Report for the Department for Business Energy and Industrial Strategy (BEIS)

Lessons Learnt from MeyGen Phase 1a
Part 1/3: Design Phase

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MEYGEN
THE TIDE OF CHANGE IN CAITHNESS

LESSONS LEARNT FROM MEYGEN PHASE 1A. PART 1/3: DESIGN PHASE

CONTENTS

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Notice:

1. INTRODUCTION

1.1 Background

MeyGen Limited (MeyGen) is a Scottish-registered company established in 2010 for the purpose of developing the MeyGen Tidal Energy Project. MeyGen was awarded an Agreement for Lease for the Inner Sound tidal development site on 21 October 2010 by The Crown Estate. The Inner Sound Agreement for Lease is for 398MW of installed tidal stream energy capacity and will be consented in two separate phases.

Phase 1 has already been consented. It is sub-divided into 3 further phases; 1A, 1B and 1C. Phase 1A is a 6MW demonstration array, which comprises four 1.5MW tidal turbines. Phase 1A reached financial close in 2014, and is now approaching completion of construction. Phase 1B will comprise a further 6MW commercial array to be installed by 2018, and Phase 1C will add another 74MW, bringing the total capacity for Phase 1 to 86MW – the extent of the secured planning consents. Phase 1C deployment is intended in 2021-2022. Phase 2 will increase the installed capacity to a total of 252MW, the extent of the currently secured grid connection capacity. Phase 3 will then require an additional expanded grid connection to build the project out to the full site capacity of 398MW.

Phase 1A of the MeyGen project is partly funded through a £10million grant from the Department for Business Energy and Industrial Strategy (BEIS) under the Marine Energy Array Demonstrator (MEAD) Fund. The remainder of the funding is from Atlantis Resources Limited, and The Crown Estate, Scottish Enterprise's Renewable Energy Investment Fund, and Highlands and Islands Enterprise (collectively with BEIS, referred to herein as the 'Funders'). One of the requirements of the BEIS grant contract is that MeyGen considers the experiences from the MeyGen Phase 1A project, which may be useful to the wider tidal industry, through a series of 'lessons learnt' workshops, and that the results of these workshops are disseminated for the benefit of the wider tidal industry.

There are anticipated to be three such workshops, each representing the main stages of the Phase 1A project. The first workshop corresponds to the period from financial close to the end of the design phase, the second workshop to the end of the construction phase, and the third workshop to the end of the initial operational phase. This report summarises the results of the first of these workshops. This report will be superseded by an updated report once the second workshop has been held, and the final report will contain the results from all three workshops.

1.2 Description of the project

A full description of Phase 1 of the Inner Sound project can be found on the Wave and Tidal Knowledge Exchange Network in document MeyGen Phase 1 Environmental Impact Assessment –MeyGen non-technical summary.

Phase 1A will deploy four turbines, three manufactured by Andritz Hydro Hammerfest (AHH) and one by Atlantis Operations UK (AOU). All the turbines are upstream, three-bladed, horizontal-axis machines, fully submerged and mounted on gravity-base foundations resting on the seabed. Each turbine will be connected to shore by its own cable to a single onshore converter/grid connection station. The onshore station includes power converters for each turbine and the connection to the local electricity distribution network.

When fully constructed, Phase 1A will be the UK's first MW-scale tidal array.

1.3 Lessons learnt process

MeyGen held an internal lessons learnt workshop covering the period from financial close to the end of the design phase. It was facilitated by an independent third party, the Offshore Renewable

Energy Catapult. The workshop included all available members of the MeyGen team and provided the widest range of experience available within MeyGen. The results of that workshop were captured by the facilitator and this public-domain report, initially prepared for MeyGen's and the Funders' comment by Black & Veatch, reproduces many of those findings, with some additional input from a separate lessons learnt workshop which was held between MeyGen, the Funders and Black & Veatch (the Funders' Technical Adviser since financial close).

In addition, information on the budgeted project costs and project performance are summarised in this report. Future reports will detail the actual expenditure compared to the budget.

2. CONTENT OF THIS REPORT

In preparing this report, it became clear that the real value is contained in the detail of the experiences, rather than in the overall generic conclusions, as such high level conclusions tended to appear either abstract or obvious and trite, and less likely to add value to the wider industry.

This report therefore provides some generic conclusions but includes a number of the detailed experiences, as the aim is to allow the wider industry to draw their own parallels between the experiences of MeyGen Phase 1A and their own ventures, even if they do not face the exact same circumstances.

2.1 Confidentiality

MeyGen and its suppliers are developing intellectual property (IP) that has commercial value to their businesses. Some of the experiences of MeyGen Phase 1A comprise part of this important IP. The sharing of this information must therefore balance the benefits of building a strong tidal industry and protecting the interests of particular companies and their investors.

The process followed in developing this report has been relatively open. However, there are some items discussed that have been withheld from publication. Wherever possible, the generic conclusion has been included in this report, and the related specific detailed experience reserved.

The MeyGen Phase 1A project interacts with many organisations. These organisations include equipment suppliers, contractors, the Funders and licensing authorities. The names of some organisations have been withheld. Where this is the case, the organisations are referred to by their role or, where even this might identify them, they are referred to as Stakeholders.

There is no intention in this report to attribute any issues to individual organisations; the aim is to help all organisations learn from the experiences of MeyGen Phase 1A, which is recognised as a world-leading 'pathfinder' project for the tidal industry. MeyGen is to be congratulated for their achievements to date and their openness in allowing this report to be published, and the contents of this report should be read and treated in that context.

3. EXPERIENCES

3.1 Leasing and consenting

- The level of detail required to meet offshore site leasing conditions, particularly in the early stages of the project, was relatively undefined. For example, differences between moorings and foundations were not clearly defined, and the scope and depth required of any third party (design) review was also unclear (see Section 3.8(b)). It would be useful to the industry if the requirements could be standardised, wherever possible, and the generic requirements communicated through online publications and conferences to the wider industry.

- In agreement with MeyGen, The Crown Estate reduced their initial requirement for a detailed Health & Safety review from monthly to annually, with only a summary level Health & Safety review being reported monthly as part of the standard monthly project progress reporting. MeyGen welcomed this as it reduced their reporting burden.

3.2 Management and contracting

- The works comprised a mix of high and low-risk activities, new and established technologies and multiple contract interfaces. MeyGen judged that it was not cost effective to use a single organisation to wrap the whole project and take all the interface risks. Consequently, MeyGen chose not to secure a full design and build (EPC) contract and instead used a multi-contract approach.
- Whilst MeyGen aimed to have two to three main contracts, actually nine contracts were required to arrive at a contract structure that was economically viable and allowed the project to reach financial close. This was a significant compromise and meant MeyGen had to devote considerably more resource to managing contractual interfaces, which were the primary source of contract claims. It is still judged sensible to keep the number of contracts to a minimum. As the technology and its risks become better understood by the supply chain, it is hoped that there will be more opportunities to reduce the number of contracts and wrap the risks appropriately into each.
- The overall approach to the management of the contingency budget should have been based more firmly on earned value. If there had been a better understanding of the design status of the project at financial close and during the early stages of the project, then the challenges remaining and the likely contingency usages could have been determined more accurately at financial close and during the project. This might have also led to different or earlier decisions being taken regarding contingency usage.
- MeyGen's management system provides contractors with a single point of contact at MeyGen; this helps simplify communication and generally works well. However, in the early stages, MeyGen did not have sufficient resources and this led to detrimental effects on project schedule. Having the right resources at the right time is a significant challenge for any project. Resourcing is a general issue applying to all parts of the project. It is discussed further in Section 3.4.
- MeyGen did not assign a specific organisational role to oversee quality assurance across the different contractors. Instead, MeyGen generally relied on their contractors to provide this assurance. This approach should be reconsidered in future projects as, whilst there is some contractual protection, MeyGen was not insulated from poor quality deliverables or the knock-on effect on schedule from any work that may have needed repeating as a consequence.
- Using an experienced and local Clerk of Works was very helpful in managing the site work. MeyGen also found that smaller, local subcontractors were generally more willing to complete work on time and take ownership. MeyGen will consider using a higher proportion of small, local contractors in future phases of the project, whilst balancing the overall intention to have fewer but larger contracts.
- Some of the coordinate systems (e.g., for the cable duct exit locations at the onshore site) used across the different contractors varied and caused confusion between contractors and their

interfaces. The coordinate systems could have been specified in advance in the Basis of Design/similar document and included in the Employer's Requirements.

- The MeyGen Phase 1A project will deploy a single Atlantis turbine and three Andritz turbines. This volume of machine production is not sufficient to drive machine unit cost reductions. Much larger volumes, associated with later MeyGen project stages (e.g. Phase 1C), are still expected to bring significant economies of scale when dedicated production facilities and tooling can be justified.
- Compared to using only a single turbine type, having two turbine types has resulted in the Phase 1A project bearing additional costs. However, it is anticipated that the experience gained by all parties will justify this cost in the later MeyGen project phases.
- The turbines are all connected to shore individually (to reduce technical risk); this did bring economies of scale in the cabling supply. However, this effect is small compared to the total cost of supply and install.
- MeyGen used the International Federation of Consulting Engineers FIDIC contracts for the majority of the work. Many contractors were not familiar with FIDIC contracts and this meant additional time was needed in the contracting stage, and also for contract management in the delivery of the project. MeyGen still expects that FIDIC can be used in future; however, depending on the suppliers' familiarity with FIDIC it is recognised that more time may be required by both parties to ensure that the project can be delivered effectively.
- The preparation of documentation required to allow the technical sign-off of contractors' work and contractors' payments was the responsibility of the contractors. The lack of sufficient detail in the contracts on the requirements of this documentation, combined with MeyGen's limited resource availability for contract management, contributed to many late submissions and in turn reduced the time available for review.
- Contractors were required to submit monthly reports, and these were often late. In addition, programme updates from contractors were often late, not provided or poor, and this combined with having nine contractors exacerbated the expected difficulties of overall programme management for such a novel project.

3.3 Health, safety and environment

- MeyGen engaged with the Health and Safety Executive (HSE) and their Diving Inspectorate early in the project and developed positive relationships with both parties, which they are keen to foster.
- MeyGen split the contracts into onshore and offshore works and used two Principal Contractors. This appears to be contrary to the guiding principles of the Construction Design Management (CDM) Regulations, where a single organisation should be in overall control. However, MeyGen judged that the skills required onshore were sufficiently different to those required offshore to justify this approach.
- MeyGen incurred significant time in reviewing, modifying and then agreeing contractors' Health & Safety and Environmental documentation.
- MeyGen found that the interpretation and working implementation of CDM Regulations varied greatly across the contractors (and their subcontractors) and it was difficult and time consuming to enforce a standard approach. MeyGen found that some issues had to be 'micro-managed'

between MeyGen's contract managers and their respective contractors. This created another interface between MeyGen and its contractors, adding to the management burden. Once implemented, MeyGen found that a standardised approach was found to be beneficial to the project.

- The above two points suggest that the supply chain generally still requires better engagement on Health & Safety and Environmental matters, and specifically on CDM, and that Health & Safety and Environmental responsibilities and standards need to be defined very carefully at the contracting stage.
- MeyGen would have benefitted from implementing a common approach to recording Health & Safety statistics and information. This would have perhaps been easier than reviewing and monitoring each contractor's approach individually. A standardised system might include:
  - A standard reporting proforma;
  - An online data capture system;
  - Better defined contractual requirements, to ensure timely and accurate reporting.

3.4 Managing resources

Every organisation has limitations on resources. Most projects would benefit from more planning and upfront effort, and the MeyGen project is no exception. Whilst more resources may have been desirable, this might not have been practically or financially viable. For example, if more resources had been devoted earlier, the development cost might have been too high and the project might not have proceeded at all. Therefore, whilst this report lists examples where additional resources would have been helpful, it does not intend to conclude that deploying additional resources would have been viable or the correct course of action. The aim of the observations is to show the implications that low resources may have on similar projects and leave it to the reader to determine what the correct course of action may be for their particular project. Most significantly:

- MeyGen sought to balance the need to provide clear and detailed information to the contractors whilst ensuring that the contractors took responsibility for the design itself. Thus MeyGen concentrated on managing the contract interfaces. If contractual interfaces had been better defined at financial close and during the project, and understood by the contractors, then there would have been fewer requirements for MeyGen to micro-manage these interfaces;
- If more resources had been available immediately after financial close, then the general problem of starting many lines of work at the same time would have been partially mitigated;
- If more time had been available for design prior to manufacturing commencing, then fewer design changes that affected the manufacturing stage would have been needed.

3.5 Design and manufacturing

This report covers the design stage and the early stages of manufacturing. At the time of the workshop, the turbines and foundations were mid-production and had not yet been delivered to the installation site, although the offshore and onshore cabling was complete and most of the onshore converter/grid connection station and its contents were also complete. By the time this report is published, it is likely that the majority of the turbines and foundations will have been installed.

- There were challenges encountered with some design changes which occurred after financial close and impacted the manufacturing stage, and this was difficult to manage given the number of contract interfaces. Once Phase 1A is complete, the design options available for future phases will be much better understood and refined. This means that in future phases of the MeyGen project, i.e. Phase 1B onwards, such design changes are expected to be significantly reduced.

- MeyGen's knowledge of the influences of turbulence improved during the detailed design phase. These influences include the loads on the turbines and support structures and the dynamic interactions between them. This improved understanding helped the detailed design phase, which consequently took longer than anticipated. Designing turbine blades for turbines of this scale at a site this energetic (with respect to wave and turbulence loads as well as non-turbulent tidal loads) was also more challenging than anticipated.
- Whilst 'design for installation' was considered early in the design phase, it was not necessarily considered in enough detail as the project progressed to the detailed design of the turbine(s). If the whole lifecycle costs of the turbine(s) and support structure(s) and their installation and maintenance had been considered and fully optimised (which generally requires very sophisticated contract strategies), some aspects of the manufacturing and installation stages may have been streamlined and significantly improved. Separating the design of the turbine installation (undertaken by the offshore contractor) from the turbine design (undertaken by the turbine supplier) may be a necessary contracting decision, but may inevitably lead to a turbine that is more difficult and costly to install.
- MeyGen did not generally engage any third party to undertake expediting, or surveillance of the manufacturing processes. This meant that MeyGen's engineering resources were stretched, and this contributed to a relatively flexible programme and a lower level of understanding of contractors' progress with technical issues than might otherwise have been the case. However, some components that were cast in China were subject to third-party surveillance.
- MeyGen would have benefitted if more welding expertise had been available, for example by having a weld inspector to call on for advice during the design and specification stages. Having a weld inspector on site during fabrication would also have helped MeyGen to track progress and resolve technical queries and issues.

3.6 Cabling

- Insurance companies have previously been exposed to significant claims on cabling on various projects, most notably on offshore wind projects. Consequently, cable design is heavily scrutinised by the insurance companies.
- DNV standard DNVGL-RP-0360 provides standardised guidance on cable stability generally; however, there is no dedicated cable stability standard for on-bottom stability in high tidal flow locations. A BSI technical specification is planned as an additional standard for cable stability in high tidal flow locations, but work has not yet started on its development.
- MeyGen sought a wide range of advice on cable design and installation before deciding on their final solution. Although modelling and tank testing did help raise confidence in the cable design, MeyGen did not find a modelling or testing methodology that could deal with the cable location at the boundary layer close to the seabed in sufficient detail and with a high degree of confidence to prove that the cable will be stable on a fractured rock seabed under the action of tidal and wave loading. MeyGen therefore plans to undertake a series of inspections of the cable to ascertain that the cable design is conservative and that the cable is stable.

- At the time of the first cable inspection, after the winter of 2015/16, the cable did not appear to have moved. However, no analysis on the conditions experienced has yet been conducted, so it is currently unclear whether the cables have experienced and withstood a below average, average or extreme annual storm event.
- The MeyGen Phase 1A cables are installed in directionally drilled ducts for around one third of their total length, before being laid on the seabed for the remainder. The lengths of these ducts were defined at the consenting stage and this led to a design that may not have been optimal. There is clearly a trade-off between the length and cost of the directionally drilled ducts and the overall cable stability. A better understanding of the potential design envelope at an earlier stage, or a more flexible consent, may have mitigated this issue.
- The cables were supplied on drums. MeyGen opted for the readily available and ostensibly cheaper larger drums. This had knock-on impacts on the costs of installation, as larger lifts were required. Smaller, potentially special order, drums would have reduced installation costs and may have been a more economic overall solution.
- MeyGen found that the best method to increase the density of the cable was by adding armouring, rather than making any changes to the main part of the cable itself, which would have had impacts on the cable handling, as above.
- The cable junction boxes were heavy and this aspect would have benefitted from more detailed planning prior to installation.
- The accuracy of the directional drilling was found to be high, with the exit points installed within a couple of metres of the target.
- The installation team attempted to use an echoscope and various other means without success to help monitor the installation of the cable (using a Remotely Operated Vehicle (ROV) was not an option). With hindsight, a different cable monitoring system, (e.g. CableFish) to guide the cable lay process would have been beneficial.
- Whilst the installation contractors achieved a high level of installation accuracy, they were unwilling to contractually guarantee their ability to do so. This is understandable given the industry's limited experience of operating in high velocity tidal stream sites.
- Improving the quality and size of the cable rollers onshore would have helped with the cable pull.
- The onshore layout must allow a sufficiently large space for the cable pull equipment.
- The cable cost was roughly equal to the cable installation cost.
- The onshore and offshore cable installation scopes were contracted separately. Given that the two scopes are so strongly aligned and interlinked, with hindsight, it may have been beneficial to have a single contract.

3.7 Installation

- MeyGen has generally found that ROVs are not suited to the conditions.
- MeyGen still prefers to minimise the use of divers for Health & Safety reasons, although divers still offer unparalleled dexterity. Divers with local knowledge were found to be the most valuable.

- MeyGen Phase 1A uses gravity foundations which have three feet, each of which requires a suitably level seabed. MeyGen has found it extremely difficult to find locations that satisfy the foundation requirements for all the feet of all the foundations. In particular:
  - Given this difficulty, MeyGen found that an earlier more detailed study of the seabed conditions, including bathymetric and visual inspection, would have been valuable;
  - Greater allowance for micro-siting the foundations should have been made, thus enabling a better positioning of the cables;
  - MeyGen should have given a higher weighting to this issue when deciding between the use of gravity base or monopile foundations in the early engineering stage;
  - The seabed at some of the individual foundation sites needed to be modified;
  - MeyGen prioritised the standardisation of the foundation design over flexibility to suit the different seabed conditions, and would have benefitted from a more flexible foundation design;
  - Seabed compaction due to the placement of the gravity base foundations is an important design driver and is difficult to determine before full installation.
- The onshore and offshore teams would have benefitted from better radios to communicate with one another.

3.8 Standards, certification and verification

(a) Standards

- The design of each Turbine Support Structure (TSS) is based on the DNVGL suite of Offshore Standards and Recommended Practices. These refer to offshore steel structures, typically for the offshore wind industry. Supporting standards, codes and guidance documents have also been applied. Whilst the adopted standards are not specific to tidal turbines, they are recognised within the industry as being amongst the most appropriate. The governing standard is DNV-OS-C101 ('Design of Offshore Steel Structures, General (LRFD Method)') which is based on the Load and Resistance Factor Design (LRFD) approach through assessment of limit states.
- The selection of the Safety Class (i.e. low, normal and high) for a structure is fundamental to the design philosophy and directs the target (nominal) annual probability of failure and thus the LRFD safety factors to be adopted for design. The selection of the Safety Class is to be justified through evaluation of risk to human life, and the environmental and economic consequences.
- Each standard is calibrated with a specific set of Ultimate Limit State (ULS) partial safety factors (i.e. Load and Resistance Factors) and environmental load combinations with a specific return period which, when jointly considered, achieve a ULS design in accordance with the target safety level. The values of these parameters can vary across standards which can potentially lead to applying partial safety factors (or load combination return period) from different standards, which when jointly considered may generate a solution that falls below the required target Safety Class.
- As of October 2015, DNVGL has introduced an offshore Standard that has been specifically developed for tidal turbines, this being DNVGL-ST-0164 ('Tidal Turbines'). Whilst the design principles remain similar to DNV-OS-C101, the new Standard provides a greater level of

guidance on developing tidal turbine specific load cases and considers representative site conditions.

(b) Certification and Verification

- MeyGen (and the Stakeholders) considered requiring third-party certification of the turbines and various other aspects of Phase 1A. However, MeyGen did not feel that this process added sufficient value for Phase 1A compared to the cost. This was primarily due to the immature nature of the technology being deployed and hence the certification process itself. Nevertheless, where type certification and testing was readily achievable, such as on the more standard aspects of the onshore works and the cables, it was pursued by MeyGen.
- MeyGen recognises that certification by a Certification Body could add value for later stages of MeyGen Phase 1, when the benefits to such larger projects could offset the costs. A certification process would generally include the following:
  - Design assessments and approvals;
  - Manufacture surveillance;
  - Installation (including transportation) surveillance;
  - Commissioning surveillance;
  - Agreement on the strategy for operational surveillance and maintenance of the certificate.
- Two of the project Stakeholders did require third-party (design) review of some aspects of the MeyGen Phase 1A project; however (perhaps considering the review needed to determine the applicability of existing standards and the immature nature of the technology), this requirement was not initially well defined. It would be beneficial if Stakeholders could specify up front the detail associated with the third party (design) review; for example, whether a detailed review of the design and the checking of various calculations was required, or only a review of the overall design methodology.
- The turbine suppliers also used third party (design) review of certain components; the approach and value of this varied – perhaps reflecting the immature nature of the industry.

(c) Marine Warranty Surveyor

- The use of a ‘can-do’ Marine Warranty Surveyor (MWS) with experience of tidal projects was extremely valuable. The good working relationship with the MWS was important as it helped the project progress with flexibility where needed, even with uncertainties.
- MeyGen brought the MWS into the project about halfway through the design phase. MeyGen judges this to be a cost-effective balance between the value the MWS can bring early in the project and the associated cost, and considers this early engagement with a MWS as a key component to the success of these aspects of MeyGen Phase 1A so far.
- The MWS satisfied the needs of the insurance company and the cost of offshore operations insurance reduced once the MWS became involved. The MWS was instrumental in ensuring that contractors understood the implications of their work on the insurance or other financing aspects. For example, the MWS actively helped enforce ‘hold points’ required by the Funders or insurance companies.

- The MWS was able to check the marine contractor's processes against the Certification Agencies' standards, without needing to formally engage with the Certification Bodies.
- Where planned processes/operations were outside the scope of the existing standards, the MWS could only note this and observe. There was no direct feedback between the MWS and the Certification Bodies for example, so these areas remain unaddressed.

4. ORIGINAL PROJECT BUDGETS

The total capital budget agreed at financial close in October 2014 for Phase 1A was £51.3m and the operating budget was c. £1.4m/year. Table 1 shows the split of the capital cost across a number of cost centres and similarly Table 2 shows the split of the operating budget.

The capital budget also included some contingency, which is shown as spread evenly across all of the cost centres in Table 1.

Table 1 Capital expenditure breakdown

CAPEX COST CENTRE	PROPORTION OF TOTAL
Project initiation and management	7%
Insurance	2%
Onshore infrastructure and grid	19%
Offshore works	13%
Cabling (including horizontal directional drilling)	9%
Substructures	11%
Turbines	39%
	100%

Table 2 Operational expenditure breakdown

OPEX COST CENTRE	PROPORTION OF TOTAL
Operating Team	4%
Operating Site (Lease and Insurance)	32%
Equipment Purchase	1%
Planned Maintenance	15%
Unplanned Maintenance	21%
Spare Parts	14%
Offshore Inspection & Maintenance	2%
Onshore Inspection and Maintenance	6%
Decommissioning	3%
Corporate operations	2%

The above costs do not include costs incurred prior to financial close, such as the costs of project development, engineering and gaining consents.

5. ORIGINAL POWER PERFORMANCE ESTIMATE

The turbine details for the Andritz and Atlantis turbines are listed in Table 3 and Table 4, respectively. The characteristics of the Phase 1A project are listed in Table 5.

The estimated average coefficient of performance (C_P) is that calculated in order for the turbines to meet their target performance. The estimate assumes that the C_P is constant from the cut-in velocity to the rated velocity (at which rated power is reached); the (reducing) C_P between rated power and the cut-out velocity is not included in this calculation. This C_P accounts for all 'water-to-wire' losses up to the export terminals of the generator. It does not include for losses in the cables to shore, power converters, transformers or cables to the grid connection point.

The energy yield given is taken from the Turbine Supply Agreements. It represents the full 25-year project life, assumes a project-wide availability of 95%, and is based on the minimum performance metrics in the Turbine Supply Agreements. The minimum performance metrics in the Turbine Supply Agreements are based only on part of the turbines' overall power curve and do not include for the performance at relatively low and high flow rates. It is anticipated that in reality the turbines will exceed their target performance. It is therefore expected that the real-world capacity factor will be significantly higher than stated below.

Table 3 Andritz Turbine characteristics

ANDRITZ TURBINE CHARACTERISTICS	VALUE
Installed capacity	1.5MW
Rotor diameter	18m
Number of turbines in MeyGen Phase 1A	3

Table 4 Atlantis Turbine characteristics

ATLANTIS TURBINE CHARACTERISTICS	VALUE
Installed capacity	1.5MW
Rotor diameter	18m
Number of turbines in MeyGen Phase 1A	1

Table 5 MeyGen Phase 1A characteristics

MEYGEN PHASE 1A CHARACTERISTICS	VALUE
Installed capacity	6MW
Number of turbines in MeyGen Phase 1A	4
Lifetime energy yield (95% availability and all system losses)	370,000 MWh[1]
Life	25 years
Estimated average turbine coefficient of performance	0.38
Capacity factor (100% availability at generator terminals, from Turbine Supply Agreements)	33%
Capacity factor (95% availability and including all system losses, from Turbine Supply Agreements)	28%

[1] Value quoted to two significant figures to preserve confidentiality.