ReDAPT Deliverable MC 9.5 – Recommendations for the Specification of Tidal Turbines

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1 MC 9.5 – TITLE AND ACCEPTANCE CRITERIA

1.1 Title of MC 9.5 Work-Package

Title: *"Recommendations for Specification and Testing of Tidal Turbine"*

NB: For the purpose of clarity this work-package has been split into 2 distinct reports:

- TG-RE-000-1028 Recommendations for the Specification of Tidal Turbines
- TG-RE-000-1036 Recommendations for the Testing of Tidal Turbines

1.2 Acceptance Criterion of MC 9.5 Work-Package

The following section is copied from the ETI ReDAPT programme acceptance criterion as stated against work package MC 9.5:

"Issued report containing complete list of parameters, units of measurement, formats and calculations required to fully specify a tidal turbine (i.e. such that a product can be assessed or selected) and a full list of assembly, pre-delivery and commissioning tests that a developer can use as their test programme."

Whilst the list of assembly, pre-delivery and commissioning tests is covered within report TG-RE-000-1036 ("Recommendations for the Testing of Tidal Turbines"), report TG-RE-000-1028 aims to address the remainder of this acceptance criterion including a list of "key" turbine parameters together with a broader spectrum of parameters required to fully define a turbine (together with units of measurement). It also raises and discusses potential for the introduction of tidal turbine "type" classes within the industry.

2 ACRONYMS

A	Amperes
AC	Alternating Current
CMS	Cable Management System
DC	Direct Current
DNV-GL	Det Norske Veritas – Germanischer Lloyd Group
EHM	Equipment Health Monitoring
ETI	Energy Technologies Institute
HATT	Horizontal Axis Tidal Turbine
Hrs	Hours
HS	High Speed
H_s	Significant Wave Height
HV	High Voltage (> 1000v)
I	Current Turbulence Intensity
Kg	Kilogrammes
LS	Low Speed
LV	Low Voltage (< 1000v)
M	Meters
Nm	Newton Meters
ReDAPT	Reliable Data Acquisition Platform for Tidal
rpm	Revolutions per Minute
s	Seconds
SCADA	Supervisory Control and Data Acquisition
t	Tonnes

TBC	To Be Confirmed
TSR	Tip Speed Ratio
U	Current Mean Velocity
U'	Root-Mean-Square of the Current Turbulent Velocity Fluctuations
UPS	Uninterruptible Power Supply
U_R	Rated Current Speed
V	Volts
Yrs	Years
V_{ref}	Reference Wind Speed
W	Watts
°	Degrees
°C	Degrees Centigrade

3 ASSUMPTIONS

In generating this document, the following assumption has been made:

a. In providing a detailed list of parameters required to specify a "generic" tidal turbine it is assumed that the major sub-system architecture is similar to the 1MW ReDAPT machine (see figures 1 and 2) – where architecture or design philosophy differs significantly from this reference machine additional parameters may be required.

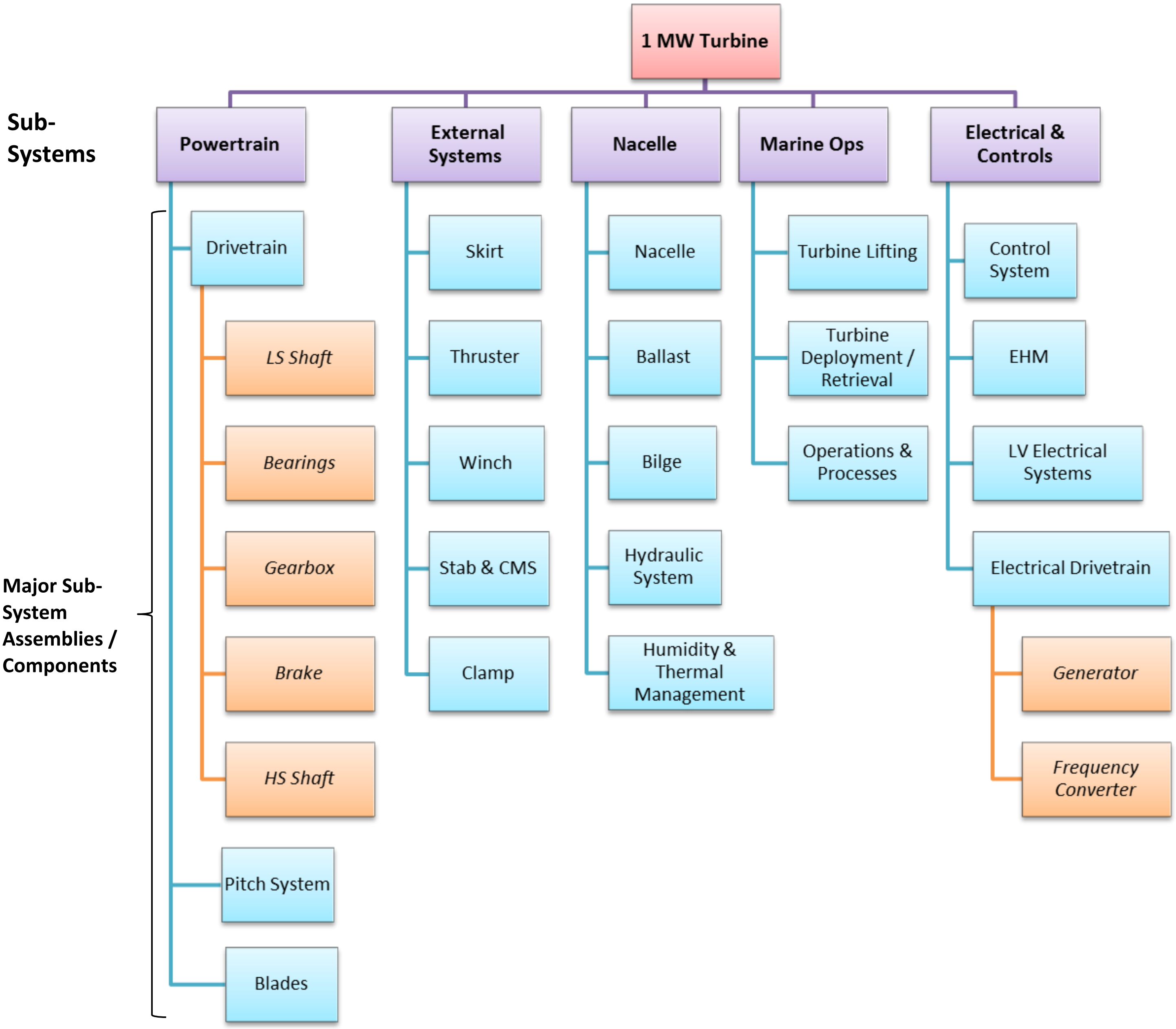
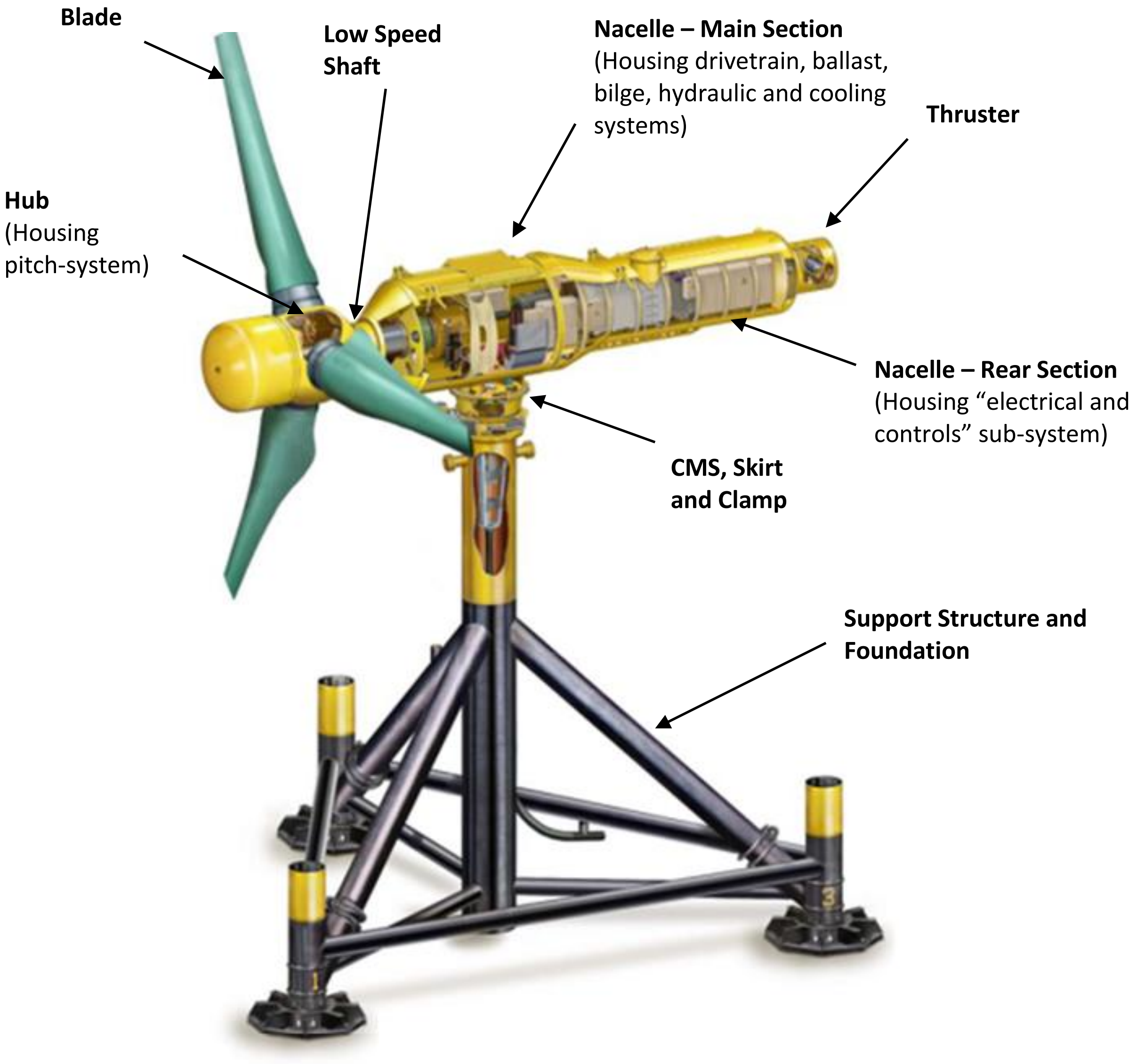


Figure 1: 1MW ReDAPT Turbine Sub-Systems (plus Major Sub-System Assemblies / Components)



4 PARAMETERS REQUIRED FOR THE SPECIFICATION OF A TIDAL TURBINE

4.1 "Key" Generic Turbine Parameters

It is recommended that any technical description of a tidal turbine include the following aspects as a minimum:

- Details of general configuration and a schematic (as per figures 1 and 2)

- Method of deployment
- Method of retrieval
- Typical cycle of operation
- Detailed plan of maintenance schedules

To augment this information, the following table provides a list of "key" generic turbine parameters which may be used to quickly compare and contrast tidal turbines of a similar configuration (as per Section 3, "*Assumptions*"):

Description	**Units**
Rotor parameters	
Rated electrical power	MW
Rotor diameter	m
Rated hub height current speed	m/s
Rated current speed at surface (ebb | flood)	m/s
Design Tip Speed Ratio (TSR)	-
RPM at rated (on design TSR)	rpm
Cut-in current speed	m/s
Cut-out current speed	m/s
Peak hub height current (U50yr)	m/s
Rotor centre line height from seabed (hub height)	m
Hub/Nacelle diameter	m
Pitch Control	-
Max pitch rate (normal generation)	°/s
Max pitch rate (emergency feathering)	°/s
Transmission parameters	
Gearbox fixed ratio	-
Rotation sense	-
Mounting	-
Brake location	-
Brake nominal torque (default for most simulations)	kNm
Maximum braking time @ rated torque and rotor RPM	s
Power Electrical parameters	
Generator No Poles	-
Generator inertia	$kg.m^2$
Power Electrics time constant	ms
Min generator torque	kNm
Max generator torque (transient)	kNm

Generator torque setpoint at rated speed	kNm
Nominal generator speed at rated power	RPM
Max generator speed for power production	RPM
Blade details	
No Blades	blades
Blade coning/sweep angle	°
Blade root station from hub centre-line	m
Support structure parameters	
Clamp plane distance beneath rotor centre line (vertical)	m
Central support column diameter	m

Table 1 - Definition of “Key” Generic Turbine Parameters

4.2 Parameters Required to Fully Specify a Tidal Turbine

In augmentation of the “key” parameters stated in Section 4.1, the following table offers a complete list of suggested parameters to fully define a tidal turbine (together with units of measurement).

(NB: Where a parameter has been included in table 1, it has been omitted from the relevant section of table 2 to prevent repetition)

4.2.1 Device Main Dimensions and Characteristics

Description	Unit
Rotor configuration	-
Distance from tip of blade to seabed	m
Distance from tip of blade to Minimum seawater elevation	m
Max mass to be lifted – installation (e.g. vessel)	t
Max mass to be lifted – maintenance (e.g. quayside)	t
Access / Methodology for Maintenance	-
Foundation Type	-
Generator Type	-
Power Control Strategy - Safety (pitch, over-speed, stall)	-
Emergency Stop Philosophy	-
Ambient design parameters Inside Nacelle	-
Maximum rotor RPM	rpm
Communication and Power to Shore	-
Hub-to-Hub and Blade Tip-to-Blade Tip Distances (multiple-rotor turbines only)	m
Reaction System (i.e. Sub Structure) Type	-
Power Electronics Converter Location (internal / external)	-
Loading	
Max Thrust	kN
Max Torque - operation	kNm
Max Torque - emergency stop (e.g. application of brake at highest flow speed due to pitch-system failure)	kNm

4.2.2 Maintenance Interval Targets

Description	Unit
Structure	
Foundation	Yrs
Substructure	Yrs
Nacelle	Yrs
Hub	Yrs
Power Take-off	
Generator	Yrs
Gearbox	Yrs
Blade	Yrs
Brakes	Yrs
Low Speed shaft	Yrs
High Speed Shaft	Yrs

Main Bearing	Yrs
Static Seals	Yrs
Dynamic Seals	Yrs
Stab and Cable Management System	Yrs
Pitch System	Yrs
Yaw System	Yrs
Auxiliary Systems	
Cooling System	Yrs
Bilge System	Yrs
Ballast System	Yrs
Electrical System	
Electrical Cables	Yrs
Transformer	Yrs
UPS	Yrs
Converter (if integral to HATT)	Yrs
Control System	
Control system (sensors)	Yrs
Controller	Yrs
Communications system(s)	Yrs
Corrosion Protection	Yrs
Hydraulic System	Yrs
Overall System Availability (% of time when equipment is fault-free and ready to operate assuming resource is within operating limits to generate)	**%**

4.2.3 Deployment and associated environmental conditions

Description	**Unit**
Sea State	
Maximum maintenance sea state	m
Maximum towing sea state	m

Max sea state (for lifting or lowering operation)	m
Max sea state (assumed for turbine in raised position if applicable)	m
Current Conditions	
Max current (towing)	m/s
Max surface current (lowering and raising)	m/s
Max current (assumed for turbine in raised position if applicable)	m/s
Wind Speed	
Maximum maintenance wind speed (surface)	m/s
Maximum towing wind speed	m/s
Max wind speed (towing)	m/s
Max wind speed (lowering and raising)	m/s
Air Temperature (°C)	
Max air Temperature	°C
Min air Temperature	°C
Water Temperature (°C)	
Max water temperature	°C
Min water temperature	°C
Installation Tolerances	
Max inclination off vertical (pitch)	°
Max inclination off horizontal (roll)	°
Max inclination off flow direction (yaw)	°
Max. turbine to support-structure misalignment	°
Deployment Window (i.e. time required to deploy)	
Foundation	Hrs
Substructure	Hrs
Nacelle	Hrs

4.2.4 Fatigue and Loading

Description	**Unit**
Turbine Design Standard	-
Fatigue Design Life	
Foundation	Yrs

Substructure	Yrs
Generator	Yrs
Gearbox	Yrs
Blade	Yrs
Low Speed shaft	Yrs
High Speed Shaft	Yrs

4.2.5 Power

Description	**Unit**
Power	
Installed capacity	MW
Number of turbine rotors per substructure	-

4.2.6 Materials

Description	**Unit**
Substructure	-
Nacelle	-
Blades	-
External Pipes (i.e. external to nacelle / exposed to seawater)	-

4.2.7 Foundation

Description	**Unit**
Type	-

4.2.8 Turbine

Description	**Unit**
Rotor rpm range	rpm
Rotor buoyancy	kN
Finishing / Coating	-
Functional Loads	kN
Ambient requirements inside nacelle	-
Fabrication approach	-
Transportation approach	-
Generator Type	-

Operating Voltage Range	V
System Arrangement	-
Insulation Class	-
Winding Wiring	-
Output Current Range	A
Max. Overvoltage	V
Min Short Circuit Level	A
Max Short Circuit Level	A
Winding Operating Temperature Range	°C
Max Coil Temperature	°C
Rectifier Type	-
Rotation Range	-
Earthing Method	-
Electrical system cooling	-
Turbine protection during towing	-
Maximum acceleration during towing	m/s^2

4.2.9 Mechanical Equipment Offshore

Description	**Unit**
Gearbox	-
Blade	-
Brake	-
High Speed Shaft	rpm
Low Speed Shaft	rpm
Pitch control system	-
Clamp	-
Stab and CMS	-
Yaw System (i.e. thruster)	-
Turbine Cooling System	-
Ballast System	-
Bilge System	-
Hydraulic system and hydraulic pumps	-
Mechanical Equipment container	-

4.2.10 Export and Control Cable

Description	**Unit**
High Voltage (Export) Cables	

Number of phases	-
Life expectancy	Yrs
Length of Cable (onshore, offshore)	m
Voltage range	V
Max losses	%
Low Voltage Power Cables	
Number of phases	-
Life expectancy	Yrs
Thickness of insulating walls	mm
Length of Cable (onshore, offshore)	m
Voltage range	V
Max losses	%
Control and Instrumentation Cables	
Life expectancy	Yrs
Thickness of insulating walls	mm
Fibre Optics	-
Data communication Cables	-
Fibre Optic Cables	-

4.2.11 Electrical Offshore Equipment

Description	**Unit**
Life expectancy	Yrs
Ring Main Unit	multiple
DC Metering	multiple
AC Metering	multiple
Generator	multiple
Transformer	multiple
Auxiliary Transformer	multiple
Electrical motors	-
Control system	-
Inverter	multiple
Inverter Control system	-
Power Converter	multiple
Power Converter Control system	-
HV Switchgear	multiple
LV Switchgear	multiple

Auxiliary Voltage system	multiple
Battery	multiple
UPS	-
Conversion efficiency	%
Conversion Type	-
SCADA	-

4.2.12 Electrical Onshore Equipment

Description	**Unit**
Life expectancy	Yrs
Ring Main Unit	multiple
DC Metering	multiple
AC Metering	multiple
Transformer	multiple
Auxiliary Transformer	multiple
Control system	multiple
Inverter Control system	multiple
Power converter	multiple
HV Switchgear	multiple
LV Switchgear	multiple
Auxiliary Voltage system	multiple
Battery	multiple
UPS	-
Conversion efficiency	%
Conversion Type	-
SCADA	-

4.2.13 Safety parameters

Description	**Unit**
Safety of personnel	-
Restart from emergency stop time	s
Installation access philosophy	-
Towing access philosophy	-
Equipment access philosophy	-
Medical evacuation philosophy	-
Emergency evacuation philosophy	-
Emergency stop time	s

4.2.14 Construction, transportation, installation

Description	**Unit**
Construction	-
Transportation and Installation	-
External Maintenance	-
Internal Maintenance	-
Remote Operation	-
Operation and Monitoring	-

4.2.15 Maintenance and Decommissioning Strategy

Description	**Unit**
Turbine Maintenance	-
Turbine Decommissioning	-
Substructure Maintenance	-
Substructure Decommissioning	-
Subsea Cable Decommissioning	-
Attending vessel (displacement)	t

Table 2 - Definition of Parameters to Define Range of Applicability and Limitations of a Tidal Turbine

5 POTENTIAL DEVELOPMENT OF GENERIC TURBINE TYPE CLASSES

In considering the list of parameters required to specify a tidal turbine (see above), the development of type-classes has been included within this report. This has previously been identified as an aspiration within the industry via the ReDAPT MC 8 work-package being performed by ALSTOM (in conjunction with DNV-GL).

The benefits of being able to utilise generic type-classes in the production of turbines include:

a) The ability to proceed with a preliminary turbine design based upon a minimum number of "fundamental" parameters as defined by its intended generic type-class, and

b) The ability for the market to easily compare and contrast different sized turbines for suitability against a particular site (e.g. a "Class 2" turbines would be suitable for a "Class 2" site).

Hence use of generic type classes is seen as offering significant benefit to the tidal turbine industry. To introduce a robust classification system however will require the list of turbine and site parameters to be distilled down (by conjunction of assumptions, formulations, etc.) into a minimum number of fundamental parameters upon which such a system could be based.

Table 3 offers a preliminary attempt at capturing those differentiating parameters, however it is recognising that further study is required in fully developing this process prior to publication by the certification authorities.

Rated Current Speed, U_R	A (e.g. >5 m/s)	B (e.g. > 4 m/s)	C (e.g. > 3 m/s)
Current Turbulence Intensity, I	Range of values TBC		
Significant Wave Height, H_s	I	II	III
Reference Wind Speed, V_{ref}	L(ow)	H(igh)	

Table 3 – How a possible generic "Type Class Table" might look (Example Only)

With reference to table 3:

Current Turbulence Intensity, I

I = u' / U

Where u' is the root-mean-square of the turbulent velocity fluctuations and U is the mean velocity.

Use of turbulence intensity values is currently being investigated - inclusion within the final classification table will be dependent upon whether its presence offers further differentiation between different turbine classes.

Significant Wave Height, H_s

H_s is defined as the mean wave height of the highest third of waves.

Significant wave height (averaged over the life of the project) is to be further examined in assessing whether the parameter may be combined with "Significant Wave Speed" within a wave spectrum – this would be desirable as wave speed has been demonstrated to have a significant impact upon the depth of water through which wave-effects can be detected (thus being a potential influence upon turbine rotors). Specifically, higher frequency waves may have increased energy at the surface however this energy rapidly dissipates with depth. Waves of a similar height but of lower frequency will have lower energy at the surface, however the effect of such waves has been shown to penetrate to a greater depth below the surface.

In addition, the use of 3 generic identifiers for H_s (e.g. I, II and III as per table 3) is also under review, as each "bucket" may be required to cover an unacceptably wide range of wave heights. (E.g. the difference between maximum wave height and minimum wave height within the same bucket may be too significant to be considered "similar"). This remains an open topic of discussion.

Reference Wind Speed, V_{ref}

Reference wind speed corresponds to the 10-min mean of the extreme wind speed, with a recurrence period of 50 years.

Reference wind speed remains a topic for discussion as this may only be pertinent for turbines operating near the surface (i.e. not deep water turbines), or for those turbines with a surface-piercing element to their operation.

As stated above whilst the introduction of a type-class system is seen as having significant benefit to the industry, a considerable amount of work remains in continuing to refine the major parameters down into a set of basic fundamental influences upon which such a classification system could be based - this work continues under the ReDAPT MC 8 work-package.