Creating an innovation ecosystem for wave and tidal energy – opportunities and challenges

The Scottish Story

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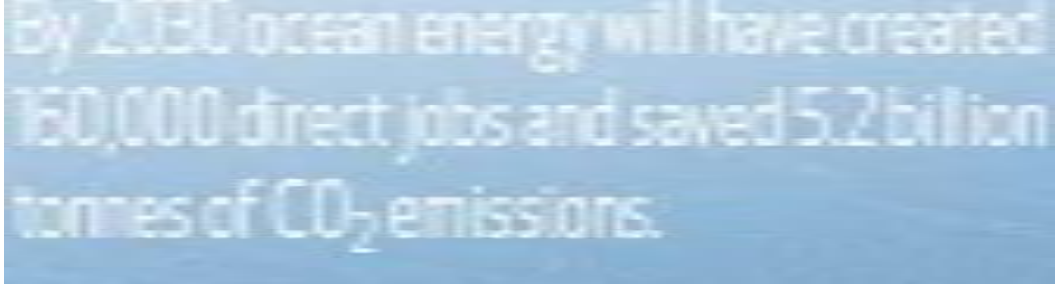
Why wave and tidal?



- Marine Energy Resources:
  - Widespread and close to 1/3 of world's population
  - Wave and tidal energy at mid-high latitudes
  - OTEC (Ocean Thermal Energy Conversion) is at tropical latitudes, so complementary with wave and tidal
  - High energy density, so space requirements will be limited

- Technologies
  - Technologies are still immature and diverging
  - Tidal: some convergence towards horizontal axis turbines
  - Unit costs of generated electricity (in £/kW and £/kWh) will be deciding factors

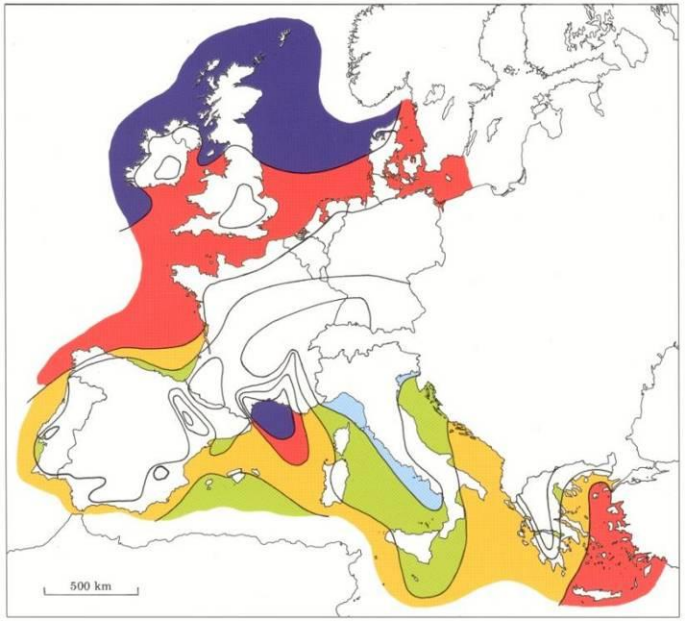
- Environmental Dividend
  - Very little environmental impact, particularly for wave and tidal
  - Marine energy resources have no other uses
  - Competition for space for other uses should be manageable

- Markets for Marine Energy
  - Utility-scale electricity generation
  - Integration with desalination/production of drinking water
  - Remote – largely diesel replacement

Why Scotland?

"*The biggest opportunity since the pioneering days of offshore oil and gas*"

- Scotland has:-
  - 206GW of offshore wind, wave and tidal potential
  - installed offshore capacity of up to 68 GW by 2050
  - higher capacity factors
  - the UK's greatest >100m deepwater potential
- 25% of Europe's wind and tidal resource
- 10% of Europe's wave potential



Wind resources over open sea (more than 10 km offshore) for five standard heights

	10 m		25 m		50 m		100 m		200 m	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
	7.0-8.0	350-600	7.5-8.5	450-700	8.0-9.0	600-800	8.5-10.0	650-1100	9.5-11.0	900-1500
	6.0-7.0	250-300	6.5-7.5	300-450	7.0-8.0	400-600	7.5- 8.5	450- 650	8.0- 9.5	600- 900
	4.5-6.0	100-250	5.0-6.5	150-300	5.5-7.0	200-400	6.0- 7.5	250- 450	6.5- 8.0	300- 600
	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300

Wave & Tidal Cluster Competitiveness

11/20/2012

From 2012

Firm Strategy & Rivalry

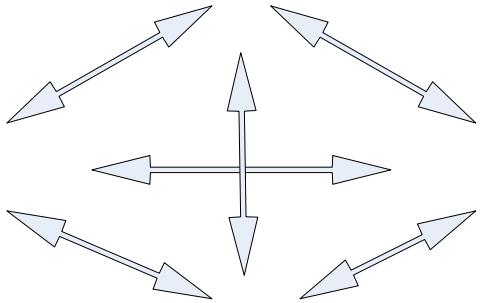
Advantages:
Opportunity exists to gain first mover advantages in Scotland – no incumbents.
Can use Scottish base to serve international markets, esp in high value activities.
Company collaborations taking place at early stage in industry development.
Strong 'energy' supply chain already developed in Scotland from Oil & Gas and conventional power sectors.
Utility companies (SSE & SP) have critical roles in driving cluster development.
Newcomers appearing – with new technologies.

Disadvantages
Small company base and many of the early innovative companies not expected to survive.
Need new companies to enter industry.
Existing companies with relevant skills and technologies not always interested at such an early and risky stage in wave & tidal.
Difficult to compete for skilled labour against established industries.
Development path planned by some companies includes being taken over.
Parent companies likely to have existing supply chains.
Manufacturing capacity for overseas markets likely to be located close to market.
Company income streams not yet defined.

Advanced Factor Conditions

Advantages
Abundant wave and tidal natural resources - esp west coast locations.
Good awareness and working links between industry and research base.
Strong energy research institutions act as sources of innovation and technology-related entrepreneurship.
Streamlined process for 'licensing' in Scotland
Energy Lab – coordination and one-door approach for strong set of existing test and demonstration facilities, esp EMEC
Crown Estate supportive.
Big equipment likely to be produced locally because of transport implications.

Disadvantages
Skills availability – competition with other related industries.
Investment difficult to secure.
Port infrastructure lacking – mismatch between existing port locations and energy sources.
EMEC at capacity – both occupier churn and expansion of facility needed.
No array testing facilities in Scotland.
Continuous cycle of device development required (with support implications).
Education & training weak – embryonic stage of industry.
Need strategic look at infrastructure requirements across all energy (wind, wave & tidal, O&G, smart grids, transmission, etc.) (see NRIP3)



Related and Supporting Industries

Advantages
Scotland has the advantage of a very strong set of existing related and supporting industries developed largely to serve Oil & Gas industry.
Synergies with emerging offshore wind industry
Wave and tidal supply chain inputs already being sourced from onshore wind industry.

Disadvantages
Wave & tidal supply chain incomplete – but can draw on related.
Oil & Gas activity on a high at present with high oil price.
Port infrastructure required for renewables – expensive.
Advantages of a 'mass market' in wave and tidal not likely to emerge – with resultant high cost implications for industry.
Some cross-overs from related industries occurring but still limited. Easier in service activities.

Demand Conditions

Advantages
Demand for renewable energy driven by ambitious climate change targets.
Demand for energy increasing worldwide.
Market demand exists for both large and small devices.
Lot of niche markets expected esp for smaller devices and devices for large energy users (eg. GSK, HP, etc.)
Ongoing innovation essential for industry development. Potential to replicate ITF model for collaborative research.
Consumer demand emerging for renewable energy.
Public sector support important driver - via ROCs and various forms of grant funding, eg WATERS 2.
Saltire Prize unique.

Disadvantages
Complex demand picture.
Demand distant from supply.
Current lack of standardisation across different markets acts against drive for cost reductions.
Development of SMART Grid technologies and infrastructure will be essential to support renewable industries in Scotland
Insurance problematic (expensive).

From 2012

RELATED & SUPPORTING INDUSTRIES

- Gearboxes
- Oils & lubricants
- Generators
- Cable mfg
- Bearings
- HSE
- Finance
- Power transmission
- Legal
- Switchgear
- Insurance
- ROV / Diving
- Skills / training
- Electrical connection
- Stakeholder consulting
- Blades
- Civil Eng.
- Coatings
- Foundry
- Cable installation
- Composites
- Instrumentation

INNOVATION & UPGRADING

- Scottish Energy Lab (50+ assets)
- Offshore Renewable Energy Catapult
- Scottish Universities
- Strathclyde TIC
- ITREZ
- ETP

- Scottish Renewables
- Scottish Enterprise
- Carbon Trust
- Highlands & Islands Enterprise
- Utilities
- Marine Scotland
- Renewables UK
- NERC
- Scottish Government
- ETI
- Crown Estate
- Technology Strategy Board
- DECC
- SDS

DEMAND

Development & Consenting

Covers all activities up to the point where contracts for devices, balance of plant and installation services are placed.

- Design & feasibility
- Physical surveys
- Environmental surveys & monitoring
- Met./ resource monitoring
- Planning & Licensing

Activities related to project feasibility inc. env. and human impact, surveying site, application for electrical grid connection and planning consent and front-end engineering design.

Device Manufacture

Devices generally consist of:
a prime-mover element coupled to a power take-off arrangement;
a reaction system and
a control system.

- Electrical & hydraulic components
- Device development
- Power take-off & control
- Fabrication
- Materials supply
- Assembly

It is likely that most device manufacturers will specify and purchase main components and assemble them into finished devices. **Could be different companies between device development and manufacture/assembly.** The balance between in-house mfg and outsourcing is likely to evolve.

Balance of plant

The balance of plant for a wave or tidal project includes all components that are not part of the device but are necessary for its construction and operation.

- Site preparation
- Foundations
- Offshore Hub/substation
- Onshore Hub/substation
- Cabling & protection
- Electrical systems
- Moorings
- Collision avoidance

Installation

Includes onshore assembly, offshore installation and on-site commissioning.

- Device installation
- Grid connection
- Commissioning
- Vessels

Stage ends with hand-over to the client.

Operation & Maintenance

All activities necessary to ensure generation for 25 year operational life.

- Power plant operation
- Performance monitoring
- Inspection
- Device repair
- Maintenance hubs

UTILITIES

System Integrators

UK Markets

- Large single-site users
- Energy storage
- Energy Utilities
- Remote communities
- Other project developers

International Markets

- Energy
- Research
- Test facilities
- Devices
- Consulting
- Services

Non-customer drivers of demand

- Scottish targets: Climate & Energy
- UK Energy strategy
- Carbon price
- RoCs (pre2017)
- CfDs (2017-)
- Renewables Obligation
- Offshore transmission regulations
- Emission performance standards
- Oil & Gas market

INFRASTRUCTURE AND INFRASERVICES

- On / off-shore accommodation
- Transport infrastructure
- Port construction facilities
- Tank test facilities
- Offshore test facilities
- Component test facilities
- Port service facilities
- Service vessels
- Transmission Grid
- Smart Grids

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Lessons Learned

- Using cluster approach provides context, can see the whole industry and its inter-linkages

Supporting the Industry – developing the innovation ecosystem

Providing the platform, e.g. EMEC

- In a new and emerging industry, you need to start at the beginning (though it goes further back than this!)

- 2001Recommendation made by the House of Commons Science and Technology Committee
- 2003EMEC established
- 2004Wave test site at Billia Croo opened
- 2004Pelamis 750 began testing at Billia Croo and became the world's first to generate electricity
- 2004EMEC initiated development of industry standards
- 2005UKAS (United Kingdom Accreditation Service) accreditation obtained
- 2006Tidal test site at Fall of Warness opened
- 2008 Open Hydro became the first tidal turbine to generate electricity to the grid in the UK

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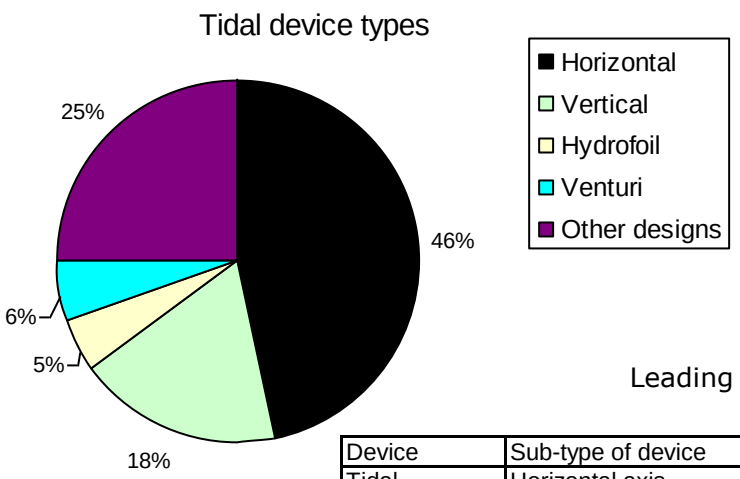
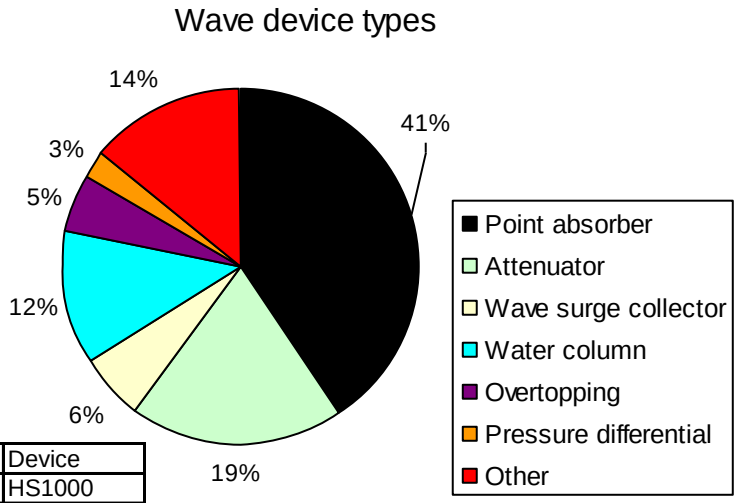
- Initial investment will be required, need to develop infrastructure for support to enable the industry

Technology Development – from 2013



88 devices



156 devices

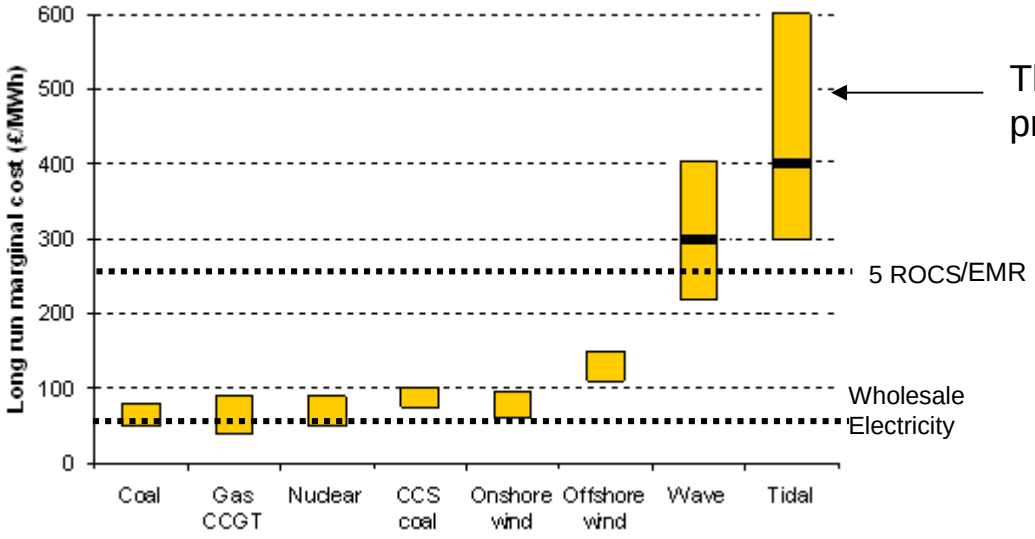
Leading devices

Device	Sub-type of device	Company	Device
Tidal	Horizontal axis	Andritz	HS1000
Tidal	Horizontal axis	Alstom	DeepGen
Tidal	Horizontal axis	Atlantis	AR1000
Tidal	Horizontal axis	Kawasaki	
Tidal	Horizontal axis	Siemens/MCT	Seagen
Tidal	Horizontal axis	Atlantis	AK1000
Tidal	Horizontal axis	Voight	
Tidal	Horizontal axis	Scotrenewables	SR250
Tidal	Horizontal or vertical axis	Bluewater	
Tidal	Venturi	OpenHydro	OC Turbine

Device	Sub-type of device	Company	Device
Wave	Point absorber	AWS	AWS III
Wave	Point absorber	OPT	Powerbouy
Wave	Point absorber	Seatricity	Oceanus
Wave	Attenuator	Pelamis	P2
Wave	Oscillating water column	Voight	Limpet
Wave	Wave surge collector	Aquamarine	Oyster
Wave	Other - rotating mass	Wello Oy	Penguin

Cost of Energy challenge

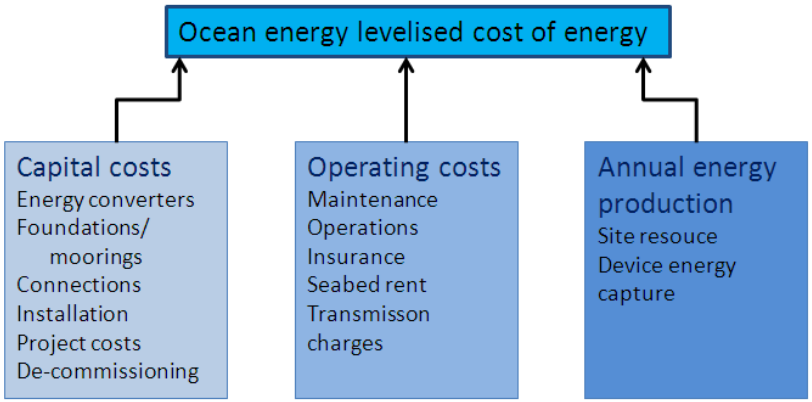
Marine power cost of energy & Scottish revenue support



These costs based on first array projects

Falls in levelized generation costs over time can be attributed to a 'learning rate'. This generally occurs due to:

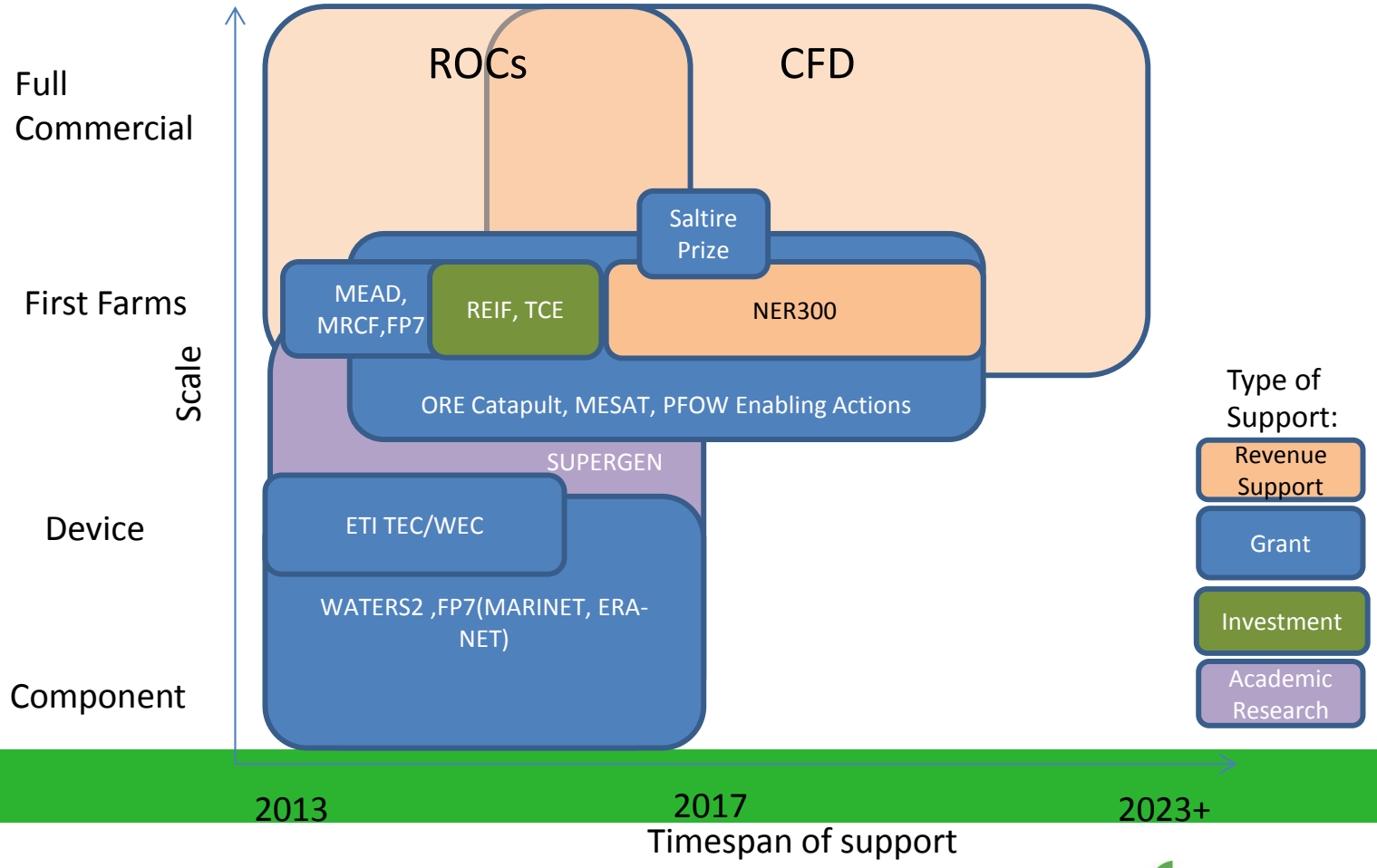
- Learning by doing
- Innovation
- Economies of scale



Lessons Learned

- Using cluster approach provides context, can see the whole industry and its inter-linkages
- Initial investment will be required, need to develop infrastructure for support to enable the industry
- Technologies and companies will come and go
- But some thing will remain constant – driving costs down
- Expert support from elsewhere may well be limited

Funding the Industry - then



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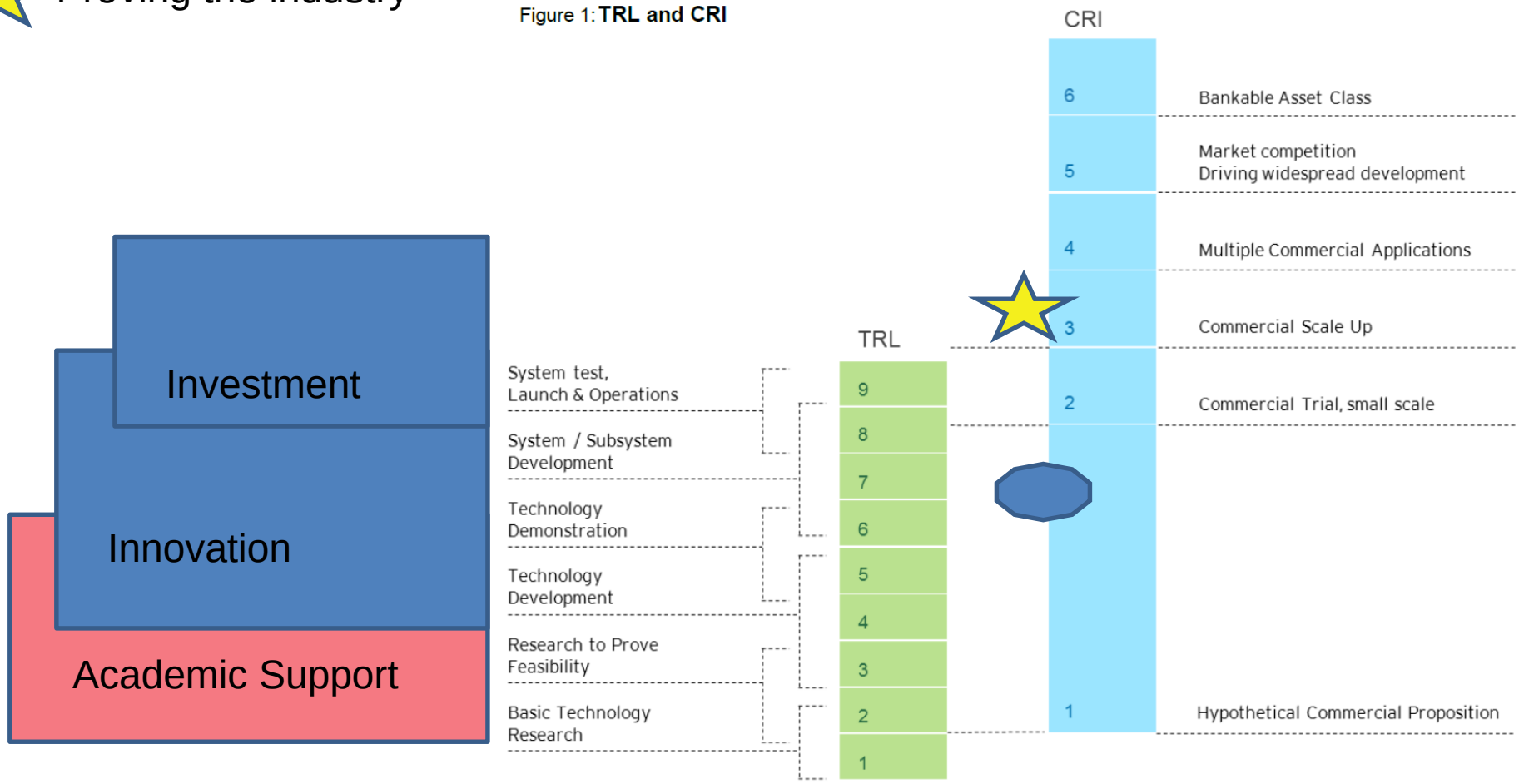
Proving the technology

Proving the industry

Funding - now

Figure 1: **TRL and CRI**



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- Initial investment will be required, need to develop infrastructure for support to enable the industry
- Technologies and companies will come and go
- But some thing will remain constant – driving costs down
- Beware optimism bias!
- Industries are not the same
- Individual industries require individual support

Supporting the Industry – opportunities for development

Consolidation

Tidal Power Scotland Limited
Two large-scale tidal projects under construction in Scotland in 2016
MeyGen (Phase 1A + Phase 1B) and Sound of Islay

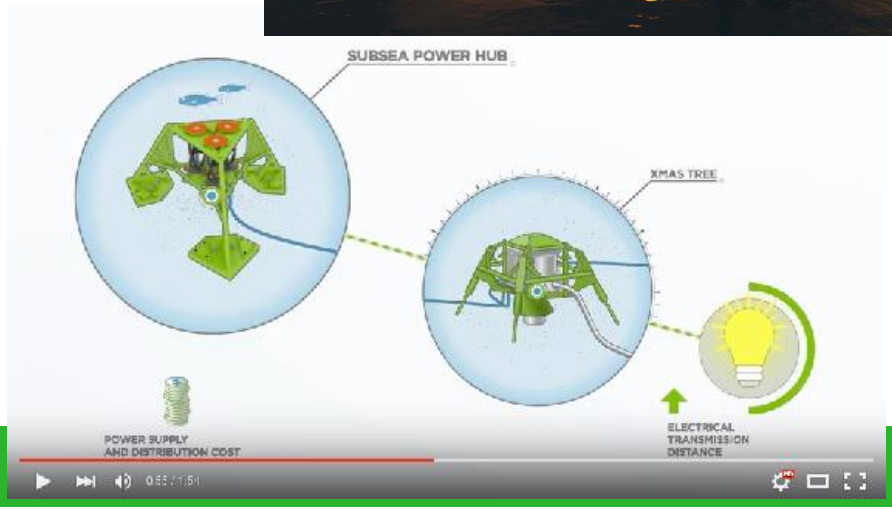
TPSL Target

170m

of tidal power projects under construction in 2016 in Scotland

Diversification

East Coast Oil and Gas – Subsea Power Hub comprises a novel seabed turbine that will use **ocean currents to generate electricity** which is then **stored in batteries**. Electrical failures within subsea umbilical cords are the primary failure point for offshore oil and gas production.



Nova REStoreSystem

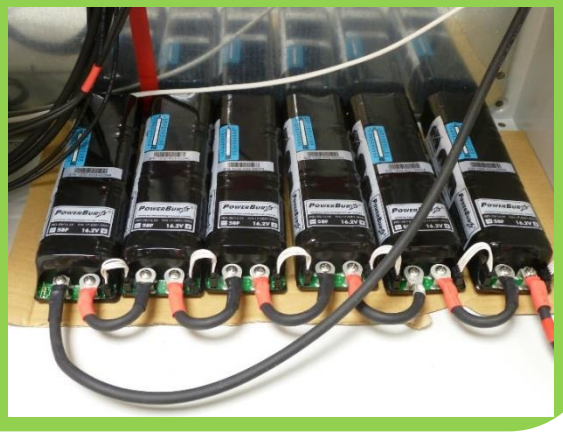
Tidal turbine emulator

User interface

Storage Medium

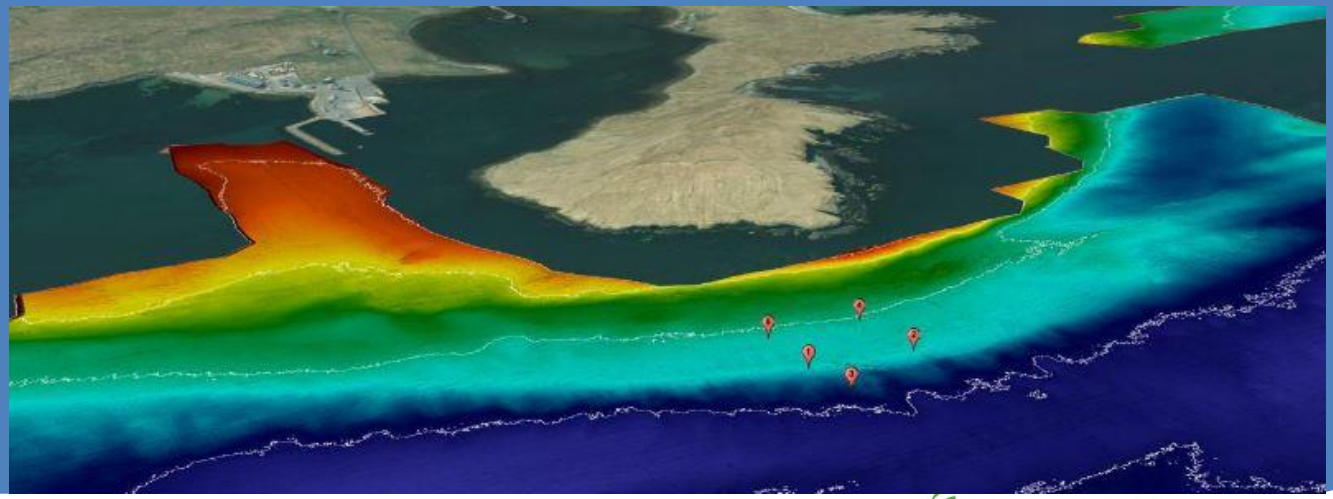
Fully functional lab

tidal simulator

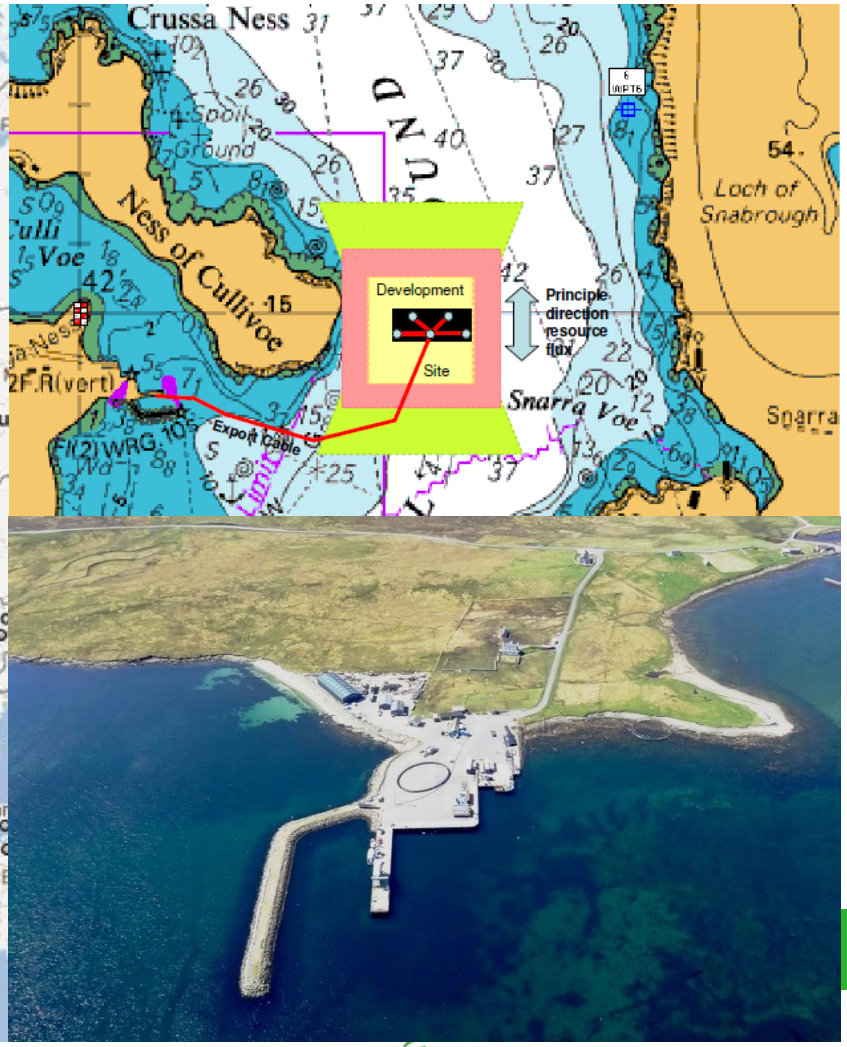


Fully operational site

Active Network Management and grid constraint



The Shetland Tidal Projects – Nova Innovation



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Building The Industry – the steps to commercialisation

- Focus on customers – niche markets, shared wins, increase demand pull
- Address common needs, e.g. Ocean Energy ERA-NET
- Focus on business development requirements – cross sectoral learning, learn from elsewhere
- Manage risks and collaborate to succeed
- Deliver Success

Thank You

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