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International Standards Development for Marine and Hydrokinetic Renewable Energy

Marine Energy Classification Systems

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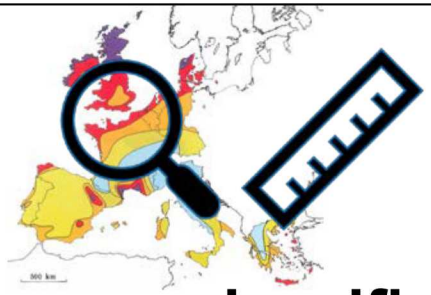
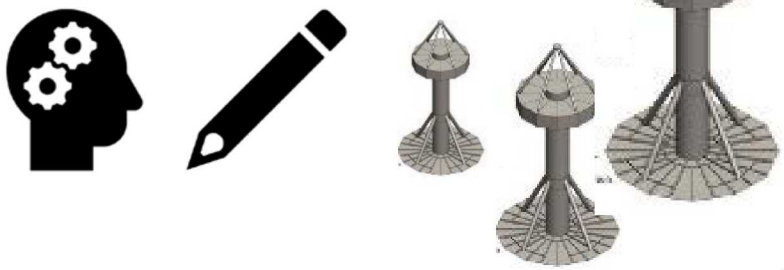
Motivation/Goal

Build MRE classification systems, resource and conditions, that, like wind, codify and support resource assessment and design for wave and tidal energy devices



Resource classification systems – support project siting, feasibility, and scoping studies, regional energy planning

Conditions classification systems – codify and streamline device design and manufacturing



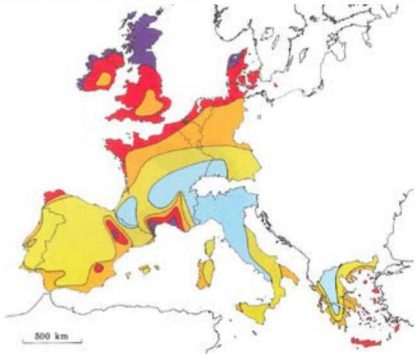
Wind Classification Systems: Reference Guides

- Wind resource classification systems
  - Support siting and resource assessment for project development
  - Main parameter, power density (W/m^2)
- Wind conditions classification systems, IEC 61400-1
  - Codify and streamline design process
  - Establish standard wind turbine design classes to streamline product line for developers
  - Main parameter, reference wind speed, V_{ref} (m/s), Class I, II, III
  - Subclass parameter turbulence intensity, I_{ref}, Subclass A, B, C

European wind energy resource classification system [Troen & Petersen 1989]

Wind resources[1] at 50 metres above ground level for five different topographic conditions

	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400



INTERNATIONAL STANDARD IEC 61400-1

Wind turbines – Part 1: Design requirements

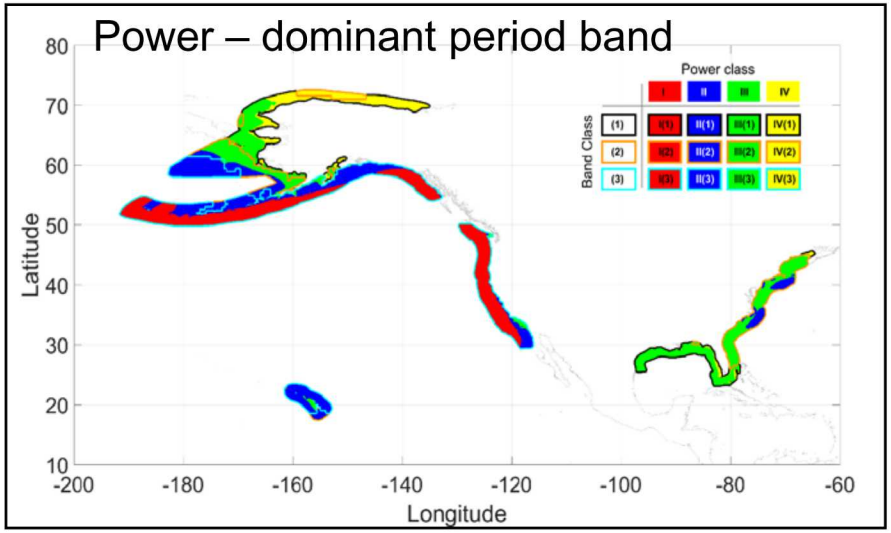
Wind turbine (conditions) classification system [IEC TS 61400-1:2019-02]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42.5	37.5	Values specified by designer
V_{avg}	(m/s)	10	8.5	7.5	
A I_{ref}	(-)	0.16 @ 15m/s			
B I_{ref}	(-)	0.14 @ 15m/s			
C I_{ref}	(-)	0.12 @ 15m/s			

Wave energy resource classification: Beta-version (Ahn et al. 2019)

- Main parameter, wave power, *J* (kW/m); Class I, II, III, IV
- Subclass parameter, T_p, peak period bandwidth, delineates three energy transfer mechanisms
  - 1, local wind seas, $0<T_P<7$
  - 2, short-period swell, $7<T_P<10$
  - 3, long-period swell, $10<T_P$
- Related standards
  - Wave resource assessment and characterization, IEC TS 62600-101:2015-06
  - WEC power performance assessment, IEC TS 62600-100:2012-08

Power class		I 22.8<*J*	II 5.7<J<22.8	III 1.1<J<5.7	IV *J*<1.1
1	$0<T_P<7$	I(1)	II(1)	III(1)	IV(1)
2	$7<T_P<10$	I(2)	II(2)	III(2)	IV(2)
3	$10<T_P$	I(3)	II(3)	III(3)	IV(3)



S. Ahn, K. A. Haas, V. S. Neary, Wave energy resource classification system for US coastal waters, *Ren & Sust Energy Rev,* 104, 54-68, 2019. https://doi.org/10.1016/j.rser.2019.01.017

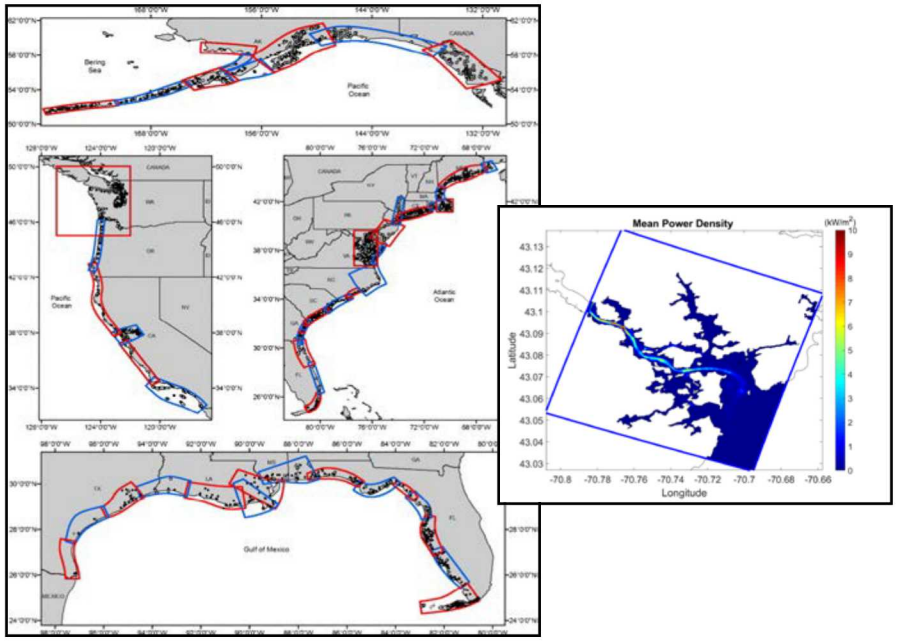
Tidal energy resource classification: Concept (strawman)

- Main parameter, tidal power density, P (W/m^2); Class I, II, III

$$P = \frac{1}{2}\frac{1}{N}\rho\sum_{j=1}^{N} U_j^3$$

- Subclass parameter TBD, *A*, a constraint on the theoretical resource
  - Multiple levels TBD
- Related standards
  - Tidal resource assessment and characterization, IEC TS 62600-201:2015-04
  - TEC power performance assessment, IEC TS 62600-200:2013-05

POWER CLASS		I 2<*P*	II 1≤*P*≤2	III 0.5<*P*<1
1	TBD	I(1)	II(1)	III(1)
2	TBD	I(2)	II(2)	III(2)
3	TBD	I(3)	II(3)	III(3)

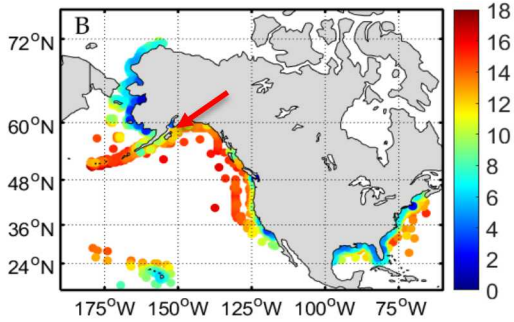


Z. Defne et al., "National geodatabase of tidal stream power resource in USA," *Renew Energy*, 16(5), pp. 3326-3338, 2012.

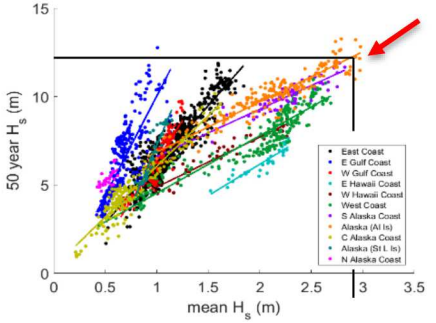
Wave conditions classification: Concept (strawman)

- Main parameter, $H_{s(ref)} = H_{s(50)}$ (m), 50-year return H_s, Class I, II, III
- Note $H_{s(mean)} = CH_{s(50)}$ for distinct wave climates
- Subclass parameter, T_p, peak period bandwidth, delineates three energy transfer mechanisms (normal operations)
  - 1, local wind seas, $0<T_P<7$
  - 2, short-period swell, $7<T_P<10$
  - 3, long-period swell, $10<T_P$
- Related technical specs, standards
  - Design requirements for marine energy systems, IEC TS 62600-2:2016-08
  - Environmental conditions & environmental Loads, DNV-RP-C205:2014

WEC class		I	II	III	S
$H_{s(ref)}$ (m)		15	10	5	**Values specified by designer**
1	T_p (s)	$0<T_P<7$			
2	T_p (s)	$7<T_P<10$			
3	T_p (s)	$10<T_P$			



Geographical distribution of Hs50 (m) for US Coast [Neary et al. 2019];
Alaska site, $H_{s(50)}$~12 m



Regional correlations extreme and mean wave heights [Neary et al. 2017];
Alaska site, $H_{s(mean)}$~2.8 m
T_p band is Class 3

$H_{s(ref)}$(site) ~ 12 m
T_p (site)~Class 3
→ SITE **CLASS I(3)**

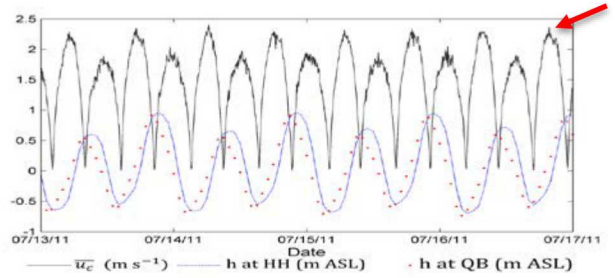
Extreme DLC based on $H_{s(ref)}$ = 15 m

Normal DLC based on $H_{s(mean)}$ = 2.8 m, $10<T_p$

Tidal conditions classification: Concept (strawman)

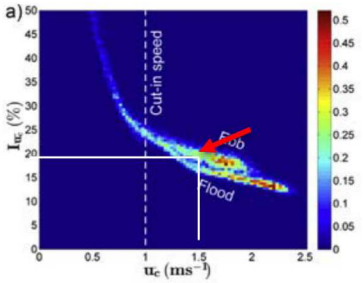
- Main parameter, V_{ref} (m/s), max,3-min avg current for extreme design load case (DLC); Class I, II, III
- Subclass parameter, I_{ref}, turbulence intensity @ 1.5 m/s
  - A, high, $0.15 < I_{ref} \leq 0.20$
  - B, moderate, $0.10 < I_{ref} \leq 0.15$
  - C, low, $I_{ref} \leq 0.10$
- Related technical specs, standards
  - Design requirements for marine energy systems, IEC TS 62600-2:2016-08
  - Environmental conditions & environmental Loads, DNV-RP-C205:2014

TEC class		I	II	III	S
V_{ref}	(m/s)	3.5	2.5	1.5	Values specified by designer
A	I_{ref} (-)	0.20 @ 1.5 m/s			
B	I_{ref} (-)	0.15 @ 1.5 m/s			
C	I_{ref} (-)	0.10 @ 1.5 m/s			



RITE site, East River: Variation of hub height mean current speed - black (Gunawan, Neary and Colby 2014)

V_{ref}(site) ~2.4 m/s



RITE site, East River: Variation of hub height turbulence intensity with mean current speed (Gunawan, Neary and Colby 2014)

I_{ref}(site) ~0.18

V_{ref}(site) ~ 2.4 m/s
I_{ref} (site)~0.18
RITE SITE **CLASS IIA**

Design for V_{ref} = 2.5 m/s, I_{ref}=0.20

Conclusions

- Wave and tidal classification systems modeled after wind
- Two types of classification, *resource* and *conditions*
- Technology agnostic classification matrices based on 1-2 parameters
- Classification systems must conform to and harmonize with IEC TC 114 standards on resource assessment, design and power performance assessment – most maintenance teams scheduling 2020 for completion
- Value of classification systems only fully realized by codification within IEC TC 114 standards

Next steps

- Document for Comment (DC) to National Committees for consideration ~2 months after the 2019 Plenary Meeting by correspondence, 30 June 2019
- Socialize classification and identify similar efforts in other TC 114 countries – Conference paper and presentation EWTEC, Naples, 1-6 September 2019.
- Based on National Committee comments, consider next steps, e.g.,
  - Work with the US TAG to develop a formal proposal following completion of technical work (by US TAG face-to-face in November, 2019, date TBD)
  - Work with respective Working Groups and the Strategic Business Plan Task Force, assuming it is reformed in 2020.

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THANK YOU

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