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InVEST model demo: Renewable Energy (Wave Energy)

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WWF
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Some WEC Devices

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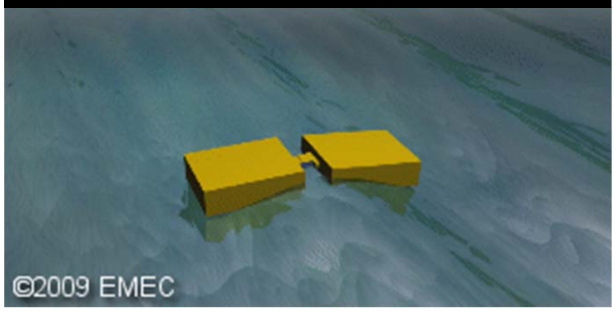
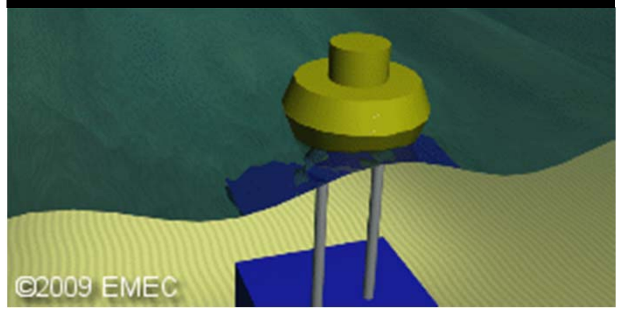
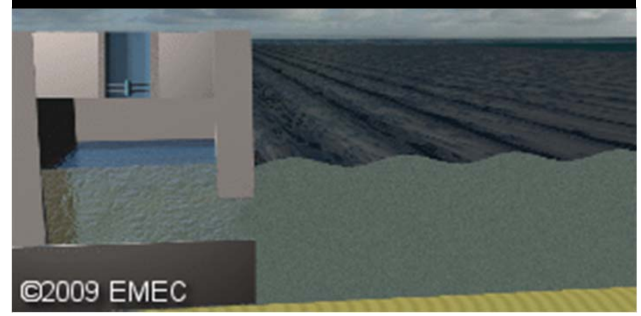
Attenuator



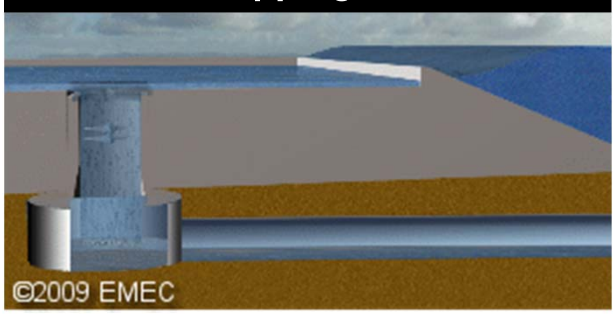
Point Absorber



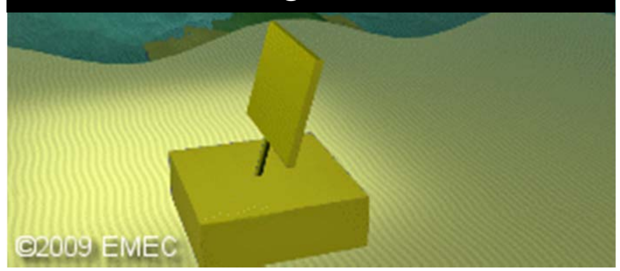
Oscillating Water Column



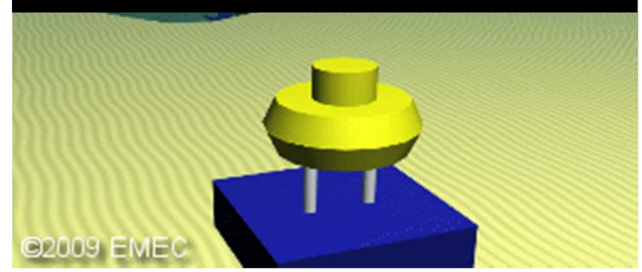
Overtopping Device



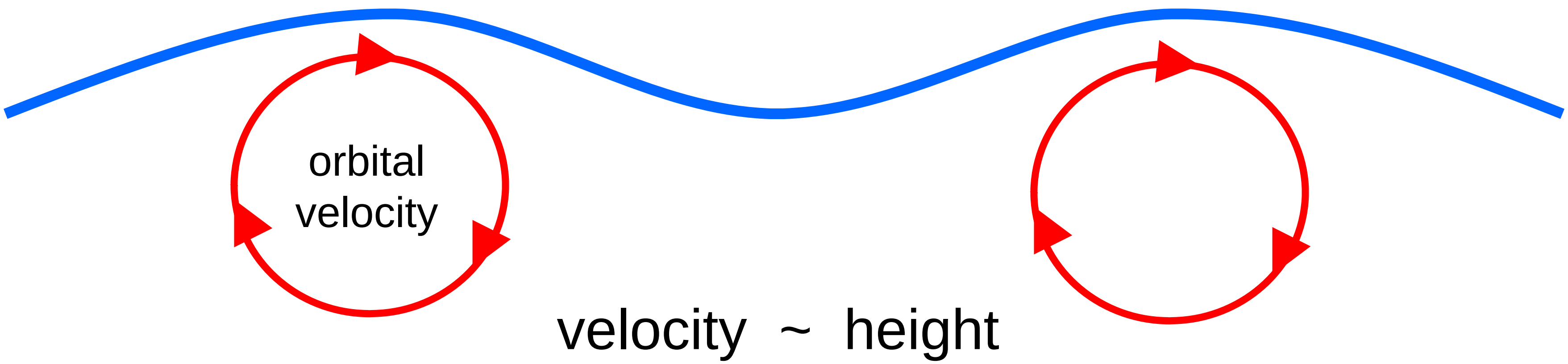
Oscillating Wave Surge Converter



Submerged Pressure Differential



About the Model



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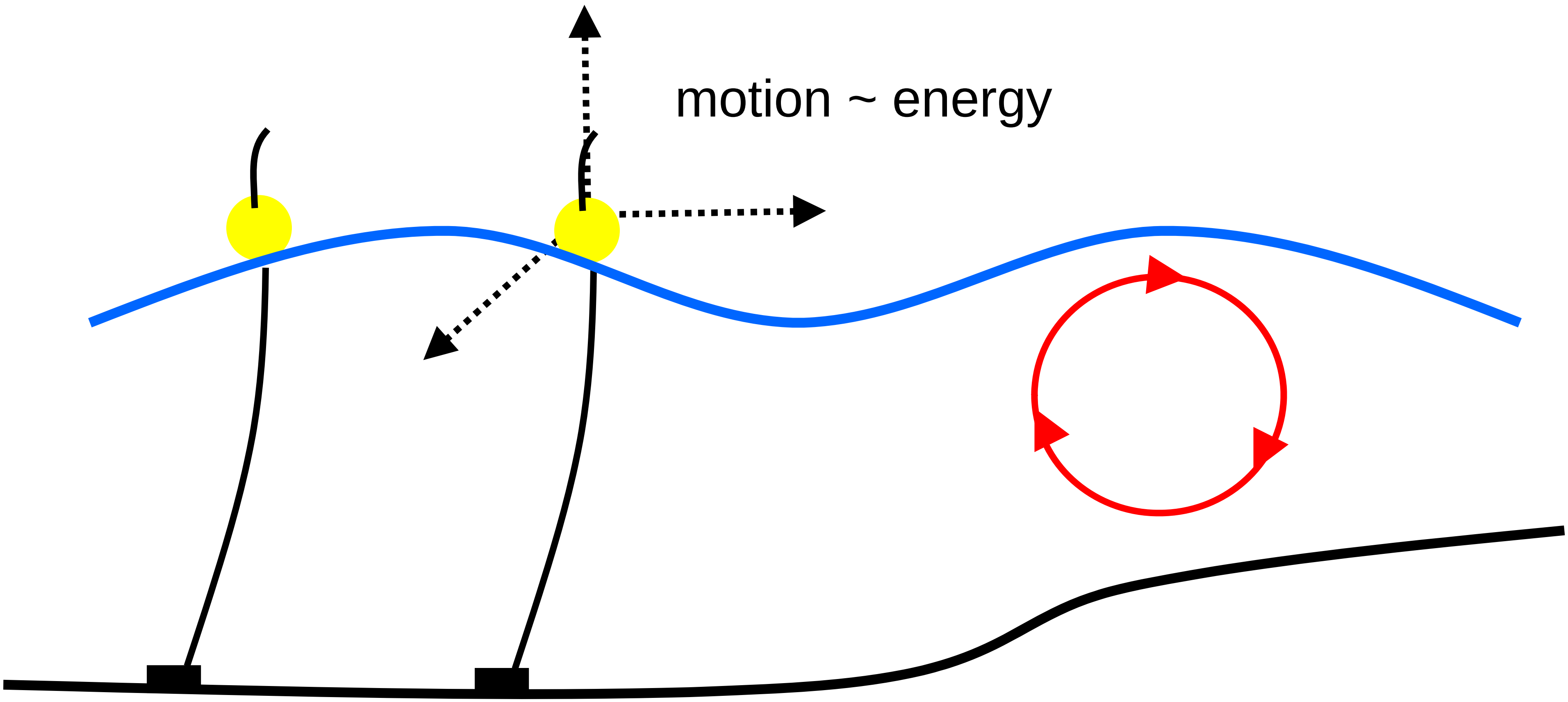

Renewable Energy: Waves

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Supply
Potential available

Service
Delivered to people

Value
Economic & social impacts

- Wave Power
- Captured Wave Energy
- Renewable electricity to grid + avoided emissions

Wave Energy Model (WEM)

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- To map and value wave energy resources
- To examine potential trade-offs
- To help decision-makers understand where best to install a WEC facility

WEM Inputs

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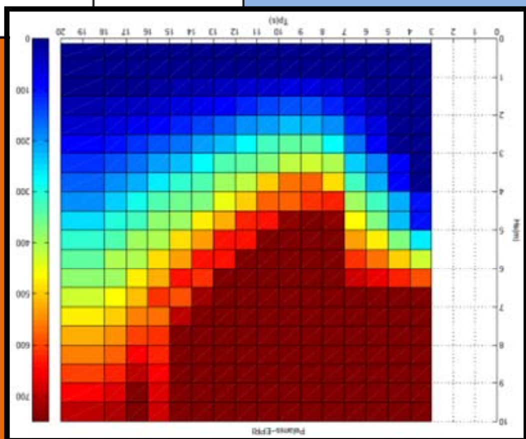
Inputs	Outputs

Sea state
wave height, period

Device operation
performance, limitations

Economic values
Cost of device, electricity, maintenance, accessibility of grid

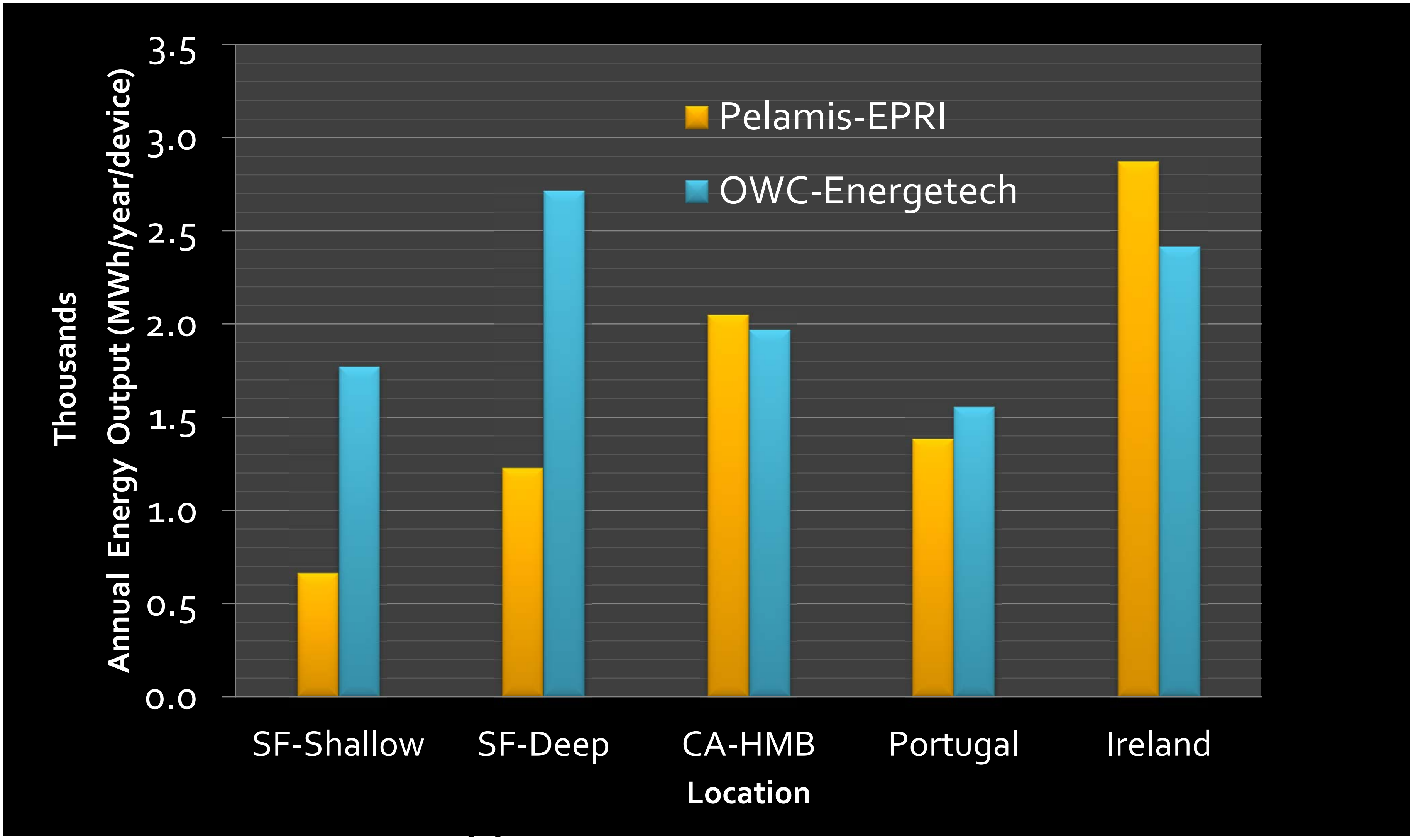
Performance and Parameters



				Wave Period (T_p) in sec						
				4.0	5.0	6.0	7.0	8.0	9.0	10.0
				0	0	0	0	0	0	0
				0	0	0	0	0	0	0
				0	0	0	0	0	0	0
				0	11	27	50	62	64	57
				0	26	62	112	141	143	129
				0	66	109	199	219	225	205
(H_s) in m	2.5	0	0	7	93	171	279	342	351	320
	3.0	0	0	91	180	246	402	424	417	369
	3.5	0	0	86	211	326	484	577	568	502
	4.									
	4.									
	5.									

NAME	VALUE	NOTE
CapMax	750	Maximum capacity of device [kW].
HsMax	10.0	Upper limit of wave height for device operation [m]: this device shuts down when wave height is bigger than HsMax.
TpMax	20.0	Upper limit of wave period for device operation [sec]: this device shuts down when wave period is longer than TpMax.

Machine Performance



Tradeoff Analysis

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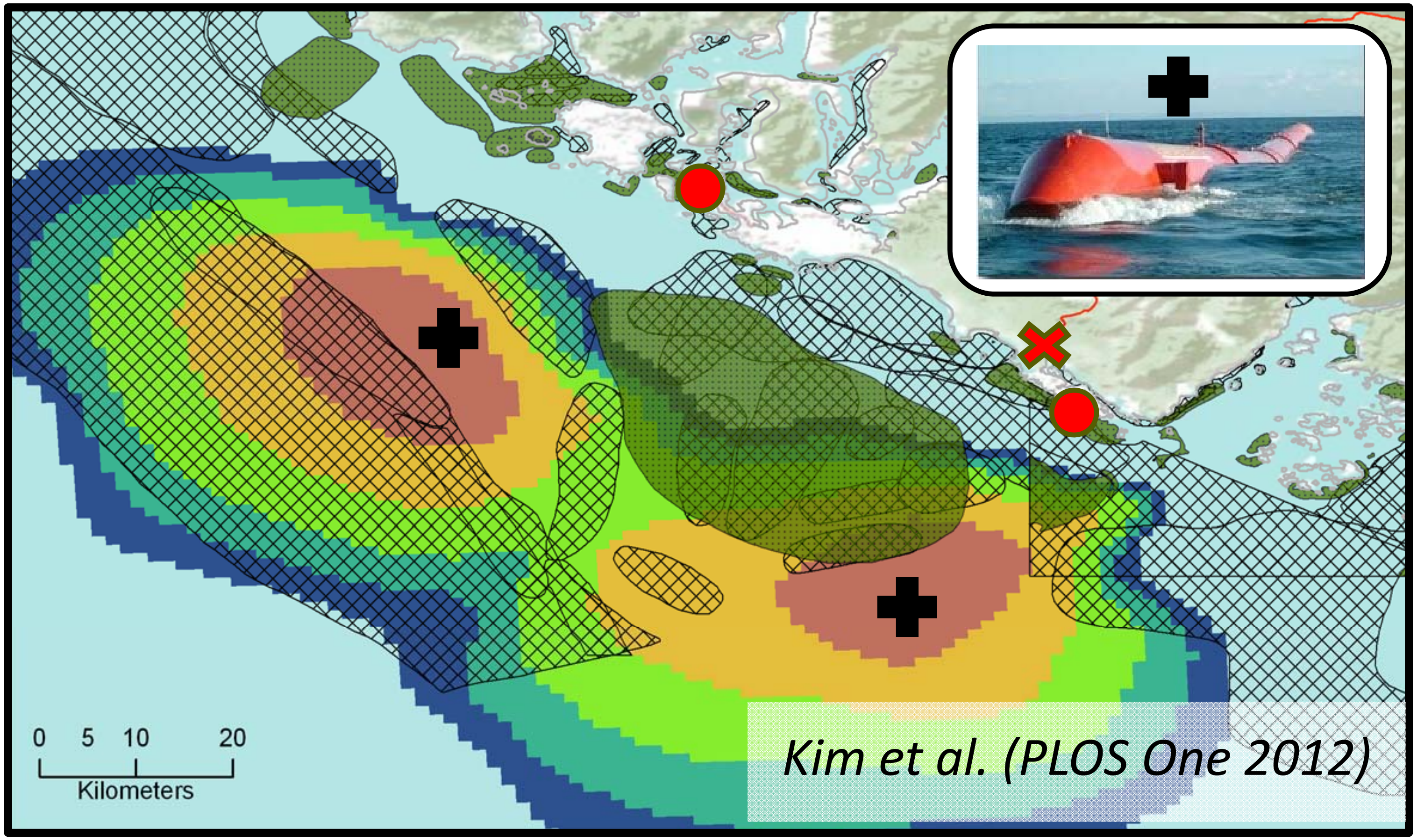
: Cable Landing Pt.
: Power Grid Connection Pt.

NPV ($ mil)
- 0 - 1.5
- 1.5 - 3.0
- 3.0 - 4.5
- 4.5 - 6.0
- 6.0 - 7.5



Commercial Fishery
- Salmon troll & net
- Crab and Shrimp

Recreational Fishery
- Salmon
- Ground fish

Wave Watch III (WW3)

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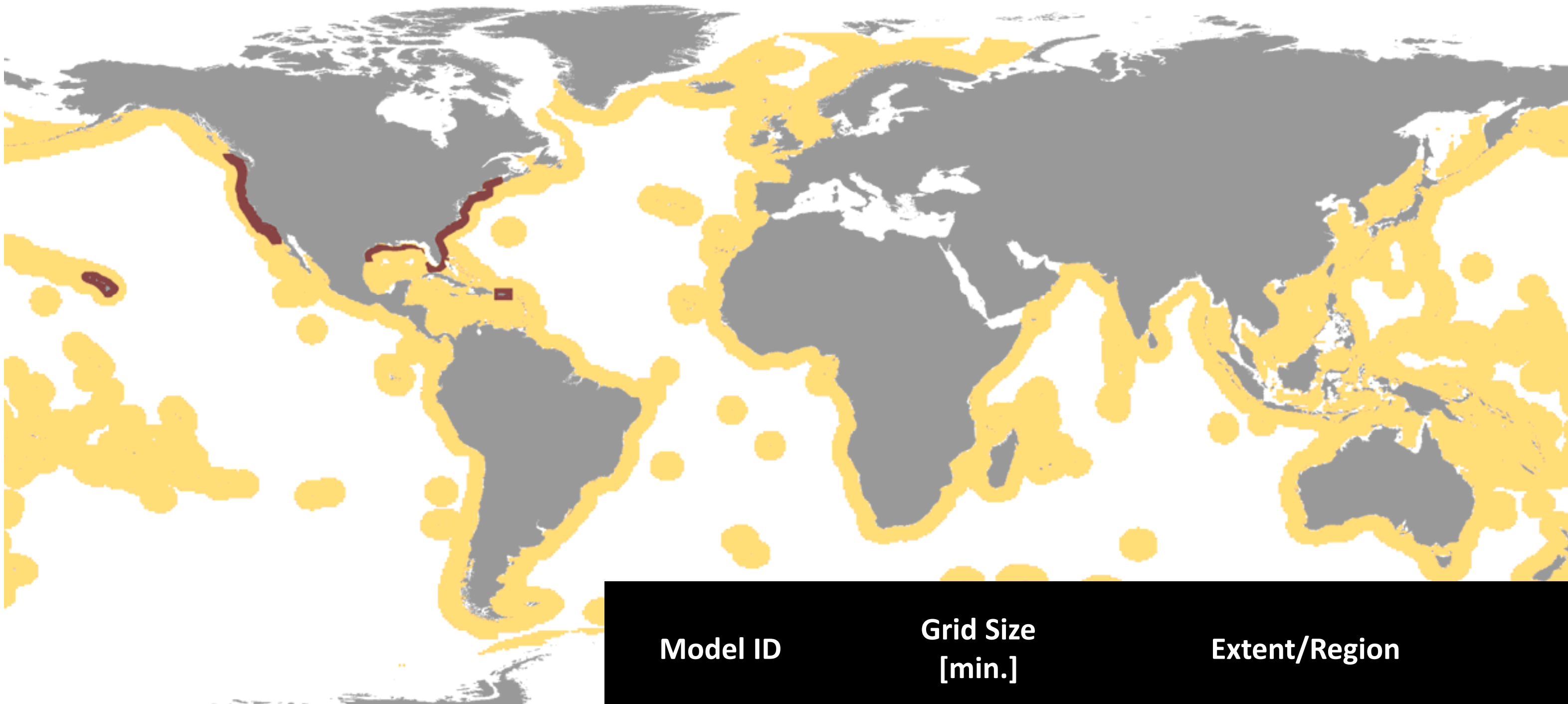

Model ID	Grid Size [min.]	Extent/Region	Year
GLO30m	30 x 30 (54 x 54km)	Global Ocean	2005-2010
WC4m	4x4 (7 x 7km)	US west coast and Hawaiian islands	2005-2010
EC4m	4x4 (7 x 7km)	US east coast and Puerto Rico	2005-2010

Running the Sample Data

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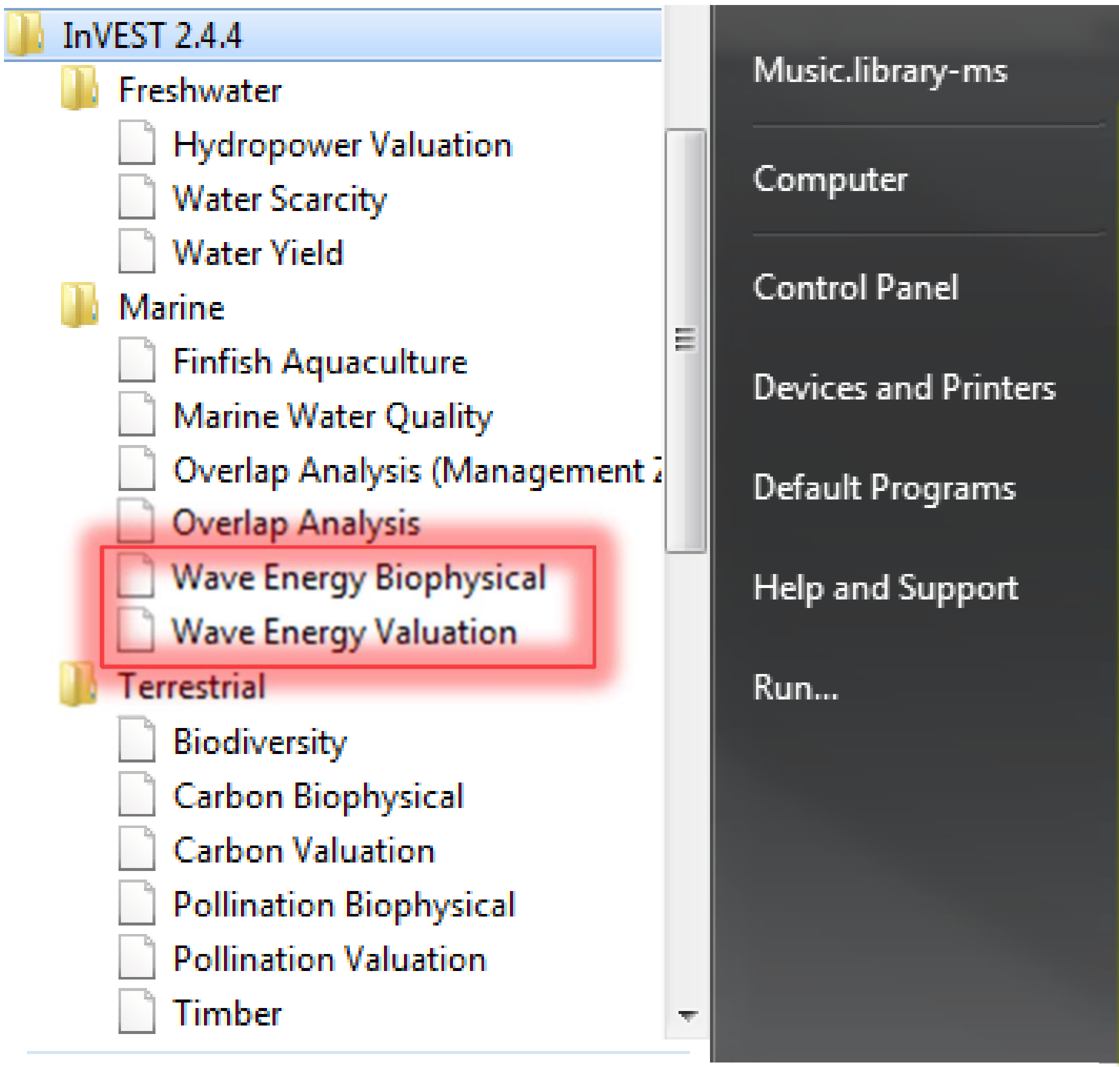
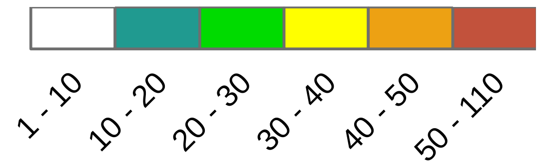
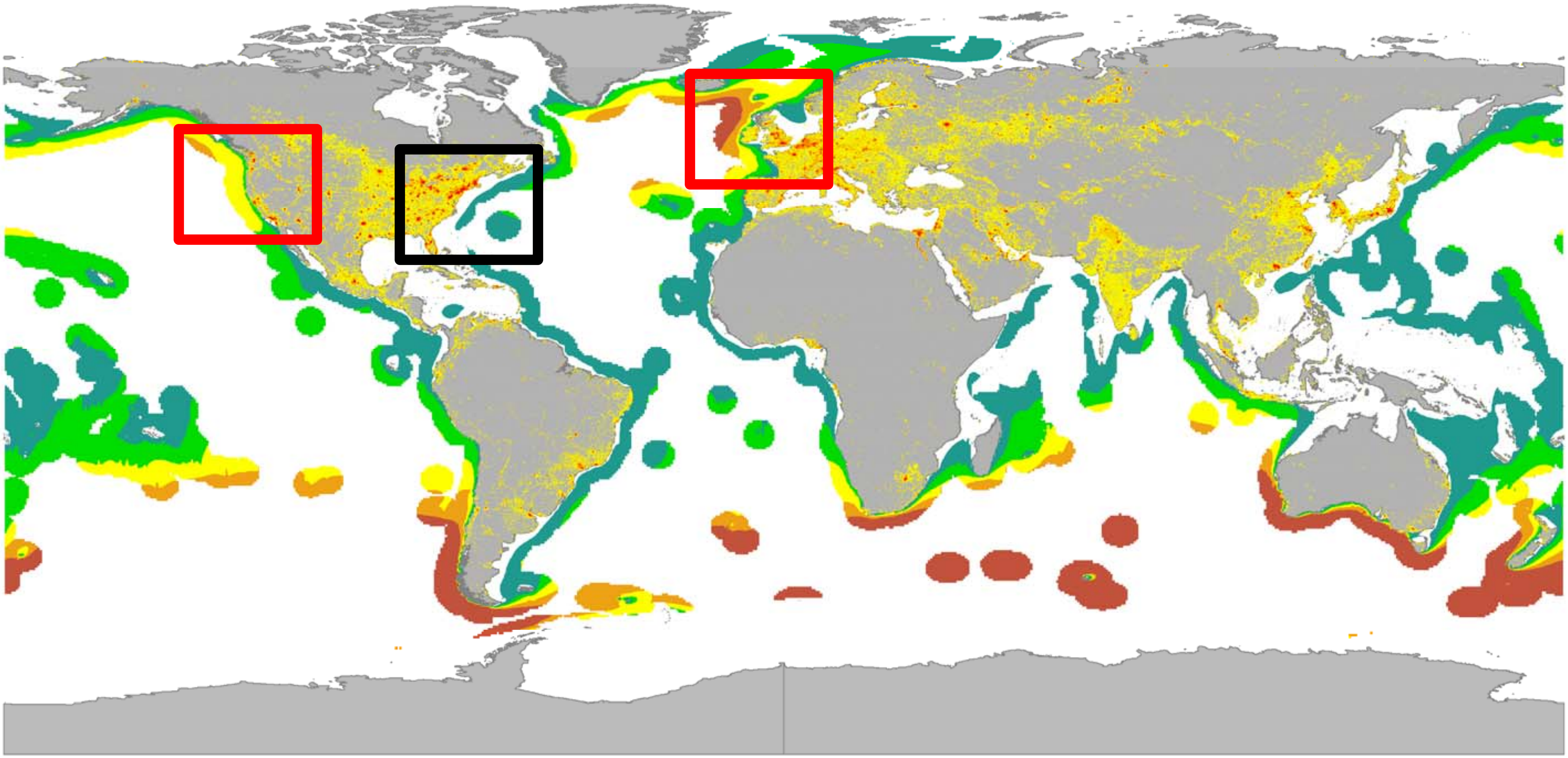


InVEST 3.0

- Launch through 'Start' menu
- Independent of ArcGIS
- Faster
- More user-friendly

Global Wave Power (kW/m)





~ 40 kW/m west coast of N. America

~ 80 kW/m between England and Island

Making the Case

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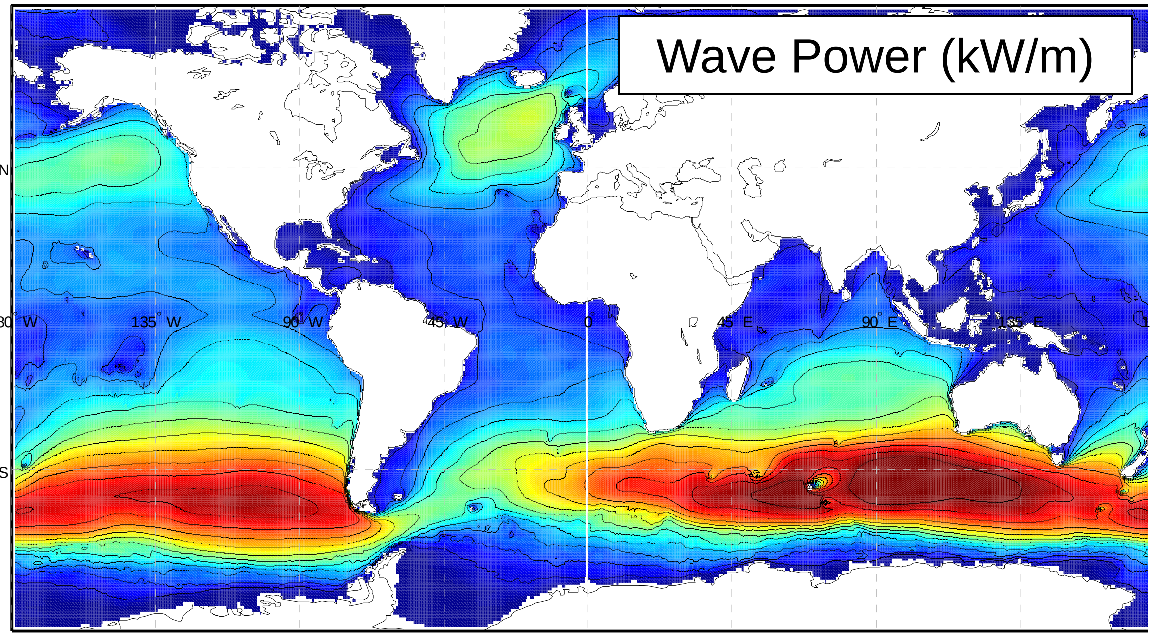
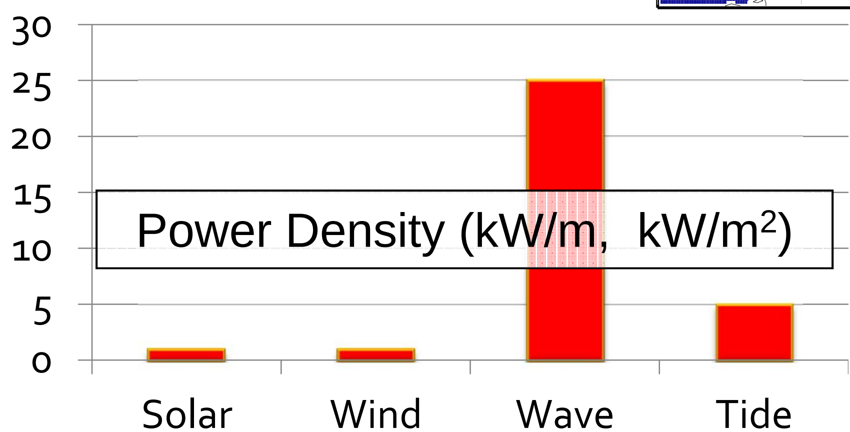
- There is harvestable energy in the world's oceans.





- High power density
- Continuous and predictable power

Technology is Improving

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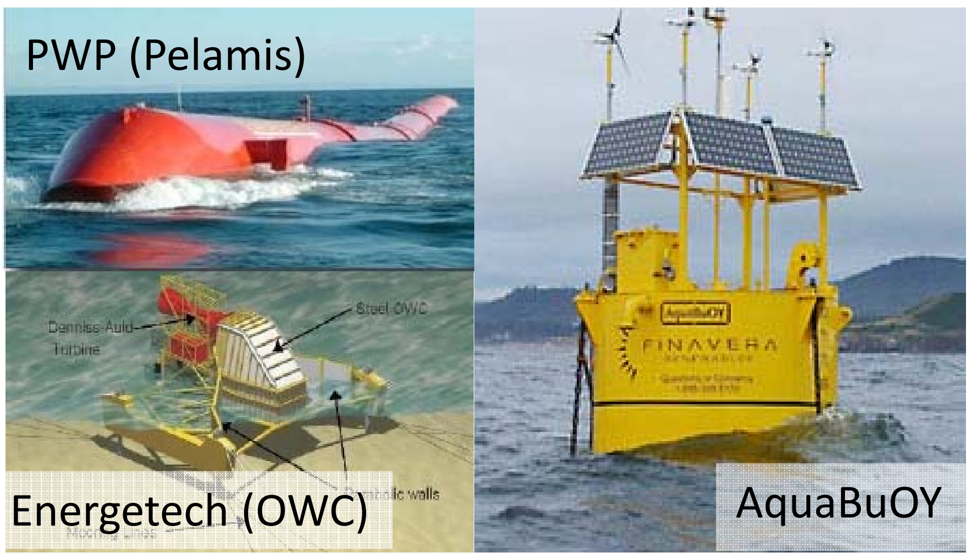
- There are numerous machines under development.



- But at varying maturity levels.

Limitations and Simplifications

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1. Captured wave energy indicates the yearly averaged energy absorbed per WEC device.
2. With no commercial-scale wave energy facilities implemented to date, obtaining accurate cost data is a challenge.
3. The distance measure from a WEC facility to an underwater cable landing point is based on Euclidean metric and does not recognize any landmass within two target points.
4. The quality of wave input data determines the accuracy of model results.
   - Default wave input data are more appropriate for global and regional scale applications

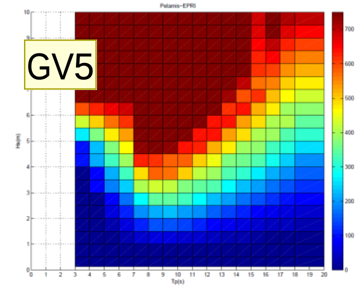
Economic Valuation

$$NPV = \sum_{t=1}^{T} (B_t - C_t)(1+i)^{-t}$$

NPV	=	Net Present Value ($)
T	=	25-year period
B_t	=	Benefits
C_t	=	C & M Costs
i	=	Discount rate, 5%

Economic Valuation

NPV =



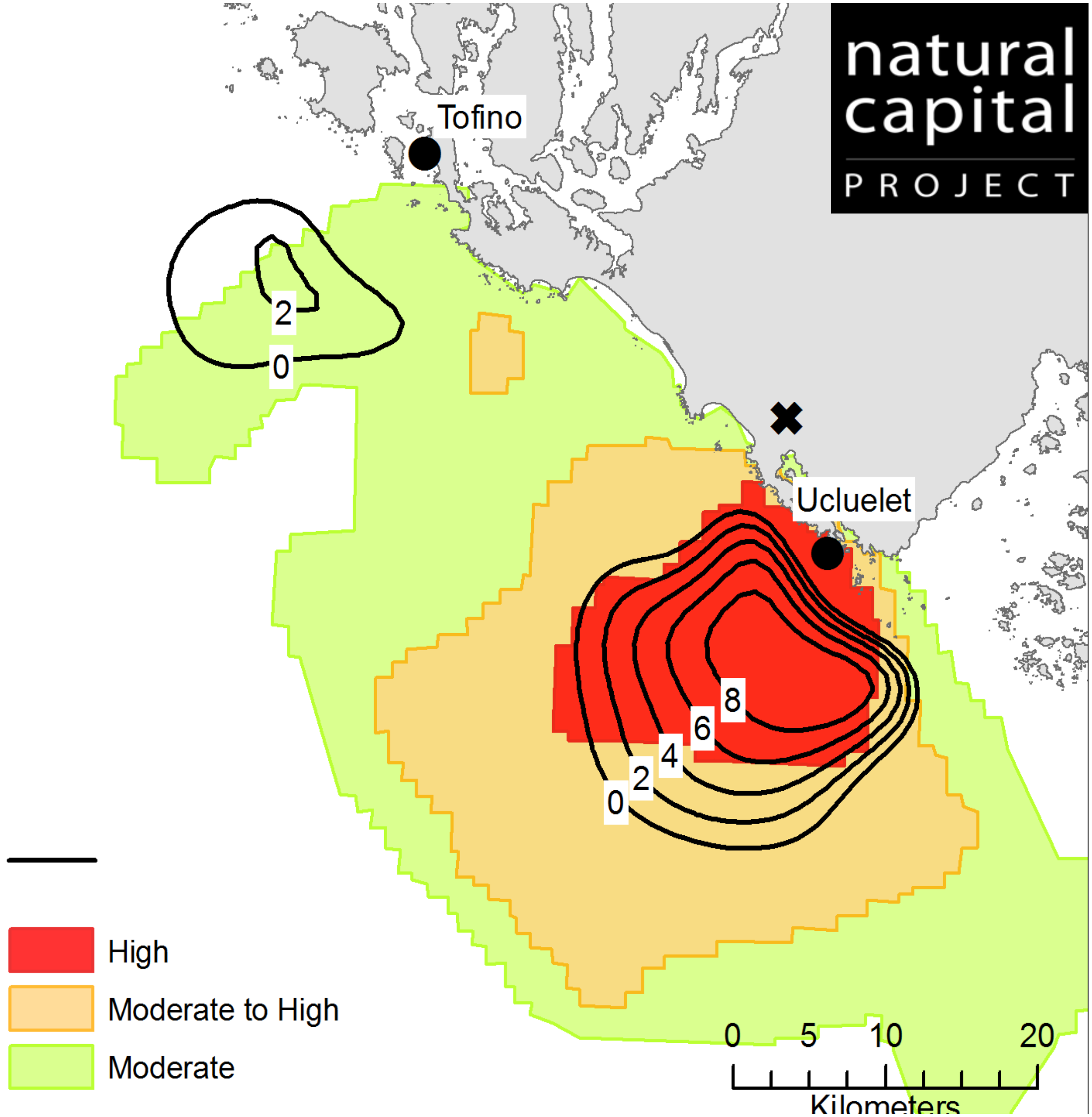
Benefits *minus* *Costs*

GV5 USE CK's ECOSYSTEM SERVICE CUES!!!

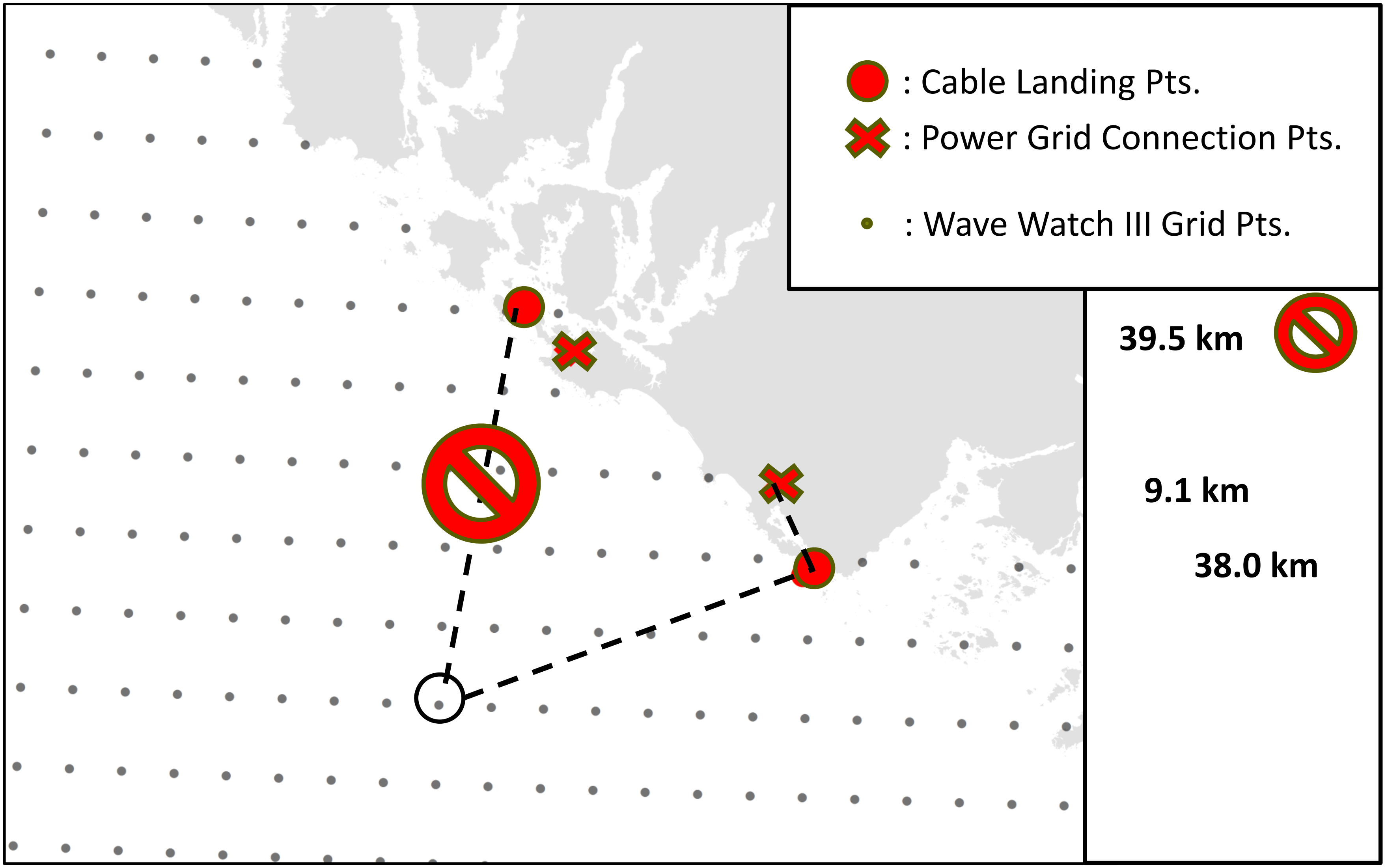
Gregg Verutes, 2/4/2012

Validation

- British Columbia Marine Conservation Atlas



Economic Valuation



WEC Device Maturity

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WEC Device	Maturity Rate	Length (m)	Width (m)	Avg. Power (kW)	WEC Type
Pelamis	**1**	**120**	**4.6**	**153**	**Attenuator**
OWC - Terminator	**2**	**25**	**35**	**259**	**OWC**
Wave Dragon	**2**	**150**	**260**	**1369**	**Overtopping**
Wave Swing	2	9.5	9.5	351	Point Abs
AquaBuOY	**3**	**6**	**6**	**17**	**Point Abs**
WaveBob	3	15	15	131	Point Abs
Offshore OWC	3	32	32	532	OWC
Wave Dog	3	5.4	5.4	16	Point Abs

(EPRI, 2005)

Compatibility Analysis

- **Cool Colored Areas = Less Value**
- Earn most money for WE at the least cost to fishing