CATAPULT
Offshore Renewable Energy

Wave and Tidal Energy Yield Assessment: a Standard Taxonomy for Losses and Uncertainties

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The absence of a standard framework for classifying and distinguishing losses and uncertainties in wave and tidal energy yield assessment acts as a barrier to understanding between stakeholders and impedes opportunities for collaboration across the industries.

To address this, the Offshore Renewable Energy (ORE) Catapult has issued guidance on how the range of losses, efficiencies and availabilities should be defined to enable a complete assessment to be performed.

Summary of findings

- Common terminology for wave and tidal resource assessment is well established. Guidance for wave and tidal resource assessment is available.
- The definition and application of losses and uncertainties, as part of wave and tidal energy yield assessment, is technically and commercially important.
- Current technical specifications provide limited guidance on what losses and uncertainties might be considered, how these may be determined and applied.
- These assessments are key elements of project planning and commercial decision making. The absence of a standard framework for classifying and distinguishing losses and uncertainties acts as a barrier to understanding between stakeholders and impedes opportunities for collaboration across the industries.
- There is a requirement for further research and development into plant performance losses and uncertainties, including site-specific power performance, device availability and device interactions.

Recommendations

- The wave and tidal industries should adopt a standard taxonomy for losses and uncertainty categories.
- The taxonomy should be used as a framework when assessing and presenting losses and uncertainties.
- The taxonomy should be used by project developers to estimate losses and uncertainties and to inform investment to reduce them.
- Lenders and investors should request the standard format provided by the taxonomy to ensure assessments from different sources and/or projects are comparable.
- The wave and tidal industries should undertake research to fill knowledge gaps in plant performance and performance uncertainties.
- The taxonomy and state-of-the-art review should be revisited bi-annually to ensure these documents remain relevant and up-to-date, reflecting progress.

There has been a large amount of research and commercial activity in the wave and tidal industries over the last decade. Much has focused on the fundamentals - understanding the resource, understanding resource/technology interactions and refining technology for extracting energy from the resource. This has improved our understanding of waves and tides as resources to be exploited, rather than operating environments (the context for naval architecture and subsea engineering).

Energy yield assessment (EYA) draws these three elements together. EYA estimates the long term resource at a project location and the energy yield expected for a given technology.

The assessment is repeated and refined during the project design and development process and informs stage gate project development decisions, including:

- Site selection;
- Resource measurement locations;
- Energy convertor technology selection;
- Array design;
- Foundation design;
- Operations and maintenance planning;
- Construction scheduling;
- Final investment decision (FID);
- Post construction performance assessment.

The modelling process has four steps:

1. Short term measurements from discrete locations are used with local oceanographic models to estimate how the resource varies in time and space.
2. The convertor technology is introduced to the model and the energy extracted by each device is calculated.
3. The impact of changes/losses/efficiencies/availabilities are calculated to give a net long term average energy yield for the project, at the point of metering (i.e. the point at which revenue is earned).
4. The uncertainty of each element of the process is assessed and combined to provide confidence levels in the yield estimate.

Guidance on the first two steps has been provided through industry technical specifications[1], but the wave and tidal industries have evolved differently from the wind industry in this respect:
the wind industry is only now, after almost 20 years of commercial activity, developing similar guidance[2].

1 *IEC/TS 62600-1 Marine Energy - Wave, Tidal and Other Water Current Converters - Part 1: Terminology* (2011), *IEC/TS 62600-201 Marine Energy - Wave, Tidal and Other Water Current Conveters - Part 201: Tidal Energy Resource Characterisation* (2015) and *IEC/TS 62600-101 Marine Energy - Wave, Tidal and Other Water Current Conveters - Part 101: Wave Energy Resource Characterisation* (2015), issued by the International Electrotechnical Committee

2 *IEC/TS 61400-15 Ed. 1.0 Wind Turbines - Part 15: Assessment of Site-Specific Wind Conditions for Wind Power Stations*, International Electrotechnical Committee (draft only n.d.)

In contrast, the latter two steps of the energy yield assessment process are only addressed by existing guidance at a high level.

To address this deficiency, ORE Catapult has issued guidance on how the range of losses, efficiencies and availabilities should be defined to enable a complete assessment to be performed. Challenges will still remain in the detailed modelling processes and assumptions.

For instance, for the transmission system, professional judgement is needed to predict how the harsh marine environment might affect efficiency and availability and how commercial warranties might best be structured. Conventional electrical design software alone cannot provide all the answers.

For novel technologies, it is particularly challenging to estimate losses, efficiencies and availabilities. It relies on assessments of technology reliability, operation and maintenance (O&M) provision and contractual arrangements.

Much depends upon how the project is operated once built. Contractually, it is thus typical to separate technical aspects from project/operational aspects. However, these hybrid technical/commercial issues do need to be understood and accounted for in the energy yield assessment process. It is not generally the function of a technical specification to apportion such risk or responsibility. Rather, a technical specification is an agreed and accepted tool to be referenced by the contract.

Standard classifications and taxonomies for losses are of similar value and it is this gap that ORE Catapult has now addressed. The taxonomy is logical, comprehensive and avoids double-counting.

A similar situation exists in relation to the uncertainty associated with the energy yield assessment process.

Uncertainties for different process elements are estimated in quite different ways. The existing technical specifications[3] address the purely technical elements of uncertainty at a high level (measurement, resource modelling and long term variability uncertainty). However, no guidance is given regarding the assessment of hybrid technical/commercial uncertainties such as energy convertor availability or power performance.

While the industries are still in the pre-commercial phase, some of these “uncertainties” are, to borrow from economic theory, true Knightian uncertainty[4] i.e. risk that is immeasurable, not possible to calculate.

It is important these are acknolwedged and assessed appropriately. Even in the maturing wind industry, the uncertainty associated with such estimations is still the source of much debate in some projects.

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3 *IEC/TS 62600-201 Marine Energy - Wave, Tidal and Other Water Current Conveters - Part 201: Tidal Energy Resource Characterisation*, International Electrotechnical Committee, 2015 and *IEC/TS 62600-101 Marine Energy - Wave, Tidal and Other Water Current Conveters - Part 101: Wave Energy Resource Characterisation*, International Electrotechnical Committee, 2015

4 Knight, F.H., *Risk, Uncertainty and Profit* (1921)

As the first commercial wave and tidal arrays move towards and through FID, it is important that losses, efficiencies and availabilities are addressed in a comprehensive and structured way: if not, we may see decisions taken based on incomplete or misinterpreted information.

Losses and uncertainties must be distinct to ensure there is no double counting or gaps. It must be clear that each element of uncertainty has been considered separately and how each value has been determined. This must all be communicated clearly and consistently to all stakeholders (technical and otherwise) to ensure risks are exposed and can be contractually apportioned and managed.

So, how do we ensure that losses, efficiencies and availabilities are defined and considered in a systematic and consistent fashion?

ORE Catapult, working with industry, has developed a standard taxonomy document for wave and tidal energy yield loss and uncertainty categories[5]. The presentation is simple and tabular, easily adopted by the industries. A similar activity was performed in the wind industry in 2013[6], which has proved particularly useful in the due diligence process.

The use of taxonomies in all walks of life is long established. Taxonomies are commonly used in biology or anthropology to group collections based on various characteristics. This, in turn, allows a greater insight into our relative knowledge about each collection and helps to identify gaps in this knowledge. They improve communication by providing a common language and framework for the presentation of research activities. More recently, taxonomies have been widely deployed in data and knowledge management in the scientific and corporate sectors.

For wave and tidal energy yield assessment, a common information structure provides distinct benefits. By ensuring logic, structure and completeness in wave and tidal energy yield loss and uncertainty categories, a taxonomy increases confidence in reporting methods.

Furthermore, results are presented consistently: this allows stakeholders to communicate information using standard categories. For example, financiers can compare studies from separate parties on a like-for-like basis.

The clear structured framework provided by the taxonomy allows stakeholders to “map out” and agree current estimates in each category. This can then be used to identify project specific gaps in knowledge and to allocate budgets to fill them efficiently, reducing risk and increasing project value.

Additionally, the use of a taxonomy allows technical stakeholders from different organisations to discuss areas of loss and uncertainty distinctly and systematically. This enhances opportunities for collaboration, from both a commercial and academic perspective.

Losses and uncertainties from representative cases studies will allow the state-of-the art in energy yield assessment to be mapped and for R&D to be prioritised by cost-benefit analysis.

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5 *Framework for the Categorisation of Losses and Uncertainty: Wave and Tidal Energy Yield Assessment*, ORE Catapult, July 2015
6 *Framework for the Categorisation of Losses and Uncertainty for Wind Energy Assessments*, DNV-KEMA and industry partners

As part of this, ORE Catapult worked with Frazer-Nash Consultancy (FNC) to produce a review of uncertainty estimation in wave and tidal energy yield assessments[7].

This review identifies that:

- Measurement uncertainties inherent to instruments are reasonably small and well understood in both wave and tidal;
- Procedures for performing temporal extrapolation are relatively well developed in tidal and fairly well developed in wave;
- Spatial extrapolation techniques are also well developed for wave and tidal projects;
- There is a requirement for further research and development activity in the area of "plant
- performance uncertainties" which encompasses (site specific) power performance, device availability and device interactions.

The first three elements are well developed and are covered in existing industry guidance for resource assessment.

For the last element, four specific activities have been identified which could be undertaken as joint industry projects (JIPs) to fill knowledge gaps:

1. Blind validation of resource modelling techniques for tidal resource assessment.
2. Aggregate analysis of wave resource validation studies.
3. Development of good practice for combining models and measurements to address spatial uncertainty in tidal resource assessment.
4. A detailed validation study of wave-current interactions.

In addition, two industry working groups are proposed to develop an independent instrument calibration standard and good practice for adjusting manufacturers' power performance data for prospective project sites.

The taxonomy is a useful contribution to a sector that is still developing. However, it has boundaries. It defines groupings and terminology; it does not define methodology or magnitude of uncertainties for a project. Stakeholders must select and agree methodologies that are considered most appropriate.

Additionally, whilst the taxonomy attempts to capture all losses, efficiencies and uncertainties associated with energy yield assessment, it does not capture every commercial risk for a project.

Finally, the taxonomy document and state-of-the-art review provide an excellent foundation upon which future commercial and academic research and development activity can be built.

Industry should regularly revisit each to ensure they remain valid and to chart progress. This should include setting priorities and reviewing which programmes and models of collaboration are most effective at advancing the state-of-the-art.

7 *Wave and Tidal Energy Yield Uncertainty: Literature Review*, ORE Catapult, July 2015

Recommended reading

Framework for the Categorisation of Losses and Uncertainty: Wave and Tidal Energy Yield Assessment, ORE Catapult, July 2015, available online at https://ore.catapult.org.uk/documents/10619/110659/Framework+for+the+Categorisation+of+Losses+and+Uncertainty/fe7ef3a4-3059-434c-9bac-464a177592bc

Wave and Tidal Energy Yield Uncertainty: Literature Review, ORE Catapult, July 2015, available online at https://ore.catapult.org.uk/documents/10619/110659/Wave+and+Tidal+Energy+Yield+Uncertainty+Literature+Review/c729bd38-e0ff-4bdb-8116-cf3b3dbe59f8

Author Profile

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He is a Chartered Engineer with a background in new technology assessment and the commercial application of energy yield assessment and site characterisation methodologies.

Ralph has a deep understanding of technical risk assessment and the technical application of novel measurement and modelling methodologies and the commercial context within which these are applied.

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