

TECHNICAL SPECIFICATION



Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization





THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.



TECHNICAL SPECIFICATION



Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization

IEC/TS 62600-101 Ed.2.0 - Preview only Copy via ILLNAS e-Shop

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.140

ISBN 978-2-8327-0036-5

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references	9
3 Terms and definitions	9
4 Symbols and abbreviated terms.....	10
5 Classes of resource assessment	11
5.1 General.....	11
5.2 Resource assessment and characterization flow chart	12
6 Study planning and data collection	14
6.1 General.....	14
6.2 Study area	14
6.3 Bathymetry	14
6.4 Existing wave data.....	15
6.5 Wave measurement	15
6.5.1 Purpose.....	15
6.5.2 Selection of measuring instrument and analysis methodology.....	15
6.5.3 Instrument calibration	16
6.5.4 Instrument deployment	17
6.5.5 Analysis of measurements	17
6.6 Wind data	18
6.7 Tidal and non-tidal current data	18
6.8 Water level fluctuation	18
6.9 Ice coverage and exceptional environmental conditions	19
6.10 Water density.....	19
6.11 Gravitational acceleration	19
7 Numerical modelling	19
7.1 General.....	19
7.2 Suitable numerical models	19
7.3 Definition of boundary conditions	22
7.4 Modelling the nearshore resource	23
7.5 Effect of WEC array on wave energy resource	23
7.6 Validation of numerical models	24
7.6.1 General	24
7.6.2 Validation data specification	24
7.6.3 Procedure.....	25
7.6.4 Extent of validation	28
7.7 Model tuning and calibration	30
8 Measure-Correlate-Predict (MCP) methods	30
8.1 General.....	30
8.2 Procedures	31
9 Data analysis.....	32
9.1 General.....	32
9.2 Characterization using two-dimensional wave spectra.....	32
9.2.1 Overview	32
9.2.2 Omni-directional wave power.....	33

- 9.2.3 Characteristic wave height..... 33
- 9.2.4 Characteristic wave period..... 34
- 9.2.5 Spectral width..... 34
- 9.2.6 Directionally resolved wave power 34
- 9.2.7 Wave system partitioning..... 35
- 9.3 Estimation of wave power using parameterized sea states 35
- 9.4 Aggregation and statistics of results..... 36
 - 9.4.1 General 36
 - 9.4.2 Mean 36
 - 9.4.3 Standard deviation..... 37
 - 9.4.4 Percentiles 37
 - 9.4.5 Monthly variability..... 37
- 9.5 Uncertainty of the resource assessment..... 37
- 10 Reporting of results 38
 - 10.1 General..... 38
 - 10.2 Selection of study points 38
 - 10.3 Technical report..... 38
 - 10.4 Digital database..... 39
 - 10.5 Presentation of regional information..... 40
 - 10.6 Presentation of information at study points..... 41
- Annex A (normative) Calculation of annual energy production (AEP) 45
 - A.1 Wave energy converter AEP at primary site 45
 - A.2 Standard methodology 45
 - A.3 Alternative methodology..... 45
 - A.4 Completeness of the capture width matrix for AEP..... 46
 - A.5 Wave energy converter AEP at a second location using measured assessment data..... 46
 - A.5.1 Connection to 62600-100..... 46
 - A.5.2 Calculate AEP at Location 2 using complemented capture width matrix and Location 2 resource data..... 46
 - A.5.3 Assessment of confidence 47
 - A.6 Example Analysis..... 47
 - A.6.1 Connection to 62600-100..... 47
 - A.6.2 Calculate AEP at Location 2 using complemented capture width matrix and Location 2 resource data..... 47
 - A.6.3 Assessment of confidence 48
 - A.7 Sources of uncertainty for AEP at Location 2 48
 - A.7.1 Comparisons between Location 1 and Location 2 48
 - A.7.2 Bathymetry and water depth 48
 - A.7.3 Current 48
 - A.7.4 Wave spectrum..... 49
 - A.7.5 Wave direction and short-crested waves..... 49
 - A.7.6 Wave converter modifications 49
- Annex B (normative) Evaluation of measurement uncertainty 50
 - B.1 General..... 50
 - B.2 Uncertainty analysis..... 50
- Annex C (informative) A method for sensitivity analysis 51
 - C.1 General..... 51
 - C.2 Specification of significance 51

C.3	Sample sea states	52
C.4	Condition of insensitivity	52
Annex D (informative)	Example calculation of long-term uncertainty	53
D.1	General.....	53
D.2	Climatic variability.....	54
D.3	Anthropogenic climatic variability	57
D.4	Conclusion.....	57
Annex E (informative)	Nearshore resource.....	58
E.1	General.....	58
E.2	Limiting water depth.....	58
E.3	Bathymetry	59
E.4	Fluctuating water level	59
E.5	Currents.....	59
E.6	Validation.....	59
E.7	Uncertainty	60
Bibliography	61
Figure 1	– Wave resource assessment and characterization flow chart	13
Figure 2	– Validation flow chart.....	28
Figure 3	– Example map of mean annual wave power.....	41
Figure 4	– Example of a scatter table summarizing a long-term wave climate in terms of H_{m0} and T_e	43
Figure 5	– Example of a wave power rose.....	43
Figure 6	– Example plot showing the distribution of wave power for different months	44
Figure D.1	– Annual wave power variability in the UK. Eleven sites in North East, North West and South West Regions [1].....	53
Figure D.2	– Comparison between mean annual power from the E04 model data set and the North Atlantic Oscillation index from 1988 to 2006 [2]	54
Figure D.3	– Recorded North Atlantic Oscillation index from 1825 to 2010 (red bars), with a five year moving average (black line) [2].....	55
Figure D.4	– Annual, 5-year, 10-year and 20-year moving averages of wave power at the a site [4].....	56
Figure D.5	– Annual mean power and running 5, 10 and 20-year mean values, 150 km North of Scotland [3].....	56
Table 1	– Classes of resource assessment	11
Table 2	– Resolution of bathymetric data	14
Table 3	– Minimum requirements for wave measuring instruments and associated analysis	16
Table 4	– Resolution of wind data	18
Table 5	– Elements of suitable numerical models.....	20
Table 6	– Minimum validation requirements	27
Table 7	– Uncertainty categories.....	37
Table 8	– Summary of wave energy resource parameters to be archived and mapped	40
Table A.1	– Table of AEP contributions.....	47
Table B.1	– List of uncertainty components.....	50

Table C.1 – Recommended sensitivity thresholds 51

Table C.2 – Recommended condition of insensitivity 52

Table D.1 – Comparison of mean average error (MAE) and maximum error (max. error) between the 3, 5 and 10-year averages of the data at the combined UK sites and the E04 Data set (WaveHub) 54

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MARINE ENERGY –
WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –****Part 101: Wave energy resource
assessment and characterization**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 62600-101 has been prepared by IEC technical committee 114: Marine energy – Wave, tidal and other water current converters. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Incorporation of annual energy production (AEP), formerly detailed in IEC TS 62600-102, as Annex A in this document and in IEC TS 62600-100.
- b) Modification to the list of terms and abbreviations

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
114/539/DTS	114/555/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62600 series, published under the general title *Marine energy – Wave, tidal and other water current converters*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document provides a uniform methodology that will ensure consistency, accuracy and reproducibility in the estimation, measurement, and analysis of the wave energy resource at sites that could be suitable for the installation of Wave Energy Converters (WECs), together with defining a standardised methodology with which this resource can be described. This document, when used in conjunction with other Technical Specifications in this series (IEC TS 62600), is intended for several types of users, including but not limited to the following:

- Project developers and investors to accurately and fairly estimate resource availability and mean annual energy production at a potential project site for income or return on investment calculations.
- Device developers striving to accurately estimate and report potential device performance, or recommend a particular device design to a project developer, given specific site conditions.
- Utilities and owners or operators in calculating reliability and predictability of power supply, as well as return on investment.
- Policy-makers, planners, and regulators who are concerned with accurately planning usage of seascape among stakeholders, optimisation of resources, and power supply issues.
- Consultants involved in producing resource data and conducting due diligence studies, who require a standard, compatible, and readable data format.

Application by all parties of the methodologies recommended in this document will ensure that continuing resource assessment of potential development sites is undertaken in a consistent and accurate manner. This document presents techniques that are expected to provide fair and suitably accurate results that can be replicated by others.

The wave energy resource is primarily defined using hydrodynamic models that are successfully validated against measured data. This document deals directly with the theoretical resource and the main focus of the defined methodology is to generate the resource information required to estimate annual energy production. The capture width of a WEC is estimated using the methodology presented in IEC TS 62600-100. Then, using the capture width information, in conjunction with the resource information generated with the methodology described in this document, the methodology in Annex A is used to calculate annual energy production. A framework for estimating the uncertainty of the wave energy resource estimates is also provided in Annex B.

The development of the wave power industry is at an early stage and the significance of particular wave energy resource characteristics is poorly understood. Because of this, the present document is designated as a Technical Specification and will be subject to change as more data is collected and experience with wave energy conversion develops.

An essential element for any published Technical Specification or International Standard is to allow an opportunity to provide feedback on its contents to the appropriate TC 114 Working Group. TC 114 utilizes a standard methodology to allow this. To submit feedback such as proposed changes, corrections and/or improvements to this document, please send an email to the TC 114 Chair using the Contact TC 114 Officers feature on the IEC TC 114 Dashboard, accessible at www.iec.ch/tc114. On the right side of the Dashboard under Further information select the link to contact the TC 114 Officers. On the subsequent page find and select the Send Email link for the Chair to access the email tool.

Complete all the required elements within the email pop-up. For the Subject field please include the document title and edition you are providing feedback for (ex: Feedback for TS 62600-1 ED2). In the Message field, include text which summarizes your feedback and note if further information can be made available (note attachments are not allowed). The Chair may request added information as needed before forwarding the submission to the remaining TC 114 Officers for review and then to the appropriate Working Group for their consideration.