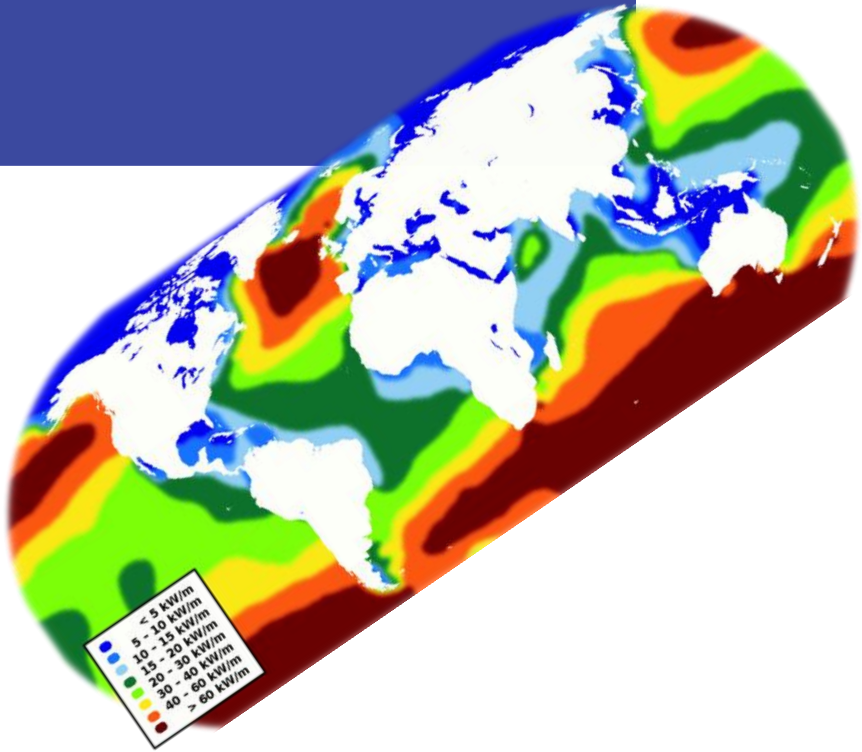
Achieving grid parity with wave and tidal energy systems



ICOE 2016

Edinburgh

Giles Hundleby and
Charlie Nordstrom

25 February 2016

BVGassociates

Agenda

Achieving grid parity with wave and tidal systems

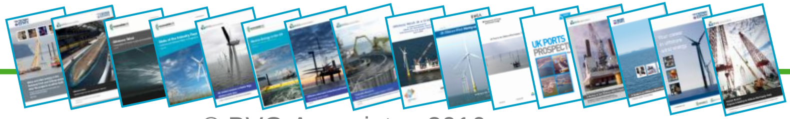
Contents

- The regular approach to projecting future costs
- A new approach
- What grid parity looks like in 2030
- Establishing a CAPEX and OPEX budget for today's systems
- Conclusions

Selected clients

BVG Associates

- Market and supply chain
  - Analysis and forecasting
  - Strategic advice
  - Business and supply chain development
- Economics
  - Socioeconomics and local benefits
  - Technology and project economic modelling
  - Policy and local content assessment
- Technology
  - Engineering services
  - Due diligence
  - Strategy and R&D support



BVGassociates

Cost of energy challenge for marine energy

Onshore wind cost is close to grid parity; Offshore wind cost will be by 2025

LCOE basics

$$LCOE = \frac{\sum_{i=-m}^{n} ((C_i + O_i + D_i) \; / \; (1+W)^i)}{\sum_{i=-m}^{n} (E_i \; / \; (1+W)^i)}$$

Where:

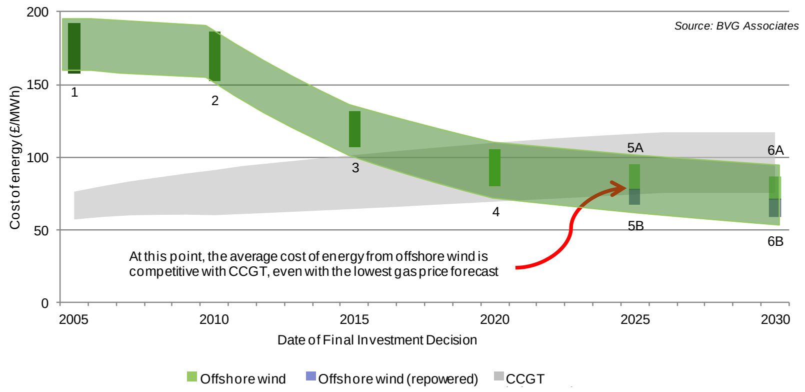
LCOE Levelised cost of energy in £/MWh
= revenue needed (from whatever source) to obtain rate of return W on investment over life of the plant
(tax, inflation etc. not modelled)

C_i Capital expenditure in £ in year i
O_i Operational expenditure in £ in year i
D_i Decommissioning expenditure in £ in year i
E_t Energy production in MWh in year i

W Weighted average cost of capital in % (real)
= (cost of debt x % dept) + (return on equity x equity portion)

n Operating lifetime
m Years before start of operation when expenditure first incurred
i i year of lifetime (-m, ..., 1, 2, …n)

Cost of energy to 2030



Comparison between cost from offshore wind and combined cycle gas turbine (CCGT) plant.

Offshore wind bars reflect range of cost of four representative, real-life projects reaching financial investment decision (FID) around each snapshot, taking into account site conditions and available technology. See description below of the status of technology, supply chain and finance at the time of each snapshot.

The broader bands incorporate the potential for fluctuations in commodity prices, including fuel, which affect the cost of energy.

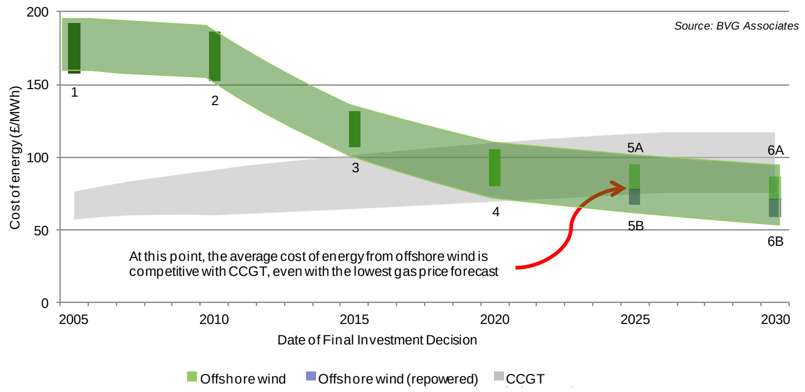
Cost of energy challenge for marine energy

Onshore wind is close to grid parity; Offshore wind will be by 2025

Challenge to meet competing cost trajectories

- On & offshore wind have improved LCOE through:
    - Longer project life
    - Larger turbine size
    - Larger project size
    - Lower WACC (lower risk)
    - Experience
- Overall these have combined to give a learning rate of c 13% on LCOE
- Offshore wind’s downward LCOE trend is on track to achieve grid parity in the mid 2020s
- There remains ample space for onshore and offshore wind energy in Europe & floating wind will enable deep-water offshore markets
- For wave and tidal to be relevant today, there must be a similar path to achieving grid parity in a reasonable timeframe and at reasonable cost – say
    - by 2030
    - After deployment of 2GW of subsidised capacity

Cost of energy to 2030



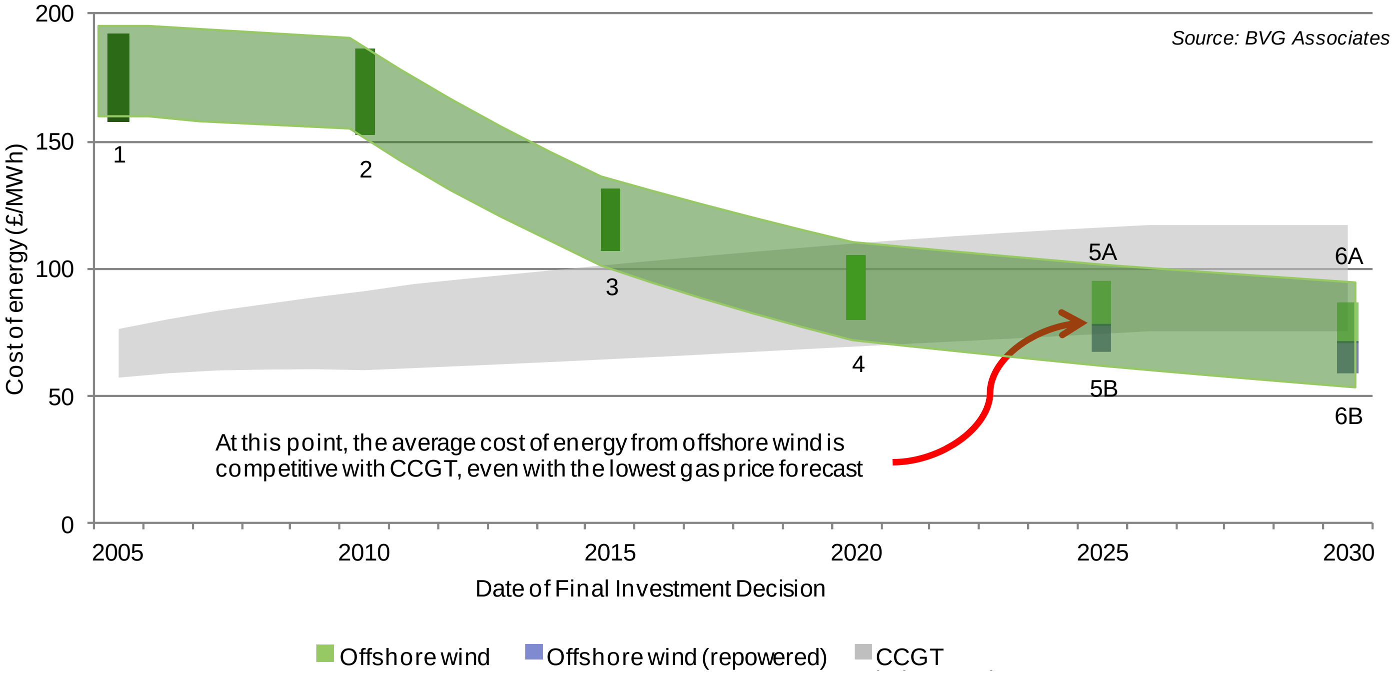
Comparison between cost from offshore wind and combined cycle gas turbine (CCGT) plant.

Offshore wind bars reflect range of cost of four representative, real-life projects reaching financial investment decision (FID) around each snapshot, taking into account site conditions and available technology. See description below of the status of technology, supply chain and finance at the time of each snapshot.

The broader bands incorporate the potential for fluctuations in commodity prices, including fuel, which affect the cost of energy.

Cost of energy challenge for marine energy

Onshore wind is close to grid parity; Offshore wind will be by 2025



Comparison between cost from offshore wind and combined cycle gas turbine (CCGT) plant.

Offshore wind bars reflect range of cost of four representative, real-life projects reaching financial investment decision (FID) around each snapshot, taking into account site conditions and available technology. See description below of the status of technology, supply chain and finance at the time of each snapshot.

The broader bands incorporate the potential for fluctuations in commodity prices, including fuel, which affect the cost of energy.

Regular approach to projecting future costs

Assess current status and quantify the impact of future innovations

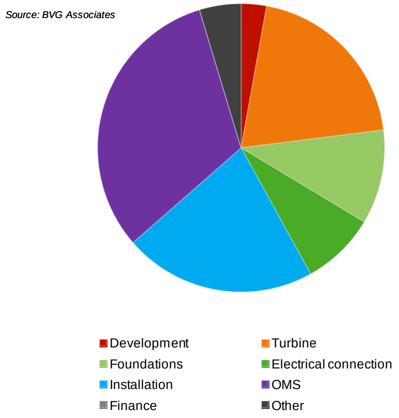
This approach says, 'What can we achieve?'

- Establish a baseline cost for prototypes and first commercial units
- Identify specific innovations
- Identify 'learning rate' opportunities
- Quantify the 'cost delta' for each innovation and for learning
- Determine which innovations can happen together or separately
- Calculate a future cost

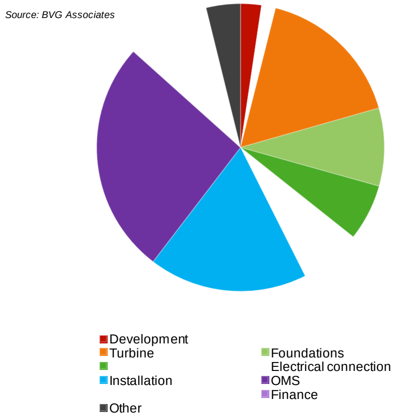
→ Merit of this approach is credibility when projecting future costs

→ Flaw with this approach is not knowing whether future cost is good enough?

Targeted innovations to reduce cost



Baseline



Impact of innovations

A new approach

Assuming grid parity can be met and projecting backwards to today's necessary starting point

High-level assumptions

- Wave and tidal must achieve grid parity by 2030

→ Grid parity means £75/MWh

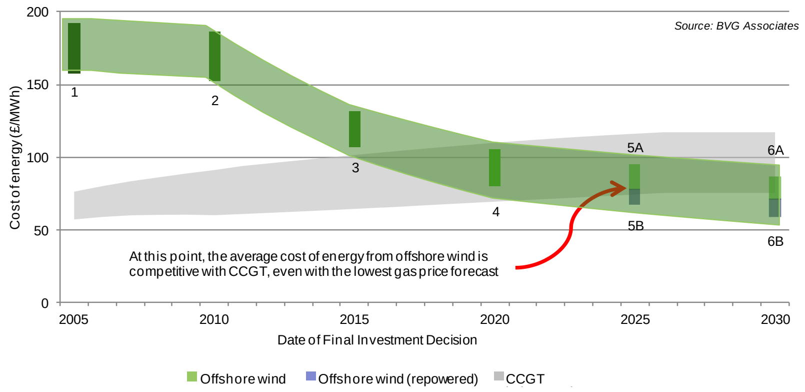
- Wave and tidal can achieve a 12% learning rate on LCOE, from today to 2030 (similar to offshore wind historical LCOE learning rate)

- Wave and tidal must get there through an affordable level of deployment and subsidy

→ Cumulative installed capacity for each technology of 2GW by 2030

→ This means a lifetime subsidy of £4bn for tidal energy and £3bn for wave energy – expensive, but potentially justifiable

Cost of energy to 2030



Comparison between cost from offshore wind and combined cycle gas turbine (CCGT) plant.

Offshore wind bars reflect range of cost of four representative, real-life projects reaching financial investment decision (FID) around each snapshot, taking into account site conditions and available technology. See description below of the status of technology, supply chain and finance at the time of each snapshot.

The broader bands incorporate the potential for fluctuations in commodity prices, including fuel, which affect the cost of energy.

A new approach for tidal

Assuming grid parity can be met and projecting backwards

High-level assumptions

- Wave and tidal must achieve grid parity by 2030

→ Grid parity means £75/MWh

- Wave and tidal must get there through an affordable level of deployment and subsidy

→ Cumulative installed capacity for each technology of 2GW by 2030

- Wave and tidal can achieve a 12% learning rate on LCOE, from today to 2030 (similar to offshore wind historical LCOE learning rate)

LCOE in 2030 for tidal devices (all in fixed 2016 £)

- Set LCOE target of £75/MWh in 2030 and determine CAPEX and OPEX budget for 2030

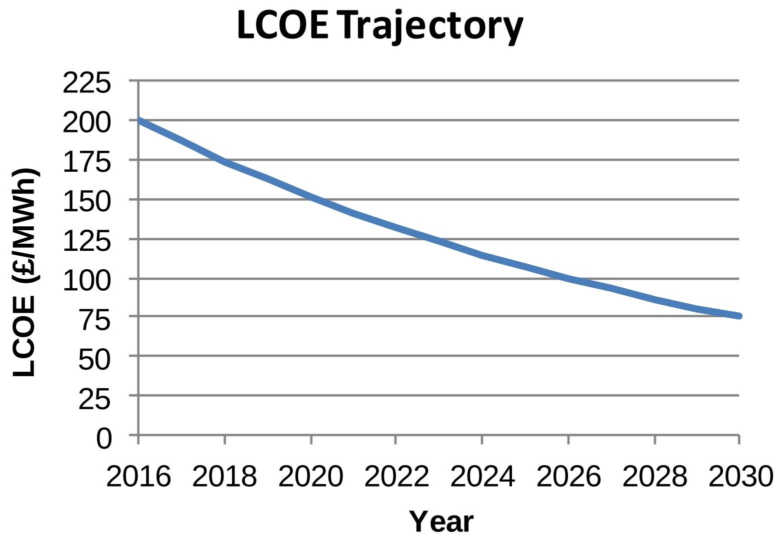
Assumptions	2030
Installed capacity in 2030 (MW)	2000
LCOE (£/MWh)	75
Net capacity factor	40%
Weighted average cost of capital	8%
Project life (years)	25
Scenario 1: Low CAPEX, high OPEX	**2030**
CAPEX budget (£/MW)	1,750,000
OPEX budget (£/MW)	100,000
Scenario 2: High CAPEX, low OPEX	**2030**
CAPEX budget (£/MW)	2,600,000
OPEX budget (£/MW)	20,000

A new approach for tidal

Assuming grid parity can be met, and projecting backwards

LCOE trajectory - £200/MWh in 2016

- Start with 2030 grid parity target and work back to 2016 target
- Use LCOE learning rate of 12%
- Assume market grows form 10 MW in 2016 to 2,000 MW in 2030



LCOE in 2030 for tidal devices (all in fixed 2016 £)

- Set LCOE target of £75/MWh in 2030 and determine CAPEX and OPEX budget for 2030

Assumptions	2030
Installed capacity in 2030 (MW)	2000
LCOE (£/MWh)	75
Net capacity factor	40%
Weighted average cost of capital	8%
Project life (years)	25
Scenario 1: Low CAPEX, high OPEX	**2030**
CAPEX budget (£/MW)	1,750,000
OPEX budget (£/MW)	100,000
Scenario 2: High CAPEX, low OPEX	**2030**
CAPEX budget (£/MW)	2,600,000
OPEX budget (£/MW)	20,000

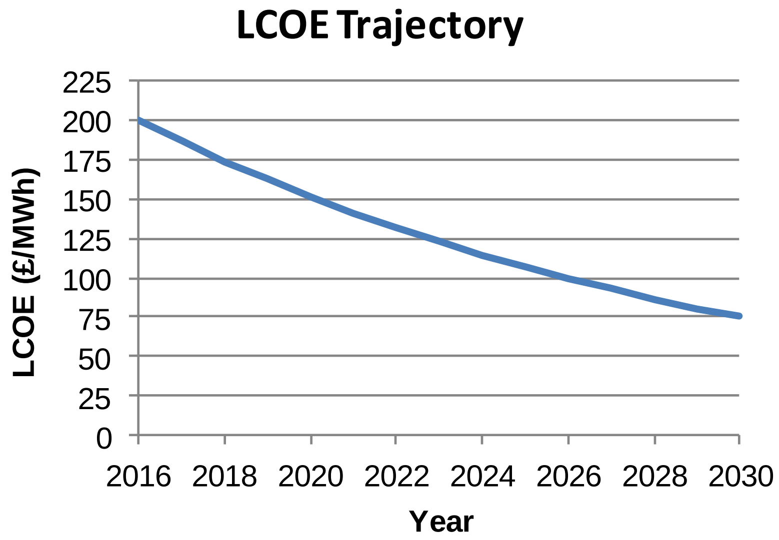
BVGassociates

A new approach for tidal

Assuming grid parity can be met, and projecting backwards

LCOE trajectory - £200/MWh in 2016

- Start with 2030 grid parity target and work back to 2016 target
- Use LCOE learning rate of 12%
- Assume market grows form 10 MW in 2016 to 2,000 MW in 2030



LCOE in 2016 for tidal devices

- Use learning rate and market growth rate to work backward from 2030 and determine LCOE target of £200/MWh in 2016

Assumptions	2016
Installed capacity in 2016 (MW)	10
LCOE (£/MWh)	200
Net capacity factor	32.5%
Weighted average cost of capital	12%
Project life (years)	20
Scenario 1: Low CAPEX, high OPEX	**2016**
CAPEX budget (£/MW)	2,850,000
OPEX budget (£/MW)	188,000
Scenario 2: High CAPEX, low OPEX	**2016**
CAPEX budget (£/MW)	4,000,000
OPEX budget (£/MW)	35,000

Cost targets - tidal

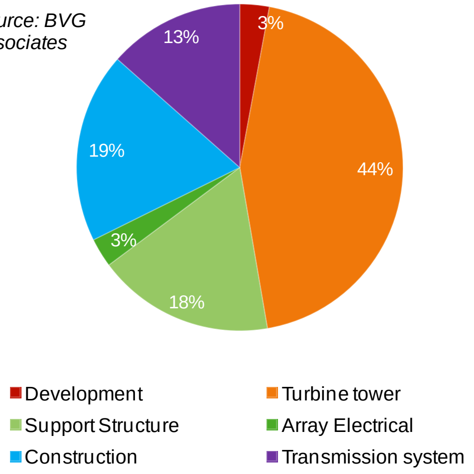
Determining the budget for tidal energy devices in 2016, to ensure future viability

2016 CAPEX targets for tidal devices

- Start with 2016 bottom-fixed offshore wind
- Reduce transmission cost by 5x (components are onshore)
- Reduce array cable cost by 25% (smaller overall footprint)

→ *Gives CAPEX of £394,000/MW for development, array electrical, and transmission*

Source: BVG Associates



Offshore wind (bottom-fixed) CAPEX breakdown in 2016

2016 budget for tidal devices (installed cost)

- Adjusting offshore wind cost model and backing out balance of station gives budget for device
- In scenario 1 (High CAPEX, low OPEX), the budget for installed device is £2,456,000/MW
- In scenario 2 (Low CAPEX, high OPEX), the budget for installed device is £3,606,000/MW

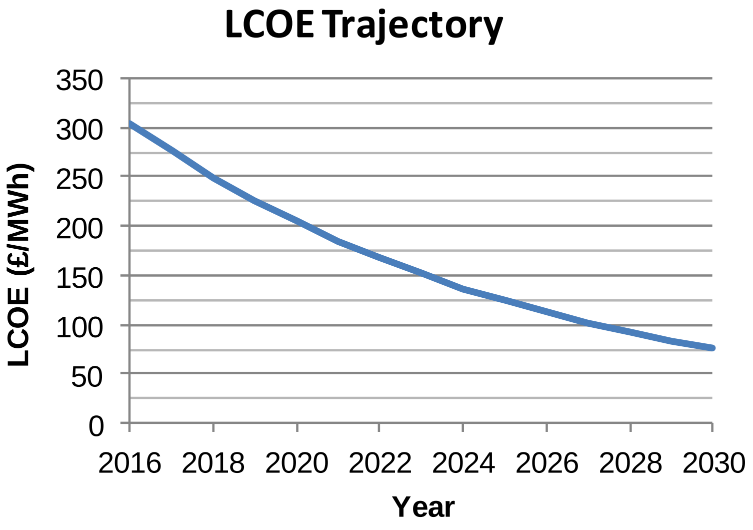
BVGassociates

A new approach for wave

Determining the budget for wave energy devices in 2016, to ensure future viability

LCOE trajectory - £305/MWh

- Start with 2030 grid parity target and work back to 2016 target
- Use LCOE learning rate of 12%
- Assume market grows form 1 MW in 2016 to 2,000 MW in 2030



LCOE in 2016 for wave devices

- Use learning rate and market growth rate to work backward from 2030 and determine LCOE target of £305/MWh in 2016

Assumptions	2016
Installed capacity in 2016 (MW)	1
LCOE (£/MWh)	305
Net capacity factor	20%
Weighted average cost of capital	14%
Project life (years)	20
Scenario 1: Low CAPEX, high OPEX	**2016**
CAPEX budget (£/MW)	2,300,000
OPEX budget (£/MW)	188,000
Scenario 2: High CAPEX, low OPEX	**2016**
CAPEX budget (£/MW)	3,310,000
OPEX budget (£/MW)	35,000

Cost targets - wave

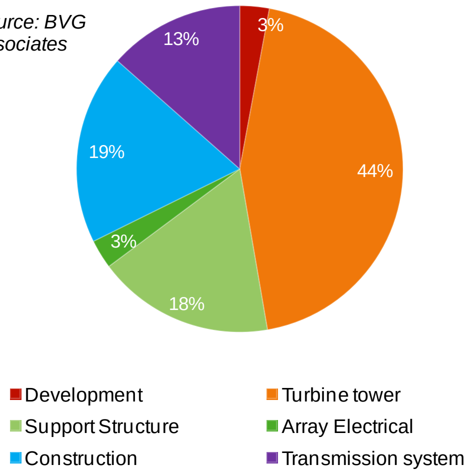
Determining the budget for wave energy devices in 2016, to ensure future

2016 CAPEX targets for wave devices

- Start with 2030 grid parity target and work back to 2016 target
- Use LCOE learning rate of 12%
- Assume market grows form 1 MW in 2016 to 2,000 MW in 2030
- Start with 2016 bottom-fixed offshore wind
- Same CAPEX adjustments as with tidal devices

→ *Gives CAPEX of £431,000/MW for development, array electrical, and transmission*

Source: BVG Associates



Offshore wind (bottom-fixed) CAPEX breakdown in 2016

2016 budget for wave devices (installed cost)

- Adjusting offshore wind cost model and backing out balance of station gives budget for device
- In scenario 1 (High CAPEX, low OPEX), the budget for installed device is £1,870,000/MW
- In scenario 2 (Low CAPEX, high OPEX), the budget for installed device is £2,879,000/MW

Cost targets vs experience

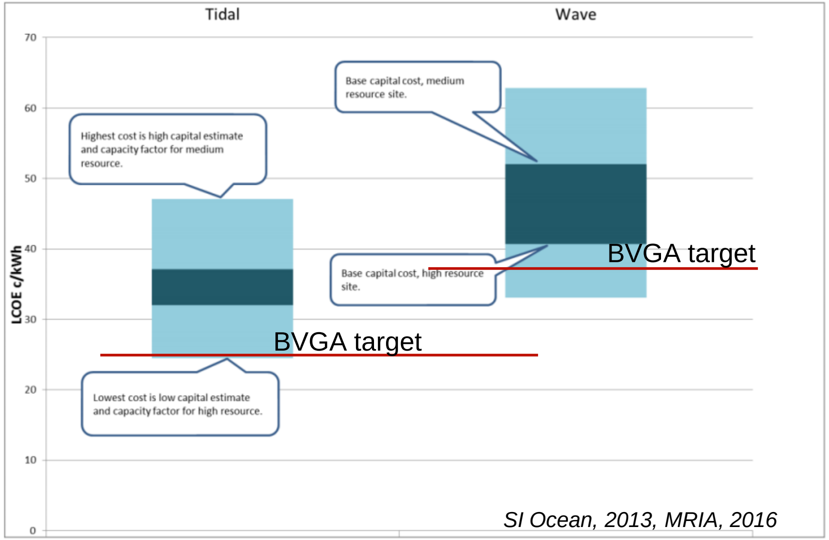
Are these 2016 LCOE targets achievable?

- Tidal energy needs to achieve £200/MWh for devices and arrays installed in 2016
- Wave energy needs to achieve £ 305/MWh in 2016
- The best devices at the best sites can achieve these targets
- How do we achieve the targets at average sites?

Reported range of LCOE

- Analysis by SI Ocean shows range of LCOE for wave and tidal

Figure 2 Early Array Costs



SI Ocean, 2013, MRIA, 2016

BVGassociates

Conclusions

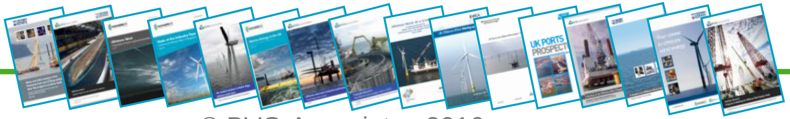
Best of the best or game-changers?

Conclusions

- To have a good chance of achieving grid parity by 2030, OPEX needs to be low and installed cost (device, foundation and installation):
    - For wave devices needs to be £1.9m to £2.9m per MW in 2016
    - For tidal devices needs to be £2.4m to £3.6m per MW in 2016
- Many devices currently under development will struggle to meet these targets
- Development and demonstration focus should be on device architectures that meet 2016 cost targets and are inherently low in OPEX (best of the best)
- Additional research focus should include:
    - Game-changing architectures
    - Dual-use applications (which could offset set balance of station costs)

BVG Associates

- Market and supply chain
    - Analysis and forecasting
    - Strategic advice
    - Business and supply chain development
- Economics
    - Socioeconomics and local benefits
    - Technology and project economic modelling
    - Policy and local content assessment
- Technology
    - Engineering services
    - Due diligence
    - Strategy and R&D support



BVGassociates

Thank you

BVG Associates Ltd.
The Blackthorn Centre
Purton Road
Cricklade, Swindon
SN6 6HY UK
tel +44(0)1793 752 308

The Boathouse
Silversands
Aberdour, Fife
KY3 0TZ UK
tel +44(0)1383 870 014

The Green Garage
4444 Second Avenue
Detroit, MI
48201 USA
tel +1 206 459 8506

info@bvgassociates.co.uk
@bvgassociates
www.bvgassociates.co.uk

BVGassociates