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Marine energy classification systems: Tools for resource assessment and design

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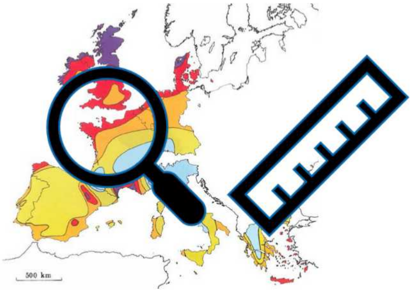
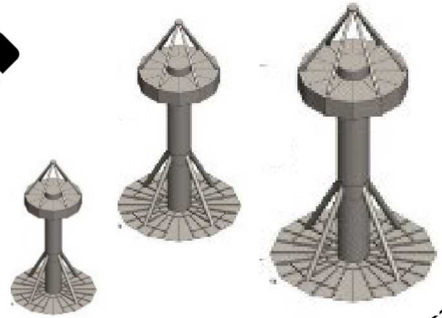
Motivation/Goal

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



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

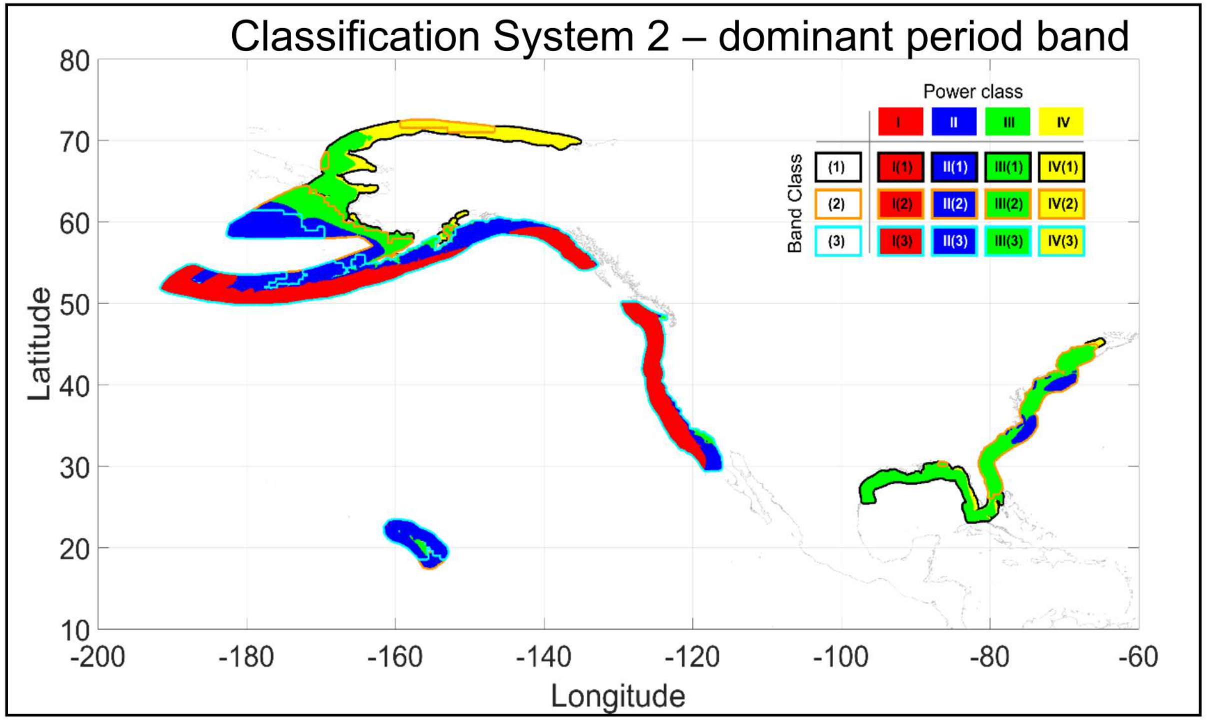
Device classification – codify and streamline device design, device-type certification, product-line development and manufacturing



Wave resource 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 $5.7<J\leq 22.8$	III $1.1<J\leq 5.7$	IV $J\leq 1.1$
1	$0<T_P<7$	I(1)	II(1)	III(1)	IV(1)
2	$7\leq T_P\leq 10$	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

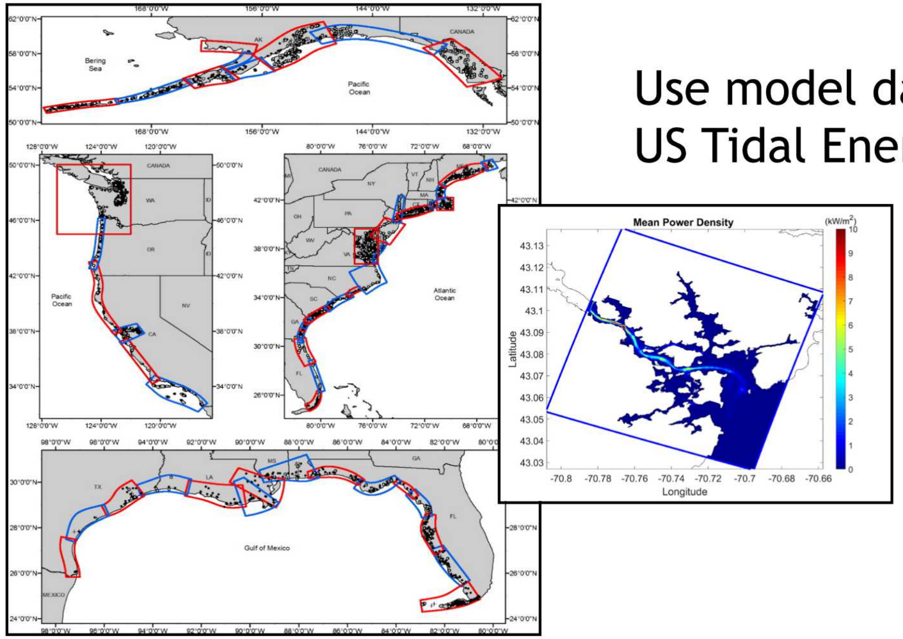
Tidal resource classification: Preliminary

- 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		$\boldsymbol{I}$ $\boldsymbol{P_m \geq 2}$	$\boldsymbol{II}$ $\boldsymbol{1 \leq P_m < 2}$	$\boldsymbol{III}$ $\boldsymbol{0.5 \leq P_m < 1}$	$\boldsymbol{IV}$ $\boldsymbol{P_m < 0.5}$
1	$\boldsymbol{A > TBD}$	$\boldsymbol{I(1)}$	$\boldsymbol{II(1)}$	$\boldsymbol{III(1)}$	$\boldsymbol{IV(1)}$
2	$\boldsymbol{TBD \leq A < TBD}$	$\boldsymbol{I(2)}$	$\boldsymbol{II(2)}$	$\boldsymbol{III(2)}$	$\boldsymbol{IV(2)}$
3	$\boldsymbol{A < TBD}$	$\boldsymbol{I(3)}$	$\boldsymbol{II(3)}$	$\boldsymbol{III(3)}$	$\boldsymbol{IV(3)}$



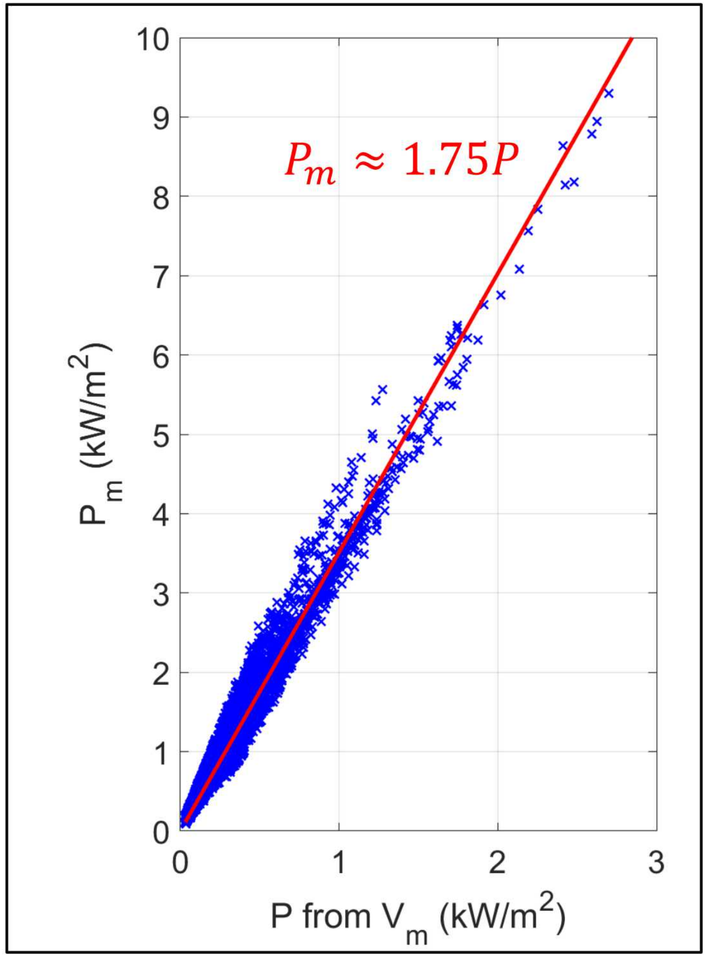
Use model data from US Tidal Energy RA

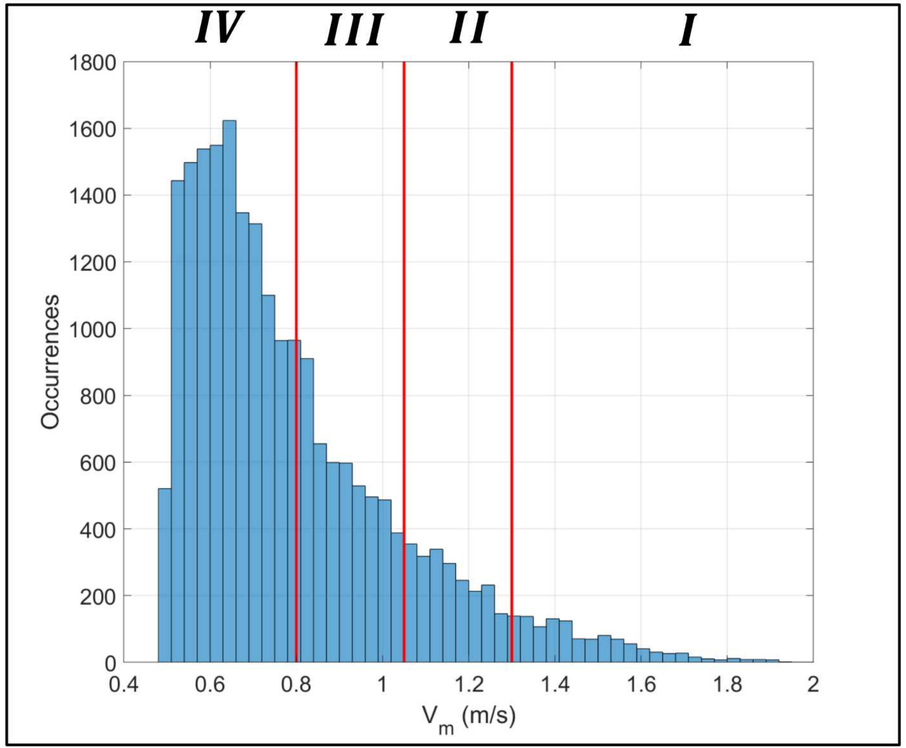
Z. Defne et al., “National geodatabase of tidal stream power resource in USA,” *Renew Energy*, 16(5), pp. 3326-3338, 2012.

Tidal resource classification: Preliminary

- Relate the mean power, P_m (kW/m^2) to the mean velocity, V_m (m/s)

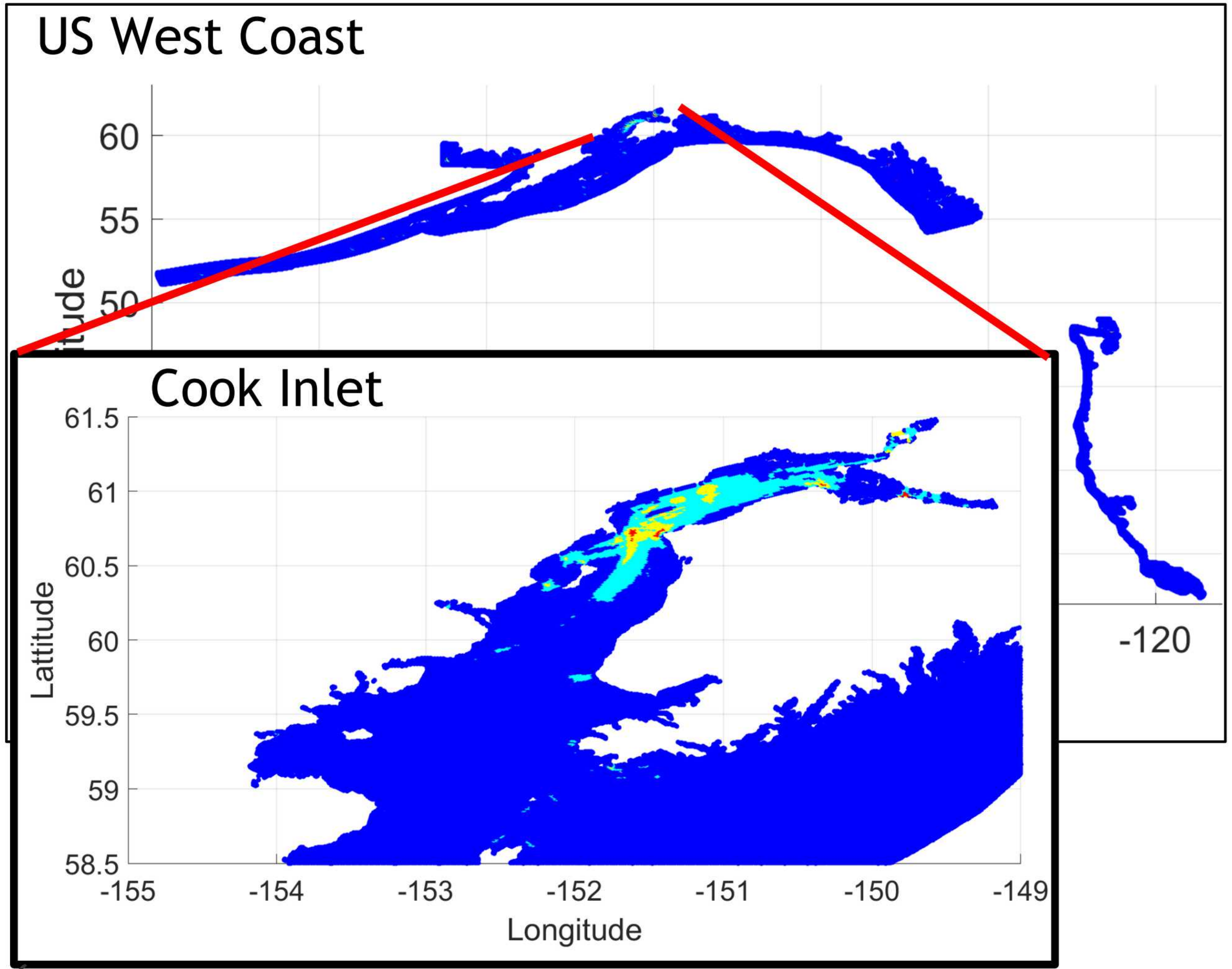
Power Class		I $P \geq 2$	II $1 \leq P < 2$	III $0.5 \leq P < 1$	IV $P < 0.5$
Mean Velocity		$V_m \geq 1.3$	$1.05 \leq V_m < 1.3$	$0.8 \leq V_m < 1.05$	$V_m < 0.8$
1	$A > TBD$	$I(1)$	$II(1)$	$III(1)$	$IV(1)$
2	$TBD \leq A < TBD$	$I(2)$	$II(2)$	$III(2)$	$IV(2)$
3	$A < TBD$	$I(3)$	$II(3)$	$III(3)$	$IV(3)$

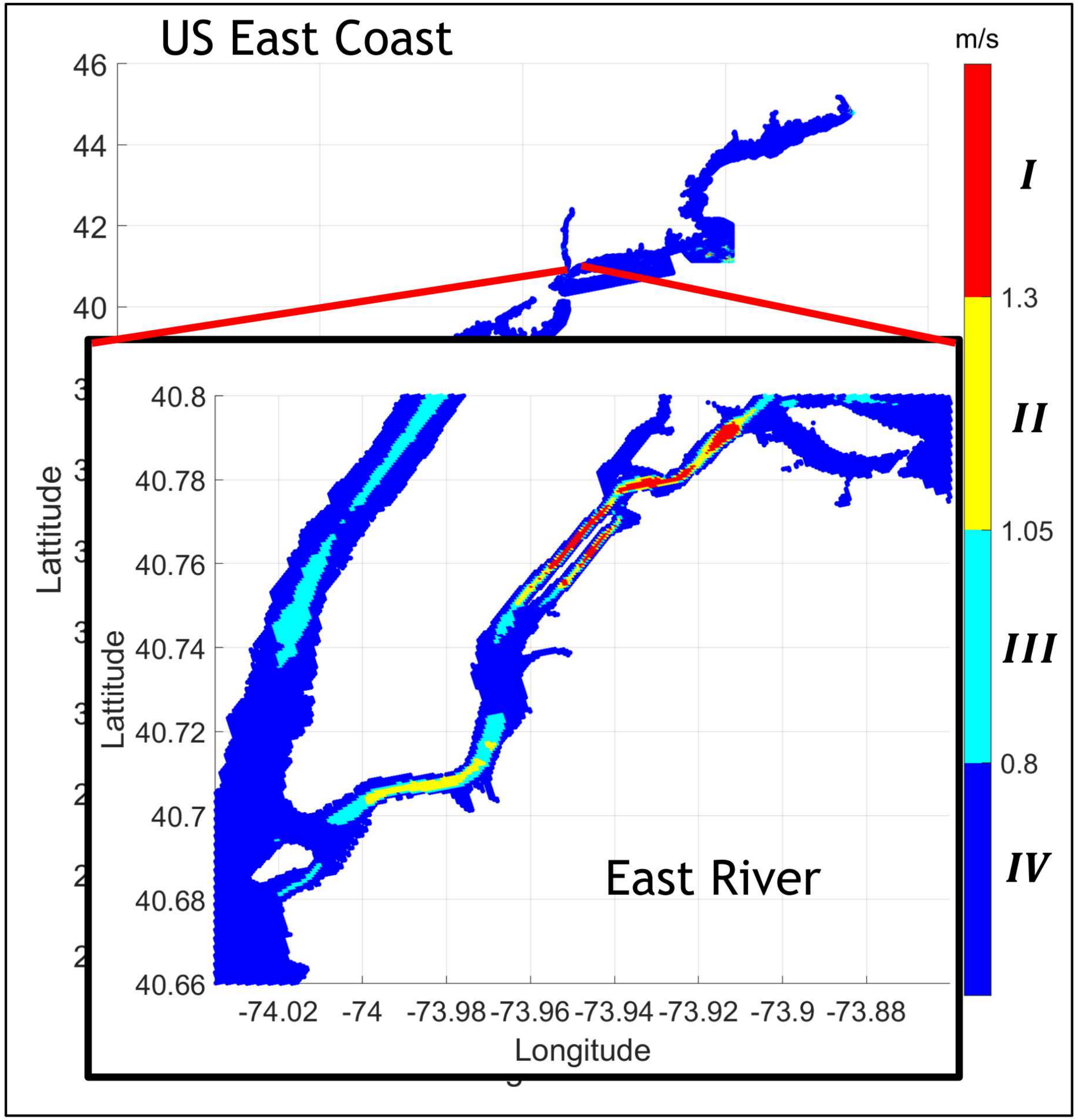




Classes can be delineated based on the mean velocity

Tidal resource classification: Preliminary

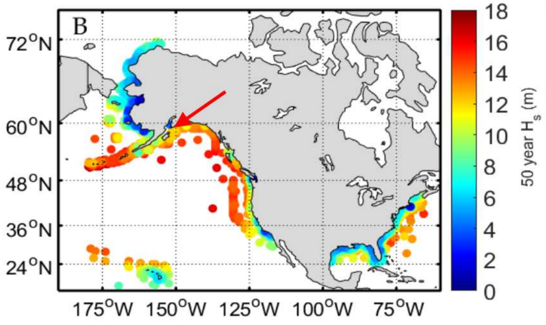




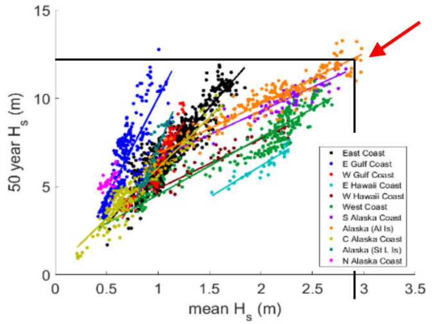
WEC classification: Preliminary

- 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)

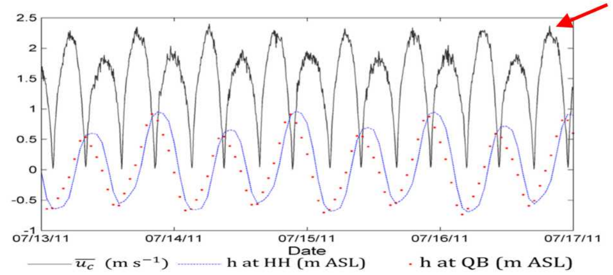
Extreme DLC based on $H_{s(ref)}$ = 15 m

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

TEC classification: Preliminary

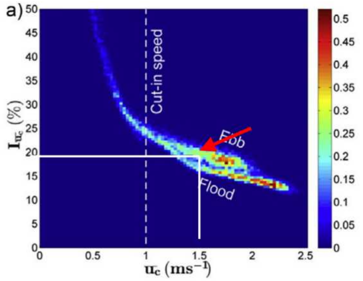
- Main parameter, V_{ref} (m/s), max,3-min avg current for extreme design load case (DLC); Class I, II, III
- Subclass parameter, I_{ref}, turbulence intensity @ 1.5 m/s
  - A, high, 0.15< $I_{ref} \leq 0.20$
  - B, moderate, 0.10< $I_{ref} \leq 0.15$
  - C, low, $I_{ref} \leq 0.10$
- Related technical 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

The US TAG is asked to endorse and deliver the following proposal to TC 114 for the integration of classification systems into standards. This proposal would be discussed and approved at the TC 114 Plenary Meeting in April 2020:

1) Update the Scope of Work of AHG 8 to include the integration of classification systems into TC 114 documents. AHG 8 would oversee the coordination and integration of classification systems across TC 114.

2) The following Maintenance Teams would consider incorporation of classification systems in their Technical Specifications during their maintenance cycle:

- MT 62600-2: Design, TS 62600-2:2019-10 {Ed. 2}
  - WAVE AND TIDAL CONDITIONS CLASSIFICATION
- MT 62600-101: Wave resource characterization, TS 62600-101:2015-06 {Ed. 1}
  - WAVE RESOURCE CLASSIFICATION
- MT 62600-201: Tidal resource characterization, TS 62600-201:2015-04 {Ed. 1}
  - TIDAL RESOURCE CLASSIFICATION

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Thank you

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P. Veers, private communication, Nov. 2018.

Marine energy - Wave, tidal and other water current converters - Part 2: Design requirements for marine energy systems, IEC TS 62600-2:2019-10.

Marine energy - Wave, tidal and other water current converters - Part 101: Wave energy resource assessment and characterization, IEC TS 62600-101:2015-06.

Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization, IEC TS 62600-201:2015-04.

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.

S. Ahn, K. A. Haas, V. S. Neary, "Wave energy resource classification system for US coastal waters," *Ren & Sust Energy Rev*, vol. 104, pp. 54-68, 2019.

Z. Defne et al., "National geodatabase of tidal stream power resource in USA," *Renew Energy*, vol. 16, no. 5, pp. 3326-3338, 2012.

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B. Gunawan, V. S. Neary, J. Colby, "Tidal energy resource assessment in the East River tidal strait near Roosevelt Island, New York, New York." Renew Energy, vol. 71, pp. 509-517, 2014.

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