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Marine energy classification systems: Tools for resource assessment and design

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VERDANT POWER

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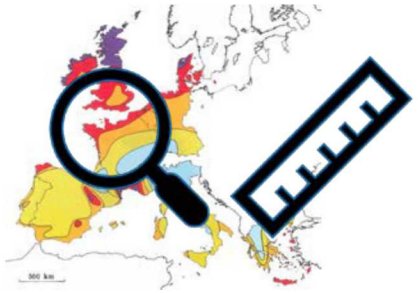
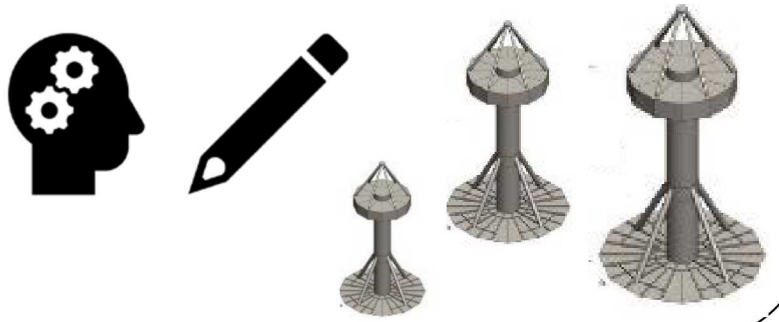
Motivation/Goal

Build marine energy classification systems that, like wind, codify and support resource assessment, design and device-type certification for wave and tidal energy devices



Project (resource attributes) classification – support project siting, feasibility, and scoping studies, regional energy planning

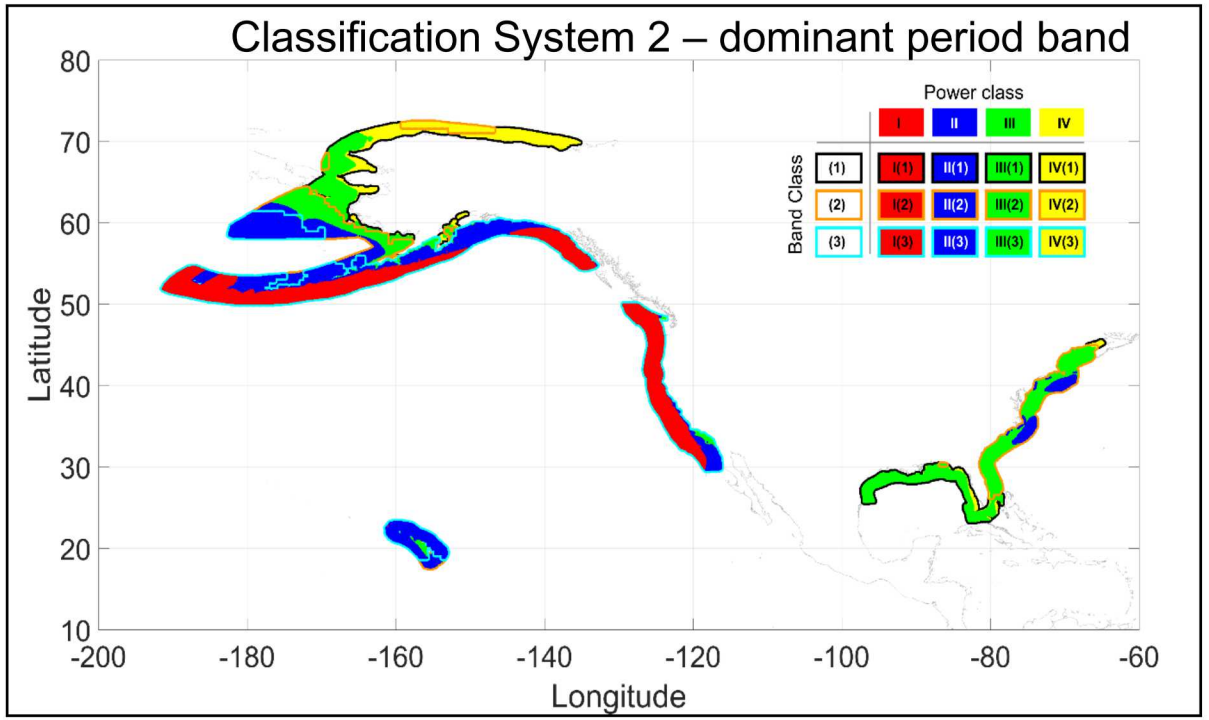
Device (resource conditions) classification – codify and streamline device design, device-type certification, product-line development and manufacturing



Wave project (resource attributes) classification

- Main parameter, wave power, J (kW/m); Class I, II, III, IV
- Subclass parameter, T_p, peak period bandwidth, delineates three WEC resonant bandwidths
  - 1, local wind seas, $0<T_P<7$
  - 2, short-period swell, $7\leq T_P \leq 10$
  - 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 $5.7<J\leq22.8$	III $1.1<J\leq5.7$	IV $J\leq1.1$
1	$0<T_P<7$	I(1)	II(1)	III(1)	IV(1)
2	$7\leq T_P\leq10$	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

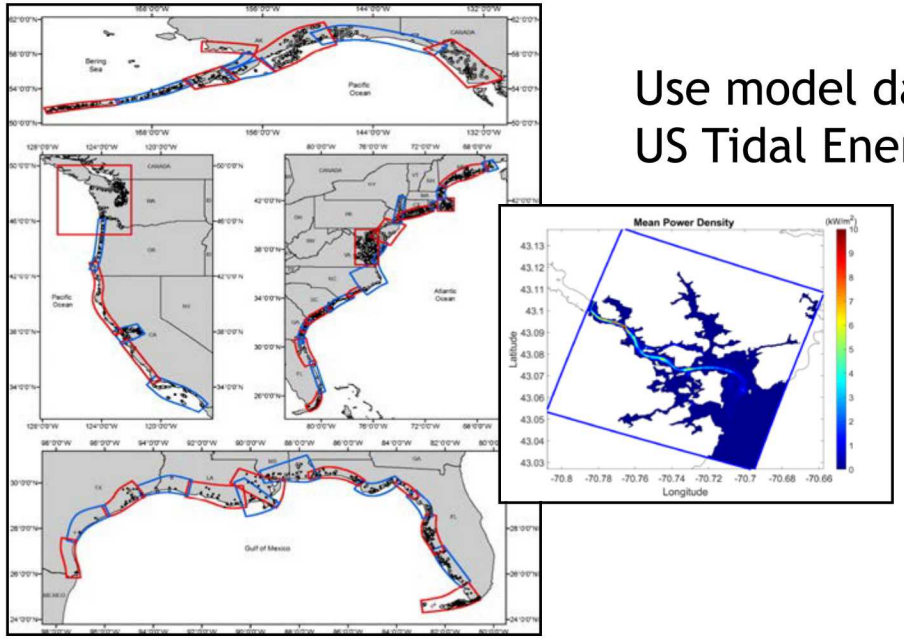
Tidal project (resource attribute) classification: Preliminary

- Main parameter, tidal power density, P_m (kW/m^2); Class I, II, III, IV

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

- 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 $P \geq 2$	II $1 \leq P < 2$	III $0.5 \leq P < 1$	IV $P < 0.5$
1	$A > TBD$	$I(1)$	$II(1)$	$III(1)$	$IV(1)$
2	$TBD \leq A < TBD$	$I(2)$	$II(2)$	$III(2)$	$IV(2)$
3	$A < TBD$	$I(3)$	$II(3)$	$III(3)$	$IV(3)$

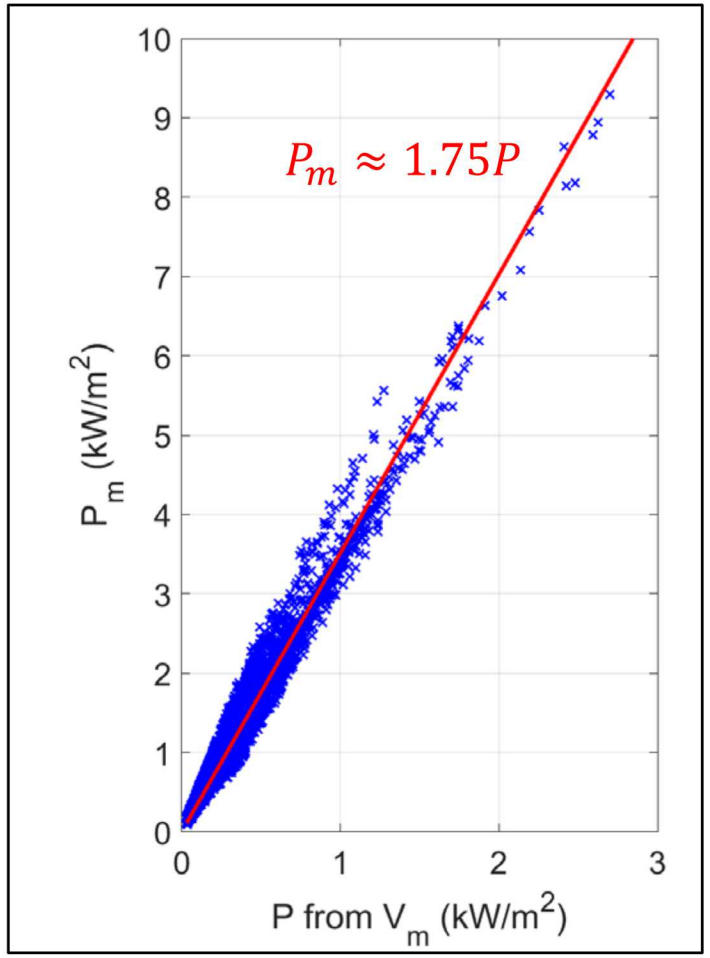


Use model data from US Tidal Energy RA

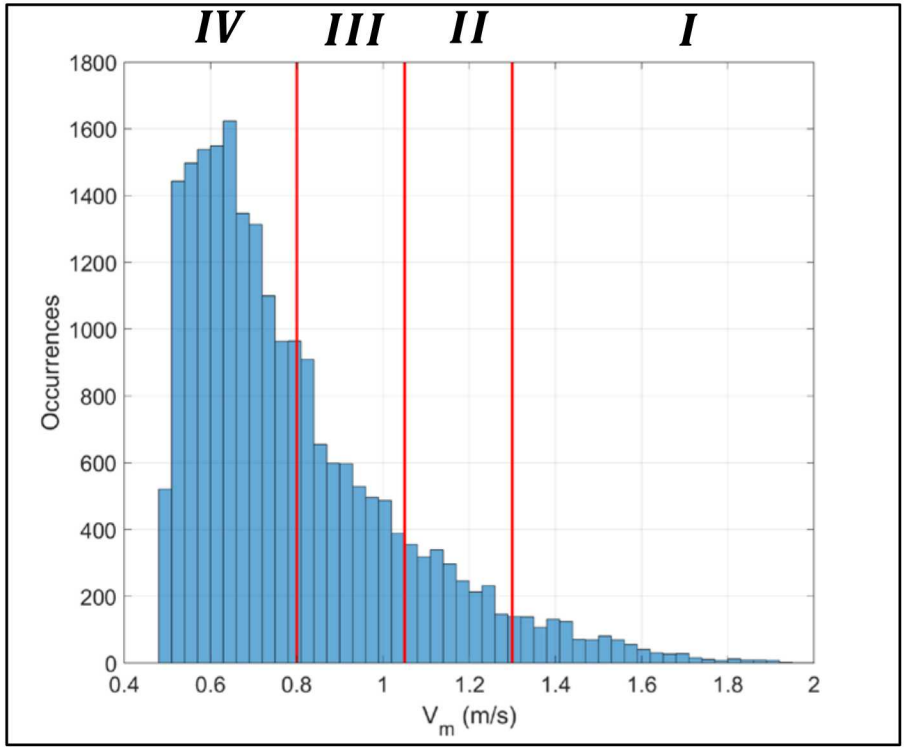
Z. Defne et al., "National geodatabase of tidal stream power resource in USA," *Renew Energy*, 16(5), pp. 3326-3338, 2012.

Tidal project (resource attribute) classification: Preliminary

- Relate the mean power (P_m) to the mean velocity (V_m)

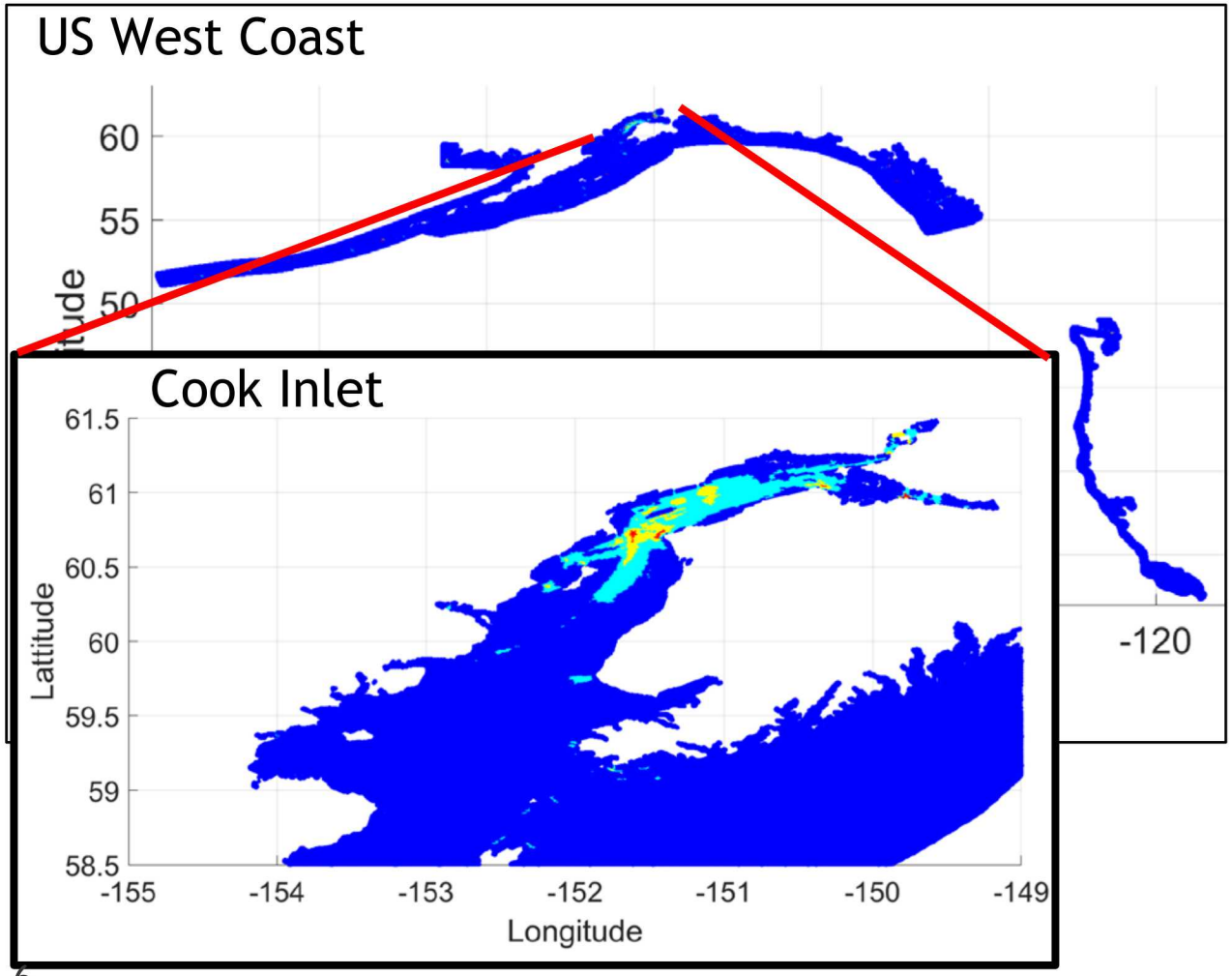


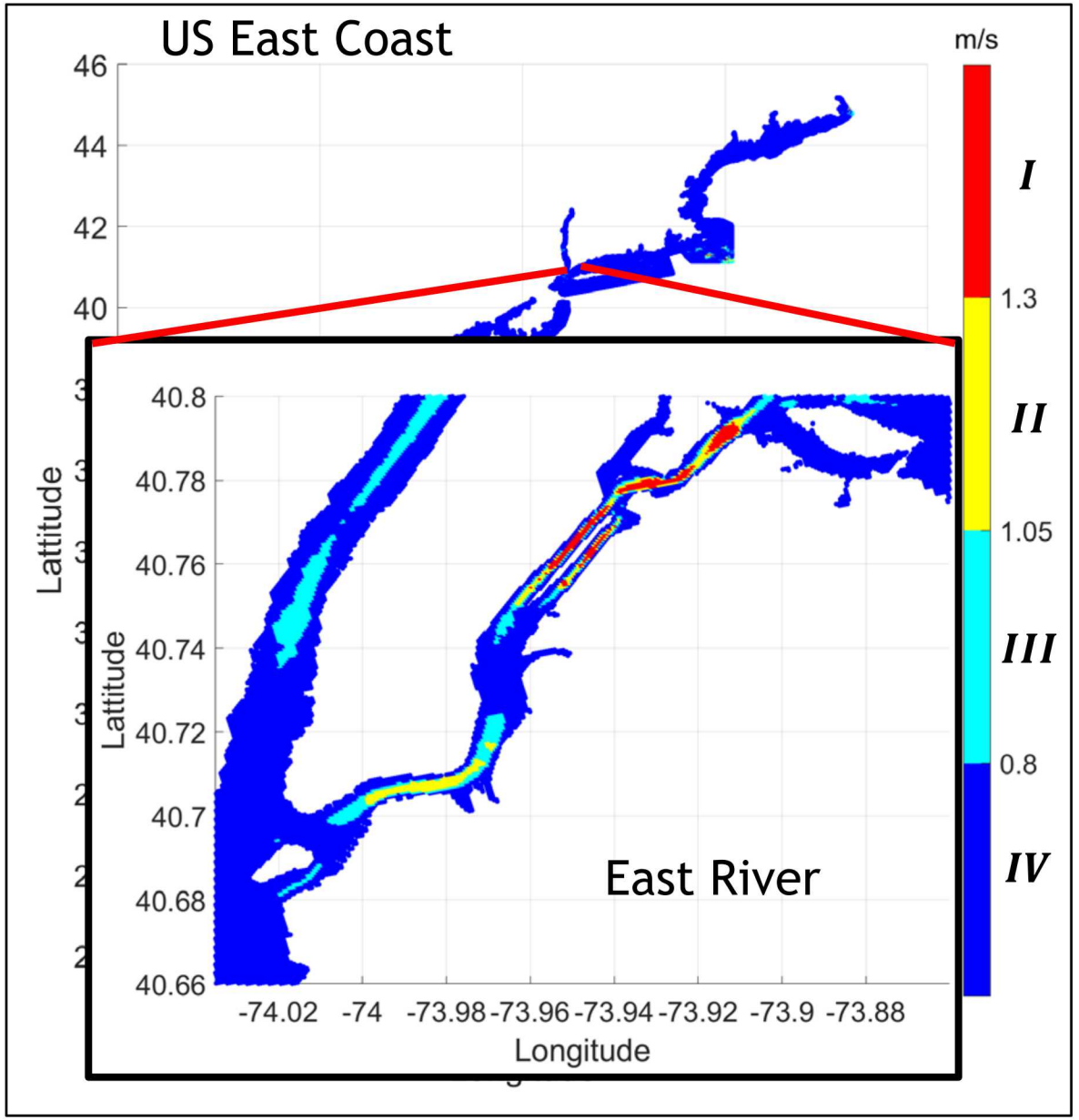
Power Class		I $P \geq 2$	II $1 \leq P < 2$	III $0.5 \leq P < 1$	IV $P < 0.5$
Mean Velocity		$V_m \geq 1.3$	$1.05 \leq V_m < 1.3$	$0.8 \leq V_m < 1.05$	$V_m < 0.8$
1	$A > TBD$	$I(1)$	$II(1)$	$III(1)$	$IV(1)$
2	$TBD \leq A < TBD$	$I(2)$	$II(2)$	$III(2)$	$IV(2)$
3	$A < TBD$	$I(3)$	$II(3)$	$III(3)$	$IV(3)$



Classes can be delineated based on the mean velocity

Tidal project (resource attribute) classification: Preliminary

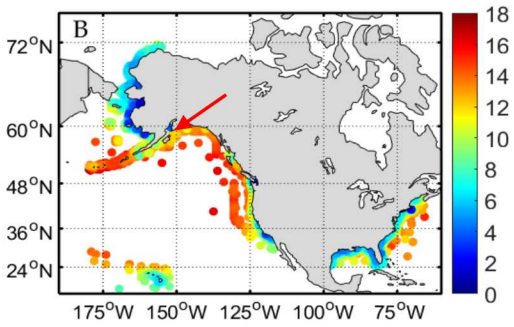




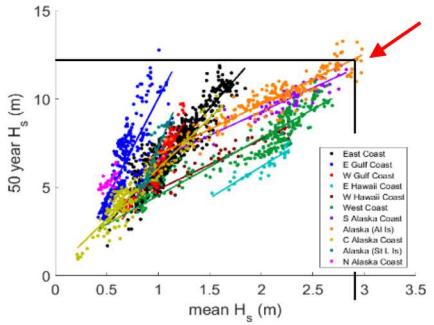
Wave device (conditions) classification: Concept (strawman)

- 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

Class		I	II	III	S
H_{ref} (m)		15	10	5	Specified by designer
1	$0<T_P<7$	I(1)	II(1)	III(1)	
2	$7\leq T_P\leq 10$	I(2)	II(2)	III(2)	
3	$10<T_P$	I(3)	II(3)	III(3)	



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. 2018];
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)

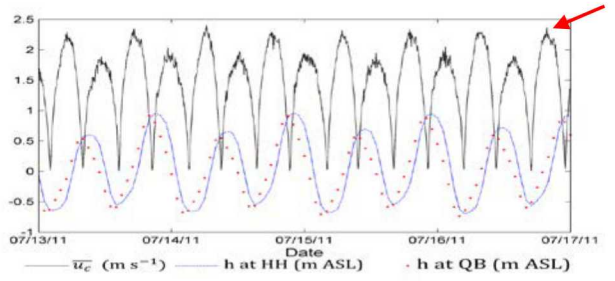
Extreme DLC based on $H_{s(ref)}$ = 15 m

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

Tidal device (conditions) classification: Concept (strawman)

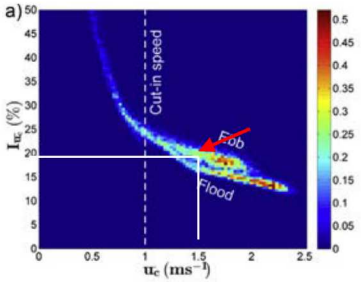
- Main parameter, V_{ref} (m/s), max,3-min avg current for extreme design load case (DLC); Class I, II, III
- Subclass parameter, I_{ref}, turbulence intensity @ 1.5 m/s
  - A, high, $0.15 < I_{ref} \leq 0.20$
  - B, moderate, $0.10 < I_{ref} \leq 0.15$
  - C, low, $I_{ref} \leq 0.10$
- Related technical specs, standards
  - Design requirements for marine energy systems, IEC TS 62600-2:2016-08
  - Environmental conditions & environmental Loads, DNV-RP-C205:2014
- FY20 studies:
  - Reviewing turbulence measurements database with NREL to identify trends
  - Standard method for determining maximum current speed, e.g., 1-percentile current

TEC Class		I	II	III	S
U_{ref} (m/s)		3.5	2.5	1.5	Specified by engineer
A	I_{ref} (-) @1.5 m/s	0.20			
B		0.15			
C		0.10			



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

Proposed motions

USTAG forms committee for planning incorporation of classification systems into standards

Maintenance teams consider incorporation of classification systems in standards during maintenance cycle:

- Design, TS 62600-2:2016-08
- Wave resource characterization, TS 62600-101:2015-06
- Tidal resource characterization, TS 62600-201:2015-04

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Thank you

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Marine energy - Wave, tidal and other water current converters - Part 100: Electricity producing wave energy converters - Power performance assessment, IEC TS 62600-100:2012-08.

Marine energy - Wave, tidal and other water current converters - Part 200: Electricity producing tidal energy converters - Power performance assessment, IEC TS 62600-200:2013-05.

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