 dollars respectively. Further the financial analysis is developed to demonstrate payback periods related to the revenue streams associated with 100 days of billable work per year. The potential revenue stream is then split to support both operating and capital costs. In the concluding section of the financial analysis, various risk factors to the financial analysis are noted. These could influence any investor decision making process to acquire such an asset to support tidal development. Potential ownership models are identified that tie back to the results of the financial model.

The result of the study was to present ranked concept designs that best represent the common tidal sector requirements for a marine asset, and to present ownership models that represents the most feasible means of bringing that marine asset into the demonstration phase of the industry. Presentation of the study report and results was made to the OERA, Nova Scotia Department of Energy and Mines, and ACOA, with responses from the group participating in the presentation being incorporated into the final revision of the study report.

2 TIDAL INDUSTRY STAKEHOLDERS

There are numerous stakeholders in the tidal industry including the Nova Scotia Department of Energy and Mines and the OERA, for which this study has been conducted. In order to determine the desired design and ownership parameters for the marine asset it was necessary to gather information from groups having a vested interest in Nova Scotia's tidal industry as well as groups having proven experience in the industry. The developers holding permits from the province and berths at the FORCE site, including FORCE itself, represent the group with the greatest vested interest in the industry. This group is either partnered with or contracted with technology providers, all of which have extensive experience in the industry, with successful technology deployments in the UK and Europe. Supporting both groups are the marine service providers, whose marine assets and marine operations experience allow the developer and their technology provider to transport, deploy, retrieve and maintain the equipment. Lastly a group of non-tidal parties considers other uses for the marine asset that might make it more viable, especially in the short-term during demonstration and early development stages.

2.1 TIDAL SECTOR

2.1.1 DEVELOPERS AND OPERATORS

The study focuses on the requirements of active Nova Scotia tidal developers at the FORCE site, in the Minas Passage, and in Grand Passage. At the FORCE site there are 5 berth holders, with Berth A held by Minas Tidal, Berth B by Black Rock Tidal Power, Berth C by Atlantis Operations Canada Inc., Berth D by Cape Sharp Tidal Ventures, and Berth E by Halagonia Tidal Energy. Big Moon Power will be deploying their keeled barge technology on the north shore of the Blomidon Peninsula. In Grand Passage there are plans by Luna Ocean Consulting Limited, and Black Rock Tidal, to test Sustainable Marine Energy's floating technology, which is also being considered for deployment at FORCE.

MINAS CHANNEL - FORCE SITE

Berth A - Minas Tidal Limited Partnership

Minas Tidal Limited Partnership was founded in 2016 and is based in Nova Scotia. Minas Energy was instrumental in the development of Nova Scotia's tidal industry including early involvement in FORCE, securing Federal and Provincial Environmental Approvals, and securing development funding from the Clean Energy Fund in 2010.

Minas Tidal has plans to use Sustainable Marine Energy's (SME) PLAT-I technology. The PLAT-I is a floating tri-hull platform held in place by gravity moorings and a mooring turret and is fitted with 4 Schottel turbines for a total power rating of 280 kW.

Berth B - Black Rock Tidal Power

Black Rock Tidal Power (BRTP) is a Halifax-based privately owned Canadian company that was founded in 2013 and has been an active participant in the Nova Scotia tidal industry. BRTP offers solutions for in-stream tidal power generation, custom energy converter systems, and related services. BRTP is specialized in the development and implementation of platforms that carry a multitude of SCHOTTEL Instream Turbines.

BRTP plans to utilize Sustainable Marine Engineering's PLAT-I floating platform.

Berth C – Atlantis Operations Canada Inc.

DP Energy is a Cork, Ireland based renewable power development company. DP Energy, at the time a joint partnership with Atlantis Resources Ltd called Atlantic Operations Canada Ltd. (AOCL), was awarded a 4.5MW feed-in-tariff by the Nova Scotia Department of Energy and Mines in December 2014. In January of 2018 Atlantis and DP Energy announced that they have entered into a conditional agreement for the sale of Atlantis' 50% interest in Atlantis Operations (Canada) Limited ("AOCL") which will be renamed after the sale is completed. The transaction, subject to formal approval of the Nova Scotia Minister of Energy and Mines, will result in Atlantic Operations Canada taking sole ownership of Berth C. Since Halagonia/DP Energy already holds the rights to develop a project at Berth E the acquisition of Atlantis' interest will allow a more integrated approach for the two projects, including the utilization of common vessel assets.

Atlantis has plans to install 2 x 2MW Scotrenewables SR2000 floating and moored turbines at Berth C. The SR2000 made history as the world's largest tidal energy converter when it was launched at the European Marine Energy Centre (EMEC) in 2016. The SR2000 has produced over 3 GWh of energy output.

Berth D - Cape Sharp Tidal Venture

Cape Sharp Tidal Venture (CSTV) is a joint venture of OpenHydro, a DCNS Group company, and its Canadian partner Emera. The firms have been working together on tidal energy since 2007 and formed Cape Sharp Tidal in 2014 to bring the latest tidal technology to Nova Scotia. CSTV successfully deployed Canada's first grid-connected 2MW demonstration turbine at FORCE in 2016. The turbine will be redeployed in the summer of 2018, following which a second turbine, which has already been manufactured, will be deployed.

CSTV utilizes OpenHydro's 2 MW open rotor turbine, which is fitted with a 16-meter diameter rotor and is mounted on the ocean floor using a ballasted steel gravity base. CSTV also utilizes their bespoke marine asset 'Scotia Tide' for transporting, deploying, and retrieving their turbine and ballasted base as a single unit.

Berth E - Halagonia Tidal Energy

Halagonia Tidal Energy holds 4.5MW demonstration power production rights at Berth E in addition to their Berth C holding (Atlantis/DP Energy). The Nova Scotia Department of Energy and Mines formally announced its intention to award the berth to Halagonia Tidal Energy at the UN Climate Change conference in Paris in 2015.

Halagonia Tidal Energy has plans to install three 1.5-megawatt turbines at Berth E. Halagonia Tidal Energy has been working closely with technology partner Andritz Hydro Hammerfest since 2013 on the project plan. The Andritz turbine is mounted on a ballasted steel sub sea base.

Big Moon Power

Big Moon Canada Corporation (BMP) is both a developer and technology provider, that holds two marine renewable energy permits for a tidal electricity project in the Bay of Fundy. The initial permit allows Big Moon Power to test a 100-kilowatt prototype that is not connected to the electricity grid for up to 14 months, while the second permit will allow the company to increase the size of its project in phases up to a maximum total of five-megawatts

The company utilizes a proprietary tidal energy system that has two main components, including a land-based generator assembly and an unmanned barge that is fitted with an adjustable keel that uses tidal flow to propel the barge. The barge is connected to the generator by high strength rope that spools off a rotating drum as the barge is driven away by the tidal flow; traveling 5 nautical miles in each direction, originating from the generator assembly.

The technology includes 3 main elements: the generator and rope drum unit that are mounted ashore; a subsea sheave or jib that works as a turning block for the rope and is anchored to the ocean floor using a gravity barge; and the pontoon barge that is fitted with the adjustable keel. The pontoon barge is approximately 60m x 50m overall, with 6m wide pontoons, and with a 50m wide keel. The keel's moving parts are accessed from the barge deck for maintenance purposes. The jib is approximately 4.5m x 4.5m x 1m and will be partially buoyant with a dry weight of app. 45t.The jib is anchored by a gravity barge that is 43m x12m x 3m and weighs approximately 3400t dry and 1975t wet. The barge will be floated out with airbags and sunk into position. The jib is the only item that will need to be removed from the water for maintenance purposes.

GRAND PASSAGE, PETIT PASSAGE, AND DIGBY GUT

Three sites have been identified in the Digby area with the tidal resource sufficient to support small scale commercial arrays: Digby Gut (47MW installed capacity), Petit Passage (13MW installed capacity) and Grand Passage (6.2MW installed capacity) [5].

The not for profit Sustainable Oceans Applied Research (SOAR) is exploring the potential for community scale tidal to supply energy to rural communities and intends to build on work done by previous developer Fundy Tidal in Petit and Grand Passage. SOAR is a partnership between Luna Ocean Consulting Ltd., DARE Technology, and Acadia University.

SOAR is currently collaborating with Black Rock Tidal Power, Sustainable Marine Energy, and Schottel Hydro to test SME's 280 kW PLAT-I tidal power system in Grand Passage. This will be a three month demonstration project that is not grid connected, with plans for deployment in Fall 2018.

2.1.2 Technology Providers

The study focuses on the requirements of technology providers that are active in Nova Scotia, at the FORCE site, in the Minas Passage, and in Grand Passage. Consideration is also given to other technology providers in order to gain from their experience, and in some cases these providers have previously been linked with sites in Nova Scotia and may well be in discussions for future consideration. At FORCE Berths A and B, and in Grand Passage, BRTP and Minas Tidal plan to utilize Sustainable Marine Energy's floating platform technology. At Berth C Atlantis Operations Canada plans to employ floating platform technology developed by Scotrenewables. At Berth D Cape Sharp Tidal will be using OpenHydro's subsea technology. At Berth E Halagonia Tidal Energy will use Andritz Hydro Hammerfest's subsea technology. And as discussed in the previous section Big Moon Power will be deploying their keeled barge technology on the north shore of the Blomidon Peninsula. Other providers that were interviewed include Tocardo, Nova Innovation and Jupiter Hydro. Other providers that have experience abroad include Atlantis Resources/Lockheed Martin and Bluewater Energy Services.

Berth A, Berth B, and Grand Passage - Sustainable Marine Energy (SME)

Sustainable Marine Energy (SME) is based in Edinburgh, Scotland, and is a developer of Tidal and Run of River energy platforms and enabling technologies. Founded in 2013 on the Isle of Wight, SME relocated to the Orkney Islands in Scotland in 2016 in order to test their PLAT-O device at the European Marine Energy Center (EMEC). In 2017 SME developed its second tidal energy platform PLAT-I, which was successfully deployed for testing in Scottish waters in November 2017.

The PLAT-I is a surface floating platform designed for run of river and inshore tidal sites. The platform has a mooring turret that allows the platform to weather-vane with the tide. The platform is fitted with four Schottel SIT250 turbines that are mounted on SIT Deployment Modules which can be quickly raised above the surface for inspection and maintenance. This also allows for the draft to be reduced by lifting the turbines when transiting to and from site.

Particulars

Max. power output:	280kW
Length:	32m
Beam:	26.7m
Draft:	7.85m (u/s rotor) (2.7m u/s turret)
Displacement:	93t
Rotor Dia.:	3-5m
Total Weight:	93t + anchors

SME also offers drilled rock adaptors, called the RAPTOR family of anchors. These are high-strength, corrosion resistant rock bolts that can be installed subsea using SME's Anchoring ROV (AROV). RAPTORS are a torque controlled double reaming type anchor, with no requirement for grout. The range consists of three anchors to suit a range of applications where moorings are required on rock.

The Schottel Instream Turbine (SIT) has a high power to size ratio producing between 54 and 70 kW grid-ready electric power depending on current and rotor diameter, which is between three and five meters. Schottel also supplies components to other tidal turbine developers. These include the design and manufacturing of hub, pitch mechanism and slow speed shaft.
In addition to turbine supplies, Schottel has developed a high precision drive especially for tidal turbines, adapted to operating in seawater and freshwater.

Berth C - Scotrenewables Tidal Power

Scotrenewables Tidal Power Limited (Scotrenewables) was founded in 2002 in Orkney to develop cost effective floating tidal stream turbines. The company has received investment from ABB Technology Ventures, DP Energy, and the Scottish Government's Renewables Energy Investment fund. The company tested increasing scales of its technology from 2003-2009, followed in 2011 by the launch of the world's first large scale floating tidal turbine, the SR250 250 kW prototype. The SR250 was tested for two and a half years at EMEC, logging more than 4,000 hours of deployment in the North Sea, and eventually being connected to the national grid.

Scotrenewables launched the 2MW SR2000 twin turbine platform at EMEC in 2016, making history with the world's largest tidal energy converter. The turbine generated 2MW peak capacity shortly after commissioning, and the SR2000 has now produced over 3 GWh of energy output, at times providing up to 25% of the electricity requirements of Orkney. The turbine is designed to DNV-GL standards, has a 20 year design life, and incorporates commercialised components from other industries. Its flexible mooring system, with a range of anchoring systems to suit most seabed types, allows it to be installed in water depths of more than 25 metres.

Particulars

Max. power output:	2000kW
Length:	74m
Diameter, max.:	4m
Draft, transport:	6m
Displacement:	500t
Hull Weight:	330t
Nacelle Weight (x2)	87t

Rotor Dia.:	20m
Anchor Weight:	400t (wet, divisible)
Total Weight:	900t

Berth D - OpenHydro

OpenHydro, formed in 2005, is a Naval Energies company specialising in the design, manufacture, installation and maintenance of marine turbines. The company's project portfolio spans Canada, France, Japan, Northern Ireland, Scotland, Wales and the Channel Islands with utility partners including Emera, EDF, Brookfield Renewable Energy Group, SSE Renewables and Alderney Renewable Energy. OpenHydro Canada was established in 2014, OpenHydro France in 2015, and OpenHydro Technology Japan in 2016. The company's open-Centre Turbine design has been tested at EMEC since 2006 and was deployed and grid connected at FORCE in November of 2016.

OpenHydro's commercial scale turbine is 16 metres in diameter and is rated at 2MW. The turbine weighs approximately 300 tonnes and is supported by a ballasted subsea base (SSB) structure weighing approximately 800 tonnes. The turbine and base, with a triangular shape giving 3 contact points, are held in place by gravity and sit 20 meters above the seabed to the top of the turbine, sufficiently deep so as not to pose a hazard to shipping. The turbine has an open center horizontal axis rotor and a magnet generator mounted inside a hydrodynamic duct. It requires no lubricant, seals, or gearbox, reducing maintenance. The Turbine Control Centre (TCC), developed by OpenHydro to produce predictable and reliable energy, is also mounted on the SSB.

The turbine and SSB are deployed and recovered with a patented system involving a heavy lift catamaran barge fitted with lifting tools on a multi purchase winch and sheave arrangement, and with a subsea alignment frame. The bespoke vessel developed by OpenHydro allows the turbine and ballasted SSB to be deployed onto or recovered from the seabed in a single operation.

<u>Particulars</u>

Max. power output:	2000kW
Diameter, max.:	20.4m
Turbine Width:	9m
Turbine Weight:	270t
Rotor Dia.:	16m
SSB Length:	32.5m
SSB Width:	30.6m
SSB Height (w/o turbine):	17.1m
SSB Height (w/ turbine):	20m
SSB Weight:	450t
Ballast Weight:	380t
Total Weight:	1100t

Berth E - Andritz Hydro Hammerfest

Andritz Hydro Hammerfest (Andritz) is tidal technology developer that was established in 1997 in Norway and moved to Glasgow in 2009. The company was the first in the world to successfully generate electricity from tidal currents and deliver power to the electrical grid.

The 300kW HS300 was installed in Norway, ran from 2003 to 2007, and was reinstalled from 2009 to 2011. The 1000kW HS1000 was the first pre-commercial tidal turbine installed at EMEC in 2011 and was connected to the grid in February of 2012. The company is developing 3 MK1 turbines, generating between 1200-1500 kW each, for the first commercial array for a tidal power project of 95MW in Pentland Firth, Scotland.

The Andritz turbine is fitted with an 18m variable pitch rotor and is designed for water depths of between 35 and 100 m, being deployed on the seabed, and being kept in position by gravity, pins or pilings. The SSB is designed to have a small footprint while the nacelle is optimized to minimize the wake effect caused by the water flows. The company has developed unique marine installation methodologies to minimize installation times and to exclude the use of divers, requiring only the support of Remotely Operated Vehicles (ROV) for monitoring purposes.

Particulars

Max. power output:	2000kW
Nacelle Dia.:	3m
Nacelle Length:	10-12m
Nacelle Weight:	200t
Rotor Dia.:	20m
SSB Length:	22m
SSB Width:	19m
SSB Height (w/o turbine):	23.5m
SSB Weight:	150t
Ballast Weight:	380t x 3
Total Weight:	1490t

Tocardo

Tocardo is a Dutch founded and based company providing tidal energy solutions. It has been an independent company since 2008 and has been fully commercial since 2012, when the first turbines and universal floating systems were sold to clients in Nepal, Japan and Canada. The company deploys their turbines at inshore locations including bridges, dams and dikes and offshore on floating and semisubmersible tidal turbine platforms. Technology development started in 1999, with testing of the first prototype in 2005 and a follow up with a long-term demonstration in 2008. The demonstration turbine is still operational today. From 2008-2012 Tocardo designed and tested of a full-scale commercial demonstrator of the T1 turbine, with a maximum power output of approximately 100kW.

Tocardo’s latest turbine is the T2 with power output of 250kW. The turbine is fitted with a patented bi-directional fixed pitch blade rotor, a passive and low maintenance design, where the two blades simultaneously turn 180 degrees for reverse flow operation. Tocardo’s semisubmersible platform is the Universal Foundation System, or UFS. The UFS is a fully integrated 1.5MW tidal power solution, with five Tocardo T2 turbines on a semi-submersible U-shaped floating platform.

The UFS is moored to the seabed and has most of its structure below the surface. The platform is de-ballasted to the horizontal orientation for towing to the deployment site and for maintenance of the turbines.

Particulars

Max. power output:	1500kW
UFS Width:	30m
UFS Depth:	25m
UFS Length:	6m
UFS Weight:	325t
Total Weight:	325t + anchors

Nova Innovation

Nova Innovation is a technology provider with site development expertise. The company was founded in 2010, growing rapidly and now employing over 30 staff. Nova Innovation deployed the world's first fully-operational, grid-connected offshore tidal energy array, deploying the first of their M100 turbines in March of 2016 at the Shetland Tidal Array at Bluemull Sound. A second turbine was deployed in August of 2016 and a third added early in 2017. Under the EnFAIT project, a Horizon 2020 project with 8 European partners, the array will be extended from three to six turbines, with a total rated capacity of 600kW. Nova is also jointly developing a tidal energy project at Bardsey Sound off the Llyn Peninsula in North Wales. Nova has been awarded an agreement for lease, and the next stage in the project is the conduct of a full environmental impact assessment.

Nova's M1 turbine produces 100kW with its subsea turbine. The turbine is attached to a t-shaped subsea base that is ballasted. The 6m long and 18t turbine was designed to be deployed and retrieved by smaller available vessels such as a MultiCat. Nova has also secured funding from the European Commission to demonstrate a direct drive tidal turbine. The project titled D2T2, (Direct Drive Tidal Turbine) is designed to produce a commercial demonstrator of Nova's direct drive tidal turbine technology.

Particulars

Max. power output:	100 kW
Turbine Length:	6m
Turbine Weight:	18t
Rotor Dia.:	8.5m
SSB Length:	15m
SSB Width:	11m
SSB Height (w/o turbine):	8.5m
SSB Weight:	30t
Ballast Weight:	120t
Total Weight:	168t

Jupiter Hydro Inc.

Jupiter Hydro is a Canadian based developer of tidal and river energy turbines. The company is developing screw type turbines with a hydraulically driven generator fitted on a semisubmersible platform. Jupiter deployed two prototype units in 2014 Jupiter and is in discussions with the Nova Scotia Department of Energy and Mines to deploy full scale demonstration units in the Minas Channel. The 3 planned demonstration units will have power outputs of 300kW, 2.3MW, and 2.4MW for a total demonstration phase output of 5MW.

Particulars

Max. power output:	2400kW
Turbine Length:	23m
Turbine Dia.:	5.5m
Turbine Weight:	40t

Atlantis Resources Corporation

Atlantis is a developer of renewable energy technology and projects. The company has more than 1,000 megawatts in various stages of development in the United Kingdom, Europe, North America, and Asia. Their developments include MeyGen, where the company recently completed the construction of phase 1A and entered a 25 year operations phase. Phase 1A at MeyGen involves the deployment of four 1.5MW turbines installed on gravity turbine support structures, producing 6MW; Phase 1B will involve the deployment of an additional four 1.5MW turbines installed on innovative foundations; and Phase 1C will see an additional 49 turbines with an output of 73.5MW. Phase 2 and 3 will see the development of an array that meets the company's permit limit of up to 398MW.

Atlantis uses the AR1500 turbine, designed by Lockheed Martin, as well as the Andritz turbine described above. The AR1500 is a 1.5MW horizontal axis turbine with active pitch and yaw capability. The turbines are affixed to the seabed using either gravity based foundations, drilled monopiles, or pinned structures, depending on the local seabed topography and geotechnical conditions. The turbines are designed for retrieval once every six years for a two week overhaul and maintenance period, utilizing a standard DP2 to retrieve the nacelles and return them to base.

Particulars

Max. power output:	1500kW
Nacelle Dia.:	2.4m
Nacelle Length:	12m
Nacelle Weight:	150t
Rotor Dia.:	18m
SSB Weight:	250-350t
Ballast Weight:	200t x 6
Total Weight:	1700t max.

Bluewater Energy Services

Bluewater Energy Services designs, constructs, installs and delivers Floating Production, Storage and Offloading (FPSO) systems, Floating Storage and Offloading (FSO) systems, Single Point Mooring (SPM) systems and Tidal Energy Conversion Systems (TEC). The first BlueTEC platform was installed and connected to the grid in the summer of 2015 at Texel in the Wadden Sea of The Netherlands. The platform initially used the Tocardo T1 turbine and early in 2016 it was commissioned with a larger Tocardo T2 tidal turbine.
The Texel platform started with a single 100 kW tidal turbine, was upgraded and fitted with a 200 kW turbine, and subsequently will be upgraded further to 500 kW carrying two tidal turbines. After that, two larger turbines will be fitted reaching 2.5 MW capacity.

Particulars

Max. output (4 turbines):	2500kW
Platform Length:	24m
Platform Weight:	25t

2.1.3 Marine Service Providers

A number of marine service providers were interviewed to gain their input on both the marine asset requirements and ownership options. The companies include local service providers having experience with the Nova Scotia tidal industry as well as a company having extensive experience in the Scottish tidal industry. The companies include: RJ MacIsaac Construction Ltd (RJMI), Green Marine (UK) Ltd., Atlantic Towing Ltd., Hughes Offshore Marine Services, and Dominion Diving Limited.

RJMI is a Nova Scotia based full service marine construction, repair and installation contractor offering solutions in marine construction, demolition and marine renewable energy since 1980. RJMI has firsthand experience with the use of floating assets to support Nova Scotia's tidal energy industry, having deployed the power cable as well as the FAST unit and its data cable for FORCE. RJMI brings a wealth of experience with marine and civil infrastructure solutions for complex marine projects.

Green Marine is an Orkney based marine contracting company which has been providing cost effective solutions for the safe installation, removal and maintenance of a wide range of tidal and wave energy devices and gravity bases since 2012. Green Marine has extensive expertise with a variety of renewable energy devices and site locations in the United Kingdom.

Atlantic Towing Limited (ATL) is a member of the J.D. Irving Limited, Group Of Companies, based in New Brunswick, and has been a leader in marine services for over 55 years. The company owns and operates a large fleet of azimuthing stern drive (ASD) tugs, conventional tugs, offshore supply vessels (OSV) and barges. ATL provided tugs, an OSV, and a barge to Cape Sharp Tidal for the transit and deployment of their turbine at FORCE in November of 2016.

Hughes Offshore Marine Services is a Nova Scotia based marine consulting firm with expertise in marine renewable installations management, marine general contracting, and offshore vessel operations and management. Hughes Offshore has been actively involved in the Nova Scotia tidal industry and has recently completed a study for port infrastructure study for OERA.

Dominion Diving is a Nova Scotia based marine service provider offering general marine services, commercial diving operations, and ROV services since 1969. The company has local tidal industry experience including early deployments of the FAST platform as well as bottom mapping services for FORCE, and marine services support to Big Moon Power for small scale testing of their technology.

2.2 NON-TIDAL SECTOR

Since the tidal industry in Nova Scotia is developing there is a need for marine assets to be employed with the provision of services to other marine industries or activities, at least until the tidal industry has enough technology deployed to require the asset(s) to be fully utilized. As such, a number of non-tidal companies and organizations were approached to gauge their needs and determine if there is commonality with the needs of the tidal industry.

McKeil Marine is an Ontario based marine service provider that specializes in marine transportation, construction and related project services. McKeil has over 60 years of history in Canada's maritime industry, providing transportation and project services for a wide range of customers and industry sectors since 1956. The company owns and operates a fleet of flat deck barges, jack up barges, sectional barges, tugs, workboats, cranes and other equipment. In 2010 McKeil installed a prototype power plant hydrokinetic turbine in the Saint Lawrence River. The turbine measured approximately 5m x 4.5m x 7m and weighed more than 120 metric tons, and was installed using a jack up barge, a flat deck barge, and two tugs.

Heddle Marine is an Ontario based marine construction firm specializing in marine fabrication and repair. The company has facilities in Ontario, Nova Scotia, and Newfoundland and offers full fabrication, mechanical, machining, electrical and hydraulic support service to both offshore and onshore for Oil and Gas clients, Industrial Facilities and all types of vessels in the marine industry. The company operates several floating drydocks, wharf facilities and shop facilities.

Canadian Coast Guard marine engineering department is responsible for the technical management of the CCG fleet. Their work includes ship construction and modernization, maintenance, life cycle management, and engineering, to name a few. CCG owns and operates a fleet of 118 vessels.

Other non-tidal sector companies and organizations are wide and varied, with numerous opportunities to take advantage of tidal industry marine assets. For example, during the course of research for this study it was found that the offshore industry had some EOI and RFP opportunities for heavy subsea lift projects, both in Nova Scotia and Newfoundland. The decommissioning of the Deep Panuke offshore installation will likely see additional subsea lift requirements. The growing aquaculture industry with large barges positioned on-site require handling of heavy gravity anchors. These opportunities may be suitable for a heavy lift barge asset, although suitable weather windows would have to be found. Smaller marine assets could be put to work at aquaculture sites, marine/civil construction projects, ocean monitoring and subsea sensor R&D projects, cable laying etc.

3 STAKEHOLDER REQUIREMENTS

3.1 DATA COLLECTION

Interviews were conducted with tidal developers, technology providers, and marine service providers. Non-Tidal industries were approached to gain knowledge of their requirements, although the marine service providers and engineering firms work with both tidal and non-tidal industries and hence were able to provide input. Interviews were conducted using a single questionnaire for both the asset requirements and the ownerships model objectives of the study. The same questionnaire was used for all roles within the tidal sector and for non-tidal sector. A total of twenty interviews were conducted. All of those interviewed are thanked for the time and effort they have taken to contribute to the study.

Table 1 - Organizations and Individuals Interviewed for the study

Role	Organization	Name and Title	Date and Location
Tidal Developer	Atlantis Operations Canada – Berth C	John Kerr, Commercial Director & Damian Bettles, Regional Manager	10 May 2018, LVE Office & Telcon
	Halagonia Tidal Energy – Berth E	John Kerr, Commercial Director & Damian Bettles, Regional Manager	10 May 2018, LVE Office & Telcon
	Black Rock Tidal Power – Berth B & Sustainable Marine Energy (SME)	Peter McKenna, Marine Manager & Babak Farsi, Project Manager	11 May 2018, BRTP Office
	FORCE	Tony Wright, General Manager	14 May 2018, LVE Office
	Big Moon Power (Dev. & Tech Provider)	Joe Fitzharris, Project Manager	17 May 2018, LVE Office
	Cape Sharp Tidal – Berth D	Alisdair MacLean, Country Manager	29 May 2018, OpenHydro Office
	Minas Tidal Limited Partnership - Berth A	John Woods & Chris Peters	31 May 2018, Telcon
Technology Provider	Nova Innovation	Gary Connor, Engineering Director	31 May 2018, Telcon
	Scotrenewables Tidal Power	Daniel Wise, Operations Manager	12 June 2018, Orkney, Scotland
	Tocardo Tidal Power	Hans van Breugel, CEO	15 June 2018, Normandy Conference
	Andritz Hydro Hammerfest	Craig Love, Engineering Manager	19 June 2018, Glasgow, Scotland
	Jupiter Hydro Inc.	Ross Sinclaire, CEO	25 June 2018, Montreal, Canada

Marine Service Provider	RJ MacIsaac Construction Ltd	Boyd MacIsaac President & Marc MacDougall, Project Manager	11 May 2018, LVE Office
	Green Marine (UK) Ltd.	Jason Schofield, Managing Director	24 May 2018. LVE Office & Telcon
	Atlantic Towing Ltd.	Tim Brownlow, Director of Industry Relations	17 May 2018, ATL Office
	Hughes Offshore Marine Services	John Hughes, President	18 May 18, LVE Office
	Dominion Diving	Robin Lohnes, CEO	17 July 2018, Telcon
Other Non Tidal	Heddle Marine	Shaun Padulo, President	30 May 2018, Telcon
	McKeil Marine	David Porter, Engineering Manager	30 May 2018, Telcon
	Canadian Coast Guard	Cliff Harvey, Director Marine Engineering	01 June 2018, Telcon

All interviews were conducted either face to face or via teleconference. The questionnaire utilized was designed to stimulate conversation and flow of information rather than to collect statistical data, and as such nobody was asked to complete and return the questionnaires. Following each interview, the notes from the open discussions were organized against the question that best fit the response. The completed questionnaires were sent to the respondent to verify the accuracy of what was recorded. The responses to all questionnaires are confidential with respect to their source, but all are collated in the master spreadsheet. The master spreadsheet is used to analyse the results of each question as presented in the next section.

3.2 Data Analysis

The wide range of roles and responsibilities of those interviewed naturally mean that the questions asked were not applicable to all, although the questionnaires proved to achieve their objective of stimulating conversations, and even questions not directly applicable to an individual or their organization often elicited knowledgeable responses. The analysis of the information collected includes ranges and averages of objective data and presents commonalities amongst subjective responses.

The analysis was conducted primarily using the master spreadsheet as described in the methodology section above. Responses for each question from each group of stakeholders was assessed and was broken down for large technology and small technology, with key commonalities and key discrepancies highlighted. The summary of data from each group was then assessed across all groups to determine a summary analysis for that question. The results of the analysis for each question are provided in 3.2.1 through 3.2.6 below.

3.2.1 Weights of Units

Regarding the weights of components and equipment to be handled, launched, deployed, and retrieved there is of course a significant difference between small tidal technology and large tidal technology. There is also a significant difference in the requirements for marine assets when it comes to floating versus bottom mounted technology, which falls under both the large and small technology categories.

In the tables below, for simplicity the responses from Nova Scotia developers and their technology provider are presented in the 'Developers' row, while the responses from technology providers that are not currently providing technology to a Nova Scotia developer are presented in the 'Technology Providers' row. The response summaries do not include all the data received, rather it summarizes the data that is pertinent to the conclusions to be drawn.

Table 2 - Summary of Responses to Question Regarding Weights of Units

Stakeholder Group	Large Technology	Small Technology
Developers	CST/Openhydro has the heaviest technology component where their SSB including ballast weighs 830t, and their turbine weighs 270t, with a single lift requirement of 1100t (for now the turbine must be fitted to the SSB ashore, but OH are developing a removable turbine). Andritz also has heavy SSB ballast requirements at 380t per node (although this may be divisible), and their turbine weighs 200t and their SSB weighs 150t. Scotrenewables' floating platform weighs 500t, where the nacelles each weigh 87t and the hull weighs 330t, while they require 400t (wet) gravity anchoring, which may be divisible. Scotrenewables uses a 350t crane (91t@12m) dockside to position the nacelle either in the water or on a barge. Big Moon's only lift requirement is the subsea jib, which weighs 45t.	SME's floating platform weighs 83t, plus anchor weight. FORCE's FAST platform weighs 15t max, they have deployed 35t anchors, and their connecting cable reels weighed 130t.

Technology Providers	Tocardo's UFS semisubmersible platform weighs 325t, plus anchor weight. Jupiter's turbine weighs 40t.	Nova's turbine weighs 18t and their ballasted SSB weighs 150t.
Service Providers	RJMI utilizes a barge fitted with an A-frame having a capacity of 150t. ATL utilizes a barge fitted with crawler crane having a capacity of 300t at 4m and 155t at 20m. Green Marine utilizes a catamaran barge fitted with a gantry crane having a capacity of 700t, and a 28m MultiCat fitted with 25t and 32t cranes and a 100t deck winch.	Dominion Diving utilizes a 22m MultiCat fitted with a 20t deck crane (20t @ 7m) and a 50t deck winch.
Other	N/A	N/A
Conclusion	Most of the large technology consists of 3 major components being the turbine/nacelle, SSB, and ballast for subsea tech; and the nacelle, hull, and gravity anchors for floating platforms. At the moment OpenHydro has the only technology requires all 3 major components to be deployed and retrieved together at a total weight of 1100t. In defining the heavy lift requirements of a marine asset, we need to look at the greatest common equipment weight that is within a 'reasonable' range. For the technology intended for use at FORCE the OpenHydro turbine at **270t** and the Scotrenewables platform hull at **260t** are the heaviest components, excluding the outlier being OpenHydro's ballasted SSB. The Tocardo UFS comes in at **325t**, while the Andritz ballast block is at **380t** (if indivisible), and these too may be outliers for consideration when determining the heavy lift capability requirements. All other components come in at **200t** or less, assuming that Scotrenewables' 400t (wet) gravity anchor is divisible.	All of the small technology can be handled by a marine asset that is sized to meet the requirements of the large technology. The developers of small technology however seek to utilize smaller marine assets to reduce costs. The small technology intended for use at FORCE is the SME platform, which weighs **83t**, but can be broken down into smaller components that can be assembled once launched, where the heaviest component is the main hull at **42t**. The FAST platform weighs **15t** max. FORCE has deployed **35t** anchors and **130t** cable reels. Nova's SSB weighs **150t** dry or **90t** wet and has previously been deployed by launching the SSB dockside and using a Multicat to lift the unit off the seabed at the dock using its deck winch, and then transiting to site with the SSB suspended.

	<u>Conclude:</u> Large technology requires a heavy lift capability of **270t** to **325t** at full reach for handling technology, and a capability of **380t** at lesser reach for ballast blocks and gravity anchors. (Note that a-frame load ratings may not allow greater capacity at lesser reach as is typical for crane ratings.)	<u>Conclude:</u> Small technology does not need a heavy lift asset, although Nova could benefit from a heavy lift vessel so as not to require a heavy crane at the dock, as could FORCE for handling the transfer of cable reels from dock to asset. Most requirements of small technology can be met with the use of a MultiCat or Tug.

3.2.2 Dimensions of Units

Similar to component weight there is a significant difference between small tidal technology and large tidal technology, and between floating and bottom mounted technology.

Table 3 - Summary of Responses to Question Regarding Dimensions of Units

Stakeholder Group	Large Technology	Small Technology
Developers	OpenHydro's technology is the largest dimensionally where the turbine including its mounting collar is 20.4m wide and 9m deep. Their SSB is 33x31m at the base and 20m high including the turbine (or 17m to the top of the turbine mounts). Andritz' turbine nacelle is 10-12m long and 3m in diameter with an 18-20m rotor. Their SSB is approximately 22x19x23.5m. Scotrenewables' floating platform has a 74m long hull that is 4m in diameter. With nacelles mounted to pivoting arms for transport such that the draft is only 6m. The nacelles are fitted with 20m rotors. The typical gravity anchors are 11x11x2m (400t wet). Big Moon's jib is 4.5x4.5m.	SME's trimaran hull is 32m and 27m wide, with a draft of 7.85m to the underside of the rotor. FORCE's FAST platform is app. 4m x 3m.
Technology Providers	Tocardo's U shaped platform is 30x25x6m. The Jupiter screw gear turbine is 23x5.5m.	Nova's turbine is 6m long with an 8.5m rotor. Their SSB is 15m x 11m on the base and 8.5m high.
Service Providers	Green Marine's gantry barge has 16m clearance between the hulls and a hook height of 10m. They have previously handled the Andritz turbine at 12m length with 18m rotor and ballast blocks at 5x5x4m.	Dominion Diving's MultiCat can handle a 20t load at 7m reach.
Other	N/A	N/A

Conclusion	In considering the maximum dimensions of units that can be handled it is necessary to determine if the unit is to be lifted and brought aboard the lift vessel or lifted and suspended without being brought aboard. It is also necessary to look at the distance that a lifting device needs to reach in order to lift an item off a dock or to clear an item from the edge of the asset, for example as a suspended item is raised and lowered. OpenHydro's combined turbine and SSB is the largest unit at 33x31x20m, and this can be considered an outlier. Assuming future ability to separate these components, the turbine will be **20.4m max dia. and 9m deep** which might reasonably be considered for lifting and bringing aboard. Andritz' nacelle at **10-12m x 3m** diameter with an **18-20m** rotor is also manageable for bringing aboard as is perhaps the SSB at **SSB=22x19x23.5m**. The Jupiter turbine at 23x5.5m is manageable The Scotrenewables platform at **64x3.8m**, plus nacelles; gravity anchor at **11x11x2m**; and the Tocardo UFS platform at **30x25x6m** can be considered as outliers for bringing aboard the asset but perhaps manageable for lifting from a dock and suspending. <u>Conclude:</u> Large technology requires a heavy lift that is capable of handling a maximum dimension of approximately **22x20m footprint and maximum height of x24m;** with a **reach of 18-20m** at maximum capacity for bringing units aboard or **9-10m** at maximum capacity for suspending the unit.	As above, all of the small technology can be handled by a marine asset that is sized to meet the requirements of the large technology. The developers of small technology however seek to utilize smaller marine assets to reduce costs. The small technology intended for use at FORCE is the SME platform, which measures **32x27m** overall, but can be broken down into smaller components that can be assembled once launched. Nova's SSB measures **15x11x8.5m** and has previously been deployed by launching the SSB dockside and using a Multicat to lift the unit off the seabed at the dock using it's deck winch, and then transiting to site with the SSB suspended <u>Conclude:</u> Small technology does not need a heavy lift asset, although SME could benefit from a heavy lift capability to enable the platform when fully assembled to be moved to and from a dock, and Nova could benefit so as not to require a heavy crane at the dock. Most requirements of small technology can be met with the use of a MultiCat or Tug.

3.2.3 DRAFT AND DEPTH CONSIDERATIONS

Given the shallow waters and dry ports affecting tidal industry operations in Nova Scotia the depth and draft of a marine asset are an important design consideration. The low water depth at the FORCE site is approximately 30m, giving approximately 10m of clearance above some of the subsea technology. The nearby ports of Parrsboro and Hantsport are dry ports, where the dockside dries out completely at low tide. Nearby shores have a large tidal range that might be used by subsea technology for transporting their devices to the seafloor for pick up or drop off by the marine asset and can be used by floating technology for launching and beaching their devices.

Table 4 - Summary of Responses to Question Regarding Draft and Depth

Stakeholder Group	Large Technology	Small Technology
Developers	Scotrenewables' transport draft is 6m. Their platform has a minimum operating depth of 25m. OpenHydro requires a minimum 10m water depth (plus depth of marine railway if used) for Scotia Tide to retrieve a turbine from the seabed. Big Moon's barge can be beached for maintenance by rotating the keel up.	SME platform floats at 1.6m hull draft, 2.7m to u/s of turret, and 7.85m to u/s of rotor (rotors can be rotated clear of the water on their struts).
Technology Providers	Tocardo's UFS platform draws 6m in transport mode and can be beached.	N/A
Service Providers	N/A	Minimize draft of asset to increase time available alongside at dry and shallow ports.
Other	N/A	N/A
Conclusion	The tidal range is a useful tool for both subsea and floating large technology. Subsea technology can be transported out to the seafloor at low tide and retrieved by the asset at high tide. The size and weight of the technology defines whether or not a prepared seabed is required for such operations. OpenHydro's Scotia Tide barge requires a minimum water depth of 10m to retrieve the turbine, making it difficult to use the tidal range for transshipment. A marine asset with either a suspended or aboard lifting capability would work well in tidal range operations.	The tidal range is a useful tool for all small tidal technology, with seabed preparation being less critical for smaller and lighter devices. <u>Conclude:</u> Minimizing the draft of support vessels extends their operational usefulness. MultiCats have low draft characteristics. Dry-out capability further extends the usefulness of support assets.

	<u>Conclude:</u> Minimizing the draft of the marine asset makes extends the operational usefulness of the asset. Note that a catamaran barge has the disadvantage of greater draft relative to a standard deck barge. The asset should have dry-out capability to take advantage of the tidal range lifting and transfer opportunities.	

3.2.4 Anchoring Method

Large and small tidal technology use similar anchoring methods with variations of weight for gravity anchors and size for screw or pile anchors. Subsea technology generally employs gravity anchors in the form of subsea bases that are either internally ballasted or ballasted with blocks, but some of the technology does include piles as a securing option. Floating technology can use gravity anchors in the form of ballast blocks or screw or driven piles. The variations in weights and sizes are related to the drag of the various devices and this is driven more by the power developed than the hydrodynamic shape of the device. All of the technology slated for deployment in Nova Scotia intend to employ gravity anchors, at least at the early stages of development (larger array numbers may warrant bringing in pile technology and equipment).

Table 5 - Summary of Responses to Question Regarding Anchoring Methods

Stakeholder Group	Large Technology	Small Technology
Developers	Andritz and Halagonia Tidal Energy intend to utilize a gravity base for their subsea technology during demonstration phase and drilled monopiles once arrays reach 10-15 turbines. Similarly Scotrenewables & Atlantis Operations Canada intend to use gravity anchors for their floating technology during demonstration phase and rock anchors as arrays are built. Scotrenewables have developed an engineered mooring system that is fit for purpose for FORCE with remote winching and load monitoring OpenHydro utilize a ballasted gravity base.	SME rock anchor system can be used in solid rock bottoms. Bruce or Stevshark anchors (3-8t) can be used in clay or silt. Gravity base anchors are inexpensive but are more trouble than drag embedment anchors. Minas prefers pin or screw anchor.
Technology Providers	Jupiter intend to use drilled anchors.	Nova prefers ballasted SSB; pin-pile anchors were tested but not found suitable due to metamorphic rock at the site.
Service Providers	Green Marine have installed large ballast blocks with their gantry barge.	Green Marine have drilled rock anchors (SME system) using their Multi Cat. Dominion Diving's MultiCat can handle anchors up to 50t (wet). They note that handling multipiece anchors of more than 20t is complicated in high current zones.

Other	N/A	N/A
Conclusion	It will be challenging to utilize the asset for large monopile drilling without dynamic positioning and heavy lift cranes (eg. Bauer renewables system). The system's heaviest component is the drilling unit at 185t, but the drilling unit, template, and monopile are tall and may be difficult for an a-frame or shear leg to handle all of these units and their storage cradles on the available deck space. Other pile drilling systems should be investigated to determine if they could be accommodated. Conclude: The asset will need to handle ballast blocks for the subsea bases of subsea technology, and gravity anchors for floating technology. The weights and dimensions of these anchoring methods are as described in the tables above. Note that the asset may not be able to handle Andritz ballast blocks (380t) and Scotrenewables gravity anchors (400t wet), even at lesser reaches, and it may be necessary for these to be subdivided.	Small technology utilizes lower weight gravity anchors and SSB ballast weight, and smaller screw and pin pile anchors with correspondingly smaller drilling equipment. Conclude: The anchoring methods for small technology can be handled by a small to medium sized MultiCat.

3.2.5 ASSETS REQUIRED FOR LOADOUT AT DOCK

Loadout at the dock refers to the means of transferring all equipment including turbines, floating platform center and outer hulls, nacelles, subsea bases, ballast blocks, anchors, drilling equipment, and all other required equipment from shore to ship, shore to surface or shore to sea floor, as applicable for the particular technology. The wide range of weights, dimensions, assembly options and launching options produces a wide range of requirements for dock transfers and hence a wide range of assets that are utilized.

Table 6 - Summary of Responses to Question Regarding Assets Required for Loadout

Stakeholder Group	Large Technology	Small Technology
Developers	Andritz has previously utilized a large shore side crawler crane (eg. LR1750, 750t @ 7m, 391t @ 20m) to transfer their equipment from the dock to a DP vessel. Otherwise consider transporters (SPMT) for RO-RO operations. OpenHydro need a large shore or ship crane to put their turbine & SSB in the water. They can otherwise use a marine railway or submersible barge, however they require a minimum of 10m water depth, plus depth of the railway or barge in order to float the Scotia Tide over the turbine for pickup. Scotrenewables typically require: craneage at dock for handling of ballast material/anchor; a Multicat support vessel for deployment of mooring systems and towage of barges; flat top barges for construction of anchors and possible transport & storage of nacelles. They also use a shore crane with a minimum 350t capacity (Demag 350-6, 91t@12m) for launching and retrieval of components including the nacelles to and from the quayside to the surface and to flat top barges. Component parts can be wet assembled in a drydock, graving dock, or sheltered water area having minimum dimensions 70m x 85m x 4m. For Big Moon a good shore facility is key – a ramp with transporters (SPMT) could be used to launch the pontoon barge, using the tide cycle and blocks. Big Moon believe that a ramp and transporters would be useful to support all of the proposed floating technology.	SME can launch their platform as one unit on a beach or a ramp with the assistance of air bags or motorized transport, then use the tide cycle to raise/lower. SME can launch individual units and bolt together in the water (requires sheltered waters). Otherwise a single point lift can be used which would require a 300-400t crane on the dock or on a barge, assuming a 16m reach (Demag 350: 50t @16m). A floating drydock, submersible barge, marine railway or ramp would be useful assets, but overall width needs to be considered. Marine railways and ramps also restrict the location versus the flexibility of utilizing the nearest accessible beach or floating asset. For launching and maintenance work using the tidal cycle, the Hantsport site has a hard pan compacted gravel bottom and 500' long wharf (in need of repair); 12m of water at high tide.

	FORCE indicated that a groundable heavy lift barge would be good for loadout and site work.	
Technology Providers	Tocardo require only a 16 Ton lift from shore, assuming the UFS has already been launched using a drydock, marine railway, tidal cycle, or heavy crane.	Nova require a dockside crane to transfer their nacelle from the quayside to a MultiCat, and to transfer their SSB from the Quayside to the seafloor for subsequent pickup by a MultiCat. Nova typically utilise medium sized MultiCats having 120t pull on the main winch, 200t-m cranes, 4 tuggers, and 4 point mooring system. No additional support vessels are required, except small line handling vessels.
Service Providers	It was stated that the ideal unit is a heavy lift (1000t) pontoon barge with a straddle carrier (eg. marine travellift) that can do dock to barge loadouts. A marine railway is good for big and heavy loads from shore to water, but a heavy lift barge may also be required for transfer operations, per OpenHydro. Good shore facilities are essential. RJMI currently uses a 26m x 9m x 3m barge fitted with an A-frame and spud legs, with a lifting capacity of 200t. Another useful asset would be a dumb barge with a 300t crawler crane, with DP capability from 3 attached tugs, and with a pile driver fitted. Docks in the UK typically have good lifting capacity, reducing the required lifting capacity of the assets. For the Bay of Fundy where dockside capacity is limited it was again stated that the ideal assets would be a catamaran barge perhaps with a RO/RO gantry crane, with support from a MultiCat with a 25-30t capacity at a radius capable of quayside lift. Large land cranes mobilized to the dock can be very expensive; heavy lift ships can be a cheaper option, but they are still expensive. Docks need to be able to accommodate a 200t crane. A dock or ramp that can integrate with a heavy lift barge would be useful. OpenHydro equipment exceeds all local dock and equipment infrastructure and requires either a heavy lift ship or a large land crane at a deep dock facility.	
Other	CCG-ITS would be interested in expanding the docking capacity in Eastern Canada, as currently there are not enough drydocks for ship repair and maintenance. CCG-ITS does not have much need for a barge with smaller lift capacity, however CCG operations departments may have such requirement for incident management, emergency response, vessels of concern etc. A gantry crane on a pontoon barge is a good asset. A submersible barge generally is not as useful as a floating drydock, however a submersible barge allows overhanging of large lifts and can be used for launching assets such as the AOPS	

<table>
<tr><td></td><td colspan="2">vessels at Halifax Shipyard. Shear leg heavy lift barges are used extensively for wind farm projects, where the device is kept on hook and tethered for transfer. Alternate uses for heavy lift barge include: ship repair and construction, repair and maintenance on offshore installations, marine construction – bridge sections, and transportation.

It was recommended to establish a location near the site suitable for a dryout barge that can be used as a work platform in lieu of dock infrastructure improvements. The tidal range is a great asset for heavy lift operations in conjunction with SPMTs. A gantry barge and the tidal range are a good combination. Alternative uses for a heavy lift barge include marine construction and decommissioning work although it is felt that there aren’t enough alternatives to justify at the moment. Pontoon barges are not that common, if considering retrofitting an existing barge. Perhaps join two canal barges together for an economical solution.</td></tr>
<tr><td>Conclusion</td><td><u>Conclude:</u>
Existing dockside operations utilize a wide range of equipment for the wide range of heavy technology. The most consistent requirement is for a heavy shore or ship lift capability, and the required capacity of this lift varies. OpenHydro’s combined components require the heaviest of lifts, whereas the multi-component lifting options for Andritz, Scotrenewables and Tocardo result in small enough cargo that a heavy lift barge capable of the weights and dimensions identified in the tables above would be feasible. The capability to lift from the quayside requires ‘air lift’ (ie. Above the surface) capability using a lifting device such as a crane, A-frame, or shear leg.

A gantry barge with a heavy lift capability has the advantage of being able to handle a higher weight but has the disadvantage of not being able to transfer the lift on or off the dock. Flat top barges that are configured to work in conjunction with such a heavy lift asset provide options for transfer of the heavy units.

A drydock or semisubmerible barge would be useful assets for loading out floating technology directly and for using the tidal range in conjunction with SPMTs for subsea technology.</td><td><u>Conclude:</u>
Small technology can utilize cranes and the tidal range at ramps or beaches for loading out their equipment. Other equipment such as drydocks, semisubmersible barges, and marine railways are also useful for small technology. While not specifically required for this equipment, a heavy lift barge capable of handling large technology could certainly be put to use with small technology, potentially simplifying their operations and justifying the charter cost.

Once again for both small and large technology a medium sized MultiCat is identified as one of the most useful assets.</td></tr>
</table>

3.2.6 Assets Required for Transit

Once the turbines, floating platform center and outer hulls, nacelles, subsea bases, ballast blocks, anchors, drilling equipment, and all other equipment required for installation are loaded out at the dock it is transported to the site for installation. In the case of subsea equipment the vessel or asset that the equipment is loaded onto will transit under its own power or by tow to the deployment location and it will begin the process of installing the turbine, subsea base, ballast and blocks, or it will begin the process of drilling piles or screw anchors, depending on the anchoring method selected. In the case of floating technology, the majority of platforms are towed out on their own hulls while the anchoring equipment that is loaded onto a vessel or asset at the dock will be taken to the site for installation.

Table 7 - Summary of Responses to Question Regarding Assets Required for Transit

Stakeholder Group	Large Technology	Small Technology
Developers	OpenHydro uses their barge Scotia Tide to tow their turbine and subsea base complete with ballast from the loadout dock to the site. The turbine and subsea base are carried by the barge using a subsea lifting and securing system whereby the subsea base and about half of the turbine remain under the water. The resistance of the submerged equipment, and to a much lesser extent the barge itself, requires an OSV with bollard pull (BP) of app 180t to tow the barge and turbine to the site and to and maintain station in the current at the site. Andritz also has heavy subsea equipment and as such has previously utilized heavy lift marine assets including the DP vessel 'Olympic Aries' (with 250t crane) for nacelle installations, and a jackup barge for foundations installation. Scotrenewables utilizes MultiCats for towing their floating platform and for towing flat top barges that are used for construction of anchors and potentially for transport & storage of nacelles.	SME has successfully used MultiCats for towing, station keeping, and anchor installation (medium sized with a 26t crane,18t crane, 50t winch, and a100t winch). They have found that for their equipment a MultiCat can replace a barge with crane & 2 tugs. SME recently used a 15m Meercat to tow the platform from its deployment site in Scotland.
Technology Providers	Tocardo requires a tug with 65T BP, and 35T BP Multicat (medium sized, 2611 or 2712).	Nova utilizes a medium sized MultiCat.

<table>
<tr><td>Service Providers</td><td colspan="2">OSV needed to support OpenHydro marine operations; tugs and Multi Cat are insufficient.

Green Marine utilize a tugs with 26T BP and Multicat with 33T BP to tow their gantry barge, and flat top barges, complete with the tidal equipment that is being transported.</td></tr>
<tr><td>Other</td><td colspan="2">See comments in table above regarding assets required for loadout.</td></tr>
<tr><td>Conclusion</td><td><u>Conclude:</u>
Large subsea technology uses large heavy lift equipment for transiting the equipment to the site. OpenHydro use their own heavy lift asset, while Andritz charters DP vessels and jack up barges. An asset capable of loading out, transiting, and deploying the subsea equipment would potentially negate the need to charter expensive heavy lift vessels and assets.

Large floating technology does not require a heavy lift asset although a multipurpose heavy lift asset could be used to transit the anchors and installation equipment to site, potentially reducing the number of anchors required by use of larger anchors.</td><td><u>Conclude:</u>
Small technology users can transit their equipment using a small to medium sized MultiCat.</td></tr>
</table>

3.2.7 Assets Required at Site for Deploying/Retrieving & Maintaining

The key operational activity in the tidal industry is deployment and connection of equipment, a process which has to be reversed, and repeated, numerous times during the equipment's' life cycle, for both routine and unscheduled maintenance. The environment in which this process occurs is a challenging one, where multiple marine assets need to conduct coordinated operations in fast moving water with reversing flow, relatively close to shore and in relatively shallow water, and surrounded by obstacles including technology and anchors on the seabed, tow lines, anchor lines, grid cables, and buoys. Large technology requires larger more powerful assets and more support vessels, and the equipment being handled is larger and heavier. Small technology faces the same environmental challenges using smaller and fewer marine assets. Subsea technology requires the equipment to be carefully located on the seabed, either as a single unit or as separate components including the SSB, ballast blocks, and nacelle, and then the equipment needs to be connected to the grid power cable. Floating technology requires gravity anchors to be positioned or piles to be drilled, anchor lines connected, and grid power cable to be connected.

Table 8 - Summary of Responses to Question Regarding Assets Required at Site

Stakeholder Group	Large Technology	Small Technology
Developers	OpenHydro and Cape Sharp Tidal utilize their bespoke launch and recovery barge Scotia Tide. The Scotia Tide and its subsea lifting frame, lifting tools and sensors provide better control and accuracy than a heavy lift vessel. For launch and recovery operations OpenHydro require additional vessels including an OSV, ASD tug and several smaller support vessels; and for cable connection operations two ASD tugs, a flat top barge with crane, and two support vessels. Andritz nacelle installations have been performed with a DP vessel fitted with a 250t crane, while foundations have been installed using a jackup barge. Heavy lifting capability and accurate positioning are key. Scotrenewables tow their platform to site. A medium sized MultiCat is utilized at site for handling of mooring systems, towage of support barges and cable connection. Scotrenewables intend to use an engineered mooring system fit for purpose for FORCE with remote winching and load monitoring. The mooring system could be deployed from a flat top barge configured to work in conjunction with heavy lift barge. A flat top barge could also be used in conjunction with a heavy lift barge for	SME's floating platform can be towed to site using a small to medium sized MultiCat. Gravity anchors or drilled anchors can be handled by a MultiCat. Their turbines can be removed and hot swapped on-site, where two turbines can be lifted at a time, and again this can be achieved with a MultiCat. A smaller vessel streaming astern can be used for basic turbine maintenance when the turbine is in the raised position. SME's device could be put on barge or towed to Hantsport for maintenance and overhaul work. Daily monitoring of the device and routine maintenance can be conducted out of Parrsboro using small fast work boat. SME have indicated that a pontoon barge or Multicat are the most valuable marine assets for their operations. FORCE utilized a 50m Barge with 150t crane for grid cable installation. A 70m barge with 200t crane was utilized for OpenHydro's cable handling. A MultiCat would be a good tool for FAST and anchor deployment. A dedicated workboat would be good. Note that mooring management becomes a challenge as more devices installed, requiring more support vessels.

	maintenance of nacelles, and perhaps the platform itself. Turbines will be hot swapped and either taken ashore or refurbished on a floating facility. The heavy lift barge in this case could be a pontoon gantry type barge where the flat top barge is sized to fit between the pontoons. For Big Moon a submersible barge (or very wide floating drydock) could be used to raise the entire barge unit for coatings and anode maintenance. Otherwise a small work boat with a Hiab crane is al that is required.	
Technology Providers	Tocardo requires only a medium sized MultiCat.	Nova has utilized medium sized MultiCats having 120t on the main winch, 200t-m cranes, 4 tuggers, and a 4 point mooring system. Only small line handling support vessels are required. Installation of their device on the sea floor using a MultiCat is facilited with the use of a custom lifting beam fitted with tools, lights etc. for remote connect and disconnect. The beam and the device are slung off the main winch of the MultiCat.
Service Providers	An anchored flat top barge with enclosure would be good for maintenance. Jack-up barges are used for this purpose in the wind turbine industry. A flat top barge with a 300t crawler crane and pile driver fitted is a useful tool. It can have DP capability utilizing 3 attached tugs with synchronized control. A medium sized Multi Cat is a key tool and is useful for other industries such as marine construction and spill response. A heavy lift DP vessel at site is risky due to currents and shallows. Green Marine has found that their 55m x 26m Gantry barge is a good asset for tidal work. The barge is a catamaran type for low resistance, has a 700t lift capacity, and has a four point lift system which is good for control, orientation, and accuracy. GM also utilizes a medium sized 2712 Multicat, an anchor handling tug, smaller support & safety vessels, and a flat top barge that fits between the gantry barge hulls to transfer lifted items to/from the gantry barge. The Green Marine fleet can handle all of the proposed FORCE technology with the exception of OpenHydro's turbine/SSB/ballast combined unit (and Andritz's technology if nacelle/SSB/ballast are handled as one unit). The tidal range would need to be utilized with a hard pan bed and transporters in order to get equipment in the water for pick up by the gantry barge. Devices, SSBs, and ballast/foundations all need to be designed with launch and recovery in mind, given the challenges of subsea work, particularly in the Bay of Fundy where visibility is poor and ROV work is limited. Green Marine utilizes cameras, acoustic cameras and ultrashort baseline acoustic positioning equipment for subsea work.	

<table>
<tr><td></td><td colspan="2">A small MultiCat having a 20t deck crane and 50t deck winch (with bow roller) is the most versatile vessel to support the industry. Larger MutiCats have greater draft, and their accommodation spaces are not compliant with Transport Canada towboat crew accommodation regulations. For large technology a specially configured barge with lifting capacity and with accommodations for 25-30 people would be useful. The asset should not be self-propelled so as to simplify operations, personnel, equipment, and certifications.</td></tr>
<tr><td>Other</td><td colspan="2">See comments in table above (assets required for loadout).</td></tr>
<tr><td>Conclusion</td><td><u>Conclude:</u>
Large technology, both subsea and floating, require heavy lift capability and deck space to deploy, retrieve, and connect their equipment. A bespoke heavy lift barge, in conjunction with support tugs for station keeping and positioning, has been successfully utilized in place of a heavy lift DP vessel. The heavy lift capability of the barge would ideally have air lift capability (crane, a-frame, shear leg, gantry) and it would ideally have over the side reach capability (crane, a-frame, shear leg). Deck space is important for handling multiple pieces of equipment.</td><td><u>Conclude:</u>
Small technology, both subsea and floating, can deploy, retrieve, and maintain their technology with a MultiCat. However there are uses for a larger asset having a heavy lift capability including transport of SME’s floating platform for maintenance and in lieu of towing, launching of Nova’s subsea base at the quayside, and deployment of FORCE’s cables.</td></tr>
</table>

3.2.8 Locations - Dock Loadout, Maintenance

The preferred/required location for loadout and maintenance is naturally as close as possible to the deployment site. The nearest ports to the FORCE site are Parrsboro and Hantsport, and these are both dry ports with no access at low tide and with infrastructure limitations. Saint John and Digby are the nearest deep water sites but have some limitations on dock infrastructure. Halifax is a good deep water site with good infrastructure but is a long transit away from the Minas Passage and Grand Passage.

Table 9 - Summary of Responses to Question Regarding Loadout and Maintenance Locations

Stakeholder Group	Large Technology	Small Technology
Developers	Andritz prefers onsite maintenance using a flat top barge or jack up barge fitted with a maintenance facility. Limited on-site maintenance can be conducted on Scotrenewables' SR2000. Saint John is the most viable location for OpenHydro just now, but alternate locations are required. Dock loadout requires a heavy lift vessel. Halifax has the water depth and dock facilities for loadout either by crane or by heavy lift vessel, but transit distance and consequent towing costs are high. A deck barge with enclosure for maintenance, located near the site, would be a good alternative, once OH has the capability to remove the turbine and TCC from the SSB. Big Moon are looking for the nearest dry port for both loadout & maintenance. A workboat needs to be located nearby (eg. Scot's Bay or Baxter's Harbour).	Black Rock Tidal and SME are considering a number of beaches near FORCE for launching and assembling their floating platform; although access rights and transport to/from the location are challenges. The main platform requires inspection every 5 years, and this can be conducted at a nearby dock, ramp, or beach facility. Turbine replacement and maintenance can be conducted in-situ and on-site. Minas Tidal and SME are considering Hantsport for loadout, and Hantpsort or Parrsboro for daily monitoring & servicing. FORCE believe that closer is better, but local dock facilities are not great. The state of port facilities including strength of docks in general is poor. Saint John has good facilities, but stevedoring services are expensive.
Technology Providers	Andritz' loadout and maintenance sites have not been determined yet, but Saint John is understood to be the only suitable location for now. Jupiter are considering either AF Theriault's Boat yard in Meteghan or the peer at Hantsport. Scotrenewables intend to use either Halifax or Saint John for	

	loadout of large items and ballast and Parrsboro or Hantsport area for maintenance. Tocardo prefer that the loadout and maintenance site be within 80 Nm.	
Service Providers	NS should partner with NB to make use of Saint John. NS & NB need to work together given that Saint John is attractive since it is closest to the site and has decent infrastructure, supply chain, transportation, etc. Similarly, Halifax has good infrastructure, supply chain, and transportation, but requires a long transit. OpenHydro require good port infrastructure for their equipment. For Green Marine operations in Scotland the nearest site location from dock is approximately 2 hours, and the furthest is approximately 6 hours. Equipment transfer from their gantry barge to their flat top barge is undertaken in sheltered waters. Typical operating limit is 1.5m Hs and 30 knot wind. Quayside lift capacity is a constraint. Note that Parrsboro is approximately 5nm from site and Hanstport is approximately 14nm.	
Other	N/A	
Conclusion	<u>Conclude:</u> Loadout facilities for large technology need to have deep water and good infrastructure, and it is preferred to be close to the deployment site. Large technology, with the exception of Big Moon, cannot be loaded out at the nearby dry ports, and either Saint John or Halifax are considered the most viable locations, with Saint John having the advantage of proximity and Halifax having the advantage of better infrastructure, services, and transportation. Maintenance locations should be in close proximity to the site. On-site floating assets such as a deck barge with an enclosure are considered a good option. A heavy lift barge would expand the available loadout locations by reducing the location's infrastructure and draft requirements. A heavy lift barge could also be used on-site for retrieval and maintenance of some heavy technology and could be used in conjunction with onsite assets such a drydock, semisubmersible barge, or flat top barges for maintenance work.	<u>Conclude:</u> Small technology has more options for both loadout and maintenance including the nearby dry ports and even nearby beaches. A heavy lift barge is not required, but if available it could be used to simplify certain loadout and maintenance activities.

3.2.9 ASSET DESIGN FEATURES REQUIRED AND/OR DESIRED

Since the majority of respondents identified their preferred design features in their responses to the questions above there were not enough responses to this question to require a summary table. The following is a list of some of the required/desired features that have been extracted from the responses:

- Catamaran hull configuration for better towing, station keeping, and positioning
- Heavy lift capability
- Flat top deck space
- Not self-propelled
- Dry-out (grounding) capability
- Shallow draft
- Temporary enclosure for maintenance
- Accommodations for 25-30
- Client room/area/container
- Workshop fitted aboard
- Compatibility with multiple flat top dumb barges
- Jack-up capability for stability
- RollOn-RollOff capability
- Variable load spreading bars for handling different equipment
- Remote winching operations with load monitoring
- Small mooring mass requirement through consideration of drag profiles
- Live tidal stream data

3.2.10 CONCLUSIONS

Weight

In defining the heavy lift requirements of the marine asset, it is necessary to determine the largest equipment weight and size to be lifted, and the extent of reach required. A reasonable heavy air lift (ie. above the surface) capability of **270t** to **330t** will encompass most of the individual component weights of the technology that is intended for use at FORCE, with notable exceptions being OpenHydro's SSB (450t, unballasted) and Andritz' ballast blocks (380t, if not divisible). Some of the large technology cannot be broken down into component weights, such as OpenHydro's turbine and ballasted SSB. Andritz can install their SSB and ballast blocks separately, and the 380t ballast blocks are divisible. Scotrenewables can remove nacelles from their floating platform which reduce the platform weight sufficiently to fall within the assumed lift capability. Of course, the more components to handle, the longer the operation, but the lesser the heavy lift requirement. It would be beneficial if the asset could handle up to 380t, perhaps at lesser reach as discussed below, so that ballast blocks and gravity anchors could be handled without being divided.

Dimensions

It is similarly necessary to assume a reasonable limit on the dimensions of equipment that can be handled, and this means excluding outliers including OpenHydro's SSB with dimensions of 33x31x20m, Tocardo's platform at 30x25x6m, and perhaps Scotrenewables' platform at 74x4m. A reasonable maximum dimension could be considered to have a **22x20m** footprint and a maximum height of **24m;** with a reach of **18-20m.** These dimensions would allow bringing aboard Andritz' SSB and OpenHydro's turbine component, as well as Andritz' and Scotrenewables' nacelles. The reach of 18-20m has been assumed so as to allow the capability to lift these components from the dock and bring them aboard the asset. Consideration is also given to having a higher lift capacity at a smaller reach such as **9-10m**, whereby the unit is left suspended rather than brought aboard. This restricted reach option depends on the type of lifting device installed on the asset, as discussed below.

The small technology intended for use at FORCE is the SME platform, which weighs 83t and measures 32mx27m overall, but can be broken down into smaller components that can be assembled once launched. Other small technology incudes Nova's equipment, the largest component of which is the SSB at 150t dry or (90t wet) and measures 15mx11mx8.5m, and which has previously been deployed by launching the SSB dockside and using a Multicat to lift the unit off the seabed at the dock using its deck winch, and then transiting to site with the SSB suspended. Small technology in general does not need a heavy lift asset to handle the lesser weight and dimensions of the technology, and most requirements of small technology can be met with the use of a MultiCat or Tug. However, the availability of a heavy lift asset would provide small technology operators with more options as to how and where they handle their equipment, with operations being simplified when the technology can be handled as a combined unit.

Depth

The tidal range can be used as a lifting device for tidal technology when used in conjunction with the appropriate assets and infrastructure. An appropriate marine asset could include a dry-out barge (ie. capable of bottom grounding), a semisubmersible barge, a floating drydock, or a shallow draft heavy lift barge. Infrastructure requirements include a dry port with a prepared hard pan seabed for large technology, or a natural seabed that is hard enough to accommodate small technology plus required transport. Transport assets for large technology include self propelled modular transporters (SPMT), large mobile all terrain cranes, or a marine railway while those for small technology include lighter equipment such as excavators and small all terrain cranes. Hantsport has a prepared hard pan seabed and a high-water depth of 12m, which should be sufficient for Scotia Tide to retrieve OpenHydro's turbine assembly, which requires a minimum water depth of 10m for the barge to float over the turbine. It should be noted that equipment loaded aboard a marine asset also needs to be unloaded at its destination, which poses challenges at the deployment site when considering semisubmersible barges and floating drydocks that do not have heavy lift capability. Scotia Tide is well suited for tidal range infrastructure operations due to its subsea heavy lift capability, and a gantry barge, especially when used in conjunction with flat top barges, is also well suited for such operations. All marine assets supporting the tidal industry extend their operational usefulness with both shallow draft and dry-out capability.

Anchoring

In determining the optimum marine asset, the types of anchoring methods for the various tidal technologies needs to be considered. The asset will need to handle ballast blocks for the subsea bases of subsea technology, and gravity anchors for floating technology. It may be challenging to size the lifting device on the asset such that it is capable of handling Andritz' ballast blocks (380t) and Scotrenewables' gravity anchors (400t wet), even at lesser reaches, and it may be necessary for these to be subdivided. In that regard a gantry barge has the benefit of a higher capacity air lift and Scotia Tide has the benefit of a very high subsea lift capability. The asset ideally would also be able to handle the equipment necessary to install pin piles, screw piles, rock anchors etc. It may be challenging to utilize the asset for large monopile drilling without including dynamic positioning capability and a heavy lift crane. For example, the Bauer Renewables system utilizes a drilling unit at 185t that can reasonably be handled but the drilling unit, template, and monopile are tall and it may be difficult for an a-frame or shear leg to handle all of these units and their storage cradles with limited range of motion and limited deck space. Other pile drilling systems should be investigated to determine if they could be accommodated. The anchoring methods for small technology can generally be handled by a small to medium sized MultiCat.

Loadout

Dock loadout of large tidal technology poses one of the greatest operational challenges and drives the requirement for appropriate marine assets, as well as land support assets and infrastructure. Large technology typically requires either a heavy shore or ship lift capability, and with shore infrastructure limitations, high costs for heavy cranes (where the shore infrastructure will support them), and a requirement for heavy lift at the deployment site, a heavy lift vessel becomes the preferred choice. OpenHydro's combined components require the heaviest of lifts and it may not be reasonable to expect the asset to be capable of lifting OpenHydro's equipment from the quayside. Large technology that is divisible into components such as that from Andritz, Scotrenewables and perhaps Tocardo can reasonably be handled by a heavy lift barge with 'air lift' and reach capability using a lifting device such as a crane, A-frame, or shear leg. A gantry barge with a heavy lift capability has the advantage of being able to handle a higher weight but has the disadvantage of not being able to transfer the lift on or off the dock. Flat top barges that are configured to work in conjunction with such a heavy lift asset provide options for transfer of the heavy units. A drydock or semisubmerible barge would be useful assets for loading out floating technology directly and for using the tidal range in conjunction with SPMTs for subsea technology, as discussed above. Small technology can utilize cranes and the tidal range at ramps or beaches for loading out their equipment. Other equipment such as drydocks, semisubmersible barges, and marine railways can be useful for loading out small technology. While not specifically required for small technology, a heavy lift barge capable of handling large technology could certainly be put to use with small technology, potentially simplifying their operations and justifying the charter cost.

Transit

Once loaded out at the dock, the tidal equipment needs to transit to the deployment site. Large subsea technology requires large heavy lift equipment for transiting and deploying the equipment. OpenHydro use their own heavy lift asset Scotia Tide for transit and deployment. Their catamaran barge is not self propelled and needs to be towed. Since the barge is configured for subsea lifting only, the majority of the turbine assembly is underwater and creates a significant amount of drag, requiring a vessel such as an OSV with high bollard pull (180T). A catamaran barge that is capable of lifting equipment clear of the water, such as Green Marine's gantry barge, has considerably less resistance and a much smaller asset can be used for towing in open water and for station keeping in high current flow areas. Andritz typically charters DP vessels and jack up barges for transiting their equipment to site. Scotrenewables' large floating technology does not require a heavy lift asset, although a multipurpose heavy lift asset could be used to transit their heavy anchors and installation equipment to site, potentially allowing the use of larger anchors and reducing the number of anchors to be installed. Small technology operators can transit their equipment using a small to medium sized MultiCat.

Site

Large technology, both subsea and floating, requires heavy lift capability and deck space for the critical operation of deploying, retrieving, and connecting. OpenHydro's bespoke heavy lift barge, in conjunction with support tugs for station keeping and positioning, has been successfully utilized in place of a heavy lift DP vessel for deployment, although it should be noted that a heavy lift vessel was also utilized to transfer the turbine assembly from the dock to the seabed for pickup by the barge. Andritz typically utilizes chartered heavy lift assets. Scotrenewables will require a heavy lift asset in order to deploy their large gravity anchors, and they envision a heavy lift asset used in conjunction with flat top barges for this operation. The heavy lift capability of the asset would have air lift capability (crane, a-frame, shear leg, gantry) and it would ideally have offboard or over the side reach capability (crane, a-frame, shear leg). The envisioned capacity of the heavy lift asset, as described above, assumes that the technology will be broken down into manageable component parts, since fully assembled devices weigh considerably more than what is envisioned as a reasonable capacity. It is hence important for the asset to have sufficient deck space for the various components of the subsea device, or subsea anchoring equipment in the case of large floating technology. Deck space can also be achieved by using flat top barges that are configured to work in conjunction with the heavy lift asset, both for offboard lift capability and gantry type capability; such approach however would require additional support assets. With these considerations in mind, a barge asset capable of loading out, transiting, and deploying large technology would potentially negate the need to charter expensive heavy lift vessels, however a number of support vessels, either owned or chartered, would be required for maneuvering and towing an asset that is not self propelled. Small technology, both subsea and floating, can deploy, retrieve, and connect their technology with a MultiCat. However, small technology could potentially make use of a larger asset having a heavy lift capability, such as lifting and transporting of SME's floating platform, launching of Nova's subsea base at the quayside, and deployment of FORCE's cables.

Maintenance

The intended or desired locations of dock loadout and maintenance activities was polled so as to get feedback regarding asset design attributes that would work best for those locations. In all cases respondents desired to use the nearest port facility, including dry ports. Loadout facilities for large technology generally need to have deep water and good infrastructure, and with the exception of Big Moon, none of the technology can be loaded out at the nearby dry ports with the existing infrastructure and existing marine assets. Saint John or Halifax are considered the most viable locations for large technology, with Saint John having the advantage of proximity and Halifax having the advantage of better infrastructure, services, and transportation. A heavy lift, shallow draft, and dry out capable barge would expand the available loadout locations by reducing reliance on the location's infrastructure and by overcoming some of the limitations posed by low water depth. A heavy lift barge could also be used on-site for retrieval and maintenance of some heavy technology and could be used in conjunction with onsite assets such as a drydock, semisubmersible barge, or flat top barges with enclosures. A heavy lift barge is not required for small technology which has more options for both loadout and maintenance, including the nearby dry ports and even nearby beaches, but if available it could be used to simplify certain loadout and maintenance activities.

Lifting Device

The type of lifting device fitted on the asset must be considered. Cranes are the most versatile type of device and are also the most expensive due to the complexity of achieving high capacity ratings for use at sea. A-frames provide high lift capacity and good reach but lack the versatility of load positioning and require sufficient space between the frame to bring an item aboard and sufficient deck space to land the item. A-frames can be positioned at the sides or ends of the asset to maximum the off-board reach, and tugger winches can be used to move items into and out of the lift zone. A-frames tend to have higher capacity throughout their full operating range relative to cranes that have lesser capacities at greater reaches. Shear legs provide high lift capacity and good reach and height but require sufficient deck space at their base to bring the item aboard, which then limits the off board reach. Gantry cranes provide very high lift capacity and good control of the lifted item, but lack off board reach capability and have limitations on deck laydown. Gantry cranes work well in conjunction with flat top barges that can fit between the hulls of the asset. Flat top barges also work well with A-frame and shear leg lifting devices to overcome deck space limitations. Mobile or RO-RO gantry cranes have good lift capacity and versatility for transferring the load, but face challenges when designing and building for use at sea. It is deemed that the best capability vs. cost and complexity is an A-frame, followed closely by a shear leg and a gantry crane.

Other Uses

Other uses for a heavy lift asset are important when considering ownership and financial feasibility, and respondents from the Non-Tidal and Other industries offered some examples when discussing preferred marine assets. A heavy lift barge would be a useful asset for:

- Transportation
- Marine construction work including docks, bridges, and breakwaters
- Wind farm construction and maintenance (especially if a shear leg is utilized)
- Maintenance of offshore installations
- Decommissioning of offshore installations
- Decommissioning of Vessels of Concern (derelict)
- Ship repair and construction
- incident management
- Emergency response

4 CONCEPT DESIGN PARAMETERS

The conclusions drawn from stakeholder responses identify a number of types of assets with a range of features that would be useful to the tidal industry. Responses identify a need for primary assets as well as supporting assets. Large technology drives the requirement for the most useful primary asset, while small technology identifies an asset that is primary to their needs and which is also a very useful supporting asset for large technology. The asset types and associated features that are deemed to be of most use are:

Primary Assets:

1. New Build Catamaran barge, with air lift capacity.
   Lifting Options:
   - A-frame that can pick lift off dock, deploy/retrieve at site, and bring lift aboard to a laydown area for maintenance and transit.
   - Shear leg that can pick lift off dock, deploy/retrieve at site, and bring lift aboard to a laydown area for maintenance and transit or leave lift suspended and secured.
   - Gantry crane with lift between hulls or through a moonpool.
   - Mobile gantry crane with ability to transfer lift ashore.

2. Modify OpenHydro catamaran barge with air lift capacity.
   Lifting Options:
   - A-frame that can pick lift off dock, and deploy/retrieve at site, and bring lift aboard to a laydown area for maintenance and transit. (Consider decking-in the area between pontoons for laydown area; or for OpenHydro the turbine can be positioned to mate with the raised SSB).
   - Shear leg that can pick lift off dock, deploy/retrieve at site, and bring lift aboard to a laydown area for maintenance and transit; or leave lift suspended and secured.
   - Gantry crane with lift between hulls or through a moonpool.
   - Mobile gantry crane with ability to transfer lift ashore.

3. Deck barge with lift capacity (lift options as described above)

4. Modify OpenHydro Barge Subsea Systems to work with other technology (use tidal range & SPMT or shore crane to put device in and out of water; water depth may be the limitation). No air lift capacity. High capacity subsea lift.

5. Semi-submersible barge – identified as useful in conjunction with hard pan bed plus transporters using tidal range for loadout purposes, and for maintenance purposes. Has limited potential for the tidal industry because it lacks the functionality of deploying and retrieving equipment from the ocean floor.
6. Floating Drydock - identified as useful in conjunction with hard pan bed plus transporters using tidal range for loadout purposes, and for maintenance purposes. Has limited potential for the tidal industry because it lacks the functionality of deploying and retrieving equipment from the ocean floor.

Support Assets:

1. Multi Cat
2. ASD Tugs
3. OSV for towing and station keeping.
4. Workboat
5. Flat top barges to work in conjunction with all primary and support assets

4.1 PRIMARY ASSET CONCEPT DEVELOPMENT

New Build:

In order to determine the economic viability of the marine asset, the most useful of the identified options has to be selected and investigated. It is deemed that the most useful asset is a catamaran barge fitted with an A-frame capable of lifting equipment from the dock. The capacity of the A-frame needs to be in the order of **270t** to **330t** at a reach of **18m** to **20m** and sized to accommodate equipment having a footprint of **22m** by **20m** and a maximum height of **24m**. A-Frame located on aft end. The barge would be decked-in between the pontoon hulls to provide a laydown area for the equipment items that are landed aboard, with a forward crossbeam that would serve to structurally connect the hulls, protect the deck area from wash, and provide above deck internal spaces. The flat deck would be fitted with tugger winches that would move equipment to and from the A-frame lifting zone and stowage areas on the deck. The main hoisting winch or winches could be located on centerline at the forward end, perhaps incorporated into a forward crossbeam; or it may be more efficient to locate the winches alongside the A-frame with turning sheaves at the base of the A-frame. The crossbeam could also house the hydraulic power unit (HPU), control room, and workshop.

In order to determine the principal particulars of a barge that can accommodate this lifting capacity and equipment size, it was convenient to start with the particulars of an existing barge that has heavy lift capability, albeit subsea lift capability, that being Scotia Tide. Some preliminary calculations were conducted using the Scotia Tide hull form and it was determined that a hull of this size can accommodate a maximum of approximately 600t at approximately 18m of reach with an A-frame positioned for either over-the-stern lifting or for over-the-side-lifting. To accommodate this lifting capacity the barge has to be heavily counterweighted using liquid or solid ballast and the deck edge comes close to immersion, making this a limit state. At the desired lift capability of approximately 300t at 18m the hull form can accommodate the lift with liquid ballasting of the ballast tanks and two of the void spaces, with a minimum of 0.5m of freeboard remaining, hence demonstrating that a barge of this size is capable of handling the lift.

<u>Principal Particulars of 'Scotia Tide' Heavy Lift Barge:</u>

LOA	64m
Breadth	37m (7m hull width, 23m between hulls)
Depth	4m
Draft	1.25m light, 2.7m deep (1250t)

The size of the required A-frame is based on the capability of lifting aboard equipment having dimensions of 22m x 20m in length and width and 24m in height. This translates to an A-frame with an approximate overall width of 25m and overall height of 26m. A-frames of this size tend to be custom designed and manufactured, and consequently their specifications are difficult to obtain, however examples of commercially available large A-frames have been found. AXTech for example have produced a 250t capacity A-frame with a width of 18m and height of 22m, with a reach of 15m at full capacity. Palfinger have indicated their interest in designing a custom A-frame with a 300t capacity at 18m reach.

See **Appendix A** for images of the 3D model that was created to demonstrate the concept design of the purpose-built barge.

Modify Scotia Tide:

Given the conclusion that a catamaran barge of similar size to the Scotia Tide would be a useful asset for supporting the tidal industry, it follows that consideration be given to modifying the existing barge. The most critical modification would be the addition of an A-frame to give the barge 'air-lift' capability. This design concept was investigated, and it was determined that a side mounted A-frame would make the best use of the existing vessel's arrangement, where the crossbeams are a prominent topside feature. A side mounted A-frame would provide the option of swinging the lifted load inboard to a decked in area or into the moonpool area created between the pontoons and crossbeams.

The A-frame to be fitted would be similar in capacity and size as that specified for the new build asset. There would be a significant cost saving on the A-frame system in this case by utilizing the barge's existing winches and their accompanying hydraulic power units. The existing topside sheave assemblies are modular to allow for reconfiguration of the barge from subsea deployment and recovery mode to bulk cargo mode, and these sheaves could be relocated and reconfigured to direct the winch line pull to the A-frame. Similarly, the winches are bolted onto their seats and the HPUs, control and storage containers, cable reels, cable tensioners are all mounted on skids fitted with standard container fittings so that all of the equipment can be removed and reinstalled as operating modes change. This modularity and multi-modality provides flexibly for utilizing the existing winches, HPUs, and sheave assemblies, and for configuring the deck arrangement more efficiently

Scotia Tide is designed with strongpoints on the pontoons that are designed to accommodate a modular deck structure that could be used for the transport of bulk cargo, for example horizontally stacked turbine units or cable reels, up to a total of 700t capacity. The decked in area could be used for positioning the components of a turbine system (ie. nacelle, SSB, ballast) as they are loaded out from the dock and transited to site for installation, or vice versa. The decked in area could also be used as a maintenance platform. Tugger winches could be used for moving the equipment into and out of the A-frame lifting zone.

The barge's moonpool area could also be utilized in situations favoring subsea work through the moonpool rather than over the side subsea work. In this case the A-frame, the barge's existing subsea system, or a combination of the two could be utilized for this work. If the moonpool was to be used it would likely be necessary to remove the barge's subsea recovery frame as the frame structure occupies a large part of the moonpool area.

Another consideration for utilizing the Scotia Tide, with or without the addition of an A-frame, is to modify the subsea lifting system to work with other technology and other subsea components. The modularity of the equipment aboard Scotia Tide, and the heavy lift capability of the subsea equipment, provides many options for reconfiguring the asset to work with a multitude of components.

In all cases where modification of Scotia Tide is considered there are some challenges that must be overcome. First and foremost is the need to reconfigure the barge from OpenHydro's operating requirements to the requirements of others. The A-frame and decking used for other technology and other industries cannot remain in place during OpenHydro operations as their added weight would cause the vessel to exceed its load line when the OpenHydro Turbine, SSB, and ballast are loaded. There would be significant cost involved with this reconfiguration. Similarly, the recovery frame and subsea lifting components of the Scotia Tide require significant removal and reinstallation work should the subsea configuration need to be changed. Note that an A-frame and decking could be utilized without the need to remove and reinstall the barge's recovery frame and subsea system, although leaving this system in place would increase the vessel's resistance hence requiring towing assets with higher bollard pull for transit and station keeping.

See **Appendix B** for images of the 3D model that was created to demonstrate the concept design of the modified Scotia Tide barge.

5 FINANCIAL MODEL, FINANCIAL ANALYSIS, AND OWNERSHIP OPTIONS

5.1 FINANCIAL MODEL

5.1.1 FINANCIAL MODEL INTRODUCTION

The financial model is based on the two barge scenarios identified in the Task 1 report. There are many variables to account for in the financial analysis, a Base Case provides an attempt to offer as straight forward an analysis as possible. The key assumptions behind the Base Case are noted throughout. To start assessing the financial implications associated with the barge scenarios, an estimate of the total potential annual demand for barge services has been made and is based on a plausible development scenario as per the Marine Renewable Energy Strategy and the utilization of the FORCE site. The project mentors provided guidance on the number of days a single barge might be commissioned annually based on the development scenario presented. In addition, mentor's advice combined with interview data have suggested a range of per day charge out rates that could be expected for a barge of the technical specifications defined under the barge scenarios. Based on their estimates two financial scenarios are presented for day charge out rates of $30,000 and $50,000 dollars respectively. Further, the financial analysis is developed to demonstrate payback periods related to the revenue streams associated with 100 days of billable work per year. The potential revenue stream is then split to support both operating and capital costs. An important qualifier is that this analysis has only considered the financial aspects related to the barges as defined, the requirements for support vessels are considered pass-through expenses from the marine contractor who is assumed to own the barge to the client who is assumed to be the developer. In the concluding section of the financial analysis various risk factors to the financial analysis are noted. These could influence any investor decision making process to acquire such an asset to support tidal development.

5.1.2 BARGE REQUIREMENTS

As part of the study interview process, barge requirements were reviewed with all potential developers at the FORCE Site to 2020.

The following summary table has been prepared to identify those projects that will require a heavy lift barge to install and to complete required maintenance. The table presents the heavy lift requirements associated with each berth at the FORCE Site. It also has a description of the technology and the amount of power to be generated.

Table 10 - Project Summary at FORCE Site

	Power to be generated and timing of installation	Description	Barge Requirements
Berth A – Minas Tidal		Small technology	None required, but heavy lift to or from dock could bring efficiencies
Berth B – Black Rock Tidal		Small technology	None required, but heavy lift to or from dock could bring efficiencies
Berth C - Atlantis Operations Canada	2 MW	Large technology Scotrenewables SR2000 floating and moored turbines	Heavy Lift for installation and maintenance
Berth D – Cape Sharp Tidal	2 MW	Large technology OpenHydro's open rotor turbine, which is fitted with a 16-meter diameter rotor and is mounted on the ocean floor using a ballasted steel gravity base.	Scotia Tide
Berth E – Halagonia Tidal Energy	3 x 1.5 MW	Large technology Andritz turbine is mounted on a ballasted steel subsea base.	Heavy Lift for installation and maintenance
Bay of Fundy – Big Moon Power		Small Technology	None required, but heavy lift to or from dock could bring efficiencies
Grand Passage – 3 sites		Small Technology	None required, but heavy lift to or from dock could bring efficiencies

5.1.3 Barge Options

In Task 1 two go forward heavy lift options have been defined. The options are described below. Both are based on providing lift capacity for the projects that require heavy lifts. Many of the small technology-based projects do not require heavy lifts and are therefore excluded from the analysis other than for a lift to or from a dock, this would result in a relatively few number of days work.

Option 1 - New Build Catamaran barge, with air lift capacity

Estimated Capital Cost (based on ROM estimate from industry) – $20 million

Principal Particulars:

Length	65m
Breadth	38m
Depth	4m
Draft Loaded	2.7m (deep)

Lifting Options:
A-frame with 270t to 325t capacity at a reach of 18m-20m (22mx20m footprint and maximum height of 24m) that can pick lift off dock, and deploy/retrieve at site, and bring lift aboard to a laydown area for maintenance, transit etc.

Option 2 - Modify OpenHydro catamaran barge with air lift capacity (must consider time and equipment required to make the conversion)

Estimated Capital Cost –$10 million (based on ROM estimate from industry)

Lifting Options:
A-frame with 270t to 325t capacity at a reach of 18m-20m (22mx20m footprint and maximum height of 24m) that can pick lift off dock, and deploy/retrieve at site, and bring lift aboard to a laydown area for maintenance, transit etc.

Scotia Tide Barge:

LOA	64m
B	37m (7m hull width, 23m between hulls)
D	4m
Draft	1.25m light; 2.7m deep (1266t)

5.1.4 Annual Demand for Heavy Lift Barge Services

To estimate the annual demand for barge services for purposes of the financial model it is necessary to develop a five-year go forward tidal development scenario. This scenario in turn provides an estimate of the number of days of work available for either of the two barge options defined. The activity in this scenario is projected over a five year period and will primarily take place at the FORCE site. It follows a roll out schedule that assumes the current projects are successful and repeatable. In addition, with guidance from project mentors potential barge days demand is split between installation and maintenance requirements. Tide cycles and weather factors have also been considered.

Table 11 illustrates the sequencing of activity at the FORCE site on an annual basis 2019-2024.

A number of additional key assumptions have been made to support the analysis including:

- Each installation requires the exclusive services of the barge for 20 days per installation.
- 5 days annual maintenance for each operation starting the year following installation.
- New Installation will take place every two years at each berth site.

This barge schedule may over extend the number of developments that can take place at FORCE Site. It is assumed another site (a Marine Renewable Electricity Area) will become available as necessary. The development sequencing in this table will result in about 27 MW being installed by 2023. Considering the overall target of 300 MW for tidal development in Nova Scotia, this is a fairly modest schedule. It is recognized that no developer is in a position to commit to the projects as set out in this schedule.

Table 11 - Heavy Lift Barge Days Required for assumed activity by Berth Site 2019-2023

	2019	2020	2021	2022	2023
Berth C – Atlantis					
Installation	20		20		20
Operation		5	5	10	10
MW (cumulative)	2	2	4	4	6
Berth D – Cape Sharp Tidal					
Installation		20	20	20	40
Operation	5	5	10	15	20
MW (cumulative)	2	4	6	8	12
Berth E – Halagonia					
Installation	20	40	20	20	20
Operation		5	15	20	25
MW (cumulative)	1.5	4.5	6	7.5	9.0
Small Technology Work - Misc	5	5	8	8	10
Total Annual Barge Days Required for Tidal	50	40	68	58	85
Other marine industry work	20	20	20	20	20
Total Annual Barge Days Required	70	95	98	133	145
Days accounted for by existing asset Scotia Tide (all work at Berth C by Open Hydro)	5	25	30	35	60
Days that can be served by a Modified Scotia Tide	65	70	68	98	85
Days that can be served by new asset	65	70	68	98	85

5.1.5 TOTAL POTENTIAL REVENUE

To estimate the total potential annual revenue that could be earned by a dedicated barge with heavy lift capacity two approaches have been utilized to inform the analysis. First, as part of the interview process with industry stakeholders, information was sought about daily rates that have been experienced to date for various marine service activities as related to Tidal development. To further support the analysis of a potential rate structure for the proposed heavy lift barge we also consulted with the project mentors to draw on their experience in both the local and other international market places.

Examples provided through the interview process undertaken as part of the barge study included:

- Self-propelled Emerald heavy lift barge quoted day rate $15,000 – $20,000 (US$) additional fees and fuel could drive total cost to $40,000. ($11,000 a day for fuel when under transit - $2000 a day on standby.)
- Open Hydro stated they paid $28,000 a day for two tugs and a barge to support Scotia Tide operations.

- A multi cat in Atlantic Canada can cost $13,000 to $15,000 per day
- A tug $10,000 - $12,000.
- In Europe a Multi cat is about $6,000 a day.
- Offshore vessels operating in Atlantic Canada cost about $55,000 per day.
- An inquiry about chartering the Scotia Tide barge for the BlackRock device suggested an approximate rate of **$30,000/day**, and if the lifting frame and tools that are fitted to the barge are not required there would be an additional cost of **$500,000** to remove and reinstall the frame (ie. part of mob/demob costs).

The project mentors have suggested a reasonable billing rate could range between $30,000 and $50,000 per day. This would be based on the estimate of 100 days per year work being available for a barge with the heavy lift capacity as defined in the two options set out above. It is important to note the financial analysis essentially begins once there is 100 days of work available. Based on these rates the potential for total annual revenue could range between $3 and $5 million. These estimates are simply derived by multiplying the 100 days of work by the high and the low estimated daily rate.

5.2 Financial Analysis

5.2.1 Introduction

The detailed financial analysis includes an examination of financing charges associated with each barge option based on a ten-year payback period. This is followed by a review of the potential revenue stream associated with the barge's working 100 days per year as estimated above. The net revenue to cover the operating costs and to provide barge owners a margin or return on investment is identified. The operating costs are estimated so an overall potential return can be provided for each option. A conclusion is then provided on overall viability associated with each option given the assumptions made on available work and billing potential. This amounts to the Base Case analysis with no subsidies considered to support the acquisition of the barge asset. The impact of possible subsidies can be considered in view of the investor risk associated with acquiring these purpose-built tidal development assets. Financial risk factors are also identified.

5.2.2 Capital Cost and Annual Financing Requirements

The starting point for the financial analysis is the consideration of capital cost and the associated financing expense. Each option is considered – Option 1 New Build is projected to require a $20 million investment. Option Two Open Hydro Modified is projected at $10 million. The Base Case analysis for each option assumes a ten-year financing term at two illustrative interest rates 5 and 8 percent respectively. The following table presents annual financing payments.

Table 12 - Annual Financing Costs

	Option 1 – New Build	Option 2 – Modified Open Hydro
Total Capital Investment	$20 million	$10 million
Financing Terms		
5 Percent	$2.5 million	$1.3 million
8 Percent	$2.9 million	$1.5 million

(for each option, annual payments based on a ten-year financing term)

The table shows that in order to meet financing requirements associated with Option 1 – New Build at $20 million at least $2.5 - $2.9 must be generated. For Option 2 – Modified at $10 million required revenue is virtually half of Option 1 at $1.3 to $1.5 million.

The next step in the analysis is to determine what proportion of revenue is required to meet the financing obligations associated with each Option considered. The following summary table sets out the results comparing revenue associated with 100 days of billable work against the financing requirements.

Table 13 - Revenue versus Financing

	Option 1 - New Build ($20 million)		Option 2 – Modified ($10 million)	
Day Rate $/day	$30,000	$50,000	$30,000	$50,000
Total Gross Revenue based on 100 days of billable work	$3.0 million	$5.0 million	$3.0 million	$5.0 million
Annual Financing Requirements				
5 percent	$2.5 million	$2.5 million	$1.3 million	$1.3 million
8 percent	$2.9 million	$2.9 million	$1.5 million	$1.5 million
Financing requirements as % of Gross Revenue				
5 percent	83%	50%	43%	26%
8 percent	97%	58%	50%	30%
Net difference between gross revenue and financing				
5 percent	$.5 million	$2.5 million	$1.7 million	$3.7 million
8 percent	$.1 million	$2.1 million	$1.5 million	$3.5 million
Viability statement	No chance of Viability	Possible viability	Possible viability	Probably viable

From the above table it can be observed is that the potential revenue stream will not be sufficient to support financing requirements for all options at the days rates proposed for the Base Case. In particular the New Build option at a day rate of $30,000 has no chance of being viable as financing would require over 80% of all revenue generated. Prospects improve for Option 1 at a day rate of $50,000 as financing requirements drop to 50- 60% of total potential revenue. Option 2 is more attractive at both day rate levels, at $30,000 financing would account for 43-50 percent of revenue generated. At a $50,000 day rate financing drops to 26-30% of revenue.

Conclusion: At the days rates examined Option 1 – New Build will not be viable without subsidy support on the capital cost. Prospects for viability for Option 2 are better than Option 1.

5.2.3 OPERATING COSTS

The second major cost component to consider in the financial analysis is the daily operating cost associated with providing barge services for tidal development work. Our project mentors provided an estimate of what these costs would potentially be recognizing that these proposed assets are not self-propelled and would still require necessary support vessels. The cost of support vessel services is not included in this analysis.

A shown in the following table total daily operating costs could be expected roughly in the range of $18,000 per day. The major operating cost components would include Crewing at $5,400, Consumables at $2,800 and depreciation/margins at almost $5,000.

Table 14 - Typical Barge Operating Costs

Major Cost Category	Day Rate $30,000	Day Rate $50,000
Crew	$5,400	$5,400
Insurance	$600	$600
Consumables	$2,800	$2,800
Annual Maintenance	$1,500	$1,500
Other Costs (harbor dues, admin etc.)	$3,300	$3,300
Depreciation and Margins	$4,800	$4,800
Total Daily Costs	$18,000	$18,000
Available for Financing (Rate-Daily)	$12,000	$32,000
Total Annual available for financing.	$1.2 million	$3.2 million

As shown on the table after accounting for operating costs total revenue generated based on 100 days of billing and a $30,000 day rate a total of $1.2 million would be available to meet financing requirements. This availability of resources for financing improves significantly if a $50,000 day rate is achieved.

5.2.4 FINANCIAL ANALYSIS RISK FACTORS

The following summary sets out a number of factors that could influence the results of the financial analysis. Given the current early stage state of the development of the tidal industry in Nova Scotia these factors could greatly influence potential investment in a barge asset by either private or public sector investors.

Table 15 - Financial Analysis Risk Factors

Factors	Factor Discussion
Planned Technology Could Change	Assumptions related to heavy lift barge requirements are based on current project proposals. To date there is no confirmation of technical viability. Heavy lift requirements could change very significantly as results of planned project are realized. Will requirements be greater than or less than those defined in the financial base case?
Assumed Project Roll Out Schedule Could Vary	The barge demand schedule is based on the 2019 deadline for installation of projects at the FORCE site. Schedule assumes deadlines are met and development is successful. Projects become immediately repeatable. Any deadlines missed or technology not proving viable will alter the schedule and render the 100 day barge demand estimate an overstatement. Perhaps significantly.
Project installation Delays	All interviewed agree the Minas Basin is a harsh marine environment due to tides and potential weather factors. The 100 day schedule assumes projects are possible with reasonable delay factors built in. Any additional delay could compound the overall schedule. Multiple development groups will be contracting the barge services – unforeseen delay in one project could greatly impact another. Total impact on days work is difficult to determine.
Availability of Support Vessels	Since the barge is not self-propelled there will continue to be a requirement for support vessels. Marine service contractors will have other business commitments that could influence implementation schedules.
Ownership of the Barge	If investment in the barge is made by a private sector investor with no subsidy, the assured availability to the tidal industry will not be guaranteed.

5.3 OWNERSHIP MODELS

There are a number of possibilities as to how ownership of the heavy lift barge could emerge. Generally, the financial and risk analysis do inform these possibilities, for this analysis three are noted:

- First, private sector initiative where full investment is made by a private company or consortium.
- Second, the private sector takes initiative to be owners but will seek public sector assistance through a capital subsidy.
- Third, a public agency acquires the barge and manages the asset to support tidal development across multiple projects.

To inform the ownership discussion a summary of stakeholder views is provided.

Table 16 - Summary of Reponses to Questions Regarding Asset Ownership

Question	Large Technology Small Technology
Who should own the asset?	Dominant response from marine service industry, developers and technology providers is that a marine service provider should own the asset. Expectation would be that a subsidy or loan guarantee would be necessary. Joint Ventures or partnerships are plausible between a marine service provider, a developer and even a marine fabricator. Possible that FORCE could play a coordinating role but only if province is a stakeholder in asset.
Feasibility of a shared asset?	Not completely ruled out by respondents. Owner of Scotia Tide saw potential to make their barge more multipurpose. Discussions have taken place and that sharing is always a good idea in theory – actual practice can be challenging priorities could conflict in terms of timing and unscheduled needs arising.
Frequency of operations?	Information indicated that about 20 days required by a barge asset for heavy lift installations. Annual maintenance would be in the range of five days. Weather and tides will be factors influencing actual time required.
Lessons Learned?	Minimum usage contacts and framework agreement can facilitate the sharing of assets. Once industry has arrived, one estimate is 50 MW in water, assets can be purchased, and local marine service providers will consider investment.

5.3.1 Private Sector

The interviews conducted with project developers and marine service providers stated a very strong preference for the barge asset to be owned by private sector interests. These could include either a marine service provider or one of the developers or even possibly a joint venture or partnership. Reasons for private sector includes greater control over operations by owners and the expedited decision making possible. The private sector would be expected to be more adept at securing alternative marine services business which could play an important role in the early stages of tidal development. This would be advantageous should the tidal development schedule not proceed in the manner set out in the earlier analysis. Marine service providers are also likely to have other marine support assets at their disposal to assist in tidal operations which would improve coordination leading to greater efficiency.

This model of ownership will be presented with significant challenges.

For the new build option and its associated $20 million capital cost, the burden associated with financing costs over 10 year payback with the expected potential revenue stream is not enticing. The risk factors associated with the assumed development schedule would also work against this model. There is little likelihood private owners will view this option as a good investment opportunity.

The modified barge option with its $10 million capital cost is owned by one of the existing project developers and was custom designed to meet their project needs. Modifying the barge would give it the capacity to service other projects. Scheduling its availability would be done working around their own needs. This option is further complicated by the current issues being faced by its owner. Under the circumstances, in the near term it is difficult to foresee action by the private sector to undertake the necessary $10 million capital investment.

5.3.2 PRIVATE SECTOR WITH CAPITAL SUBSIDY

Interest by the private sector could be greatly enhanced if a subsidy was available to support the capital investment. Interviews with marine service providers did express interest in barge ownership provided they received assistance on the capital investment required. Although the analysis has not been completed on a lower capital cost, the project mentors stated that if the private sector investment requirement could get down about $5 million the concept could be of interest to private sector marine service providers.

In the case of the new build option, this would require a subsidy in the order of $15 million. For the modified barge option, the subsidy could be in the order of $5 million. There would be challenges associated for the private sector with subsidy option as well. Typically with this form of government support, various conditions would be attached to the way the barge services could be sold in the market place. Until negotiated, the private sector may or may not find the conditions acceptable. Other types of public sector support could also be considered such as loan guarantees or interest forgiveness.

5.3.3 PUBLIC SECTOR AGENCY OWNERSHIP

A third option for ownership emerged as part of the interview process. This option would see a public-sector agency invest in the barge asset and then deploy it in a manner to support overall tidal development. It is assumed they would be mandated to do this on the most equitable way possible. FORCE was suggested as a possible agency or as an example of publically supported group that is directly involved in the industry as a provider of infrastructure.

The main challenges with such a model of ownership include many of those often associated with public sector delivery.

- Slowness of decision-making as the full balance of public interests are considered.
- Public sector procurement is often more complicated and a very time consuming activity, procurement done directly by the private sector is more timely.
- With multiple developers seeking barge services, the public agency would need strict criteria for access to the barge.
- The Public agency would need to work with the private sector providers of support vessels and would be subject to their other business opportunities and might not have as strong as business relationship.

6 RECOMMENDATIONS FOR FURTHER STUDY

The contents of this study, as defined by the original scope of work, can be expanded to include a more detailed look at some of the key findings and conclusions of the study. The study can also be updated to reflect recent changes in the industry, including the unfortunate demise of OpenHydro. Suggested follow on work includes:

1. Update changes to FORCE berth allocations and the technology that is intended to be deployed at each berth.
2. MultiCats are identified as a useful marine asset for the tidal industry, particularly for small tidal. Transport Canada regulations however do not permit sleeping quarters situated below the waterline, which is a common arrangement for these vessels. The arrangement can be modified to switch the below deck sleeping quarters with other above deck spaces. Further investigation of the availability of vessels having such arrangement could be made.
3. There is no longer a need to consider modifications to the Scotia Tide for handling air lift of the OpenHydro turbine.
4. Update the status of the asset Scotia Tide.
5. Include the cost to purchase the Scotia Tide in the modified Scotia Tide business case scenario.
6. Research available heavy lift A-frame specifications and costs for the modified Scotia Tide business case scenario.
7. Research available heavy lift asset specifications and costs to develop an additional business case scenario.
8. Prepare a user variable spreadsheet of the financial model.

7 REFERENCES

[1] (source: IEA-OES Annual Report, 2009).

[2] Fundy Ocean Research Centre of Energy (FORCE) (2018) [online], http://fundyforce.ca/technology/, accessed 02 May 2018.

[3] Gardner Pinfold Consultants Inc., & Acadia Tidal Energy Institute (2015), Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada and Canada, April 2015

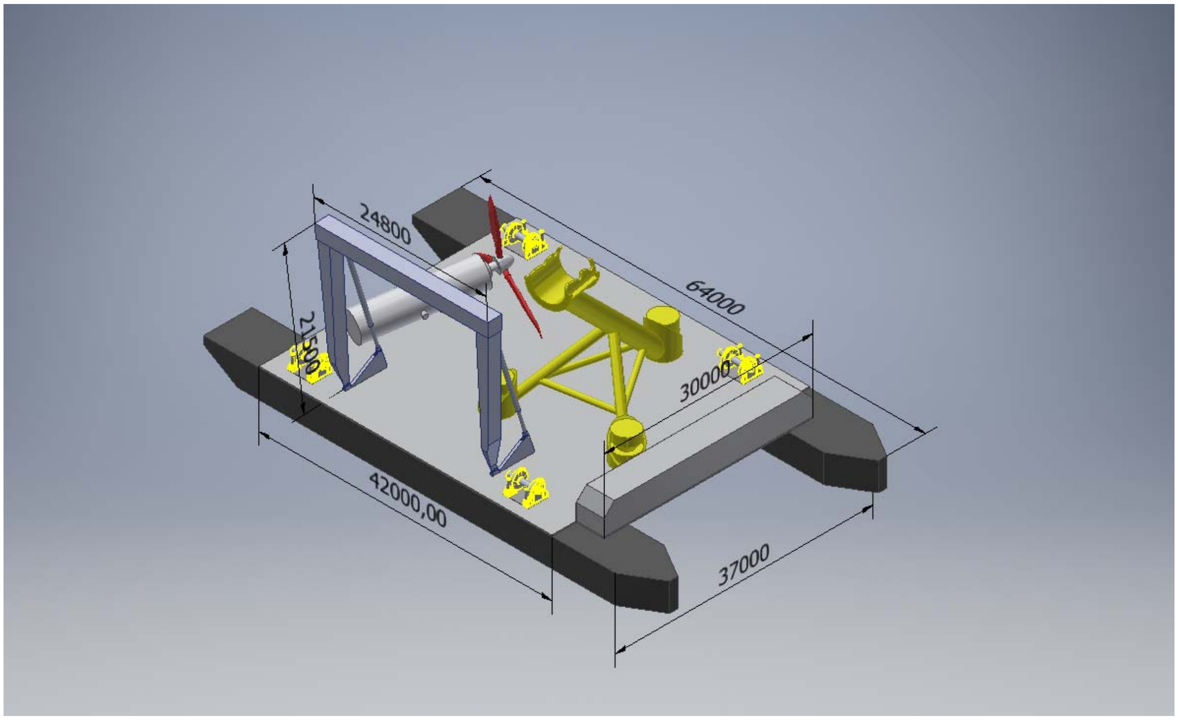
[4] Collective Wisdom Solutions (CWS), exp. Services Inc. and Maritime Tidal Energy Corporation (2011) Marine Renewable Energy Infrastructure Assessment prepared for Nova Scotia Department of Energy and Mines, August 2011.

[5] Allswater, Cruz Atcheson and Innosea (2016), MRE Infrastructure Assessment Update prepared for Offshore Energy Research Association, August 2016.

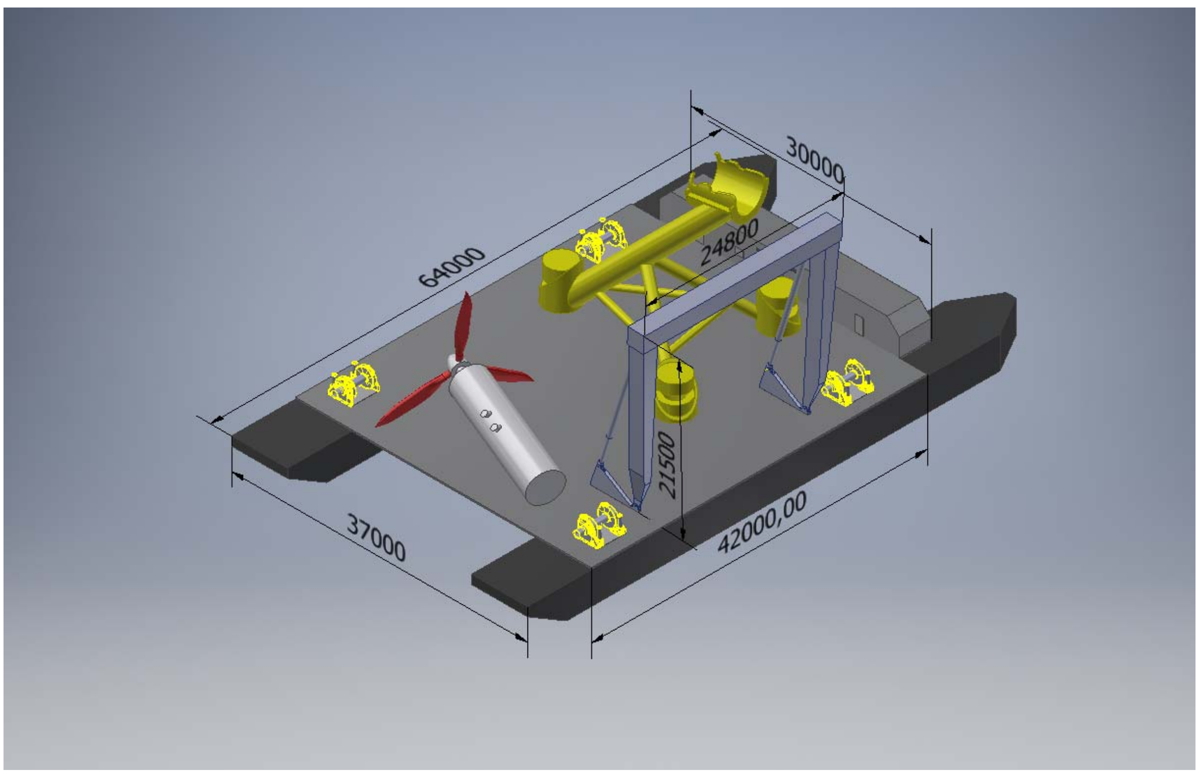
[6] Marine Renewables Canada (2018) [online], https://supplychain.marinerenewables.ca/, accessed 03 May 2018.

[7] Nova Scotia Department of Energy and Mines (2018) [online], https://energy.novascotia.ca/renewables/marine-renewable-energy/current-activity, accessed 03 May 2018

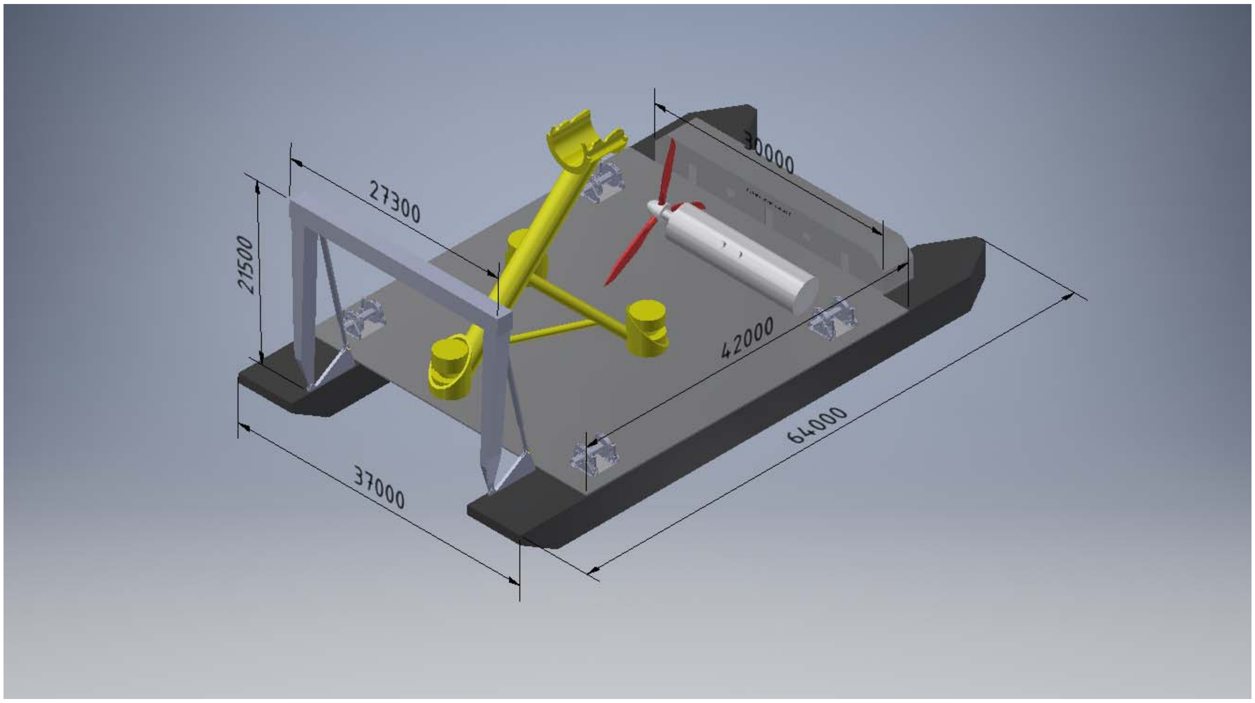
APPENDIX A: IMAGES OF CONCEPT DESIGN OF PURPOSE-BUILT BARGE



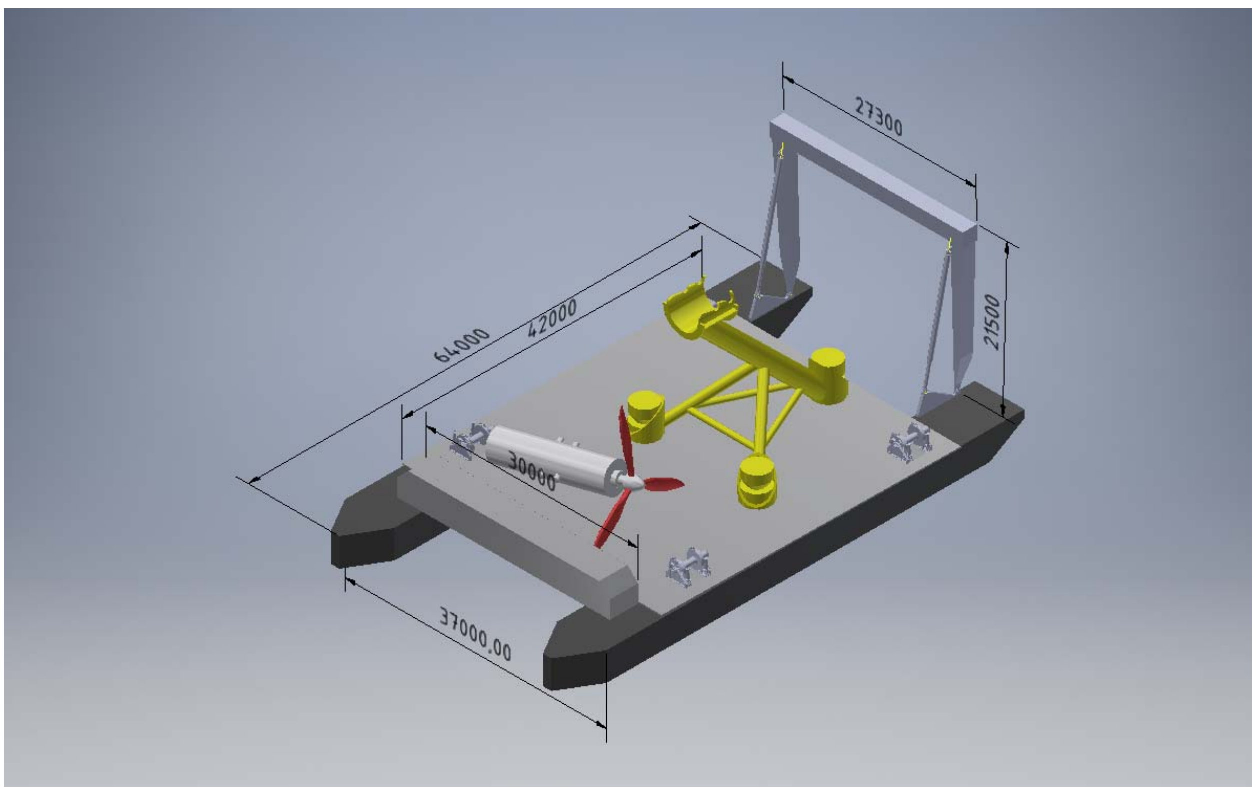
New Barge Fitted with Side Mounted A-Frame, Showing Andritz Turbine & SSB



New Barge Fitted with Side Mounted A-Frame, Showing Andritz Turbine & SSB

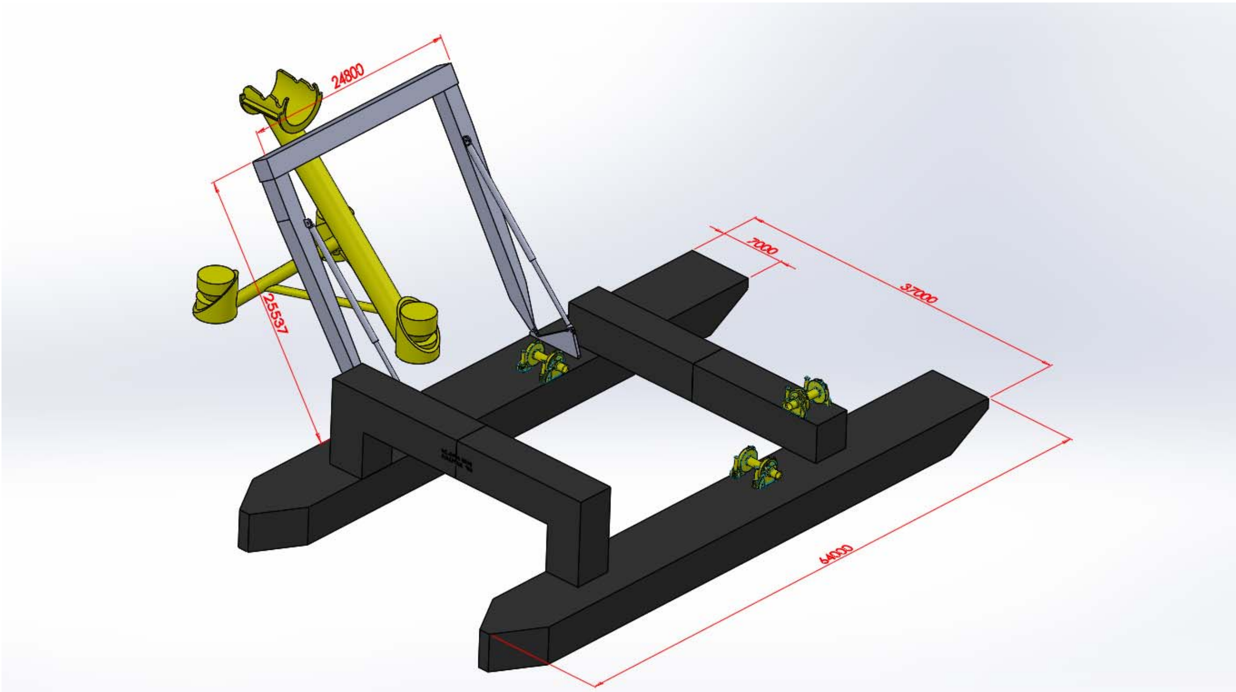


New Barge Fitted with Stern Mounted A-Frame, Showing Andritz Turbine & SSB

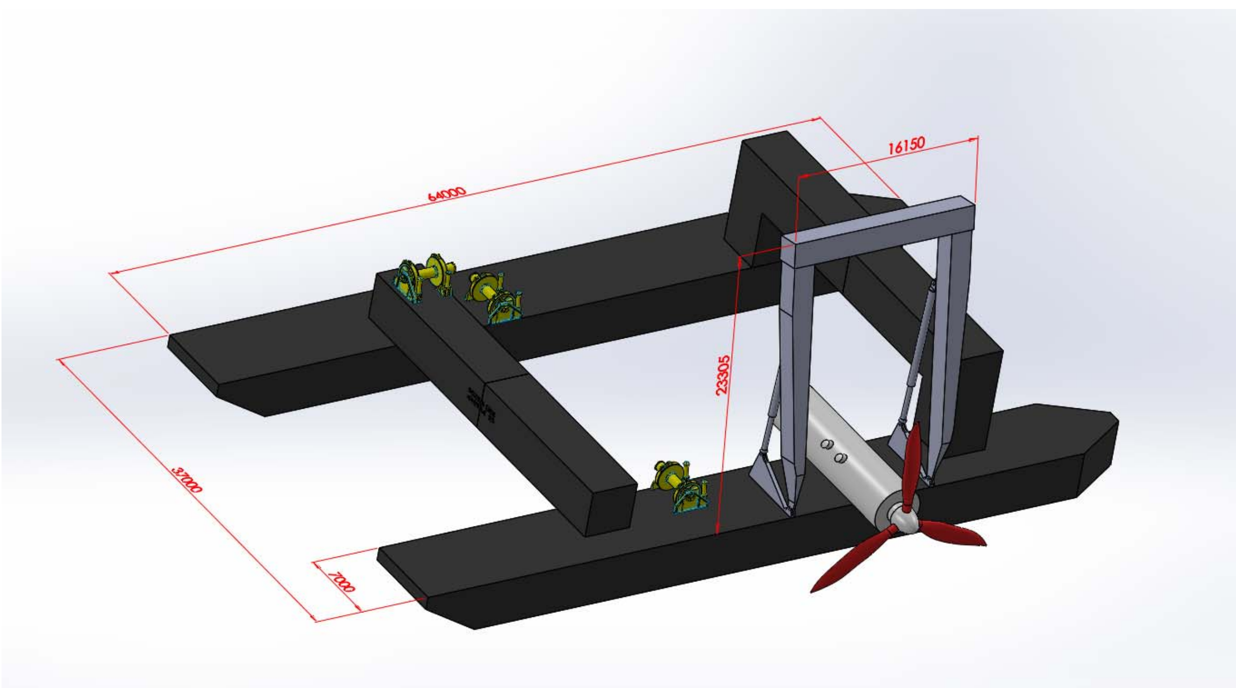


New Barge Fitted with Stern Mounted A-Frame, Showing Andritz Turbine & SSB

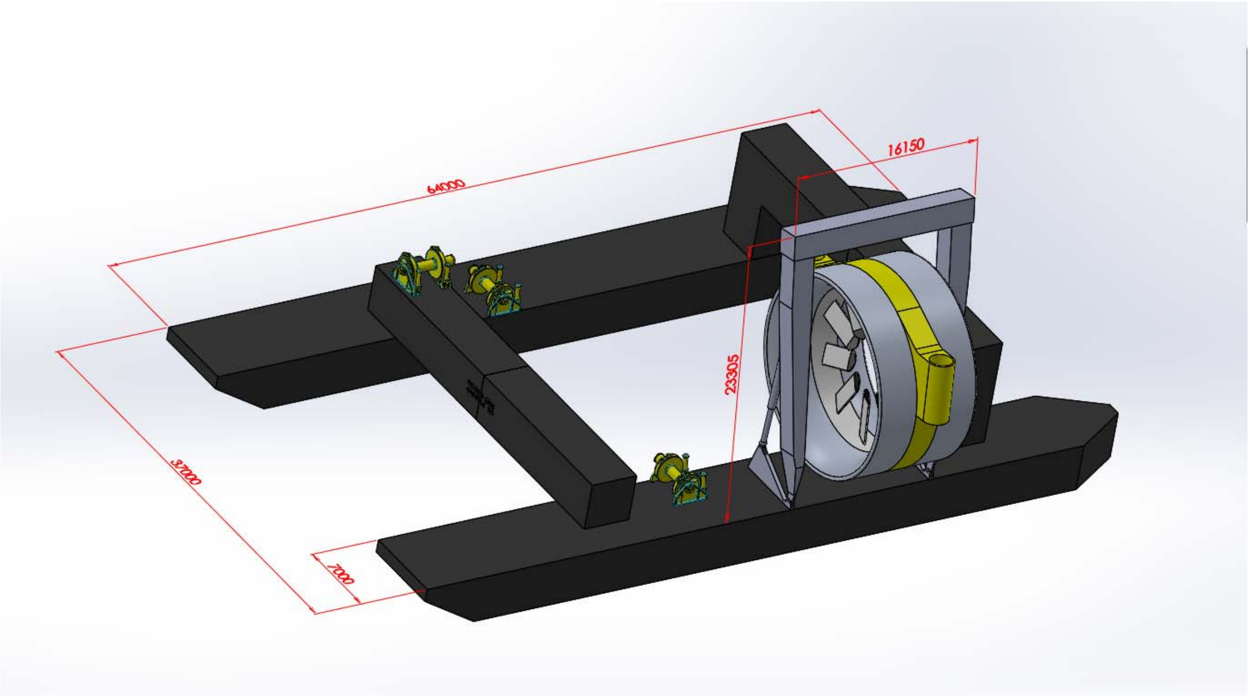
APPENDIX B: IMAGES OF CONCEPT DESIGN OF MODIFIED SCOTIA TIDE



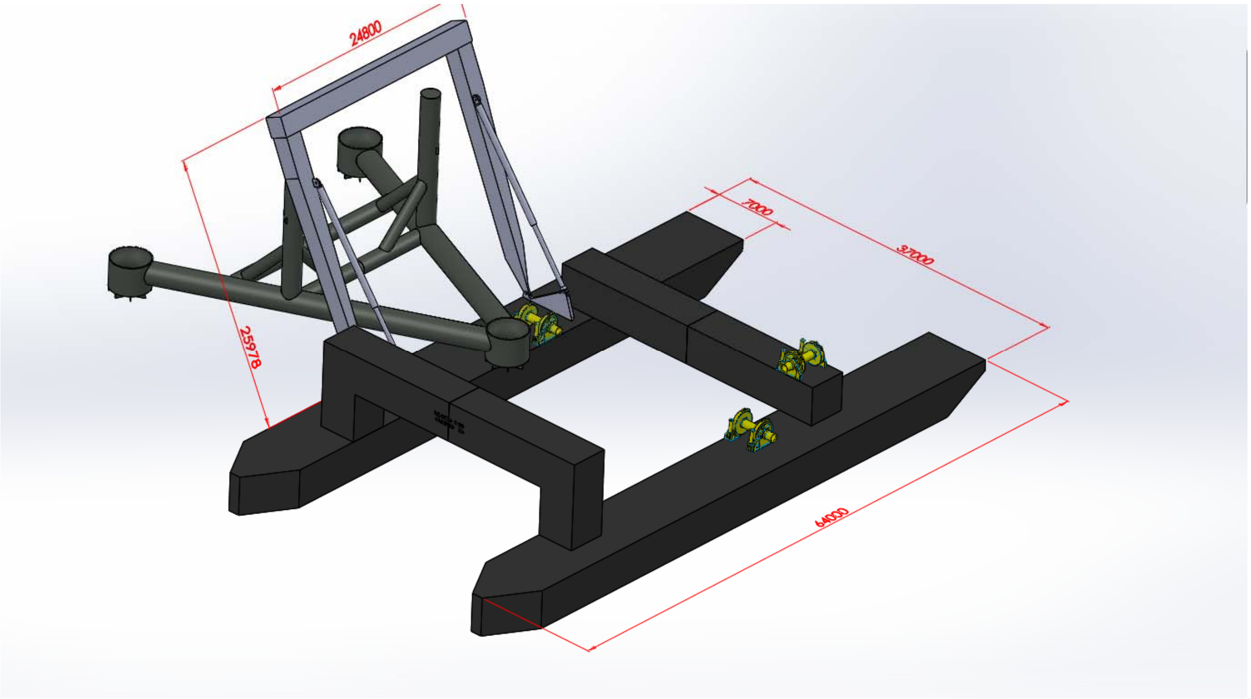
Scotia Tide Modified for Andritz Hydo Hammerfest Subsea Base



Scotia Tide Modified for Andritz Hydo Hammerfest Turbine Nacelle



Scotia Tide Modified for OpenHydro Turbine



Scotia Tide Depicted with OpenHydro Subsea Base – Not Feasible Due to Weight and Dimensions of Ballasted SSB