Northwest Power and Conservation Council

December 1, 2010

MEMORANDUM

TO: Council Members

FROM: Jeff King

SUBJECT: Presentation from the Oregon Wave Energy Trust

The Oregon Wave Energy Trust (OWET) is a nonprofit public-private partnership that supports the research, development, and deployment of ocean wave energy projects in Oregon. The Trust initiative is cited in Action GEN-7 of the Sixth Power Plan as a model approach for commercializing and confirming promising resources.

In May of 2009, OWET and consultant Pacific Energy Ventures (PEV) began the Utility Market Initiative (UMI), a project intending to "align the regional electric utilities with the resource potential of the wave energy industry and establish useful tools and effective strategies to address identified technical needs." An overview of the UMI project is attached.

Therese Hampton and Justin Klure of PEV will present a summary of the UMI project and its initial evaluation results.

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Utility Market Initiative

Oregon Wave Energy Trust (OWET) is a nonprofit public-private partnership funded by the Oregon Innovation Council. Its mission is to support the responsible development of wave energy in Oregon.

OWET Project Contacts

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Pacific Energy Ventures (PEV) is a consulting firm specializing in the commercialization of early stage technologies and developing public-private partnerships.

PEV Project Contacts

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Project Purpose

Align the needs of the regional electric utilities with the resource potential of the wave energy industry and establish useful tools and effective strategies to address identified technical needs.

In order for the wave energy industry to successfully transition from pilot to commercial scale projects, technical and market challenges must be addressed, which requires close collaboration between the utility and wave energy industries. To date, Oregon utilities have been interested in wave energy, and some have invested resources to explore its potential; however, more work is needed to elevate wave energy as a viable resource for Oregon utility companies.

Project Overview

In February 2009, Oregon Wave Energy Trust (OWET) kicked off a project titled the Utility Market Initiative (UMI). Pacific Energy Ventures' (PEV) proposal, which included a broad multi-disciplinary team, was selected and the effort began in May 2009. A summary of the project tasks are outlined below:

***Task 1*- Utility Engagement:** Creation of a Wave Energy Utility Advisory Committee to guide and oversee efforts of the project.

***Task 2*- Resource Potential:** A comprehensive examination of the wave resource and existing wave energy conversion technologies.

***Task 3*- Business Model:** Estimates of the cost and value of wave energy and a review of alternative price support mechanisms.

***Task 4*- Grid Integration Tools**: An integrated systems analysis that evaluates the existing transmission capability of the system. Development of key technical and operation information: interconnection requirements, scheduling parameters, and other operational elements.

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Key Findings

Utility Participants

Vickie VanZandt, Convener

Mark Tallman, PacifiCorp

Dee Outama, PGE

Dana Toulson, Snohomish PUD

Pat Ashby, Tillamook PUD

Terry Oliver, BPA

Kevin Watkins, PNGC Power

Bill Toman, PG&E

Mike Wilson, Central Lincoln PUD

Dave Sabala, Douglas Electric Cooperative

Technical Team

PEV, Project Lead

Ecofys

EPRI

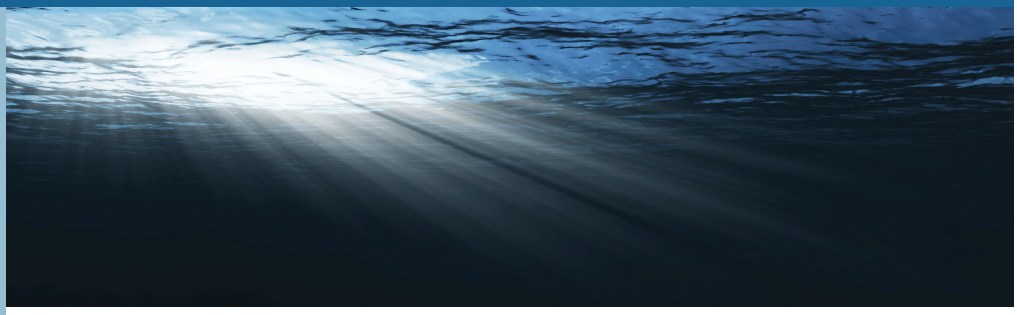
Energy Focused Resources

Groundswell Energy

Garrad Hassan

Loren Baker Consulting

Powertech Labs



Resource Potential

- EPRI estimates 18,000 MW of rated capacity from ocean energy is available off the West Coast; primarily off the coasts of Oregon and California. ***(Technology and Market Assessment)***
- There are 22 active wave energy technology developers; 4 are pursuing some sort of development in Oregon. ***(Wave Energy Technology Review; Oregon Wave Project Database)***
- Between 50 and 500 MW of wave energy capacity is likely to be sited off the coast of Oregon by the end of 2025. ***(Wave Energy Capacity Profile)***
- The wave energy resource has a high winter peak and a summer trough and a gradual transition between seasons. ***(Wave Energy Resource Assessment)***

Business Model

- The cost of wave energy is 2-4 times the current value to the utility community. ***(Value of Wave Energy Analysis)***
- The wave energy industry will require price support mechanisms to help bridge the gap from demonstration to commercialization. Some support options better address utility interests than others. ***(Price Support Alternatives Analysis)***

Grid Integration

- The current electrical system on the Oregon Coast can integrate 430 MW of ocean resource without significant additional infrastructure investment. ***(Scenario Analysis of Electrical System)***
- WaveWatch III, an existing NOAA wave forecasting system, can predict wave height and wave period with a mean absolute error of 15%. With modifications and upgrades, the mean absolute error is expected to be reduced. ***(Wave Energy Forecasting Requirements)***

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OWET Toolkit:

Utility Market Initiative (UMI)

Justin Klure, Partner
Therese Hampton, Senior Associate

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Oregon Wave Energy Trust (OWET)

- Nonprofit public-private partnership funded by Business Oregon through the Oregon Innovation Council.
- Supports the responsible development of wave energy in Oregon.
- The Oregon Way - OWET emphasizes an inclusive, collaborative model to ensure that Oregon maintains its competitive advantage and maximizes economic development.

OWET Focus

- State-wide Environmental Assessment
- Community Outreach
- Research and Development
- Regulatory Streamlining and Coordination
- Utility Markets

UMI Program Overview

1.0 Utility Engagement
Establish effective mechanisms to engage utility planners and industry to accelerate market growth.

2.0 Resource Potential
Provide concise, comprehensive information to utilities and industry on technology and resource.

3.0 Business Model
Create effective business protocols, determine 'value', identify incentives, and develop technical standards.

4.0 Grid Integration Tools
Develop technical tools for utility integration.

UMI PROGRAM OUTCOME: *Engaged and informed utility and industry partners armed with useful **tools** and **strategies** to successfully integrate wave energy into NW power grid.*

UMI Technical Team

PEV assembled a broad multi-disciplinary team to support and develop specific project tasks.

- Ecofys
- EPRI
- Energy Focused Resources
- Groundswell Energy
- Garrad Hassan
- Loren Baker Consulting
- Powertech Labs

Project Schedule

June - December 2009:

- Establish and work with Utility Advisory Group
- Conduct and summarize technical work
- Conduct Utility-Industry Workshop

January 2010:

- Final report to OWET and team members

September 2010:

- Presentation of Results at OWET Conference

December 2010:

- Presentation of Results to interested parties

Utility Engagement (Task 1)

Approach

Engage utility community and wave energy industry at a policy and leadership level and integrate into existing work groups.

- Vickie VanZandt, Convener
- Mark Tallman, PacifiCorp
- Dee Outama, PGE
- Dana Toulson, Snohomish PUD
- Pat Ashby, Tillamook PUD
- Terry Oliver, BPA
- Kevin Watkins, PNGC Power
- Bill Toman, PG&E
- Mike Wilson, Central Lincoln PUD
- Dave Sabala, Douglas Electric Cooperative

Outcome

An engaged utility industry with detailed understanding of how wave energy technologies perform, cost of integration, and how to value the resource.

Resource Potential (Task 2)

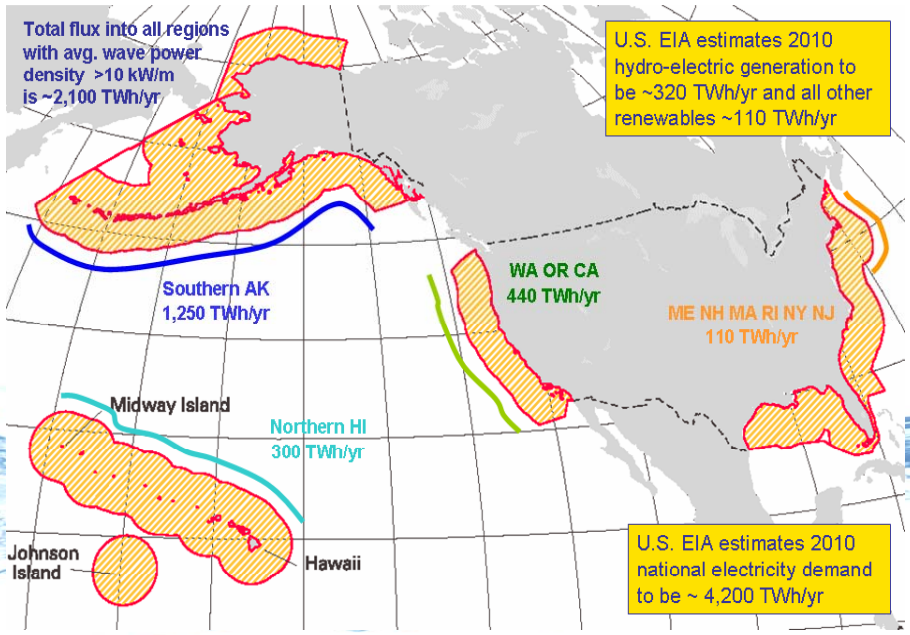
Approach
Provide information about technology and resource potential in formats easy to grasp, yet detailed enough to inform technical decision making.

2.1 Technology Assessment *(EPRI/Garrad Hassan)*
2.2 Wave Resource Assessment *(EPRI/Garrad Hassan)*
2.3 Capacity Profile *(PEV/EPRI)*
2.4 Resource and Interconnection Maps *(PEV)*

Outcome
A comprehensive summary of Oregon wave energy generation potential and installed capacity limits, project development timing and locations.

Resource Projection

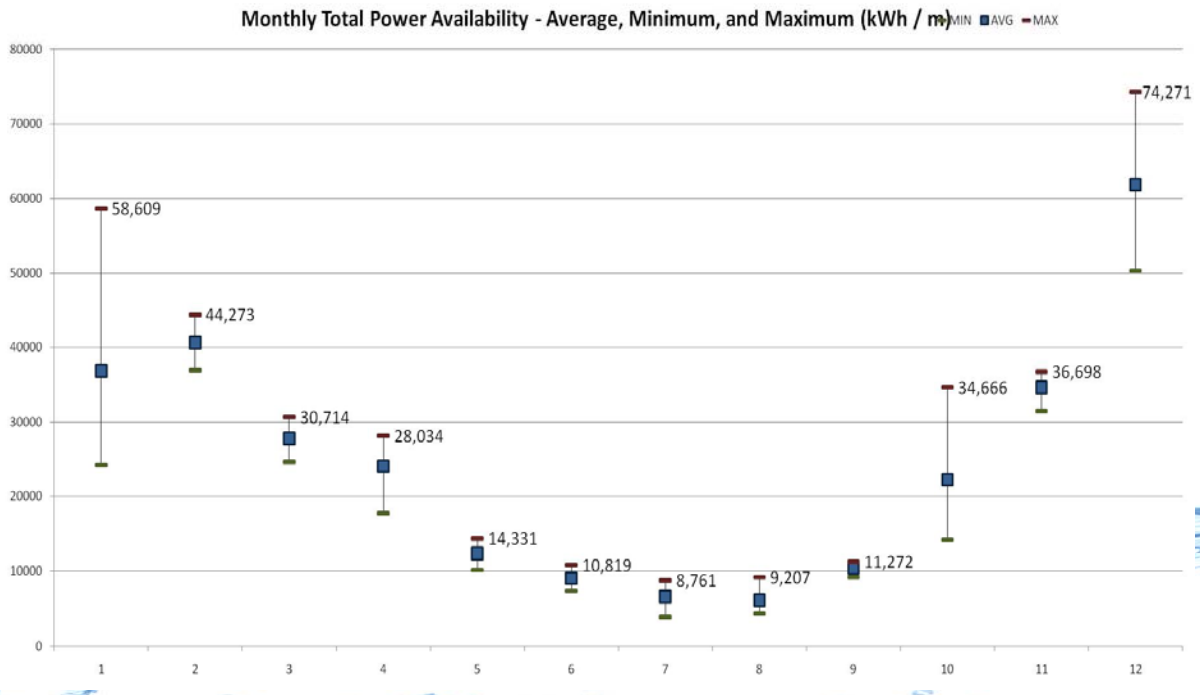
EPRI estimates 18,000 MW of rated capacity and 6,000 aMW is available from ocean energy potential off the west coast.



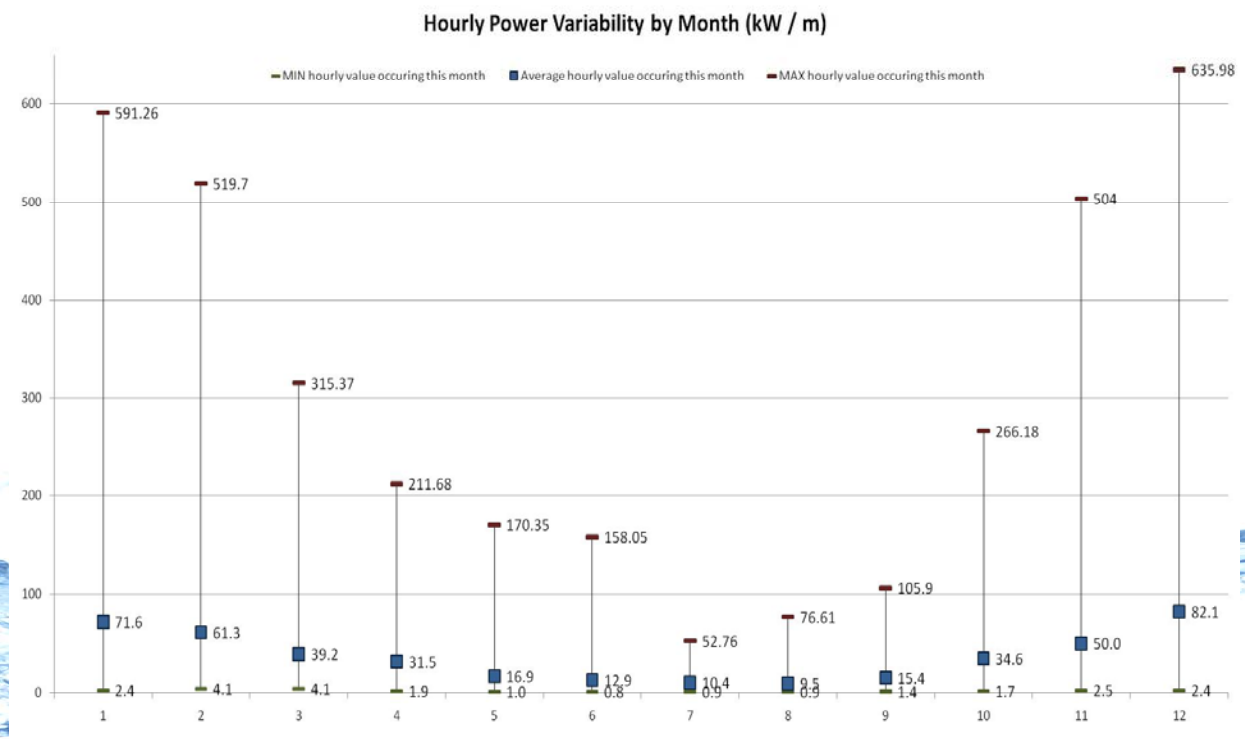
Monthly Resource Profile

- NOAA collects wave height and wave period information at buoys in various ocean locations.
- All buoy data is public information. However, data quality varies significantly.
- For this analysis:
  - 5 years of hourly data collected from NOAA buoy 46229 off the coast of Reedsport, Oregon.
  - This buoy was selected because of the quality of the data set and does not necessarily represent the optimum wave depth.
- The data analyzed represents resource potential, not power production. Wave energy technologies will not be able to extract the full resource potential.
- Some peaks shown in the graphs will be softened because the technology will not be designed to capture the peak power.

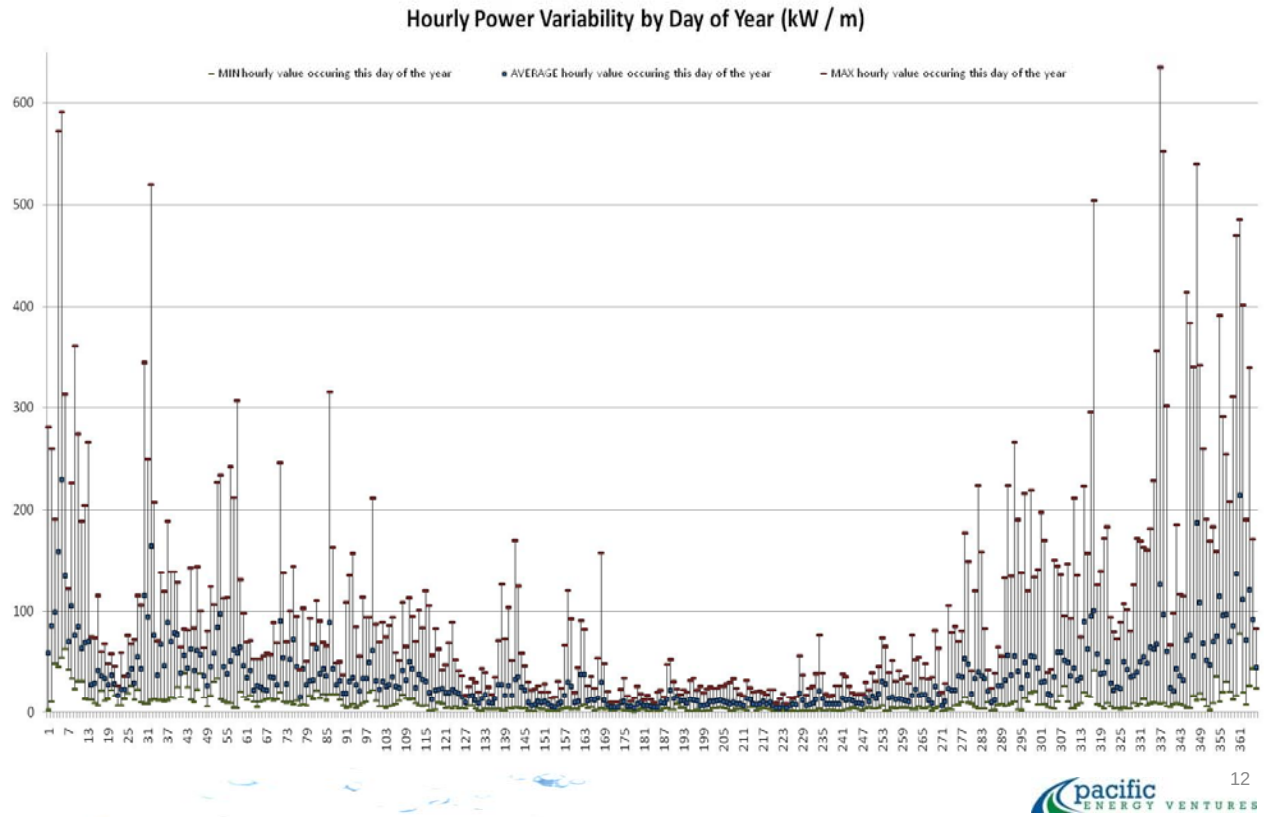
Monthly Resource Profile



Hourly variability - month

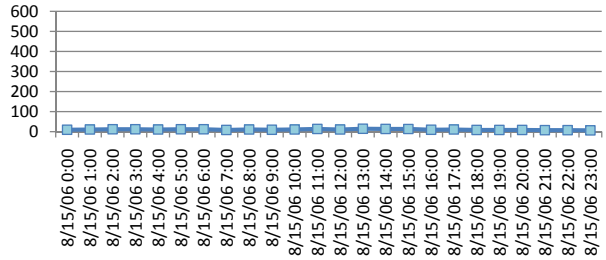


Hourly Variability - Day

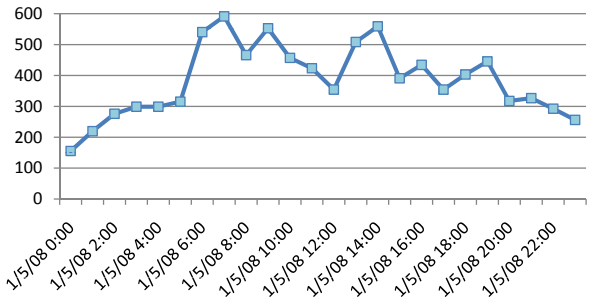


SAMPLE 24-HOUR PERIODS

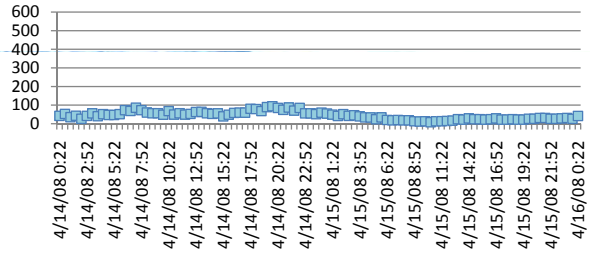
Hourly Power (kW/m) - 8/15/06 Calm Summer Day



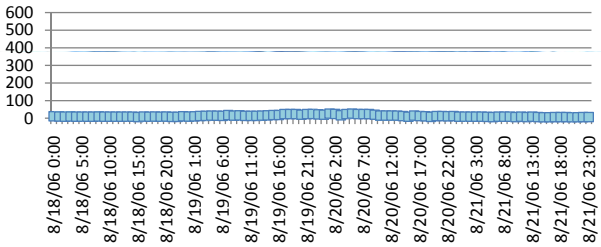
Hourly Power (kW/m) - 1/5/08 Storm



Hourly Power (kW/m) - 4/14/08 through 4/17/08, mild storm becoming calm



Hourly Power (kW/m) - 8/18/06 through 8/21/06, calm days with a storm event inbetween



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FORECASTING POTENTIAL

WaveWatch III

- WaveWatch III is a third-generation wave forecasting model developed by NOAA and used by many coastal water users (US Coast Guard, fisherman, etc.) to track swells and storms.
- Wave Watch III provides forecasts for 4 different hours in the day for next hour and 1, 2, and 3 days out.

Initial Results

- The EPRI analysis developed a mean absolute error (MAE) for each month of the year. An annual average MAE was also developed.
- Relative to the annual average, the mean absolute error for both wave height and wave period was approximately 15%.
- Without generation information, the accuracy of this forecasting tool relative to expected utility requirements of day ahead forecasts within +/- 5% and hour ahead within +/- 1.5% cannot be determined.

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Developer Profile

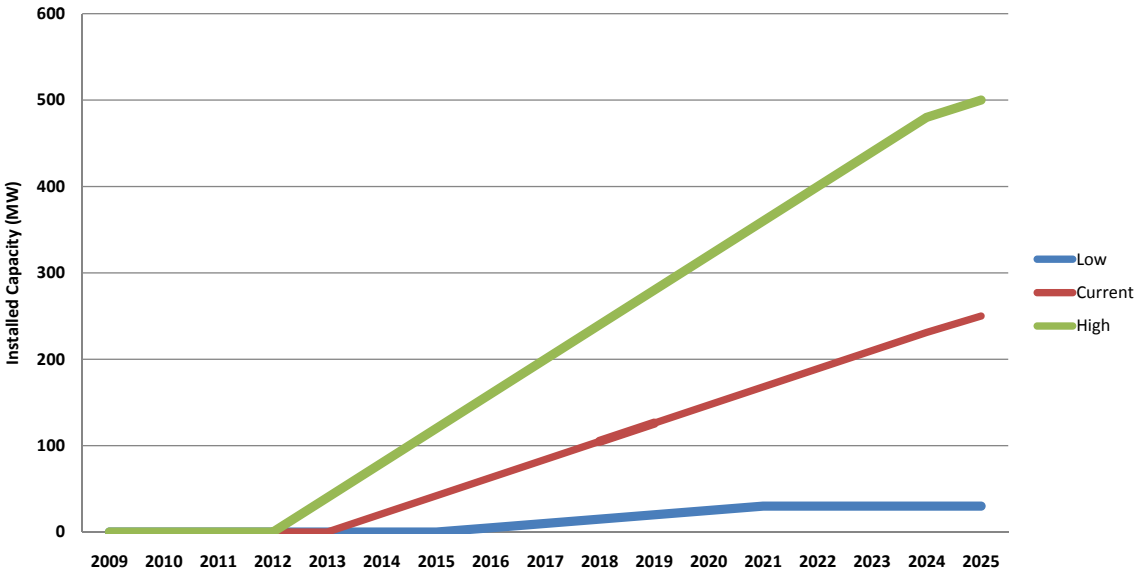
Industry Summary

- There are an estimated 73 wave energy developers from 20 different countries.
- Criteria were developed to assess the state of progress of the technology companies.
- A shortlist of developers was selected if they met at least 5 of the criteria established.
- 22 developers met at least 5 of the criteria; 4 of the developers are pursing development in Oregon

Leading Developers

Total Number of Developers	22
Nationalities	13
Company History > 5 yrs	77%
Staff > 10 full-time	55%
Investment > $15 M	46%
Power Take-Off	86%
Deployment Strategy	36%
O&M Strategy	14%
Numerical Modeling	82%
Experimental Modeling	100%
Prototype Deployed at Sea	68%
Independent Verification	30%
Full-Scale Prototype	27%

Wave Energy Capacity Profile



Capacity Profile Key factors

Market Considerations:

- Market Prices
- Economic Conditions
- Market Demand for Renewables
- Federal Tax Incentives & Price Supports
- State Tax Incentives & Price Supports

Siting Considerations:

- Marine Spatial Planning
- Port Infrastructure
- Regulatory Process
- Transmission Capacity

Technology Considerations:

- Cost of Wave Energy Conversion Technology
- Pace of Wave Energy Conversion Development
- Carbon Capture Storage Technology Development
- Solar Technology Development
- Viability of Nuclear Development
- Biomass Technology Development

Business Model (task 3)

Approach

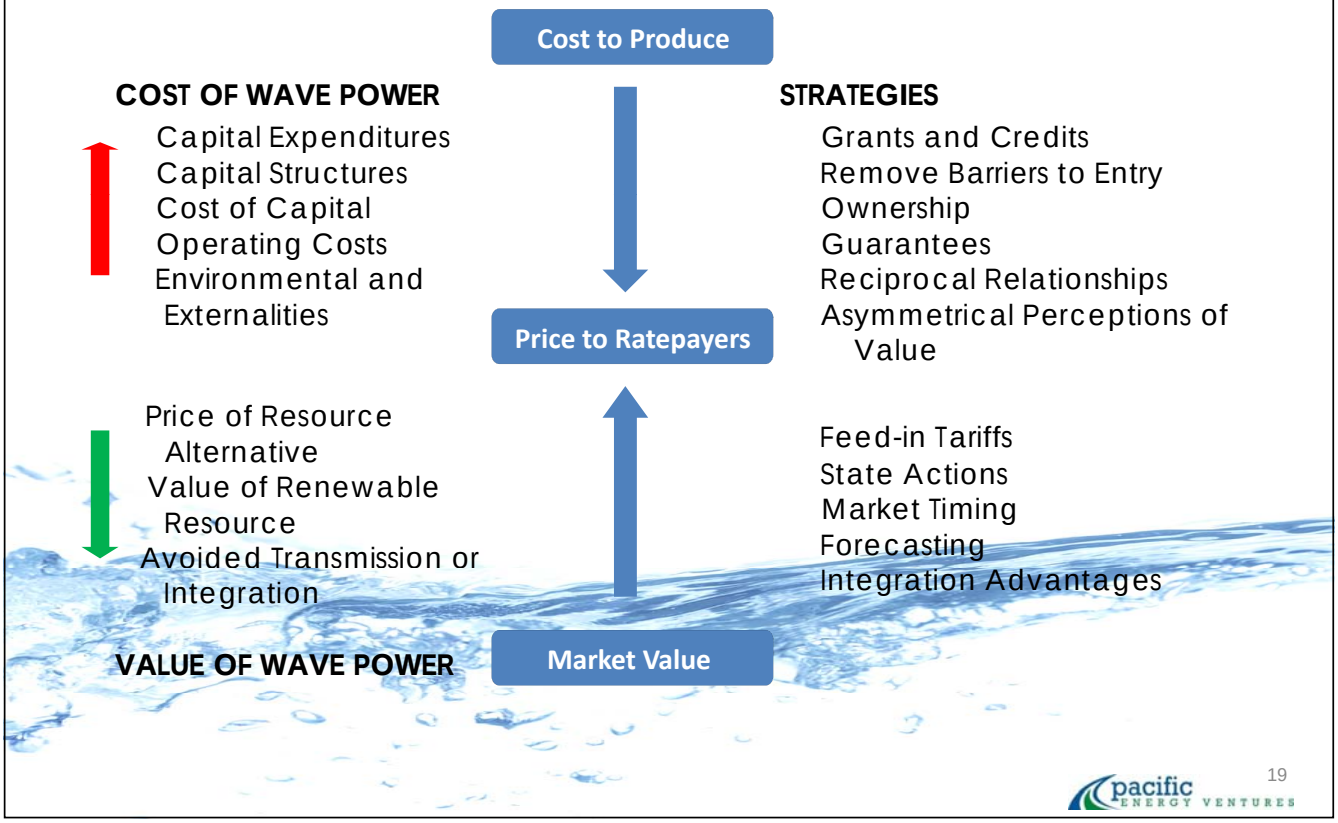
Provide easy to use and understandable information to inform a collaborative effort that engages utilities, industry, and key regulators.

3.1 State of the Industry Report *(PEV/UMI Team)*
3.2 Price Support Mechanisms *(PEV/UMI Team)*
3.3 Value of Wave Energy *(Energy Focused Resources)*
3.4 Effective Business Model and Protocols *(Loren Baker Consulting)*
3.5 International Standards Development *(PEV)*

Outcome

A 'Transaction' model developed by the utility and industry community; including an assessment of existing policies, gaps, and set of new policy recommendations to enhance market conditions for industry development.

Cost and Value of Wave Energy (Task 3.3)



Cost vs. Value

COST

Cost range depends on:

- Level of federal incentives
- Capital costs
- Available capital structure

The estimated cost of wave energy ranges between ***$220/MWh and $475/MWh.***

VALUE

Value range depends on:

- Market alternatives
- REC value
- Integration costs

The estimated value is estimated to be between ***$114/MWh and $124/MWh.***

Price Supports are Necessary

Price Support Analysis

<table>
<tr><th>Investor Owned Utilities</th><th>Publicly Owned Utilities</th><th>Wave Energy Developers</th></tr>
<tr><td>▪ Reasonable cost recovery is assured.
▪ Reflects ratepayer interests either through legislation or PUC direction.</td><td>▪ Maintains ability to manage rates consistent with Board Direction.</td><td rowspan="2">▪ Reduces project capital costs.
▪ Subsidizes cost of energy.
▪ Supports a transition to conventional financing/market competitiveness.
▪ Creates incentive to purchase wave energy.</td></tr>
<tr><td colspan="2">▪ Maintains utility discretion in resource acquisition decisions.
▪ Does not influence real-time dispatch of resources.
▪ Utility actions required for national benefit be funded by national resources.</td></tr>
</table>

Grid Integration (Task 4)

Approach

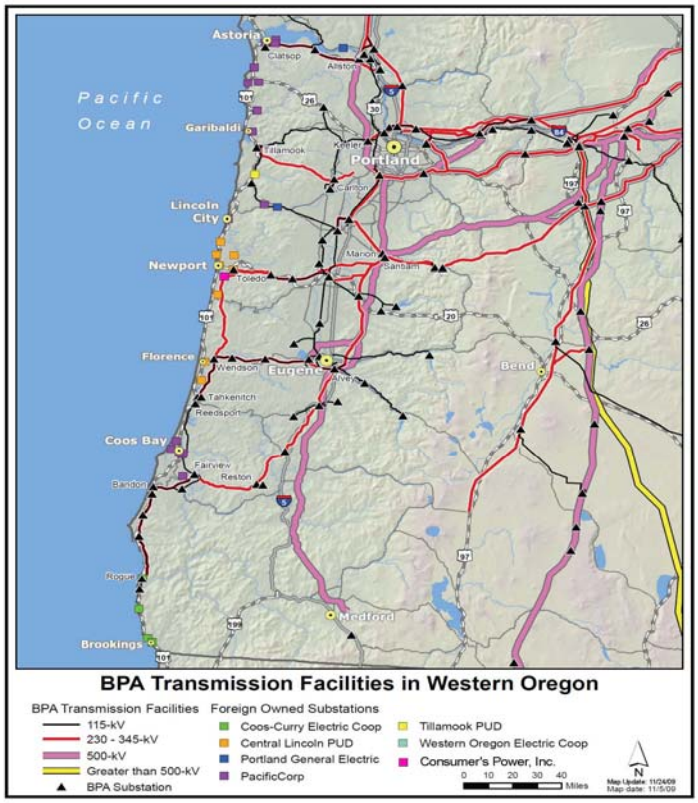
Utilize existing utility and industry expertise to synthesize and communicate existing information and expand and develop new tools where necessary.

4.1 Interconnection Guidelines *(PEV/Groundswell)*
4.2 Integrated Systems Analysis *(Powertech)*
4.3 Forecasting Tools *(PEV/Groundswell/EPRI)*
4.4 Scheduling Parameters *(Ecofys)*
4.5 Other Utility Considerations *(Ecofys)*
4.6 Telemetry *(Ecofys)*

Outcome

A set of effective tools and guidelines that will facilitate the future integration of wave energy into the utility grid.

Oregon Transmission



BPA Interconnection Process

BPA Transmission Interconnection Process Overview*

Project Licensing Process	Generation Interconnection Process BPA Transmission and/or Local Host Utility
Project Concept	Determine if connection is directly to BPA system or to a host utility → *Coastal Transmission Map* INITIAL CONSULTATION with BPA Customer Service Engineer and Host Utility → *Preliminary Project Questions*
Preliminary Federal Permit Processing	DETAILED PROJECT CONSULTATION– with BPA Customer Service Engineer and Host Utility → *Detailed Project Questions*
Federal License Application	Generation Interconnection Application → *•Process Summary •Application* 1. *FEASIBILITY STUDY* – determines if interconnection is feasible and determines a recommended facility option. 2. *SYSTEM IMPACT STUDY* - Detailed studies to define specific electrical requirements for recommended facility option. 3. *FACILITIES STUDY* - More accurate project cost estimate and refined implementation schedule. 4. *NEPA* - National Environmental Policy Act Review.
Construction	Interconnection Agreement

*BPA Transmission Service is secured through a separate process

INTERCONNECTION FINDINGS

Integration Study

- A high-level grid integration study was conducted by Powertech Labs Inc.
- Two powerflow base cases representing hevay summer and heavy winter conditions for the year 2019 were used.
- Known planned system upgrades prior to 2019 were included.
- Both steady-state and time-domain analysis were carried out.
- West to east transfer capacity limits were evaluated assuming simultaneous additions of wave energy resources at each of the twelve points of interconnection.
- Though local reactive compensation resource additions would likely be needed are not trivial in cost, they were not considered in this analysis.

INTERCONNECTION FINDINGS

Aggregated Capacity

- The aggregated capacity limit is approximately 430 MW – *assuming wave power generation from twelve POIs simultaneously, under a set of contingencies and criteria.*
- Without contingencies, the total estimated capacity is 630 MW.
- Judicious POI selection and refined/relaxed contingencies would indicate higher capacity for wave power addition.
- The key limiting factor is line overloading. Overloading was experienced in the base case as well as the resource addition cases. Although it was not assumed in the study, local transmission owners and local utilities will make system upgrades necessary to address these issues.

INTERCONNECTION FINDINGS

Individual POI Capacity

Area	Substation (Owner)	kV level	MW Capacity (minimum)
Astoria	Clatsop (BPA)	230	105
	Astoria (PAC)	115	510
Tillamook	Tillamook (BPA)	230	140
	Garibaldi (TPUD)	115	10
Newport	Toledo (BPA)	230	400
	Newport (CLPUD)	69	60
Reedsport	Reedsport (BPA)	115	180
	Gardiner (BPA)	115	80
	Tahkenitch (BPA)	230	320
Coos Bay	Hauser (BPA)	115	120
	Bandon (BPA)	115	40
Cushman	Wendson (BPA)	230	480

INTERCONNECTION FINDINGS

Network Bottlenecks

From Bus	To Bus	Relevant POI
GLASCOW 115	HAUSER 114	All
LAKE SID 115	REEDSPRT 115	Reedsport BPA, Tahkenitch BPA, Wendson BPA
GARDINER 115	TAHKNICH 115	Gardiner BPA, Hauser BPA
MORISON 115	NORWAY 115	Bandon BPA
ASTOR TP 115	SEASIDE 115	Astoria PAC
ASTOR TP 115	LWSCLARK 115	Clastsop BPA
GARIBALD 115	TILLAMOK 115	Garibaldi BPA
BEAVER 115	TILLAMOK 115	Tillamook BPA
SS 107	TOLEDO 69	Newport CLPUD
TOLEDO 230	WENDSON 230	Toledo BPA

Potential Next Steps

Advanced Resource Characterization

- Gather sufficient resource information to provide statistically meaningful 'utility style' probabilistic analysis of monthly, daily and hourly variability.
  - Identify data sources with appropriate wave diversity and time period
  - Prepare probabilistic analyses of variability
  - Analyze data for anomalies and trends
- Apply the resource variability information to develop estimates of system integration costs.

Ability to Forecast

- Further evaluate WaveWatch III tool to discern the forecast error associated with hour-ahead and day-ahead forecasts.
  - Continued evaluation of WaveWatch III to include multiple locations and multi-year analysis.
  - Evaluate the effects and sensitivity of wave height and wave period error on expected generation levels.
- Pursue validation of the tool with the Reedsport and NNMREC site to validate academic findings.

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