Pelamis WEC Technology

- Articulated cylinder
- Swings head-on to incident waves
- 4 x main segments, 3 x joints
- Wave induced joint motion resisted to absorb power

- 140m long, 3.5m diameter
- 750kW rated power
- Capacity factor 0.25-0.4

Breakthrough technology with unique competitive advantages
OPD – key strengths

Board of Directors

Management, Finance, Admin (5)
- Health & Safety and QA

Sales and Marketing (4)

Technical (28)
- R&D, Design & Testing

Production (22)
- Joint Module Manufacture
- Pelamis Assembly

Offshore Operations (4)
- Installation
- Operation & Maintenance

Skills, expertise and experience to deliver business plan

- Effective strategic planning and corporate governance
- Efficient company and financial management and administration, focus on H&S & QA
- Global sales & marketing strategy & team
- World class engineering team, supported by Atkins (verification), Frazer Nash (reliability)
- Established team & base, ‘lean production’ philosophy from the outset (‘Toyota’ principles), rigorous knowledge capture and feedback
- Established team & procedures, currently growing to meet demand. Introduction of use of installation contractor for moorings

Commercial in Confidence
PAST: Development to Full-Scale Prototype

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- **Concept development**
- **Primary R&D & modelling**
- **7th-Scale prototype**
- **Full-scale R&D & design**
- **Full-scale joint test**
- **Production prototype**
- **Cost reduction & performance enhancement**

Rigorous, staged & efficient R&D
Pelamis Concept Summary

- **Self-referencing**
  - Buoyancy: Buoyancy (Strong Forces)

- **Resonance**
  - High theoretical limit ~ Wavelength/2
  - Roll bias: Damping only

- **Survivability**
  - Tuneable resonance response
  - Buoyancy limited in short steep waves
  - De-referencing in large longer waves

Breakthrough technology with unique competitive advantage
Competitors almost exclusively ‘POINT ABSORBERS’
- Ultimate power capture limit ~ wavelength/6

PELAMIS is a ‘LINE ABSORBER’
- Ultimate power capture limit ~ wavelength/2

Breakthrough technology with unique competitive advantage
Resonance – Roll Bias

Tuneable inclined motion

- Non-resonant: equal damping
- Resonant response: differential damping

Breakthrough technology with unique competitive advantage
Survivability – Buoyancy Limited

Breakthrough technology with unique competitive advantage
Survivability – Buoyancy Limited

- Self-limiting ‘hydrostatic loading’
  - => limits absorbed power in large waves

Breakthrough technology with unique competitive advantage
# Development to Full-Scale Prototype

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Rigorous, staged & efficient R&D
# Primary R&D – Numerical Modelling

<table>
<thead>
<tr>
<th>Program</th>
<th>Application</th>
<th>CPU</th>
<th>Body - Dynamics</th>
<th>Hydro - Dynamics</th>
<th>Control</th>
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<tbody>
<tr>
<td>Pel_freq</td>
<td>Global Optimisation</td>
<td>2 secs</td>
<td>Linear</td>
<td>3D</td>
<td>Linear</td>
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<tr>
<td>Linear</td>
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<td>2D</td>
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<td>Freq. Domain</td>
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<tr>
<td>Pel_ltime</td>
<td>Control</td>
<td>2 hours</td>
<td>Linear</td>
<td>3D impulse</td>
<td>Non-Linear</td>
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<tr>
<td>Linear</td>
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<td>3D</td>
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<tr>
<td>Time Domain</td>
<td>Fatigue</td>
<td></td>
<td></td>
<td>2D</td>
<td></td>
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<tr>
<td>Pel_nltime</td>
<td>Survivability</td>
<td>4 days</td>
<td>Non-linear</td>
<td>2D(d)</td>
<td>Non-Linear</td>
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<td>Non-Linear Time Domain</td>
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Primary R&D – Experimental Model Testing

- Testing conducted over a range of scales:
  - $80^{th}, 50^{th}, 33^{rd}, 20^{th}$ & $7^{th}$ scale
- Verification of numerical models
- Survivability in extreme seas

Breakthrough technology with unique competitive advantage
Primary R&D – Modelling
Primary R&D – Modelling
# Development to Full-Scale Prototype

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**Concept development**

**Primary R&D & modelling**

**7th-Scale prototype**

**Full-scale R&D & design**

**Full-scale joint test**

**Production prototype**

**Cost reduction & performance enhancement**

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Rigorous, staged & efficient R&D
7th Scale Power Take-Off Rig

- Ballscrew actuation rig used to test power take-off system and provide experimental verification of power take-off simulation
1/7th Scale Machine

- Primary transmission functionally identical to full-scale system
- Prototype for full-scale control hardware
1/7\textsuperscript{th} Scale Machine
1/7th Scale Machine
1/7th Scale Machine
Development to Full-Scale Prototype

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Rigorous, staged & efficient R&D
Full-Scale Test Rig

Full-scale joint test rig moment time series

- - - demand  --- applied

Time (s)

Moment (normalised)
Rams and Control Manifolds

Tandem (2 piston) design
Two per axis
All valves in ram manifold with control card also local
Flexible hoses to main manifold
Accumulators and Reservoirs

Piston accumulators with gas back-ups
Large enough to smooth output between wave groups
Bladder type sealed reservoirs
Motor Generator (MG) Set

- 2 x 125kW 690V induction generators per module
- Variable displacement motors
- Single package incorporating filtering, switchgear, PFC & controls
- Full instrumentation and interlocks
Full-Scale Test Rig
Development to Full-Scale Prototype

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Rigorous, staged & efficient R&D
Assembly of Full Scale Prototype Modules
Assembly at Rosyth
Graphical User Interface (GUI)

- Point and click windows environment
- Similar to established SCADA systems
- Integrated alarm system
- Limited graphical information
- Operates in conjunction with independent visualisation system for plotting and analysing data in near real-time
GUI Prototype Sub-windows

Hydro Module 2: Sway Axis

Power Module 1: Environment

Board Diagnostics

Power Supply

 Sensors

Analogue Values

Power

60V insulation resistance
16.4 MΩ

80V insulation resistance
34.6 MΩ

Faulty supply
32.8 MΩ

Power factor
0.38

Transformer Switch Gear Controller

Line currents

R 9.3 mΩ

Y 5.9 mΩ

Line voltages

R 695 V

Y 695 V

Control

Pre Comp (M)

Controller
Prototype Testing Summary

- Emphasis on protecting the system while establishing reliability
- 1000 hours operation to date
- All testing to date in modest waves <4m Hs, (<7m Hmax)
- Conservative control setting used (joint angles < 1/3 available range)
- Have been a few teething problems – nothing major or fundamental
- Absorption & conversion agrees with predictions
- Peak instantaneous power of >600kW on each axis
- Peak electrical output ~200kW in 25kW/m (Hs 2.0-2.5m)
- Average electrical output of 100kW in 20kW/m
- Typical capture widths 4-6m, consistent with projections for settings used
- Typical overall conversion efficiency 60-70% (at <200kW) as per predictions
- Machine in water 16 months – no significant corrosion or fouling
- Operational procedures recently refined for smaller boats
# Development to Full-Scale Prototype

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Rigorous, staged & efficient R&D
Cost Reduction

Cost reduction drivers:
- Technological advances
- Cost of capital
- Economies of scale

Source: European Commission ATLAS
WAVE ENERGY - major resource + feeder markets

- WORLD  > 2000 TWh/yr, £500bn CAPEX (c.f. existing hydro & nuclear)
- eg UK  > 80 TWh/yr (~20%), >£20bn CAPEX
- eg Portugal > 12 TWh/yr (~25%), >£5bn CAPEX
Enersis – Project #1

Enersis
- Portugal’s largest developer of renewable projects
- Subsidiary of Semapa
- Aim to be Portugal’s leading wave developer

Project phase 1:
- Three Pelamis P1A machines
- 2.25 MW
- 5km off Aguçadoura
- 50m water depth
- Cable + substation in place
Enersis – Project expansion

Phase 1
- Three Pelamis P1A 750KW machines
- Production underway
- Permitting and consents secured

Phase 2
- Letter of intent
- Expand project to 24MW
- Grid connection rights secured

Phase 3
- Multi-site deployment
Production for Portugal

Component/ sub-suppliers:
Main tube fabricator
Main tube castings
Power module fabricator
Hydraulic rams
Accumulators
Generator Pack

Assembly/commissioning: OPD

Production of 3 machines progressing to cost and schedule
Fife - Methil
Fife - Methil
Camcal - Lewis
Camcal - Lewis
Scotland

- Consortium development
- Plan: phased wave farm
- Grid connection applied for
- Target: first stage 2006
- Key DTI/Scottish Executive market enablement mechanisms
South West England

Wave Hub
- Cornwall
- Consenting and permitting in progress
- 20MW (30MW ultimately)
- Initially allocated in 5MW tranche
- Anticipated 2007

Ocean Prospect
- 5MW at Wave Hub
United States

Electrical Power Research Institute

- Public/private project part funded by DOE, NREL and individual states
- Project: five state wave energy sites in Maine, Oregon, Washington, Hawaii, Massachusetts + city of San Francisco
- Pelamis selected by EPRI as the best and only system currently recommended for deployment.
- Target installation 2007
- Funding for ocean energy approved in recent Energy bill
Other potential market opportunities

**OTHER PROPOSALS AT VARIOUS STAGES**

- **France** (potential for feed-in tariff to be put in place 2006)
- **Spain** (potential for feed-in tariff to be put in place 2006)
- **New Zealand** (sites identified North and South Island)
- **South Africa** (OPD Office in SA, high level of interest)
- **Norway** (scoping study with Norsk Hydro)
- **Canada** (Developed original BC Hydro project on Vancouver Island)
- **Others** (Japan, Chile, Australia, Ireland etc)

**INITIAL POTENTIAL** *(1GW=c.€1.5bn)*

- Europe/Scandinavia >10GW
- USA/Canada >10GW
- South America >10GW
- Western Australia/NZ > 8GW
- South Africa > 4GW

**ULTIMATE POTENTIAL** *(Source: World Energy Council)*

>2000TWh/year, >£500bn