

# MHK Levelized Cost of Energy (LCOE) Analysis

**Al LiVecchi**

National Renewable Energy Laboratory  
al.livecchi@nrel.gov 303.384.7138  
February, 2017

## **MHK Levelized Cost of Energy (LCOE) Analysis:**

MHK technology development and adoption will be accelerated both domestically and internationally through research and development (R&D) programs targeted utilization of baseline cost scenarios, and standardized reporting methodologies and assumptions.

## **The Challenge:**

Prototype MHK technologies require significant cost reduction before they can compete with other forms of energy. Limited technology and project cost data exist for the different technology types, making it challenging to assess baseline costs and identify high-impact R&D opportunities.

## **Partners:**

- MHK Industry members
- Pacific Northwest National Laboratory (PNNL) – Desalination, Reference Models
- Oak Ridge National Laboratory (ORNL) – System Cost Breakdown Structure, LCOE Methodology
- Sandia National Laboratories (SNL) – Reference Models
- ReVision – Reference Models

## Technology Maturity

- Test and demonstrate prototypes
- Develop cost effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for Innovative MHK systems and components
- Develop tools to optimize device and array performance and reliability
- **Develop and apply quantitative metrics to advance MHK technologies**

## Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- Support research focused on retiring or mitigating environmental risks and reducing costs
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

## Market Development

- Support project demonstrations to reduce risk and build investor confidence
- **Assess and communicate potential MHK market opportunities, including off-grid and non-electric**
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- **Expand MHK technical and research community**

## Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- **Exchange of data information and expertise**

## Technology Maturity

- Test and demonstrate prototypes
- Develop cost-effective approaches for installation, grid integration, operations and maintenance
- Conduct R&D for innovative MHK systems and components
- Develop tools to optimize device and array performance and reliability
- **Develop and apply quantitative metrics to advance MHK technologies**

## The Impact

### Reference Model

- 3 current energy converter (CEC) designs (1 tidal, 1 ocean current, and 1 riverine) and 3 wave energy converter (WEC) designs, and corresponding economic analysis made publicly available to enable baseline comparison

### Wave Prize Metric Development

- LCOE analyses used to develop baseline ACE metric used in the wave prize, resulting in technology acceleration and broadening of the wave energy industry

## Market Development

Support project demonstrations to reduce risk and build investor confidence

- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

## The Impact

### Funding Opportunity Announcement (FOA) LCOE Support

- Robust and uniform technology baseline assessment
- Provides insight into cost composition to inform industry and DOE R&D efforts

## Market Development

- Support project demonstrations to reduce risk and build investor confidence
- **Assess and communicate potential MHK market opportunities, including off-grid and non-electric**
- Inform incentives and policy measures
- Develop, maintain and communicate our national strategy
- Support development of standards
- **Expand MHK technical and research community**

## The Impact MHK-powered Desalination

- Determined baseline estimate for the cost of clean water produced through WEC powered Desalination
- Identification of market potential for MHK technologies that expand the MHK industry into non-electric sectors that are end-use markets and have synergistic technology and market development aspects

## Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks and identify promising markets
- **Exchange of data information and expertise**

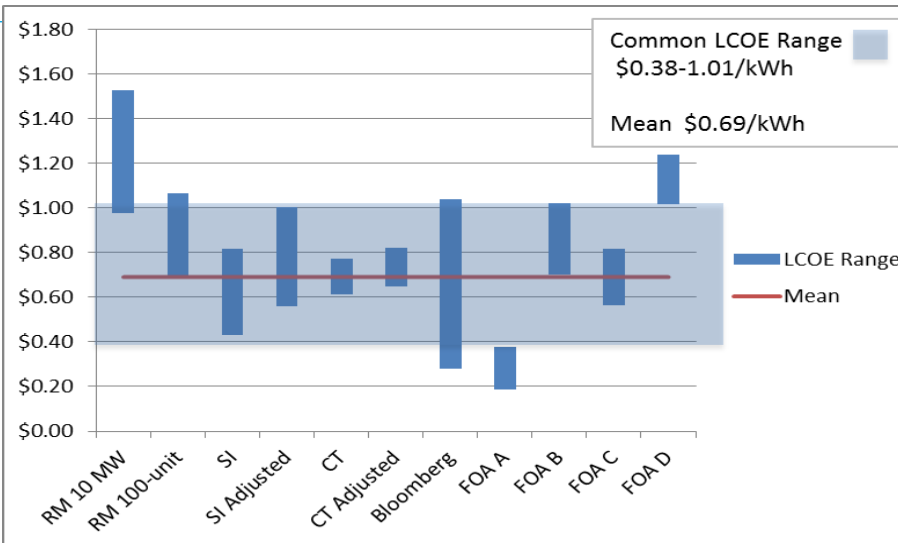
## The Impact

### LCOE Analysis, Guidance and Cost Breakdown Structure (CBS)

- MHK-specific LCOE methodologies and reporting formats enable uniform analysis across U.S. and international MHK stakeholders
- Methodology used by industry stakeholders, university partners, and international researchers to create a common format for data exchange
- LCOE analysis used to target cost reduction pathways
- Focusing R&D development on high-impact areas will accelerate technology maturation through performance increases and cost reductions

## Approach:

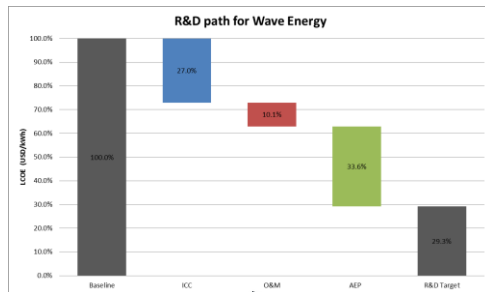
- Engage technology-agnostic, neutral third-party national laboratories that have the ability to collaborate with a wide range of industry players and stakeholders and deliver objective analyses across a range of renewable energy technologies
- Leverage existing renewable energy technology analysis methodologies developed for EERE and develop MHK-specific LCOE methodology
- Compile and translate international and domestic LCOE data to assess the existing state-of-the-art (see below); determine LCOE benchmarks, targets, and cost reduction opportunities using a standardized methodology and assumptions
- Publicly disseminate LCOE methodology, framework, and analyses
- Evaluate the potential of non-electric markets in the United States, starting with wave-powered desalination



- MHK LCOE estimates have high levels of uncertainty
- Standardized reporting methodology, assumptions, and cost reporting framework enables LCOE comparisons across domestic and international entities



- LCOE analysis and benchmarks used by the Program to target high priority R&D activities that reduce installed capital costs and increase annual energy production.
- Efforts have led to the definition of the primary Wave Energy Prize metric (ACE Metric).
- Exploration of non-electricity end uses (e.g. desalination) have suggested synergistic near-term market opportunities for MHK technologies.
- As technology benchmarks mature, data reevaluated and used to further advance the MHK R&D and LCOE targets.



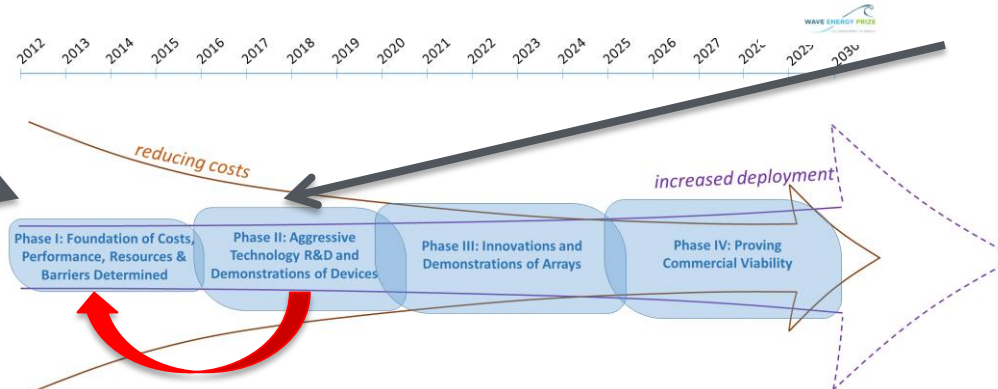
**The ACE Metric**

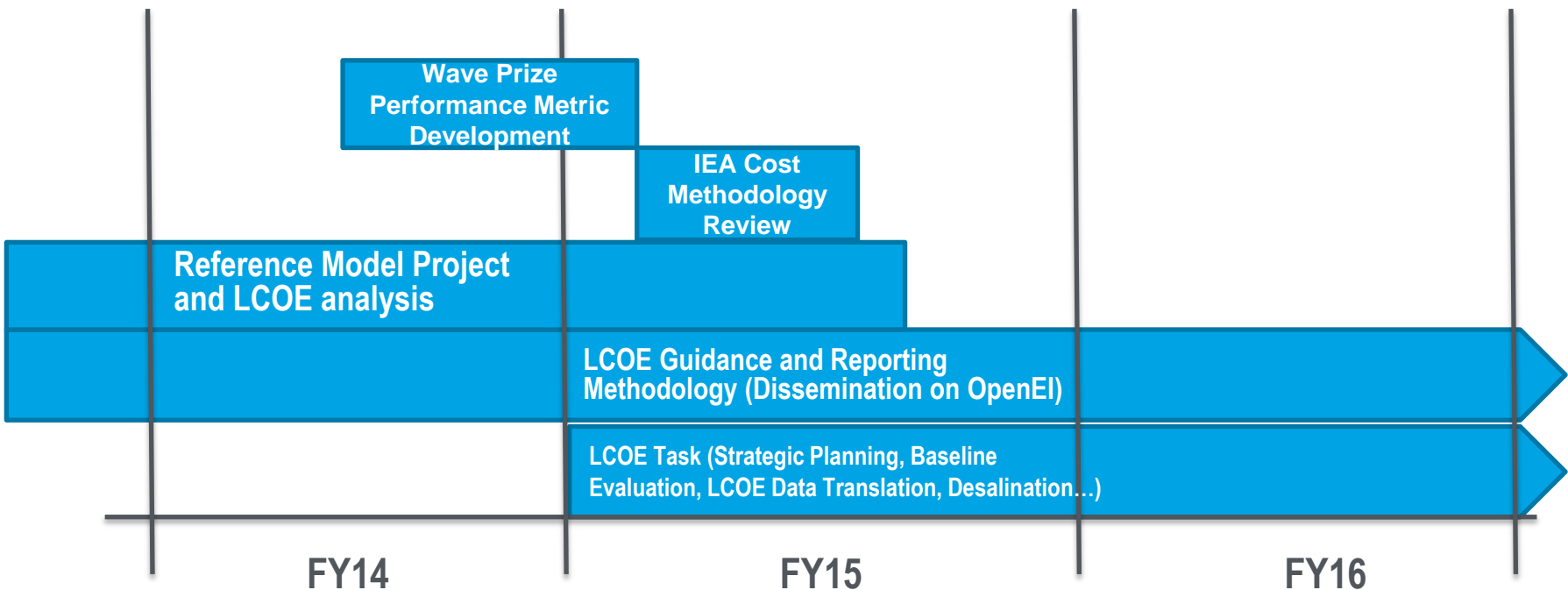
The Prize has selected ACE as a proxy for LCOE for comparing low Technology Readiness Level WEC concepts

$$ACE = ACCW / CCE$$

Average Climate Capture Width (ACCW) = The absorbed power of the device (kW) divided by the wave energy flux per meter crest width in kW/m

Characteristic Capital Expenditure (CCE) = Total Surface Area (m<sup>2</sup>) x Representative Structural Thickness (m) x Density of Material(s) (kg/m<sup>3</sup>) x Cost of Manufactured Material per unit Mass (\$/kg) for all applicable materials.





- LCOE work originated in FY10 under the Reference Model Project (FY10), which was completed in FY15
- Wave Energy Prize Metric Development completed in FY15
- LCOE methodology development, cost and performance data collection and composition and trend analysis and alternate end-use analysis continuing

## Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$0k	\$0k	\$377k*	\$0k	\$410k**	\$0k

\* \$150k was transferred from Field Measurement Campaign to FOA 1310 support; this was carryover funding, but is counted here as new BA since it is new funding to the project

\*\* \$320k of \$410k BA funds planned for effort in FY17 (Desalination and Market Study)

45% of total funding was costed by the end of FY16

## Partners, Subcontractors, and Collaborators:

- SNL—Reference Model Project lead
- PNNL—Reference Models, Desalination, Non-Electric Market Opportunities
- FOA recipients—LCOE cost and performance data
- Marine Energy Council of the National Hydropower Association—Annual LCOE review

## Communications and Technology Transfer:

- LCOE guidance and System Cost Breakdown Structure (SCBS) developed in collaboration with the Wind Energy Technologies Office, ORNL, and industry stakeholders
- As guidance and SCBS have been utilized, industry feedback has been employed to refine guidance documents and deliver direction on how to effectively use and modify the MHK SCBS
- Reference Model project has also provided detailed cost analysis and LCOE methodology reports, which serve as technology and economic baselines
- The Reference Model LCOE analysis was performed in collaboration between NREL and ReVision

## Communications and Technology Transfer:

### LCOE Documentation

- OpenEI: Water Power Page – DOE Guidance and Framework [http://en.openei.org/wiki/Gateway:Water\\_Power#Water\\_Power\\_Databases\\_.26\\_Tools](http://en.openei.org/wiki/Gateway:Water_Power#Water_Power_Databases_.26_Tools)
- MHK LCOE Reporting Guidance [http://en.openei.org/community/files/doe\\_lcoe\\_reporting\\_guidance\\_2015\\_10\\_09.docx](http://en.openei.org/community/files/doe_lcoe_reporting_guidance_2015_10_09.docx)
- MHK System Cost Breakdown Structure [http://en.openei.org/community/files/generalized.cbs\\_.draft\\_mhk\\_aug.1.2014\\_0.xlsx](http://en.openei.org/community/files/generalized.cbs_.draft_mhk_aug.1.2014_0.xlsx)
- LCOE Reference Resource [http://en.openei.org/community/files/lcoe\\_reference\\_resource\\_2016\\_01\\_27.xlsx](http://en.openei.org/community/files/lcoe_reference_resource_2016_01_27.xlsx)
- LCOE Reporting Guidance Presentation with Example Case and Audio [http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/0/05/MHK\\_LCOE\\_Guidance\\_Presentation\\_w\\_Audio\\_.pptx](http://prod-http-80-800498448.us-east-1.elb.amazonaws.com/w/images/0/05/MHK_LCOE_Guidance_Presentation_w_Audio_.pptx)
- NREL Risk Register [http://www.nrel.gov/docs/fy15osti/63258\\_template.xlsx](http://www.nrel.gov/docs/fy15osti/63258_template.xlsx)
- Reference Model Cost Models <http://energy.sandia.gov/rmp>
  - RM1 (<http://energy.sandia.gov/download/21275/>)
  - RM2 (<http://energy.sandia.gov/download/23279/>)
  - RM3 (<http://energy.sandia.gov/download/23667/>)
  - RM4 (<http://energy.sandia.gov/download/23669/>)
  - RM5 (<http://energy.sandia.gov/download/23713/>)
  - RM6 (<http://energy.sandia.gov/download/23739/>)

## FY17/Current research:

LCOE effort will continue to assess the status of MHK technology costs and drivers and identify significant cost reduction opportunities and areas of significant uncertainty through detailed analysis and cost modeling. Opportunities in applications other than utility electricity generation will be assessed.

In FY 17, the team will:

- Complete more detailed assessment of WEC-powered desalination
- Develop MHK technology operations and maintenance cost assessment tool to empower more accurate cost assessment
- Support DOE FOA 1310 recipients in LCOE assessment and risk management
- Complete initial assessment of high-potential end-use markets beyond utility-scale electricity generation
- Work with DOE to develop graphics representing LCOE trends and R&D impact

## Proposed future research:

- Detailed analyses of opportunities and R&D pathways for alternate end-use markets synergistic to utility scale electricity generation
- Once O&M cost assessment tool is complete, detailed analyses can be performed on MHK technologies that previously used lower fidelity analysis techniques to elucidate high-impact R&D opportunities