Part 3

Impact of Improvement on Characterisation and Modelling - 25mins



RealTide Project

Dr Jan Erik Hanssen 1-Tech BV, Brussels





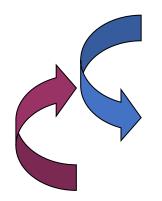
@ realtide@bureauveritas.com

https://www.realtide.eu

RealTide business case: Methodology

Cost modelling

- Bottom up
- Costing of arrays and farms
- Detailed... but not excessive
- Estimates LCoE from resource, construction & operations cost
- Immediate on-screen feedback facilitates sensitivity studies
- Allows quantifying role of Opex on a par with that of Capex



Market evolution modelling

- Top down, calibrated by costing-model data
- Rational approach to evolution of markets
- Assumes current SET-Plan targets reached: LCoE = 150 €/MWh by 2025, 100 by 2030
- Allows creating scenarios with varied sensitivity to deployment parameters
- Baseline comparison Capex is innovative off-shore wind (i.e. deepwater/floating)

INPUTS	Dearple case used for LCeE estimation	TIDAL CONVERTERS S			VICE SPECIFICATIONS	COST CALCULATIONS		LIFETIME COST A		CAPEX Cost Breakdown	fieth	RealTide Market Evol 2021 March update	lution Model												[
		Type and Characteristics of machine: Input Capture Width Factor, or use Reference D	Security of X = Y =.	Floating or Fixed Platform				WW DEVICE	ISE NW TIDAL FARM	2% 9%		2021 march update		<u> </u>											
enter data in green cells only		Input Capture Width Factor, or use Reference D	nico Raterenco Devico 75%	Floating or Fixed Platform Platform Stabilization Method	Floating Platform Burgary Stabilized	Fard fabrication & construction Platform Structural Costs (No. 41 Units)	EU80-6	4.300.500 0.000	205.424.000	- 25	Plation Strained Costs Names of Units					Tidal Arrays	s Validation I	Phase				Deployment I			
		Select Reference Device Type	Multiple Paint About		442	- and the second part of the	ECHOP 4				Moorinal Archor Cost			I I						2030's: Gr	owth	2040's: Consol	lidation	Maturit	N I
TIDAL FLO	W PARAMETERS	WEC X Dimension	7.5	Platform Structural Material	Steel Plate	Additional WEC Structure and Arcillaries	EURO-C	558,859 EURO (26.825.242		Additional VEC Structure and Anolitaties VEC PTO Cover			2025	2026	2027	2028	2029	2020	2031.35	2020 40	2041-45 2	046 2050	2050's	Beyond
		WEC Y Dimension m	150	Mass of Platform (Concrete)	Terrer -	WEC PTO Cost	EURO-C*	2.601.925 0180 4	124.092.410		Structure Upgradec			2023	2020	2021	LOLO	2025	2030	2031-33	2030-40				Deyond
Specify parameters, or select site:	Specify Incident Researce	WEC Z Dimension m	•	Mass of Platform (Steel)	Terrer 1.000						 Ved Turbine Cost Device Installation Cost 					annu	al averages				"annual" =	averages over	each 5-year p	seriod	
Wave Spectral Type	IONSWAP 2.41	WEC Capacity/Load Factor	25%	Platform Ballast Material	Terret 2.000	Wind Tarbine Cast (Vamber of Units)	EURO-E	- BURD 4		- 25	Offshore Cableg Cost/Device	-> TWh produced	p.a.	low	0.030	0.080	0.147	0.287	0.525	5.78	20.0	42	70	105	151
Significant Wave Height	· 2.41	What Further 4 characte		Platform Ballatt Required Additional WEC Companyors Mat		Structure Upgrades (for heavy WTs)	EURD-E	- 80804			 Of shore Cable Installation Cost/Desice Of shore Substation Cost/Desire 	GW installed	cumulative		0.009	0.023	0.042	0.092	0.150	1.65	5.74	42	20	20	42
Aretage Wave Period Abargs specify Wind resource:	, 14.0	tio, of converters per platform		Additional WEC Compensity Mat Mass of WEC Concrete or Special		Utor Platface CAPEX	EURO-6	7,465,284 8480 4	158 111 451		Onahore Cabling per Device	Gilli Installed	cumulative		0.009	0.023	0.042	0.082	0.130	1.65	5.71	12	20	30	43
Average Annual Wind Speed	m/s 8.18	Tidal Turbine Model cha		Mail of WEC (Inter()	Tannes 240	Charl Plantani John K	ECHUR .	7,451.464		05	 Onahore Substation per Desice Project Management 			I I											
Distribution Function	Weibell			Ballion Material	Segurater	Off. shore CAPSE breakdown	-			05 225 55	 Project stangement 	new capacity added in perior	d M97		9	14	19	40	68	1500	4064	6286	8000	10000	13000
Shape Parameter k	1.99	tiumber of Units 4-Platforms) in park	45	Ballout Required	Terest 2.000.	Installation Cost at site	EURO-C	242,856 01804	11.579.701				a,	1 1		4	10	40	4	F	10001	0200	E		10000
	ed Distribution			WEC PTO Type	Rydroefics	Moorleg/Ancher Cett	EURO-4	175,000 80804				 over # years in period 			1	1	1	1	1	5	0	5	5	5	c
wire spec	es disenseen			Mooring Line Material	Steel Wire Rope					Lifetime Costs Breakdown	Then	 annual new capacity 	MW/a		9	14	19	40	68	300	813	1257	1600	2000	2600
		PLATFORM N		Archar Type	Drag Embedment Archor	Offshare Cabling Case	EURO-E	1.101.125 8180 4		- 105	100.00	 													
	142	Salestracture Hall Mass Taes WEC Structure Mass Taes	** **	Alumber of Meaning Lines Alumber of Archers		Offshare Cable Installation Cost Offshare Substation Cost	EURO-E	565,333 BURO 4	25,388,000																
* ¥ *		Tatal Ballant (Fapplicable) Ten	45	16.00 Distance Others	kre 30	University Subscription Cox	ENNOR	665.45¥ 8400	12.552.400			capex, new TCT capacity	€k₩	high	4,500	4,000	3,500	3,000	2,500	2,250	2,100	2,000	1,900	1,800	1,650
8.7	0.4	Ancillary Structural Components Ten		 Alumber of Sag Beats 		Orchere Substation	EURO-4	245.999 8180 4	11.797.400		32%	Reference caney Floating	a Wind **		3,000		2 500		2 175		1.825		1.650		1 500
	- Vebul	Stractural Upgrades Tee		- Tening Speed	inta 1	Onahave Cabling	EURO-4	234.375 BURO 4	11.253.000			interest topolo, i robain	y				8,000				1,020		,000		1,000
0 Wild Same	- 20 Cars Distribution	Salestracture Total Mass Tee		00.00 Project period in years	jdorit changej 22						 Distant Station Costs Nation of the 		wind (see NB note)		50%		40%		10%		75%		75%		10%
wise spee	ea (mes)	Tetal Mass Salistinactaire = TBCs Tee		FALSE Years of commercial operation	10	Off-shore portion of CAPEX	EURO-6	1.070.512 8480 6	155.784.101	25	 Mooring/Auchor Cost Additional VEC Streamers and Analitation 	 annual capex on TC power	€m/a	1 1	39	57	67	120	170	675	1707	2514	3040	3600	4290
				itili for WT (ctrict) and towers but varies	Healer tarkiner	Project Management and Contingencies	ECRO-4	1.070.511 0.000	51.384.595		VEC/PTO Cost Structure Upgrades	cum, investments TC power	fim		39	96	163	283	453	3.828	12 363	24,934	40.134	58,134	79 584
FINAN	ICIAL INPUTS	POWER OUTPUT C	ALCULATIONS	Levelised (ost of Energy (LCoE)		-					com. Information of power	- Contraction of the Contraction	+ +			100	2000	400	0,020	12,000	24,004	40,104	55,154	10,004
Choose Discount rate coverbally		PER PLATEO	8M	Levelised e	our of EllerBy (ECOE)	Tetel CAPEX	EURO-K	11.775.636 BURO 4	545,233,547		1% Device Installation Cost 1% Officience Califiers Cost														
Fail 2012 4 to 7% (actual projects)	1.p.a. 6.00	Average Tidal Power Output 81				Tetal CAPES/rated power, instaked on al	6.06, 5.7 V	3.62			Distore Cable Installation Cost/Device #16 Offshore Substation Cost/Device	#machines installed per yea	r	~	9	14	13	20	34	120	325	419	533	667	867
Overs 2811:0.5%, UK respondents		Annual Tidal Energy Production Gra	h 7.12	Unit (Platform) CAPEX, on situ	EURO-€ 11.775.4	16				25		- average power/machine	MW/		1.0	1.0	1.5	2.0	2.0	25	2.5	2.0	2.0	2.0	2.0
	Public over case 20 years	Average Wave Power Output (CMP) 20 Average Wave Energy Eventuation (CM)	542	Discounted Unit Lifetime OPER OPER w/s of CAPER	5URO-6 1,983.4						 Ondices Substation per Desice Project Management 	- average powervitaciane	101.01	+ +	1.0	1.0	1.5	2.0	2.0	2.5	2.0	J.0	5.0	3.0	3.0
Feed in Tariff or equivalent dar Wave Energy 40		Average Tidal Power Output as		OPEX so's arCAPEX Platform Lifetime Cast	EURO-€ \$11,759,1	OPEX incolutions Structure Maintenance Costs	EURO-4	2,245,000 81804	160.512.000	19%	Decounted OPEX														
	AUX1 0	Annual Energy Production DI		Platform Lifetime Energy Product		2 WELFED ON Care	EURO-C	3.334.077 80804	150,415,717			#machines operational		10	19	33	46	66	100	700	2.325	4.421	7.087	10,421	14,754
in the second se		contraction of					Land	111111				- avg. power, all installed	M/6/	<15457	1.0	1.0	1.2	1.2	1.6	2.4	2.49	2.71	2.92	2.99	2.91
		Annual Platform Energy Production 01	n 7.1	LCoE	K/MWh 196.7	Wind Darbing Maintenance	EURO-C	- BURO 4		Undiscounted OPE)	K Breakdown	- avg. power, an misaned	19199	110100	1.0	1.0	1.4	1.4	1.9	2.4	2.40	6.01	2.02	2.00	2.01
		- Nominal Full Load Hours per year	2,290	Park CAPEX	Celi 1	Mooring System Maintenance	EURO-C	5.250 00804		1	1.000														
		- Norrival (Grass) Capacity Factor	0.9%	Park OPEX Discounted	<ris td="" <=""><td>Transmission System O&M</td><td>EURO-€</td><td>343.512 DURO 4</td><td>16,344,557</td><td>25, 25,15</td><td></td><td>TCT-blade segment (</td><td>Prime Mover)</td><td>2025</td><td>2026</td><td>2027</td><td>2028</td><td>2029</td><td>2030</td><td>by 2035</td><td>by 2040</td><td>2045</td><td>2050</td><td>2050's</td><td>Beyond</td></ris>	Transmission System O&M	EURO-€	343.512 DURO 4	16,344,557	25, 25,15		TCT-blade segment (Prime Mover)	2025	2026	2027	2028	2029	2030	by 2035	by 2040	2045	2050	2050's	Beyond
		Anneal revenue from Pewer sales Creit	ise 0.99	ParkLifetiwe Cest (TLC)	Colo C	Rent/Davice	EURO-E EURO-E	255.564 BURO 4 235.533 BURO 4				rer plute segment p	, march morely	LOLD	LOLO	LOLI	LOLO	LOLD		.,			2000	Lose a	a contraction of the second
		Platform Rated Power 87	1	ORTATION	4/0Wh 1/	Went/Device	EURO-K	91,122 BURO	11.554,611																
		- Effective Rated Power No.		Section Number Property, 12 percent	f els	0	10004				Structure Maintenance Costs	#blades sold per year		<10	21	36	32	50	85	300	813	1.048	1.333	1,667	2.167
OTHER ENERGY	RESOURCE AT THIS SITE	CAPEX per factor Wave Paper 1 4/4	# 972	Grees Hawkast Revenues, Wind	£ # 4 #	0 Undiscounted Library OPEX	EURO-6	7,411,716 8/80 6	155,761,411		 VECPTO-OMMCover 	-> capex share on blades		unknown	20%	20%	20%	20%	15%	12.5%	12.5%	10%	10%	10%	10%
Incident Wave Resource st	/W//w 52	FOR THE WHOLE OFFSHO	RE ENERGY PARK								Vec PTO DeProven		C 4 141		20 76	2079	200	2070	076	14.070	14.370	200	1070	10.70	10.70
	244.0%	Total Park Power Rating M		Net Present Value, NPV	Cmillion -77	Total Lifetirse Cost 4, Indiscourted)	EURO-C	19.387.374 BURO 4	920.993.959		Nooing/Actor Matterance	capex amount on blades	€kW	>1000	900	900	/00	600	3/5	281	263	200	190	180	165
	104(0)	Annual Energy Production 019	5 341.9	Internal Rate of Setury, BR	* #DIV/	21					Transmission Symen OSMICavice	TCT blade market size	€m/a	2	7.7	11.4	13.4	24.0	25.5	84.4	213	251	304	360	429
											Insurance/Device														

Snapshot: Costing model ("Main" screen inputs)

INPUTS 20-unit, 100MW farm, Turbine capex § 2m/NW.		ENERGY CONVERT	ERS SPI	ECIFICATIONS	PLATFORM SPECIFICATIONS				
	3km offshore - No offsh		Wave Energy Converters (WEC's):		(For wind-only, or Tidal, X = Y = Z				
enter data in green cells only	Skill difshore - No difsh.	substation, som deep.	Input Capture Width Factor, or use Refer	ence Device	Reference Device	Floating or Fixed Platform		Floating or Bottom-fixed	
outputs in yellow highlight cells			N/A		75%	Platform Stabilisation Method		Mooring Line Stabilised	
	OW PARAMETI	EDC	Select Reference Device Type		Multiple Point Absorber	Water Depth	m	50	
HDAL FL		EKS	WEC X Dimension	m	0	Platform Structural Material		Steel Plate	
			WEC Y Dimension	m	0	Mass of Platform (Concrete)	Tonnes		
lean Annual Power Density	2.2 kW/m2		WEC Z Dimension	m	0	Mass of Platform (Steel)	Tonnes	500	
lean Annual Current Speed	2.0 m/s		WEC Capacity/Load Factor		25%	Platform Ballast Material		Seawater	
ite:	Generic high energy site					Platform Ballast Required	Tonnes		
			Tidal Converter used (category)			Additional WEC Components Mate	rial		
idal Current Speed distribution:			RealTide concept		1	Mass of WEC (Concrete or Special)	Tonnes		
dal carrent opeca astroation			incarriac concept			Mass of WEC (Steel)	Tonnes		
1	1					WEC Ballast Material	Tonnes	Seawater	
							-	seawater	
	J		Number of Units (=connection points)	in park	20	WEC Ballast Required	Tonnes		
						WEC PTO Type		Direct Drive	
0.03		-	PLATFO			Mooring Line Material		Chain	
				-		N/A		Drag Embedment Ancho	
G 0.02			Substructure or Hull Mass	Tonnes	500.00	N/A		5	
			WEC Structure Mass	Tonnes	-	N/A		5	
0.01		_		Tonnes	-	Distance Offshore	km	3	
			Ancillary Structural Components	Tonnes	-	Special Vessel cost, Tug Boat Equiva		30	
			Structural Upgrades (if required)	Tonnes	-	Towing Speed	knts	2	
								22	
0 1	2 3	4	Substructure Total Mass	Tonnes	500.00	Project period in years		22	
0 1	$U_0, m/s$	4	Substructure Total Mass Total Mass Substructure + Turbine (-s)	Tonnes	1,000.00	Years of commercial operation	20		
0 1	$U_0, m/s$	4		Tonnes	1,000.00				
0 1 ignificant Impact Factor (SIF)		4	Total Mass Substructure + Turbine(-s) POWER OUTPL	Tonnes JT CALC	1,000.00 includes allowance 100t/MW fo	Years of commercial operation	etween turbines		
¯0 1 ignificant Impact Factor (SIF)	$U_0, m/s$	4	Total Mass Substructure + Turbine(-s) POWER OUTPL	Tonnes	1,000.00 includes allowance 100t/MW fo	Years of commercial operation r WT (=THM) and towers but varies be	etween turbines		
¯0 1 ignificant Impact Factor (\$IF)	$U_0, m/s$	4	Total Mass Substructure + Turbine(-s) POWER OUTPL	Tonnes JT CALC	1,000.00 includes allowance 100t/MW fo	Years of commercial operation FWT (=THM) ond towers but varies be Levelised Co	etween turbines ost of En	ergy (LCoE)	
ි 1 ignificant Impact Factor (SIF)	$U_0, m/s$	4	Total Mass Substructure + Turbine(-s) POWER OUTPL	Tonnes JT CALC	1,000.00 includes allowance 100t/MW fo	Years of commercial operation rWT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site	etween turbines <mark>OSt Of En</mark> EURO€	ergy (LCoE)	
¯0 l ignificant Impact Factor (βIF)	$U_0, m/s$	4	Total Mass Substructure + Turbine(-s) POWER OUTPL	Tonnes JT CALC	1,000.00 includes allowance 100t/MW fo	Years of commercial operation r WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX	etween turbines ost of En	ergy (LCoE)	
	U ₀ , m/s	4	Total Mass Substructure + Turbine(-s) POWER OUTPO PER F	Tonnes JT CALC PLATFORM	1,000.00 includes allowance 100t/MW fo	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX	etween turbines ost of En EURO€ EURO€	ergy (LCoE) 16,42	
	$U_0, m/s$	4	Total Mass Substructure + Turbine (-s) POWER OUTPL PER F Average Tidal Power Output	Tonnes JT CALC PLATFORM	1,000.00 includes allowance 100t/MW fo CULATIONS 1993	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX Platform Lifetime Cost	etween turbines ost of En EURO€ EURO€ EURO€	ergy (LCoE) 16,422 6,753 23,173	
	U ₀ , m/s	4	Total Mass Substructure + Turbine(-s) POWER OUTPO PER F	Tonnes JT CALC PLATFORM	1,000.00 includes allowance 100t/MW fo	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX	etween turbines ost of En EURO€ EURO€ EURO€	ergy (LCoE) 16,422 6,753 23,173	
FINA	U ₀ , m/s	4 6.00	Total Mass Substructure + Turbine(-s) POWER OUTPO PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production	Tonnes JT CALC PLATFORM	1,000.00 includes allowance 100t/MW fo CULATIONS 1993	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE	etween turbines ost of En EURO€ EURO€ EURO€	ergy (LCoE) 16,422 6,753 23,173	
FINA	U ₀ , m/s	6.00	Total Mass Substructure + Turbine (-s) POWER OUTPL PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year	Tonnes JT CALC LATFORM kW GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX	EURO E EURO E EURO E EURO E EURO E	ergy (LCoE) 16,429 6,753	
	U ₀ , m/s	6.00	Total Mass Substructure + Turbine (-s) POWER OUTPL PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor	Tonnes JT CALC PLATFORM kW GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Energy Production LCOE Park CAPEX Park OPEX Discounted	euroe euroe euroe euroe euroe gwh e/MWh emin emin	ergy (LCoE) 16,429 6,753	
FINA	U ₀ , m/s	6.00	Total Mass Substructure + Turbine (-s) POWER OUTPL PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year	Tonnes JT CALC LATFORM kW GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492	Years of commercial operation rWT (=THM) ond towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX Platform Lifetime Energy Production LCOE Park CAPEX Park DEX Discounted Park Lifetime Cost (TLC)	EURO E EURO E EURO E EURO E GWh E/MWh E mIn	ergy (LCoE) 16,429 6,752 23,177	
FINA	U ₀ , m/s	4 6.00	Total Mass Substructure + Turbine (-s) POWER OUTPR PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor Annual revenue from Power sales	Tonnes JT CALC LATFORM kW GWh GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9%	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park (DPEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh	EURO€ EURO€ EURO€ EURO€ GWh €/MWh €mln €mln €mln €Mh	ergy (LCoE) 16,429 6,752 23,177	
FINA	U ₀ , m/s	6.00	Total Mass Substructure + Turbine (-s) POWER OUTPL PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor	Tonnes JT CALC PLATFORM kW GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park OPEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh	EURO E EURO E EURO E GWh EURO E GWh EMN Emin Emin Emin	ergy (LCoE) 16,429 6,752 23,177	
FINA	U ₀ , m/s		Total Mass Substructure + Turbine (-s) POWER OUTPR PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor Annual revenue from Power sales	Tonnes JT CALC LATFORM kW GWh GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9%	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park CAPEX Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh Grass Nominal Revenue, Waves	tween turbines ost of En EURO€ EURO€ EURO€ GWh €/MWh €mIn €/GWh €/GWh €/Mh	ergy (LCoE) 16,429 6,752 23,177	
FINA implified WACC iot used but reserved for future of OTHER ENERGY	U ₀ , m/s		Total Mass Substructure + Turbine(-s) POWER OUTPI PER F Average Tidal Power Output Annual Tidal Energy Production Annual Tidal Energy Production - Nominal Full Load Hours per year - Nominal Full Load Hours per year - Nominal revenue from Power sales Rated Power (per connection point)	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park OPEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh	tween turbines ost of En EURO€ EURO€ GWh €/MWh €mIn €mIn €mIn €/GWh €/GWh	ergy (LCoE) 16,429 6,752 23,177	
FINA	U ₀ , m/s		Total Mass Substructure + Turbine (-s) POWER OUTPR PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor Annual revenue from Power sales	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park CAPEX Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh Grass Nominal Revenue, Waves	tween turbines ost of En EURO€ EURO€ EURO€ GWh €/MWh €mIn €/GWh €/GWh €/Mh	ergy (LCoE) 16,425 6,752 23,177 3	
FINA implified WACC iot used but reserved for future of OTHER ENERGY	U ₀ , m/s	THIS SITE	Total Mass Substructure + Turbine(-s) POWER OUTPL PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal Coross) Capacity Factor Annual revenue from Power sales Rated Power (per connection point) FOR THE WHOLE O	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park CAPEX Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh Grass Nominal Revenue, Waves	tween turbines ost of En EURO€ EURO€ EURO€ GWh €/MWh €mIn €/GWh €/GWh €/Mh	ergy (LCoE) 16,429 6,751 23,177 150.1	
FINA implified WACC iot used but reserved for future of OTHER ENERGY ncident Wave Resource fean Wind Speed	U ₀ , m/s	THIS SITE 5 or less 6.0	Total Mass Substructure + Turbine (-s) POWER OUTPR PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor Annual revenue from Power sales Rated Power (per connection point) FOR THE WHOLE O Total Park Power Rating	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh FFSHORE EI	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0 5.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX Platform Lifetime Cost Platform Lifetime Energy Productio LCOE Park CAPEX Park CAPEX Park (DPEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh OPEX/GWh Gross Nominal Revenue, Waves Gross Nominal Revenue, Wind Net Present Value, NPV	EURO E EURO E EURO E GWh EURO E GWh EURO E GWh Enin Emin Emin Emin Efowh Efowh Emin Emin Emin	ergy (LCoE) 16,422 6,752 23,177 3 150.1	
FINA implified WACC iot used but reserved for future of OTHER ENERGY neident Wave Resource	U ₀ , m/s	THIS SITE 5 or less	Total Mass Substructure + Turbine(-s) POWER OUTPL PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal Coross) Capacity Factor Annual revenue from Power sales Rated Power (per connection point) FOR THE WHOLE O	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh FFSHORE EI	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0 NERGY PARK 100.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Cd Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as% of CAPEX Platform Lifetime Cost Platform Lifetime Energy Production LCOE Park CAPEX Park DEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh OPEX/GWh Grass Nominal Revenue, Waves Grass Nominal Revenue, Wind	EURO E EURO E EURO E GWh EURO E GWh EURO E GWh Enin Emin Emin Emin Efowh Efowh Emin Emin Emin	ergy (LCoE) 16,425 6,752 23,177 3	
FINA implified WACC iot used but reserved for future of OTHER ENERGY ncident Wave Resource fean Wind Speed	U ₀ , m/s	THIS SITE 5 or less 6.0	Total Mass Substructure + Turbine (-s) POWER OUTPR PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor Annual revenue from Power sales Rated Power (per connection point) FOR THE WHOLE O Total Park Power Rating	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh FFSHORE EI	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0 NERGY PARK 100.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX Platform Lifetime Cost Platform Lifetime Energy Productio LCOE Park CAPEX Park CAPEX Park (DPEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh OPEX/GWh Gross Nominal Revenue, Waves Gross Nominal Revenue, Wind Net Present Value, NPV	EURO E EURO E EURO E GWh EURO E GWh EURO E GWh Enin Emin Emin Emin Emin Emin Emin Emin	ergy (LCoE) 16,422 6,752 23,177 3 150.1	
FINA implified WACC iot used but reserved for future of OTHER ENERGY ncident Wave Resource fean Wind Speed	U ₀ , m/s	THIS SITE 5 or less 6.0 2.0	Total Mass Substructure + Turbine (-s) POWER OUTPR PER F Average Tidal Power Output Annual Tidal Energy Production Annual Platform Energy Production - Nominal Full Load Hours per year - Nominal (Gross) Capacity Factor Annual revenue from Power sales Rated Power (per connection point) FOR THE WHOLE O Total Park Power Rating	Tonnes JT CALC LATFORM kW GWh GWh GWh GWh FFSHORE EI	1,000.00 includes allowance 100t/MW fo CULATIONS 1993 17.5 17.5 3,492 39.9% 5.0 NERGY PARK 100.0	Years of commercial operation WT (=THM) and towers but varies be Levelised Co Unit (Platform) CAPEX, on site Discounted Unit Lifetime OPEX OPEX as % of CAPEX Platform Lifetime Cost Platform Lifetime Energy Productio LCOE Park CAPEX Park CAPEX Park (DPEX Discounted Park Lifetime Cost (TLC) CAPEX/GWh OPEX/GWh OPEX/GWh Gross Nominal Revenue, Waves Gross Nominal Revenue, Wind Net Present Value, NPV	EURO E EURO E EURO E GWh EURO E GWh EURO E GWh Enin Emin Emin Emin Emin Emin Emin Emin	ergy (LCoE) 16,429 6,753	

Tidal arrays

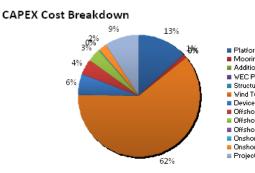
- Arrays consist of five 2-MW installations (twin turbines)
- Costing similar for fixed (e.g. monopile or GBS) or floating

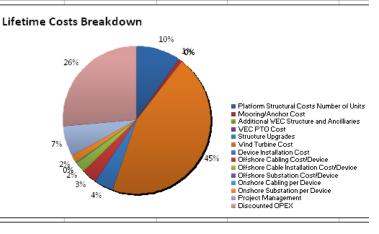
Early-stage Tidal Farms

- Farms consist of at least 2 x 2MW rated turbines per connection point
- Typically 100MW, using twenty 5-MW installations
- Snapshot is for early tidal farm that (just) reaches the 2025 SET-Plan target for tidal

Snapshot: Costing model ("Main" screen outputs)

COST CALCULATIONS	LIFETIME COST ASSESSMENT								
	5.0	MW PLATFORM	100	MW OFFSHORE ENERGY PARK					
Yard fabrication & construction									
Platform Structural Costs (No.of Units)	EURO€	2,150,250	EURO€	43,005,000					
Additional WEC Structure and Ancillaries	EURO€	-	EURO€	-					
WEC PTO Cost	EURO€	-	EURO€	-					
Wind Turbine Cost (Number of Units)	EURO€	10,000,000	EURO€	200,000,000					
Structure Upgrades (for heavy WT's)	EURO€	-	EURO€	-					
UNIT (Platform) CAPEX	EURO€	12,150,250	EURO€	243,005,000					
Off-shore CAPEX breakdown									
Installation Cost at site	EURO€	921,456	EURO€	18,429,125					
Mooring/Anchor Cost	EURO€	196,061	EURO€	3,921,216					
Offshore Cabling Cost	EURO€	700,000	EURO€	14,000,000					
Offshore Cable Installation Cost	EURO€	529,400	EURO€	10,588,000					
Offshore Substation Cost	EURO€	-	EURO€	-					
Onshore Substation	EURO€	375,000	EURO€	7,500,000					
Onshore Cabling	EURO€	60,000	EURO€	1,200,000					
orration and a contra									
Off-shore portion of CAPEX		2,781,917	-	55,638,341					
Project Management and Contingencies	EURO€	1,493,217	EURO€	29,864,334					
Total CAPEX	EURO€	16,425,384	EURO€	328,507,675					
Total CAPEX/rated power, installed on site	M€/MW	3.29							
OPEX breakdown									
Structure Maintenance Costs	EURO€	1,672,000	EURO€	33,440,000					
WEC PTO O& M Cost	EURO€	-	EURO€	-					
Tidal Turbine Maintenance	EURO€	22,352,697	EURO€	447,053,944					
Mooring System Maintenance	EURO€	5,882	EURO€	117,636					
Transmission System O&M	EURO€	366,467	EURO€	7,329,344					
Insurance/Device	EURO€	361,358	EURO€	7,227,169					
Rent/Device	EURO€	328,508	EURO€	6,570,154					
Utilities/Device	EURO€	143,484	EURO€	2,869,680					
Undiscounted Lifetime OPEX	EURO€	25,230,396	EURO€	504,607,927					
Total Lifetime Cost (Undiscounted)	EURO€	41,655,780	EURO€	833,115,602					
				Toob					
				<u>I.ICCII</u>					





Undiscounted OPEX Breakdown



Platform Structural Costs Number of Units
 Mooring/Anchor Cost
 Additional WEC Structure and Ancilliaries
 WEC PTD Cost
 Structure Upgrades
 Wind Turbine Cost
 Device Installation Cost
 Offshore Cable Installation Cost/Device
 Offshore Cable Installation Cost/Device
 Offshore Substation Cost/Device
 Onshore Cabling per Device
 Onshore Substation per Device
 Project Management

Structure Maintenance Costs
 WEC PTO 0&M Cost

Wind Turbine Maintenance
 Mooring/Anchor Maintenance
 Transmission System 0&M/Device

Insurance/Device
Rent/Device

Utilities/Device

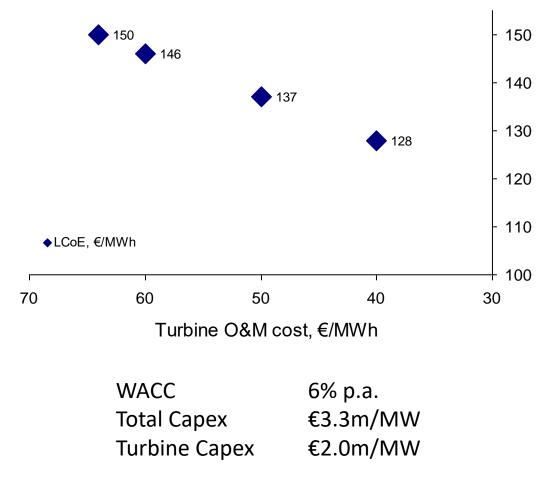
Output screen

- This case has total Capex €3.3m / MW
- Model allows "free" parameter variation
- Graphic breakdown of each cost category

Example results 1: O&M cost can have major influence on LCoE

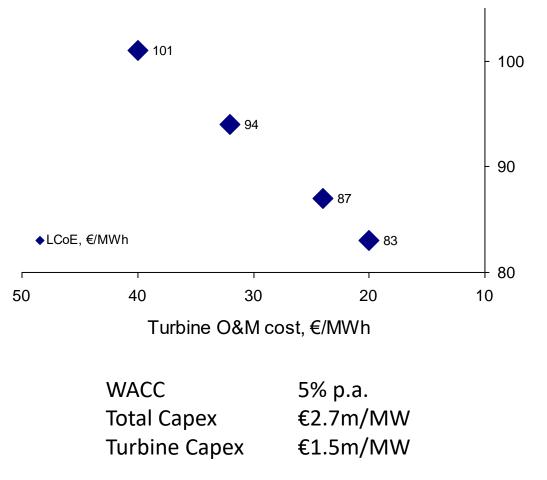
Arrays and early stage farms (to 2030)

LCoE at constant Capex & production



Commercial tidal farms (2030's)





Example results 2: Influence of cost reduction on market take-off

Market-evolution mode snapshot, example out

installed MW worldwide

		RealTide Market Evolu	tion Model				GLOBA	L SCENA	RIO FOR	TIDAL-ST	REAM PC	WER		
		2021 July version												
						Tidal Array	s Validation	Phase				Deploymen	t Decades	
odel		FLH/year assuming 40%	: 3500							2030's: O	òrowth	2040's: Con	solidation	Matur
Juei				2025	2026	2027	2028	2029	2030	2031-35	2036-40	2041-45	2046-2050	2051-55
utput						ann	ual averages				avei	rages over ead	ch 5-year perio	d
ulpul		TWh produced	p.a.	0.025	0.035	0.080	0.150	0.320	0.600	5.78	20.0	42	70	105
		GW installed	cumulative	0.01	0.020	0.033	0.053	0.101	0.181	1.660	5.724	12.0	20.0	30.0
		new capacity added in period,	MW		10	13	20	49	80	1479	4064	6286	8000	10000
		- over # years in period			1	1	1	1	1	5	5	5	5	5
	1	- annual new capacity	MW/a		10	13	20	49	80	296	813	1257	1600	2000
	1500	capex, new tidal stream	€/kW	4,500	4,000	3,750	3,500	3,000	2,750	2,250	2,100	2,000	1,900	1,800
,		Reference capex, Floating	Wind **	3,000		3,000	2,750		2,250		1,825		1,650	
		cost premium TC over offshore wi	nd (see NB note)	50%			27%		22%		15%		15%	
		annual capex on TC power	€m/a		40	48	70	146	220	665	1707	2514	3040	3600
		cum. investments TC power	€m		40	88	158	304	524	3,851	12,386	24,957	40,157	58,157
•		#machines installed per year*	***	<5	10	13	20	32	40	99	271	314	400	333
	- 1000	- average power/machine	MW	1	1.0	1.0	1.0	1.5	2.0	3.0	3.0	4.0	4.0	6.0
1		# MW-scale machines operation	nal	10	20	33	53	85	125	618	1,973	3,544	5,544	7,211
		- avg. power, all installed	MW	1	1.0	1.0	1.0	1.1	1.4	2.7	2.90	3.39	3.61	4.16
•		TCT- <u>blade</u> segment (Pr	rime Mover)	2025	2026	2027	2028	2029	2030	by 2035	by 2040	2045	2050	2050's
1	500													
I	500	#blades sold per year		<15	25	32	50	81	100	246	677	786	1,000	833
		capex share on blades		>20%	20%	20%	20%	20%	15%	12.5%	12.5%	10%	10%	10%
LCoE	= 100€/N	capex amount on blades	€/kW	>1000	800	750	700	600	413	281	263	200	190	180
	chieved	Tidal blada markat aiza	€m/a	<2	8.0	9.6	14.0	29.1	33.0	83.2	213	251	304	360
a	1			I I				I	I		I		I	
I	- 0													
2.5	ר													
Z.Ə 🖌	2													

3.5 Capex, €/MW

3

LCoE = 150€/MWh achieved

4

4.5

REALTIDE



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 727689 Interreg Atlantic Area European Regional Development Fund

MONITOR

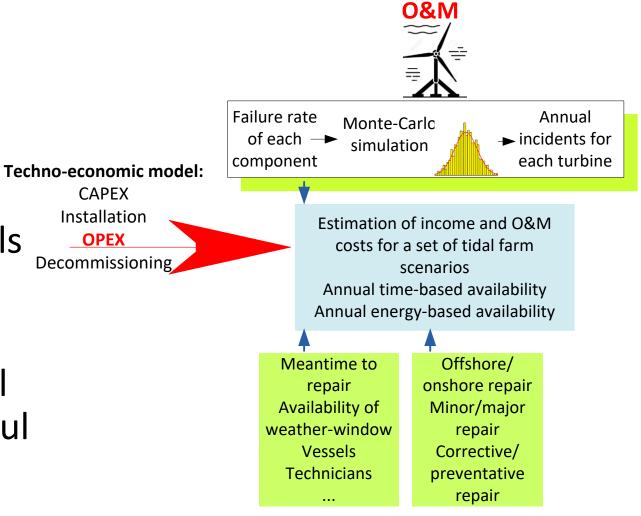
EUROPEAN UNION

Operation and Maintenance (O&M) Model Mitra Kamidelivand University College Cork



Impact of O&M model

- The O&M model is useful for the assessment of tidal turbines' maintenance strategies and their costs.
- The model runs scenarios and details annual numbers of fails, downtime hours and energy, vessel costs, etc.
- These quantify the reliability of tidal turbines at all stages which are useful for the asset owners, device designers and developers.





Outputs & lessons learned

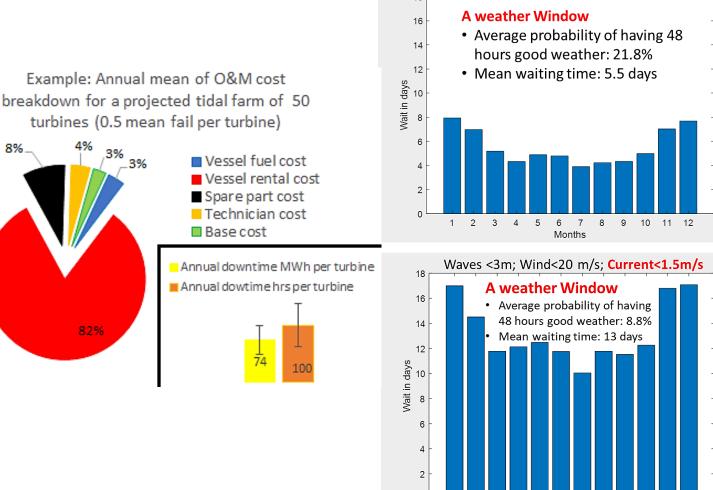
Waves <3m; Wind<20 m/s; Current<2m/s

1 2 3 4 5

6 7 8 9 10 11 12

Month

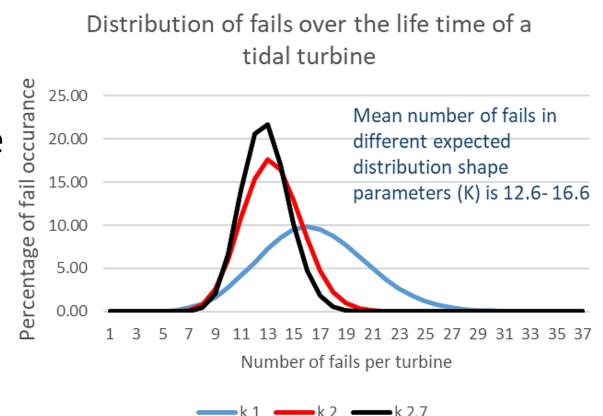
- An iterative approach to the O&M analysis can inform the decisions about the direction for reliability improvements.
- Weather window limits should consider a max wave height but also wave period, wind speed and current speed.





Research highlight

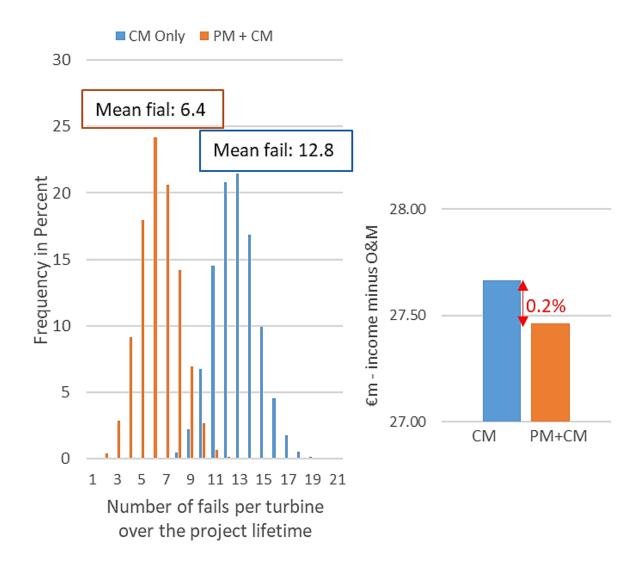
- Decreasing the uncertainty in the number of fails a turbine experiences in its life, assists decision making about the turbine maintenance strategy.
- This will increase the accuracy of the forecasting of the cost of energy for tidal turbines.





Research highlight

- Compared to only corrective maintenance (CM), preventative maintenance (PM) decreases the number of turbine fails by 50% in the example
- But PM+CM decreases the uncertainties/risk in project.







- Alpha version of the model is to be published in MONITOR Deliverables
- For this presentation, a paper is under preparation
- Contact: <u>mitra.kamidelivand@ucc.ie</u>

REALTIDE



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 727689





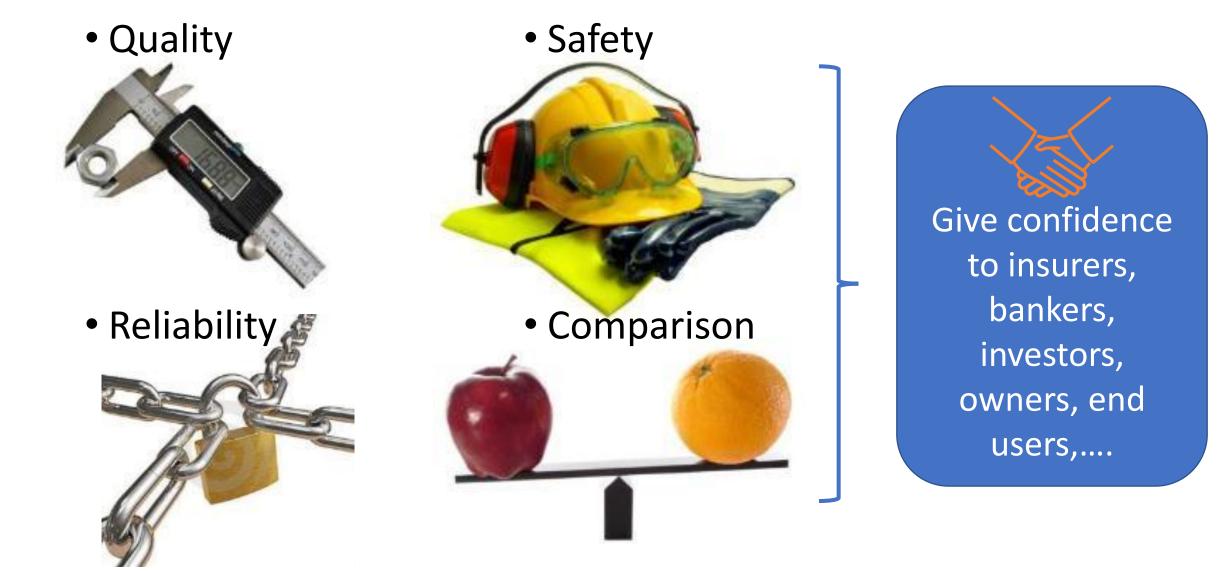
EUROPEAN UNION

MONITOR

Standardisation Stéphane Paboeuf Bureau Veritas Marine & Offshore



Why asking for standardisation?





Existing standards

- IEC TC114 IEC 62600 series Marine energy - Wave, tidal and other water current converters
 - Design requirements
 - Mooring system
 - Electrical power quality
 - Acoustic characterization
 - Resource assessment and characterization
 - Power performance assessment
 - Testing
- DNVGL-ST-0164, DNVGL-SE-0163
- BV NI603, NI631
- EMEC Guidelines
- EQUIMAR Protocols









• MT 62600-200 is currently preparing the 2nd edition of the tidal power performance assessment TS

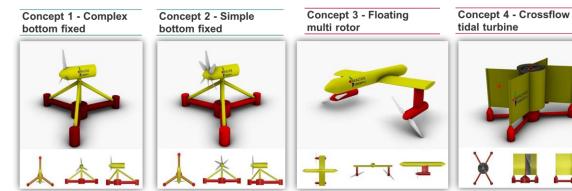
IEC

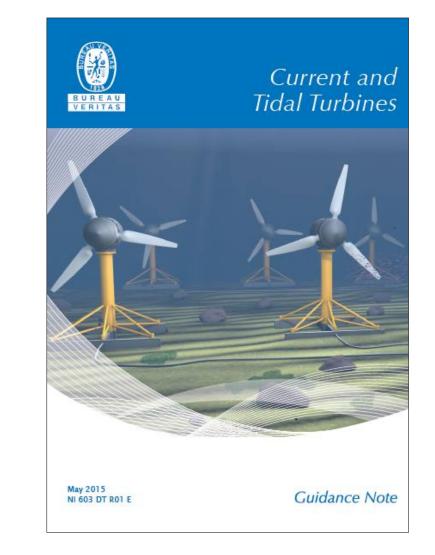
- MT 62600-201 is currently revising the 2nd edition of the tidal resource assessment and characterisation
- PT 62600-202 has been commented
- TS 62600-2 was published in November 2019, TS 62600-3 in May 2020 and TS 62600-30 in August 2018, none are currently being revised.



Bureau Veritas NI603

- Fatigue methodology for blade made in composite materials (WP1),
- Reliability database access (WP1),
- Condition monitoring protocol (WP4),
- Testing procedures (WP4),
- Calculation methods: analytical (BEMT) and numerical (CFD) (WP3 and WP5).

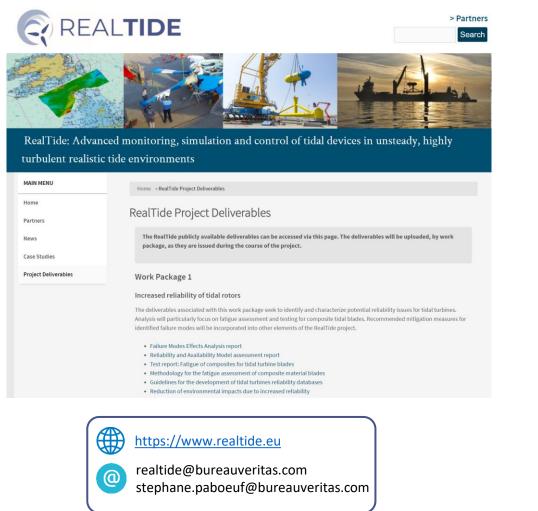






Public documents

• Public reports



Scientific Publications

Туре	Title	Authors	Title of the Journal/Pro c./Book
Poster	Keys to taming the cruel sea: Critical enabling steps towards commercial exploitation of unsteady flow, highly turbulent real tide environments	O. Benyessad, N. Larivière-Gillet, D. Ingram, B. Sellar, P. Mayorga, P. Salazar, E. Nicolas,	ICOE2018
Conference	Reliability of Composite Tidal Turbine Blades	M. Arhant, Peter Davies, S. Paboeuf, and E. Nicolas	ICCM22
Conference	Improving reliability of tidal turbines: a new step by step methodology for initial quantification of criticality and recommendations	Vincent P. LE Diagon, Pedro M. Mayorga, Ana I. Mayorga, Ningxiang Li,	EWTEC2019
Conference	Tide-to-wire Model Development for Realistic Tide Environments	Joseph Praful Tomy, Marios C. Sousounis, Stéphane Paboeuf, and Jonathan K. H. Shek	EWTEC2019
Conference	Currents, wave and turbulence measurements: a view from multiple industrial- academic projects in tidal stream energy	M. Dorward, B. Sellar; C. Old; P. R. Thies	IEEE-OES
Conference	Implications of asymmetric beam geometry for convergent acoustic Doppler profilers	Harding S, M. Dorward, B. Sellar, M. Richmond	IEEE-OES
Journal	Dynamic, Fully Coupled, Electro-mechanical Models of Tidal Turbines	Arturo Ortega; Joseph Praful Tomy; Jonathan Shek; Stephane Paboeuf; David Ingram	Journal Energies
Journal	Field validation of an actuated convergent-beam acoustic Doppler profiler for high resolution flow mapping	S. Harding, M. Dorward, B. Sellar, M. Richmond	Journal of Measurement
Journal	Single-beam acoustic Doppler profiler and co-located acoustic Doppler velocimeter flow velocity data	M Jourdain de Thieulloy, M Dorward, C Old, R Gabl, T Davey, DM Ingram,B. Sellar	Journal Data
Journal	On the use of a single beam acoustic current profiler for multi-point velocity measurement in a wave and current basin	M Jourdain de Thieulloy, M Dorward, C Old, R Gabl, T Davey, DM Ingram, B. Sellar	Journal Sensors
Conference	Application of ply-by-ply fatigue analysis methodology in the design of a full-scale tidal turbine blade	Joseph P. Tomy, Luc Mouton, Stéphane Paboeuf, Mael Arhant,	EWTEC2021
Conference	Material and structural testing to improve composite tidal turbine blade reliability	P. Davies, M. Arhant, N. Dumergue, E. Nicolas, S. Paboeuf, P. Mayorga	EWTEC2021
Conference	Experimental assessment of the loads to which tidal turbines are subjected using conditions derives from field measurements	D. Ingram et al.	EWTEC2021
Conference	Increased Reliability of tidal turbines thanks to a better knowledge of realistic tidal conditions, use of RAM analysis, advanced monitoring, maintenance strategies and intelligent design components	Vincent LE DIAGON, Pedro Mayorga, Manunnggal Sukendro, Ningxiang Li,	EWTEC2021

REALTIDE



This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 727689





EUROPEAN UNION

MONITOR

Reality bites: the challenge of adapting your device in a real site Erwann NICOLAS SABELLA SA



Tidal turbine environment

- Operation in harsh environment:

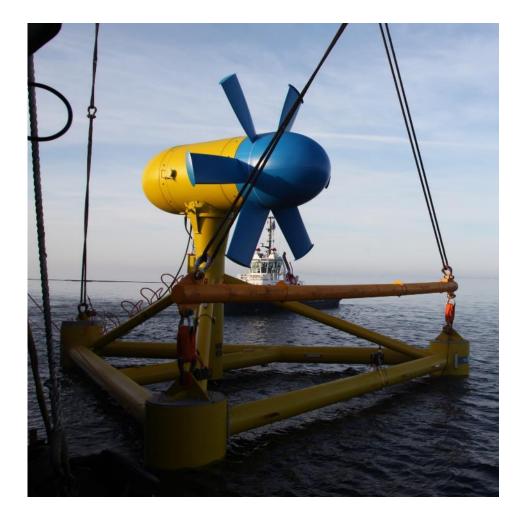
- high currents,
- waves
- unsteady flow,
- fouling, abrasion....

- Installed on seabed:

- no internal inspection possible, supervision by sensors,
- no on-site repairs.

- Specific conditions for each site:

- Current velocity, wave high, turbulence intensity → power production, extreme loads, fatigue loads
- Bathymetry \rightarrow size of rotor
- Water temperature \rightarrow cooling, type of fouling





lessons learned

- A minor failure can require the turbine to be retrieved and repaired onshore;
- The turbine retrieval requires an expensive offshore operation with a DP vessel with a high crane capacity;
- Few weather windows for offshore operations (during neap tide, with good waves conditions): risk of long downtime for maintenance.

Reliability represents a key factor in the tidal turbine business model, particularly for OPEX (limiting maintenance operations) and revenues (reducing downtime).





Reliability assesment

- FMEA → Define a list of equipment failure modes with effects on tidal operation,
- RAM assessment → Define global system reliability and identify critical components to improve design and/or monitoring
- VMEA → Understand the influence of uncertainties on components designed for a specific site (blades)

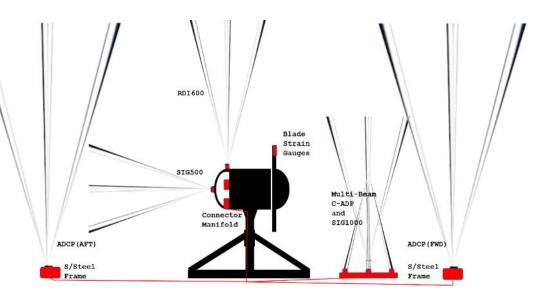


Sub-	Assembly	RAM	Failure	МТ	TR (Hou	ırs)	Production
system	Assembly	Component rate		Major	Minor	Trivial	Impact
tem	Nacelle	Nacelle Body	1.13%	1.69%	0.14%	0.01%	100%
mic Sys	Rotor	Blades	8.50%	1.69%	0.18%	0.02%	100%
Hydrodynamic System	ROLOF	Pitch System	17.07%	1.21%	0.16%	0.01%	100%
Hydı	Yaw	Yaw	11.33%	1.69%	0.13%	0.01%	50%



adapting to the environment

- Each site is different, need a high level of flow characterisation to adapt design and control of turbines
 - Adapt blade design to maximise power capture
 - Characterise the influence of unsteady flow on power variation and on load fluctuation
 - Refine mission profile for fatigue assessment (foundation, blades)

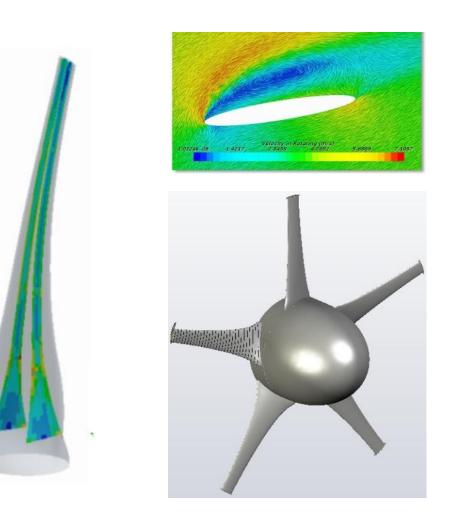








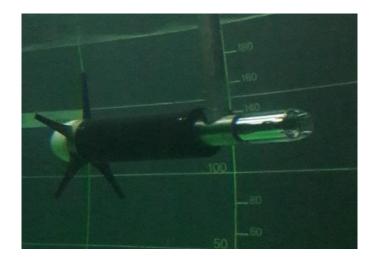
- BEMt \rightarrow preliminary rotor design
- Tide to wire model → optimisation of turbine control for the site, mission profile for electrical conversion components
- LCoE model → economical viability of the solution, design to cost
- CFD → blade design optimisation, pressure field for structural design





Lab testing

- Tank testing → check the rotor characteristic (Performance, thrust, TSR), define influence of current + waves + turbulences on blade loads
- Prototype blade test → check the blade behaviour with static and fatigue loads to validate the structural design

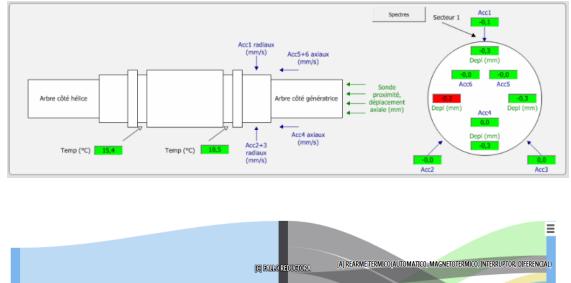


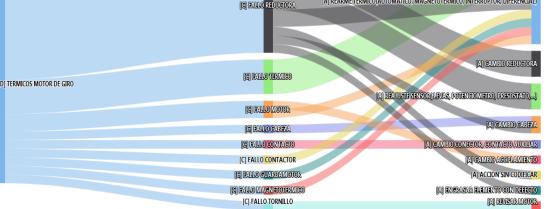




Monitoring

- Define an adapted monitoring technique to measure the critical parameter on each critical component
- Develop a SCADA analysis to detect failure by measuring variation on monitored parameters
- Detection of failure before it occurs, avoid unexpected maintenances and prepare preventive maintenance





Part 4

Panel Discussion and Questions – 15mins