The Pelamis Wave Energy Converter

- An update on performance and operational aspects

Max Carcas
Business Development Director

OCEAN POWER DELIVERY LTD.
www.oceanpd.com

OCEAN POWER DELIVERY

- Incorporated January 1998
- £7.5m VC investment 2002-2004
- £2.5m support from UK DTI
- Based in Edinburgh
- Combined ‘wave’ experience of over 50 years
- 32 full-time personnel

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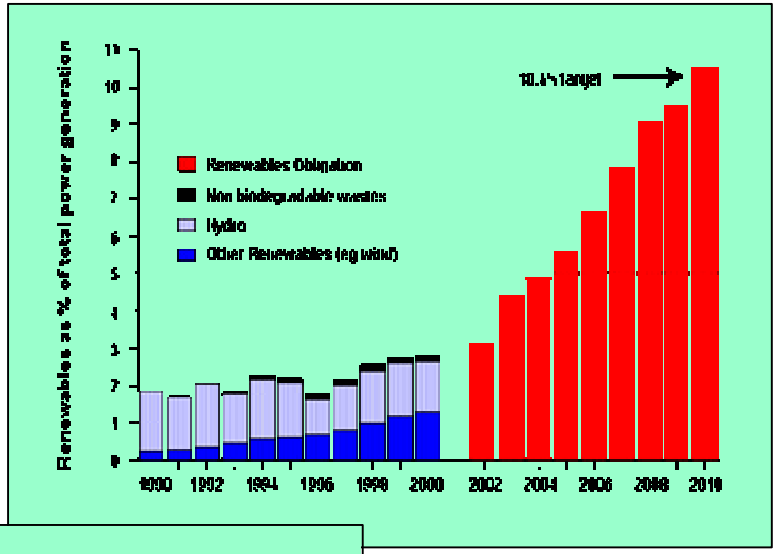
ENERGY POLICY DRIVERS

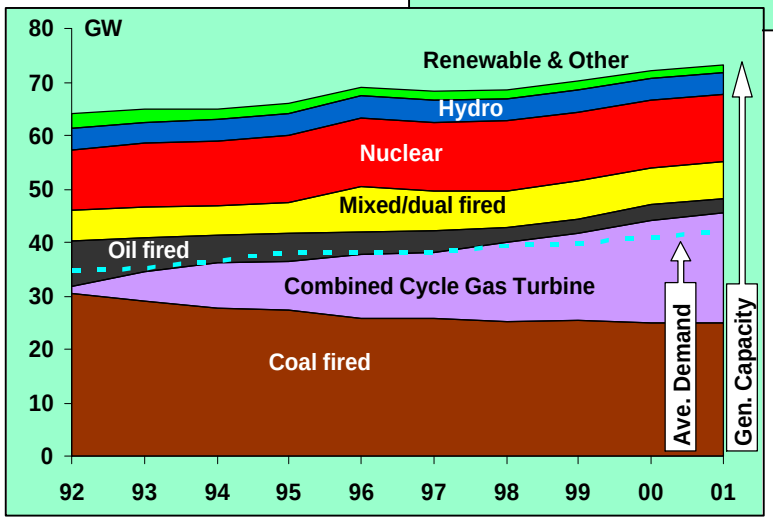
UK ENERGY POLICY OBJECTIVES:

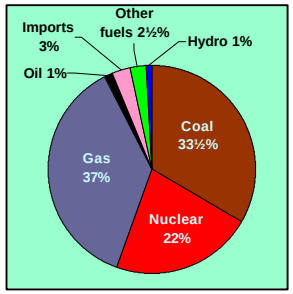
<u>Environmental:</u>
- Global warming
- EU/UK Kyoto commitments

<u>Socio-economic:</u>
- Hidden costs of conventional generation
- Renewables increasingly affordable
- Industrial-economic potential

<u>Security of supply:</u>
- Electricity demand continuing to rise
- Existing power plants reaching end of life
- UK to be net importer of gas in <5 years







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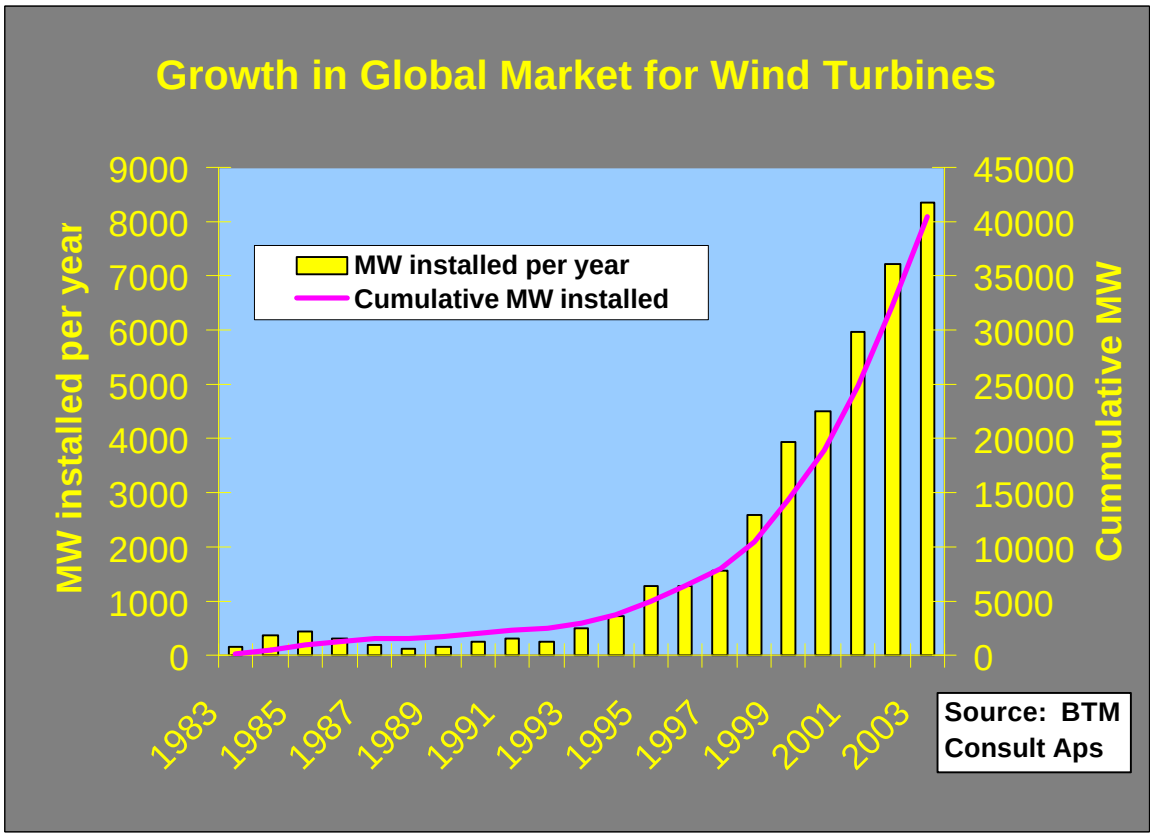
WIND POWER

- Today >40GW installed, 8GW last year
- Fastest growth area in electricity generating industry
- Denmark: >20,000 employed, $3-4bn in exports
- Costs of generation have fallen by ~80% as market has grown
- In the UK first commercial wind farm was only developed 12 years ago



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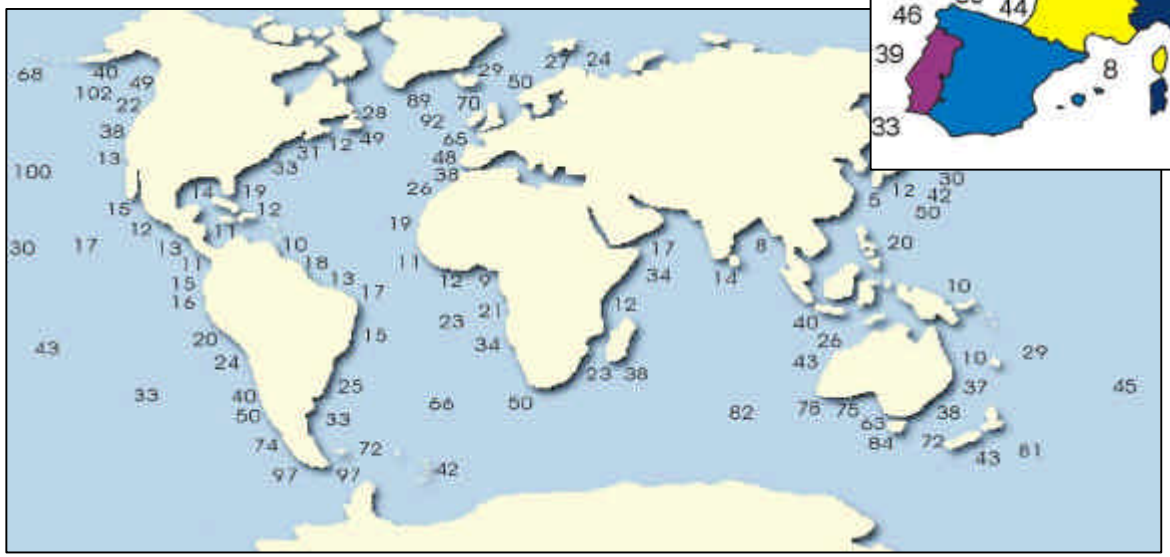
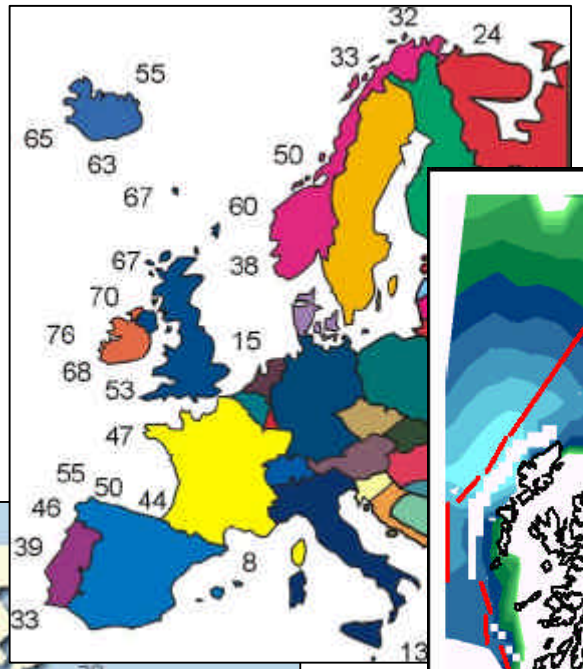
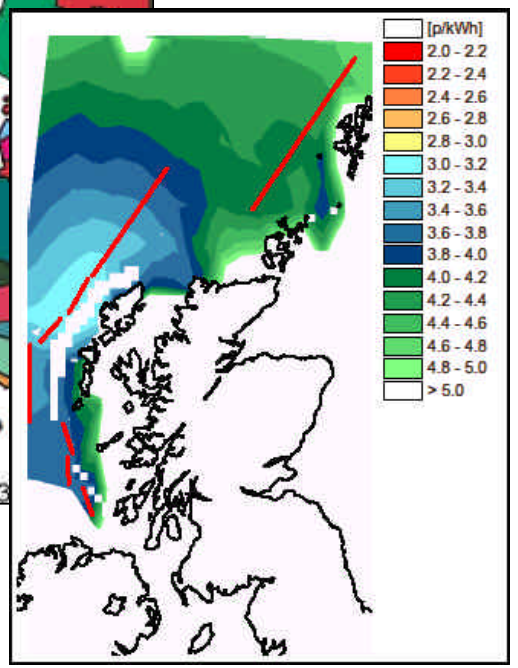
WHY WAVE ENERGY?

Huge Resource & Market

- Most dense renewable resource
- UK ~50-80TWh/year
  ~15-25% UK demand
  >£20bn CapEx
- World >2000TWh/year
  >£500bn CapEx







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WHY WAVE ENERGY?

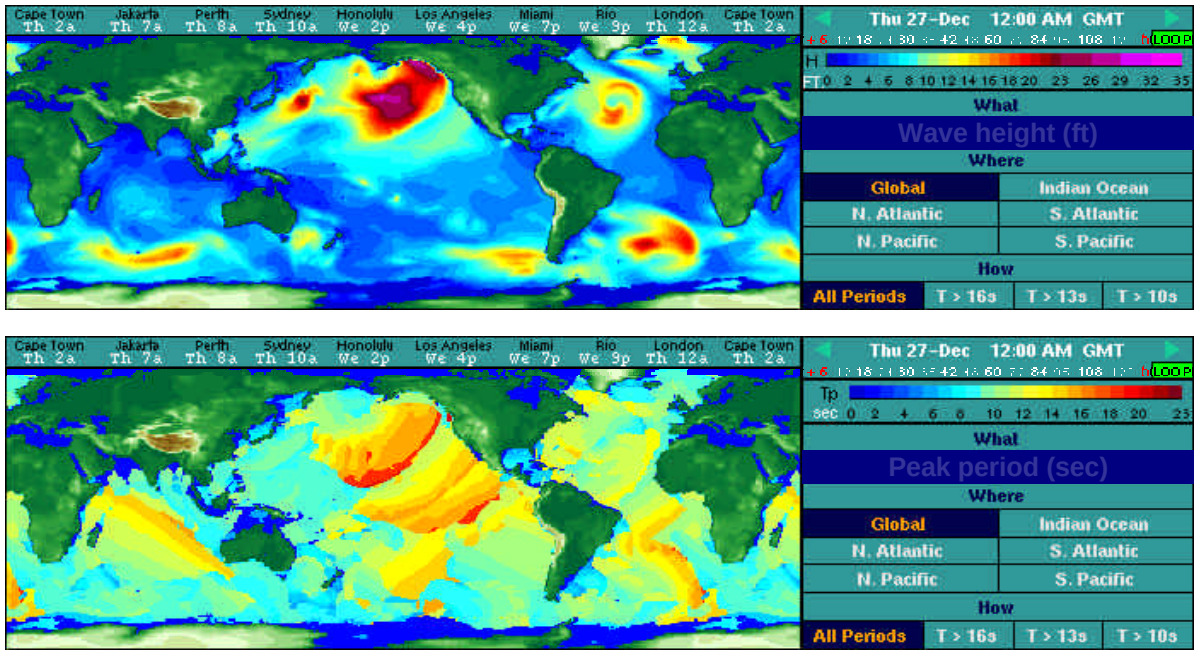
Forecastability

-Numerous calibrated WIND-WAVE models

-Existing offshore forecasting services

-Immunity to local climatic effects

- Small hourly & diurnal variation



Wave forecast images courtesy of LOLA

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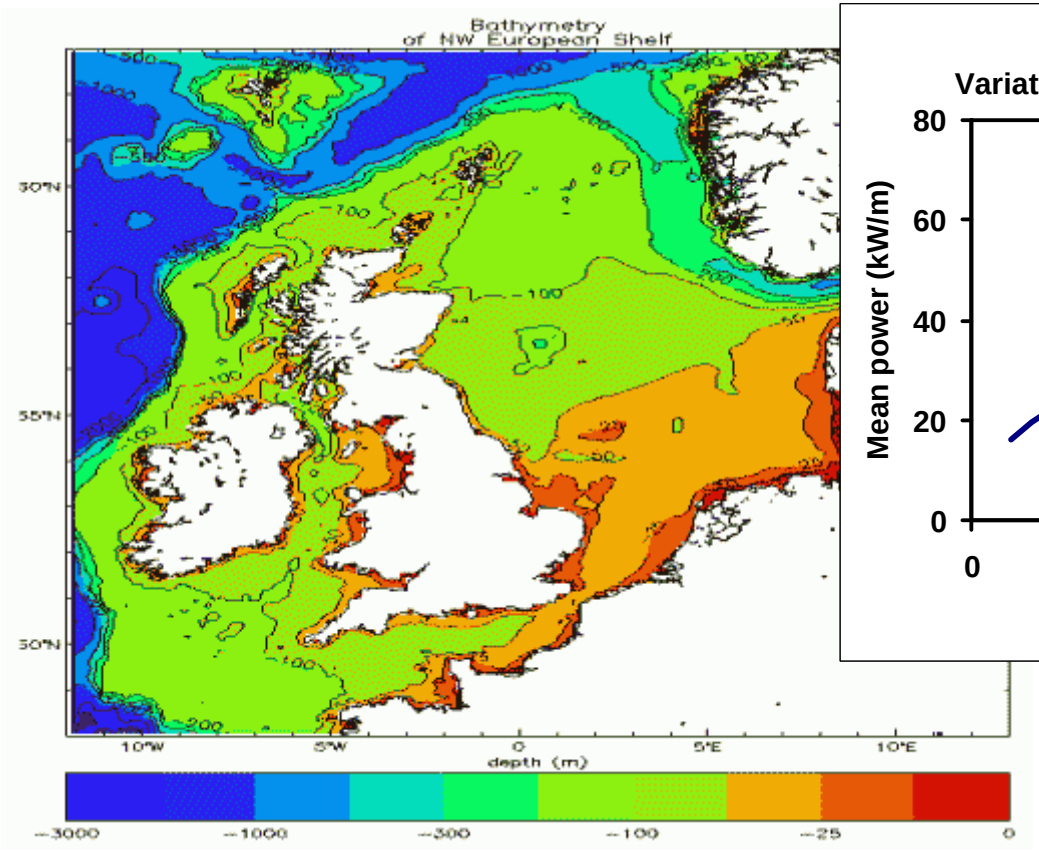
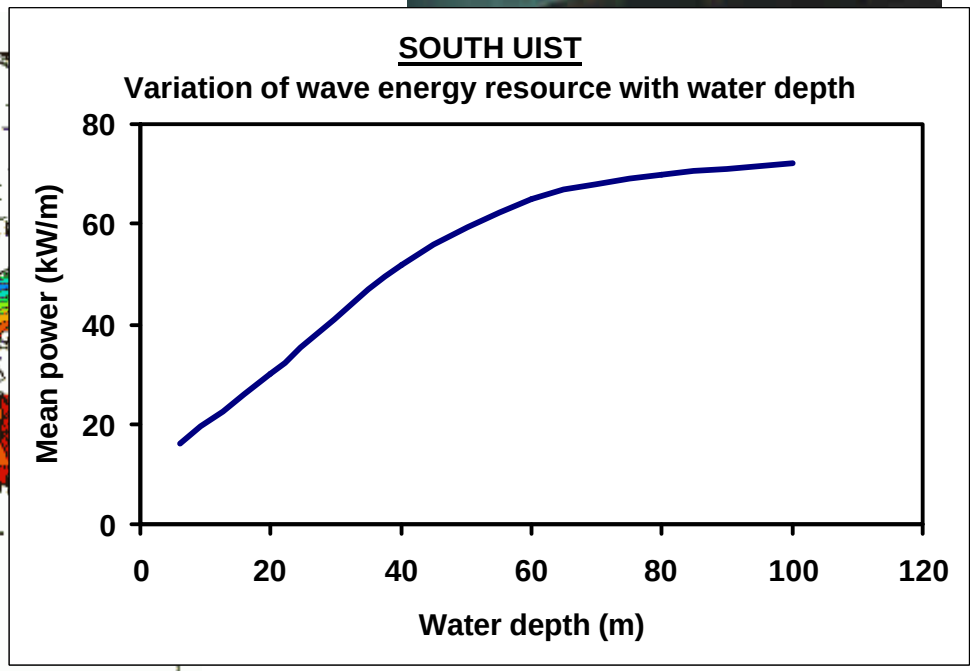
WHY OFFSHORE…?

- **Best resource in deep water >50m**
- **Plenty of space plus high 'power-density'**
- **Minimal environmental impact**
- **Minimum visual intrusion**





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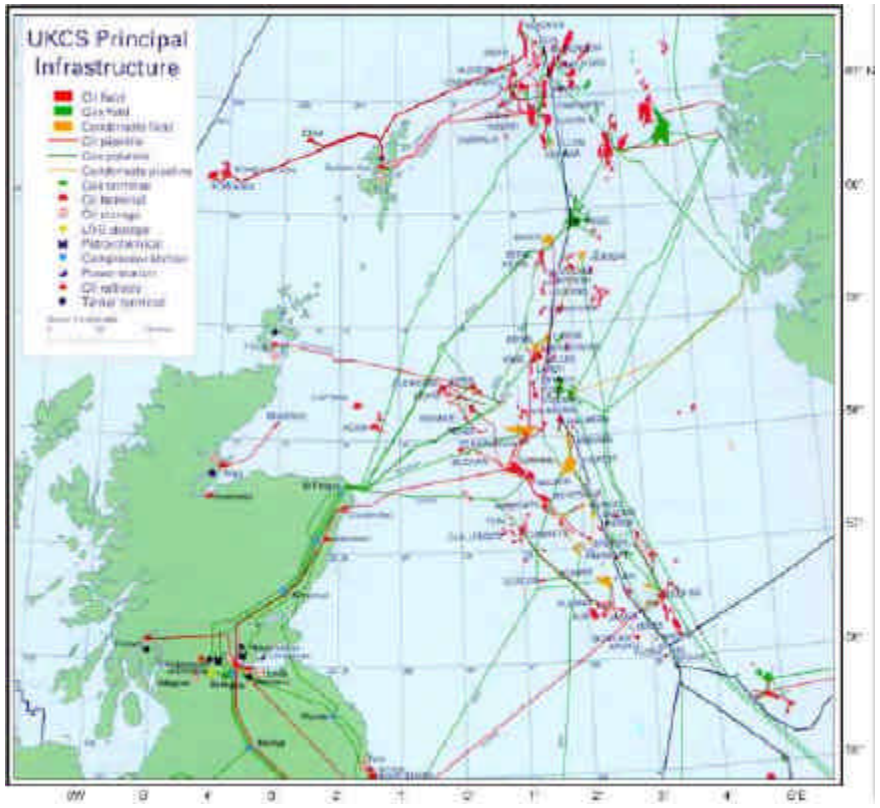
OFFSHORE TECHNOLOGY

The offshore/marine sector's contribution:

"No major technical barriers to the development of wave energy prototypes have been identified. All issues raised under design, construction, deployment and operation can be addressed by transfer of technology from other industries, especially the offshore industry"



DTI Report - Wave Energy: Technology Transfer & R&D Recommendations
Ove Arup, October 2000

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THE PELAMIS WEC

Concept

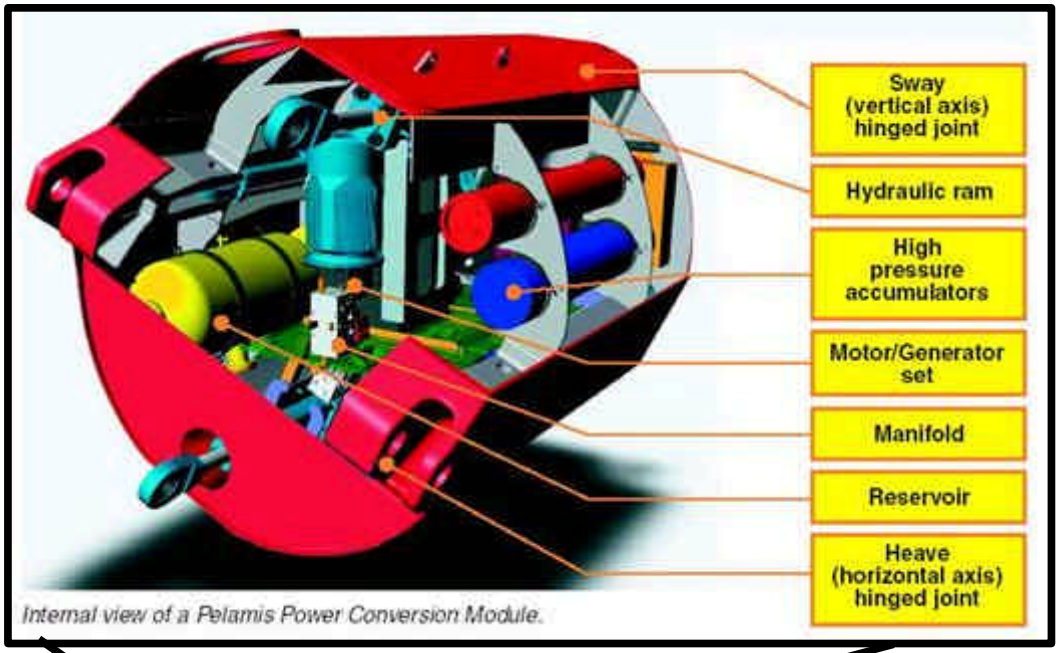
– Articulated cylinder
– Self-referenced
– Slack moored
– Head-on to incident waves

Power Conversion Module

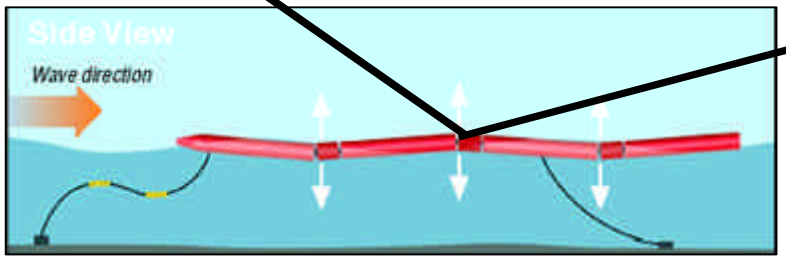
- 4 x hydraulic rams (2 heave, 2 sway)
- 2 x 157kVA/ 125kW motor/generator sets
- 250kW rating

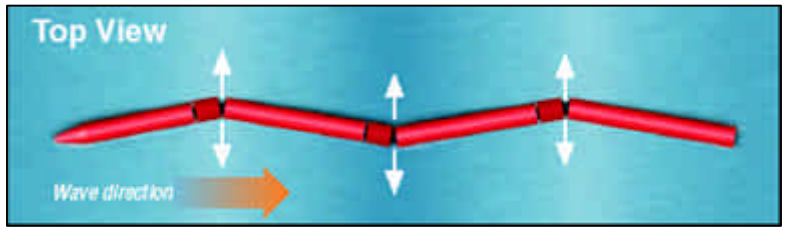
Complete machine

- 150m length
- 3.5m diameter
- 750kW rating
- 2.7GWh p.a.



Internal view of a Pelamis Power Conversion Module.





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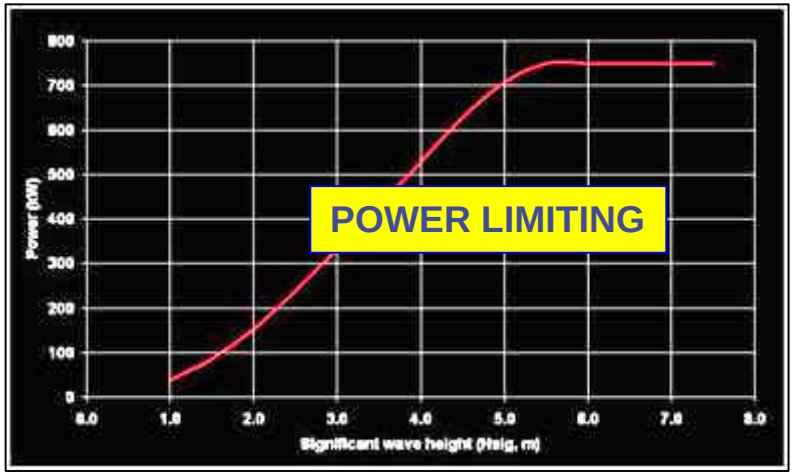
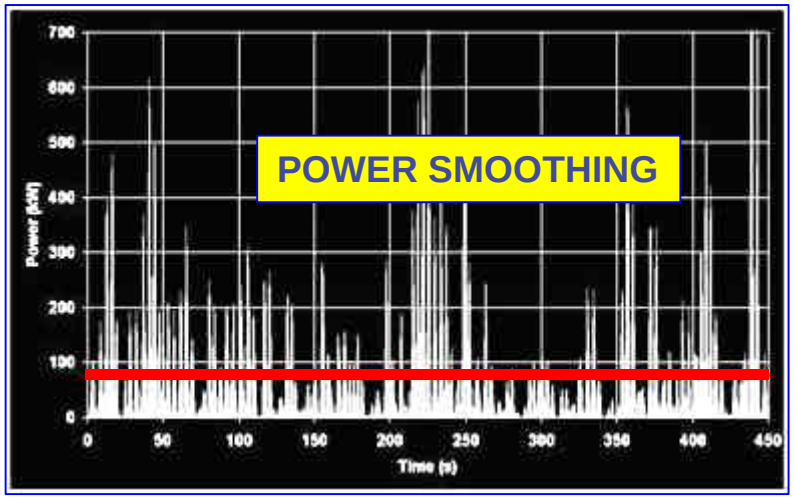
KEY FEATURES

- Survivability – core theme…
- 100% available technology
- Hydraulic Power Take Off
- Power smoothing
- Tuneable
- Maximum flexibility
- Minimum work on-site
- Off-site maintenance





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DEVELOPMENT PATH

Experimental Modelling
- 14 tank test programmes
- 5 test models at 80th, 50th,35th,33rd & 20th scales
- Survivability characteristic validated
- Numerical power predictions validated
- Mooring dynamics validated
- Further tank programmes

Numerical Modelling
- Frequency domain simulation
- Time-domain simulation
- Structural analysis
- Power take-off & control
- Mooring dynamics
- Extreme load analysis

1/7th scale full systems prototype

Independent Design Verification

Full-scale Power Conversion Module

ATKINS

Full-scale, pre-production prototype

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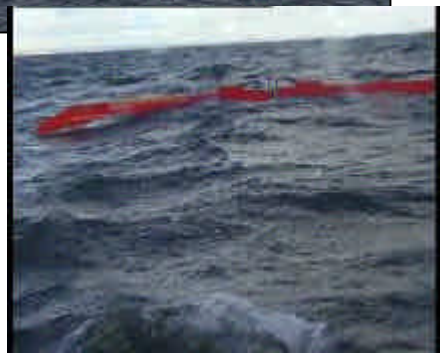
1/7th SCALE PROTOTYPE

-‘Full systems’ prototype
- Same hydraulics system
- Same control system
- First tests October 2001
- Concept verified at 1/7th scale



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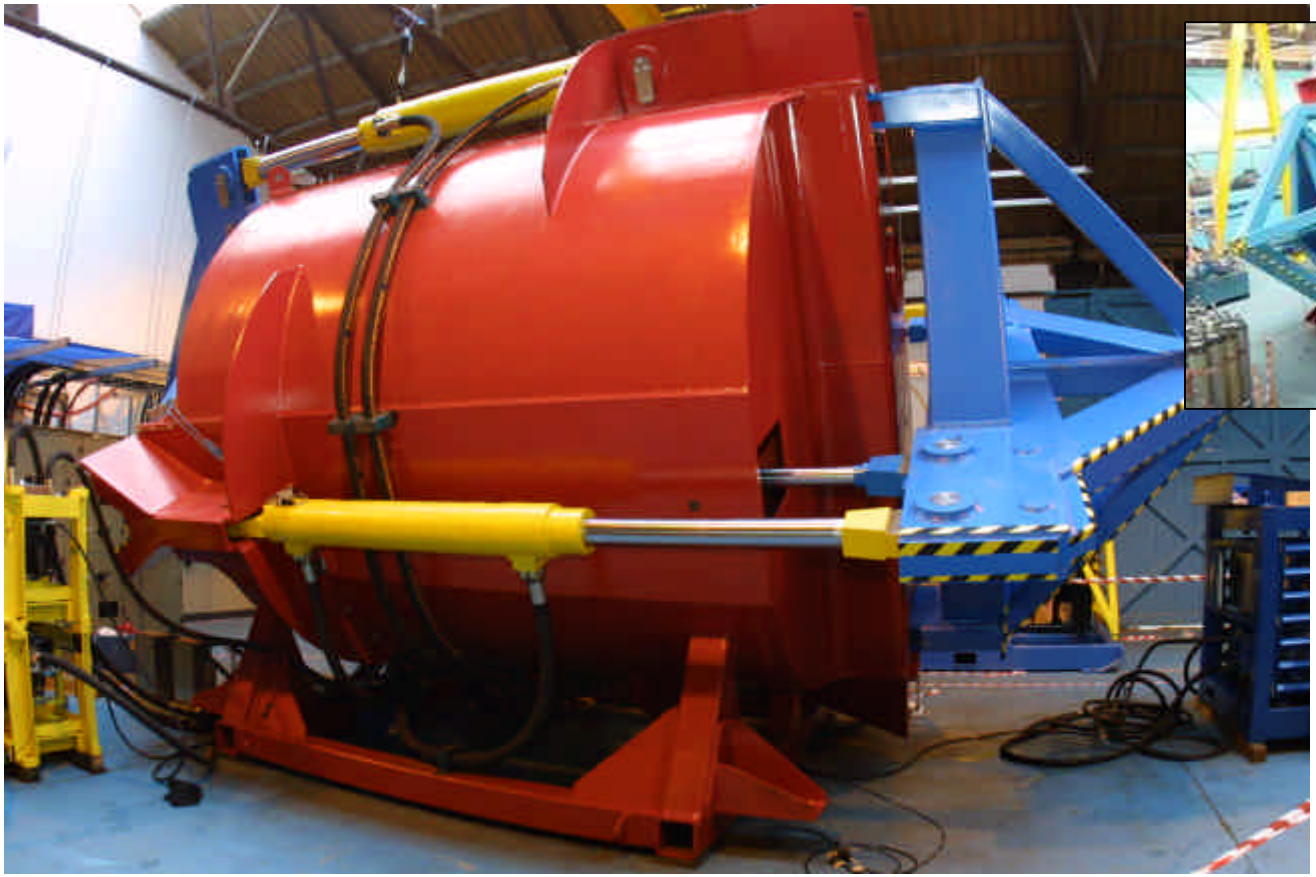
POWER CONVERSION MODULE TEST-RIG



Successful verification of full-scale power take off system on land

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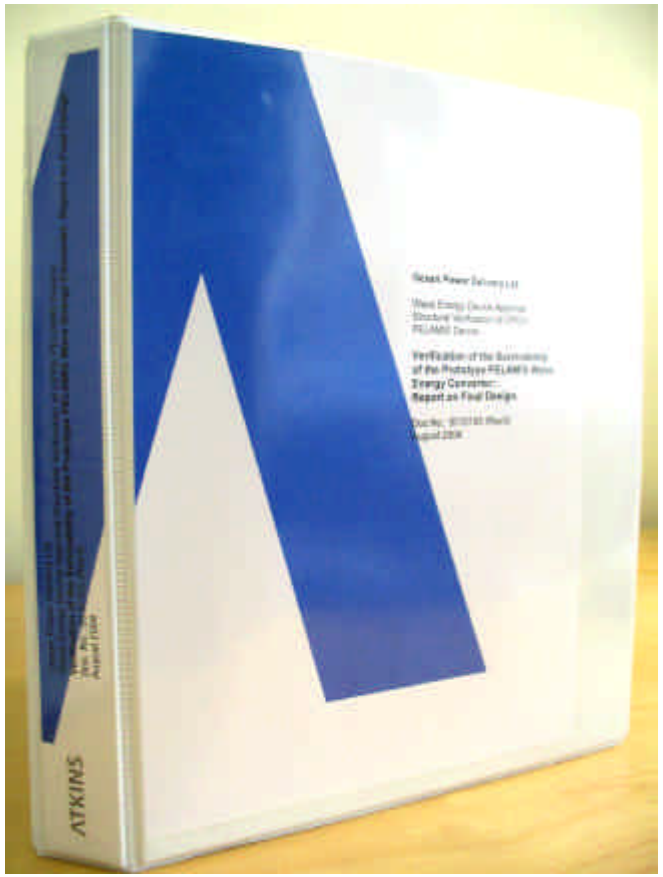
DESIGN VERIFICATION

ATKINS

- Work undertaken by WS Atkins, Europe's premier offshore design consultants
- All aspects of design and construction
- Assessed to same factors of safety as manned offshore oil & gas installations
- Application of DNV/API offshore design codes
- Fatigue and extreme load analysis over design life of machine (ULS, ALS, FLS)
- Verified and insured



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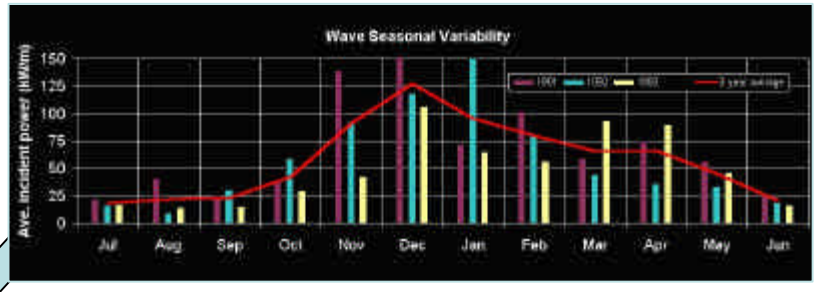
FULL-SCALE PROTOTYPE

- Machine is pre-production prototype
- Supported by UK DTI
- Build/assembly through managed subcontracts

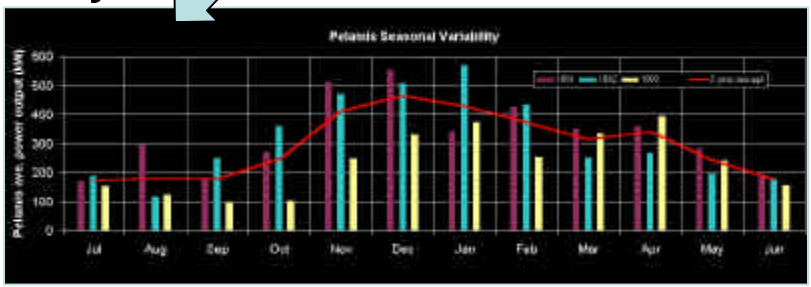
- Initial sea trials behind vessel
- Testing at EMEC

- Power prediction
- Connection/ detachment
- Survivability, operability, maintainability, reliability



Power period (T_{pew}, s)

Significant wave height (H_{m0}, m)	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
0.5	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle	idle
1.0	idle	22	29	34	37	38	38	37	35	32	29	26	23	21	idle	idle	idle
1.5	32	50	65	76	83	86	86	83	78	72	65	59	53	47	42	37	33
2.0	57	88	115	136	148	153	152	147	138	127	116	104	93	83	74	66	58
2.5	89	138	180	212	231	238	238	230	216	199	181	163	146	130	116	103	92
3.0	129	198	260	305	332	343	332	315	292	266	240	219	210	188	167	149	132
3.5	-	270	354	415	438	440	424	404	377	362	326	292	280	230	215	202	180
4.0	-	-	462	502	540	548	530	499	475	429	384	366	339	301	267	237	213
4.5	-	-	544	635	642	648	628	590	562	528	473	432	382	356	338	300	266
5.0	-	-	-	739	726	731	707	667	670	607	557	521	472	417	369	346	328
5.5	-	-	-	750	750	750	750	750	737	667	658	586	530	496	446	395	366
6.0	-	-	-	-	750	750	750	750	750	750	711	633	618	558	512	470	415
6.5	-	-	-	-	750	750	750	750	750	750	750	743	668	621	579	512	481
7.0	-	-	-	-	-	750	750	750	750	750	750	750	750	676	613	584	525
7.5	-	-	-	-	-	-	750	750	750	750	750	750	750	750	686	622	593
8.0	-	-	-	-	-	-	-	750	750	750	750	750	750	750	750	690	625



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P-750 PROTOTYPE ‘PHILOSOPHY’

- Pre-production unit
- 15 year design life
- Conservative design
- Design independently verified (WS Atkins)
- Systems proven
- Moorings system as for farm
- Fully instrumented
- SCADA
- Insured

ATKINS

DESIGN DRIVERS:

- Build methods
- Deployment methods
- Maintenance methods

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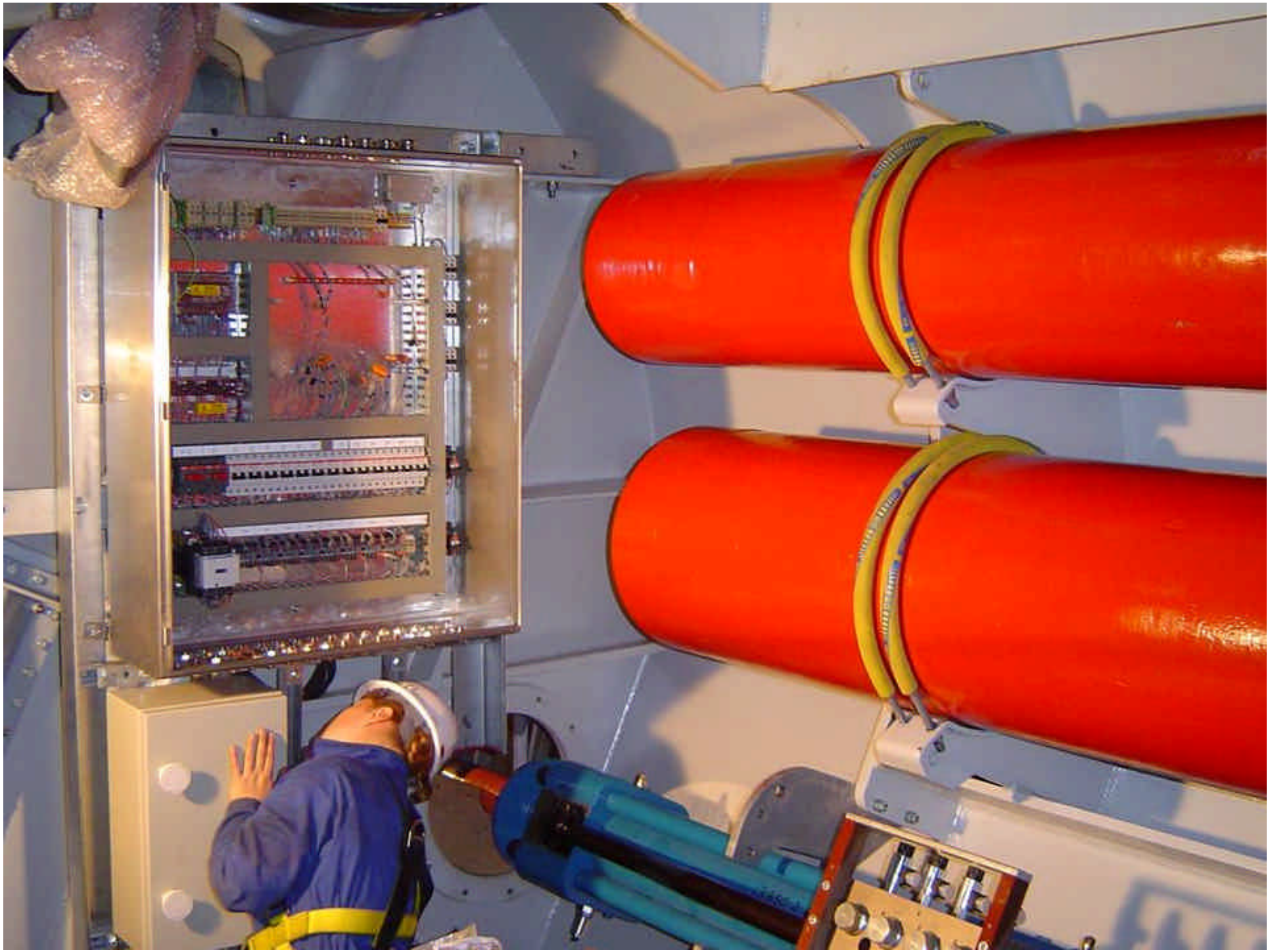
MODULE FABRICATION, STONEHAVEN


AINSCOUGH

HYDRAULIC SYSTEMS, WISHAW


POWER MODULE ASSEMBLY, NEWMAINS




TUBE FABRICATION, METHIL


KVAERNER OIL & GAS

FINAL ASSEMBLY, ROSYTH

EMEC

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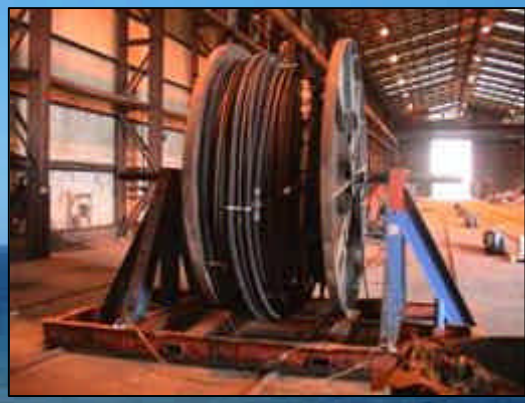
EMEC, ORKNEY



MOORINGS INSTALLED

PELAMIS INSTALLED


Image © Aquatera.co.uk

ONWARD PROGRAMME

- **Rigorous testing of prototype**
- **Commercialisation**
- **Project development…**

  (Cornwall, Scotland, Portugal, USA + others…)
- **Target = demonstration projects installed during 2005**

Year	2003				2004				2005			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4
FULL-SCALE DEMONSTRATOR												
Build												
Launch												
Test												
PROJECTS - PHASE ONE												
PROJECTS - PHASE TWO												

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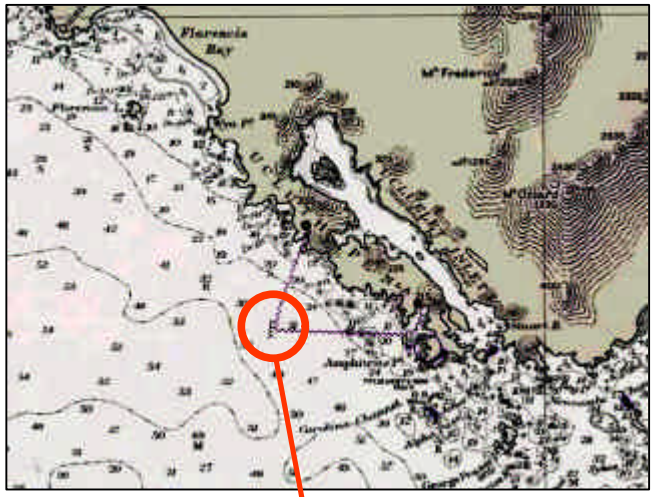
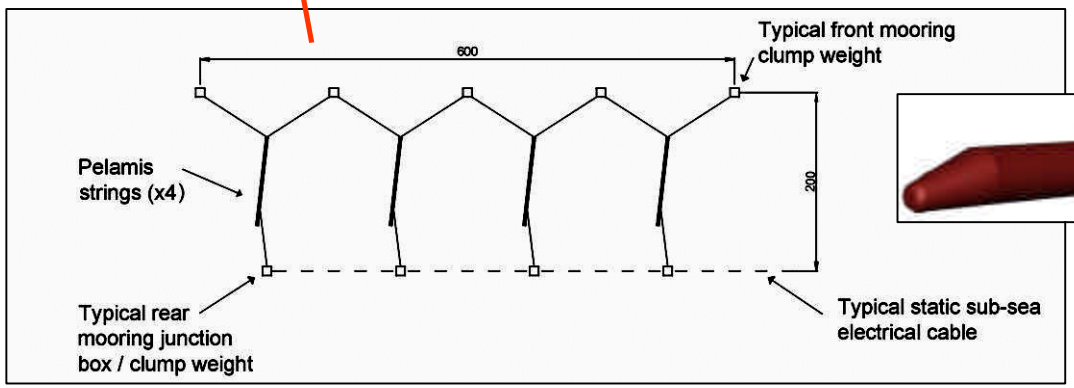
PROJECTS – PHASE ONE



Example (2005)

- 4-10 x 750kW machines
- 3-7.5MW rated output
- BUT infrastructure & development work for whole project



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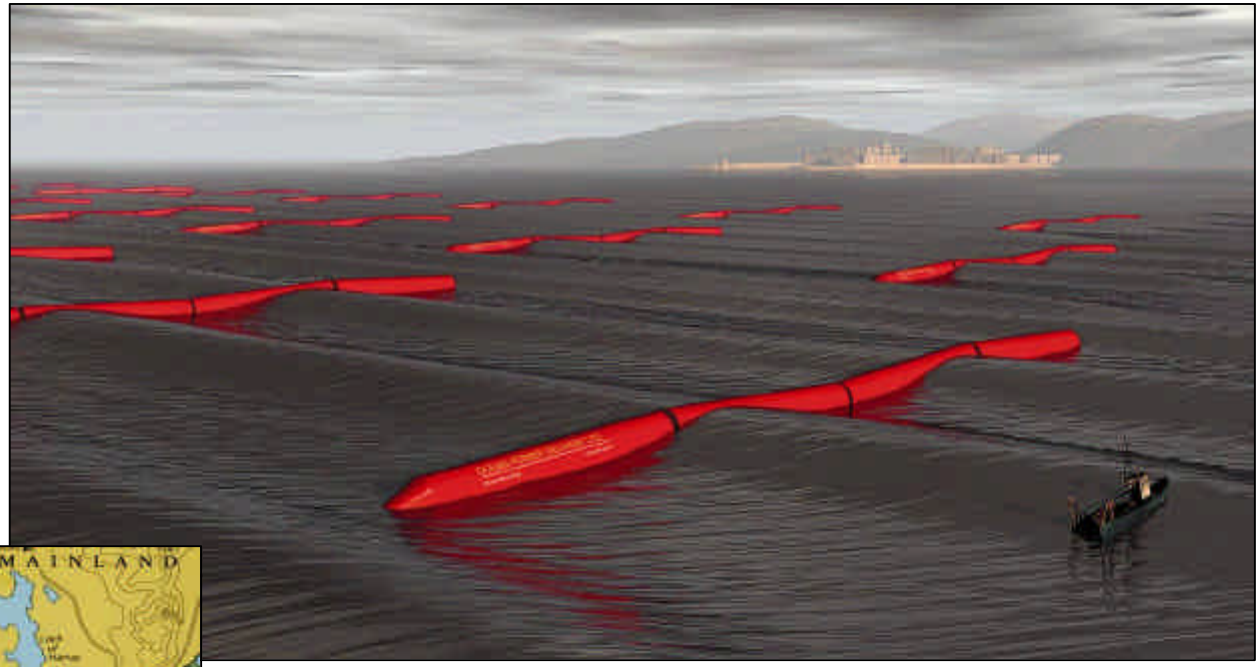
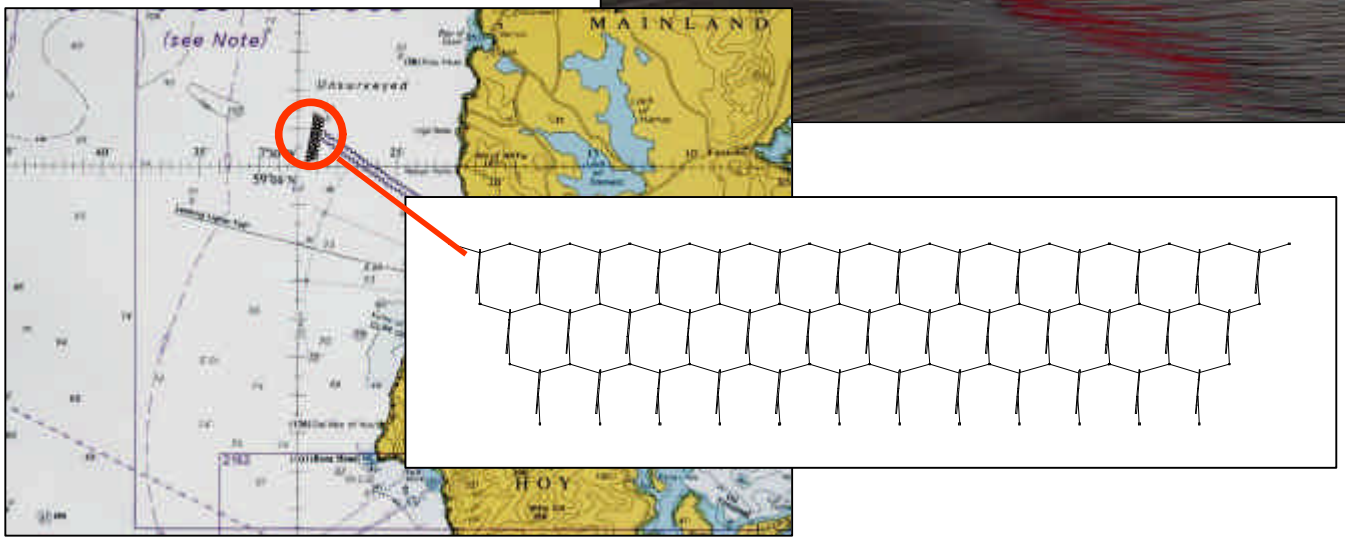
PHASES TWO AND ONWARDS

EXAMPLE

- 39 x P-750 machines
- 30MW
- £30-50m installed cost
- 2.0km x 0.5km
- 30 MW/km^2
- 110 GWh/year
  (~20,000 homes)





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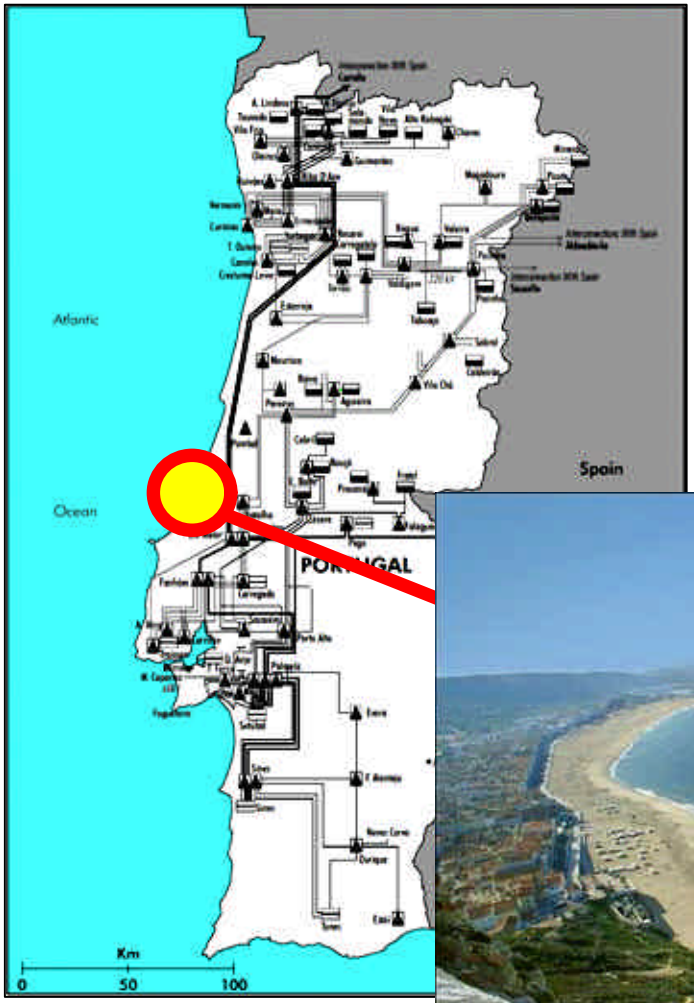
PORTUGAL



GRUPO ENERSIS

- 3-5MW demonstration, Nazaré
- Target build/install 2005
- Wave measurement underway
- Survey underway
- Local manufacturing content
- 20MW accepted by DGE

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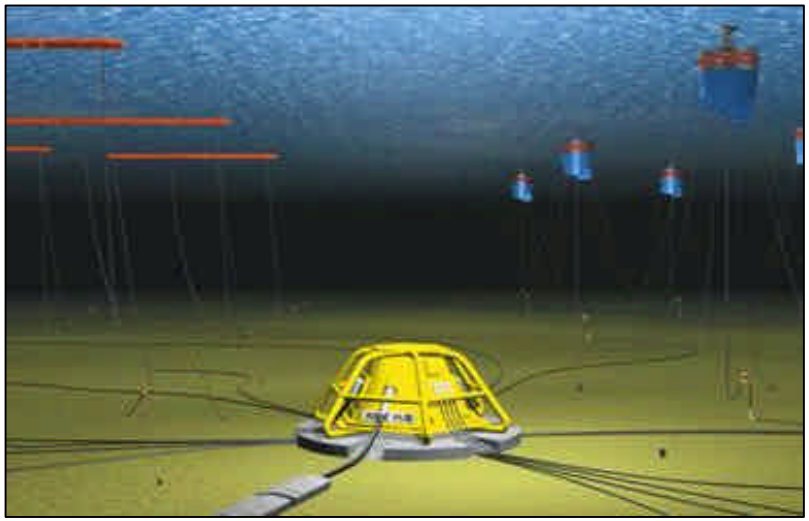
SW ENGLAND

WIND PROSPECT

- Wind Prospect (2nd UK wind farm, Burbo)
- Ocean Prospect formed
- Phased wave-farm deployment
- Demo at 'Wave Hub'?
- General site survey underway
- Target installation 2006



OCEAN PROSPECT

WIND PROSPECT

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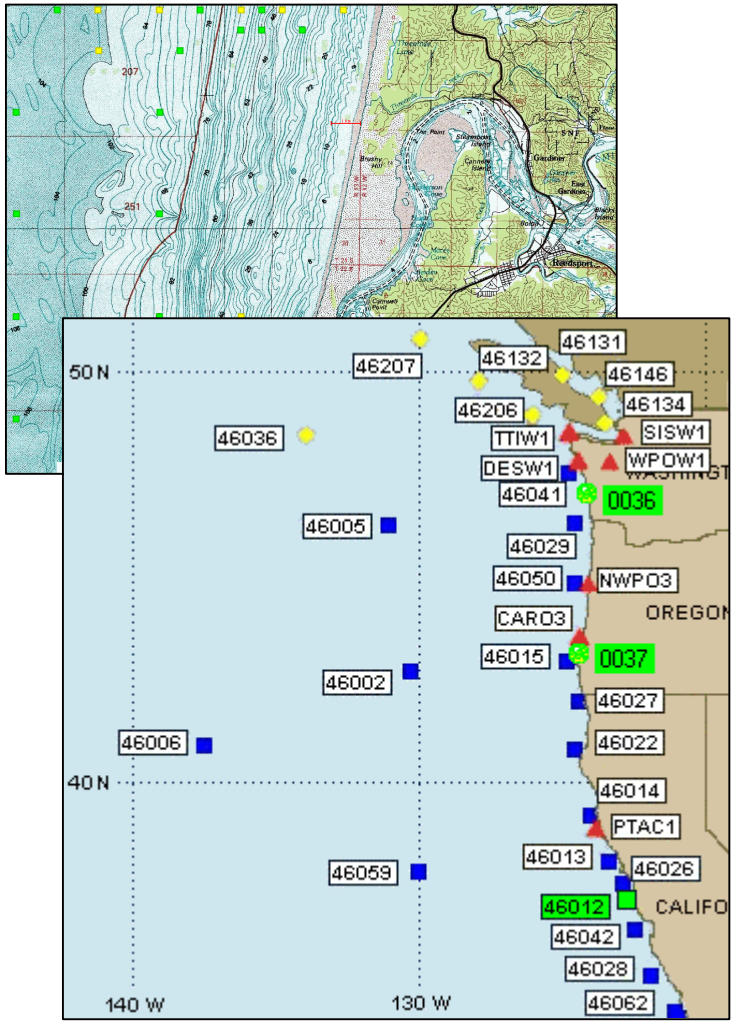
UNITED STATES OF AMERICA

Electricity Innovation Institute



Electrical Power Research Institute

- Public/private project part funded by DOE, NREL and individual states
- Project: four state wave energy demonstration projects in Maine, Oregon, Washington, Hawaii
- Pelamis selected by EPRI as the best and only system currently recommended for deployment.
- Target installation 2006

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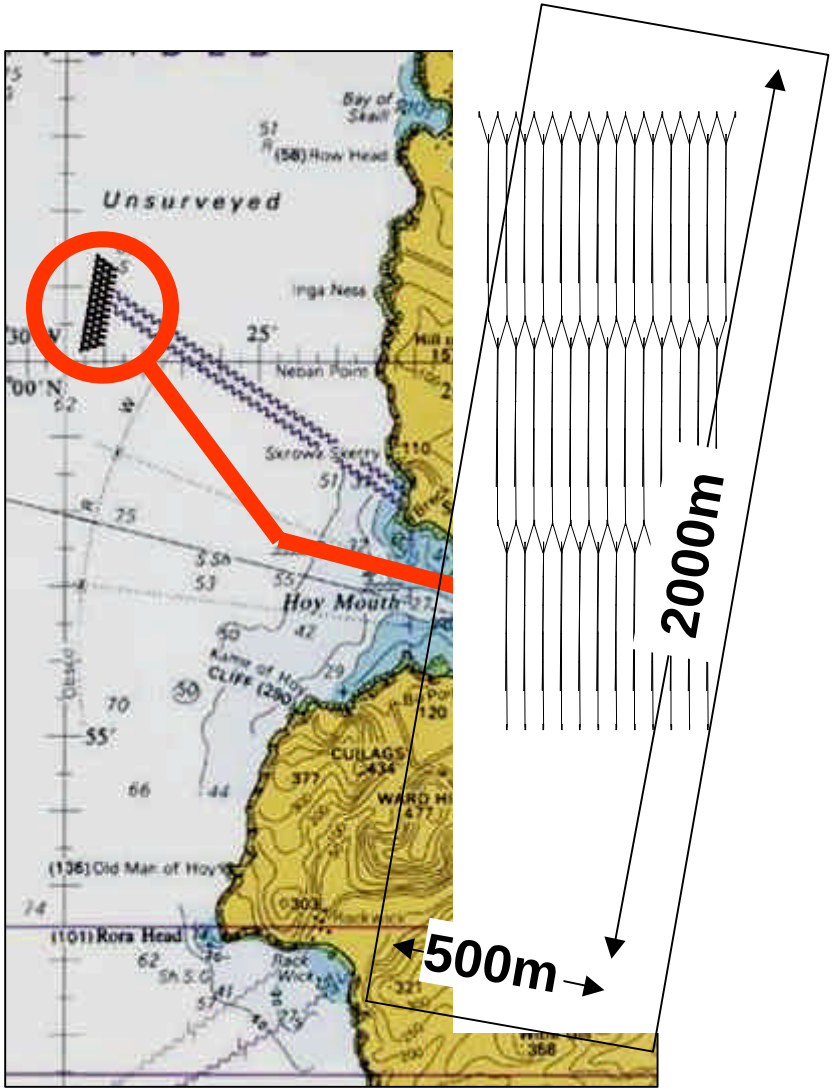
SCOTLAND



ScottishPower amec

- Consortium development
- Sites identified
- Staged development
- Target: first stage installed 2005/6
- Onward routemap defined
- Expected funding from £50m DTI marine deployment fund

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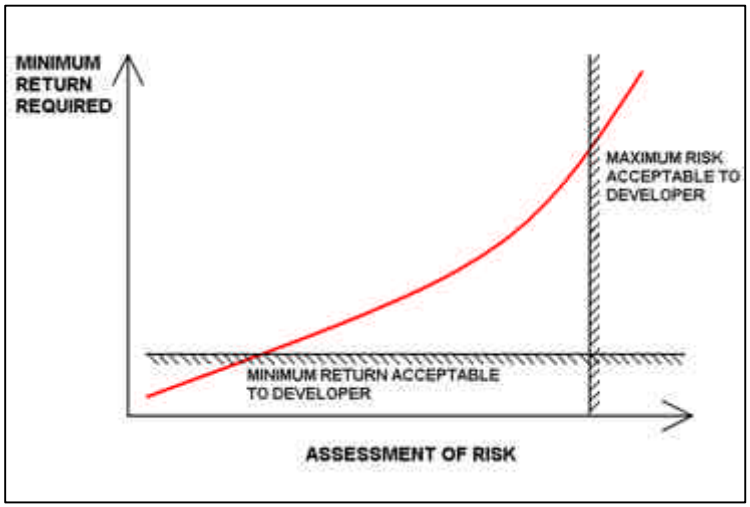
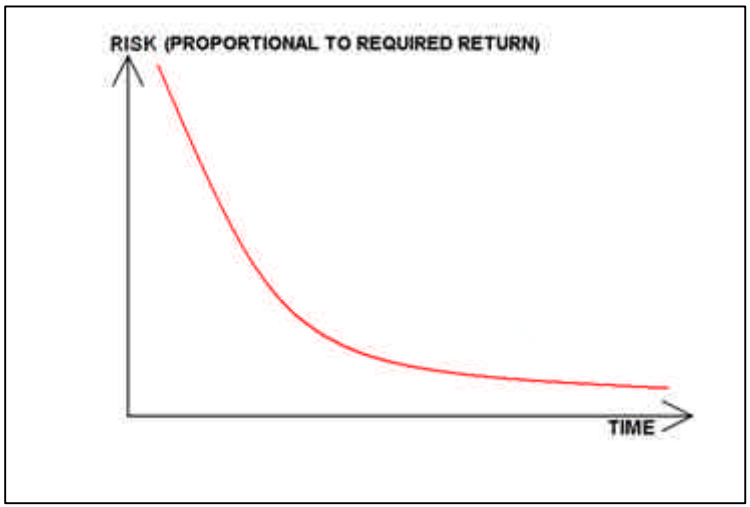
COST REDUCTION MECHANISMS

- Required returns on capital
- Economies of Scale
- Learning by doing

REQUIRED RETURNS





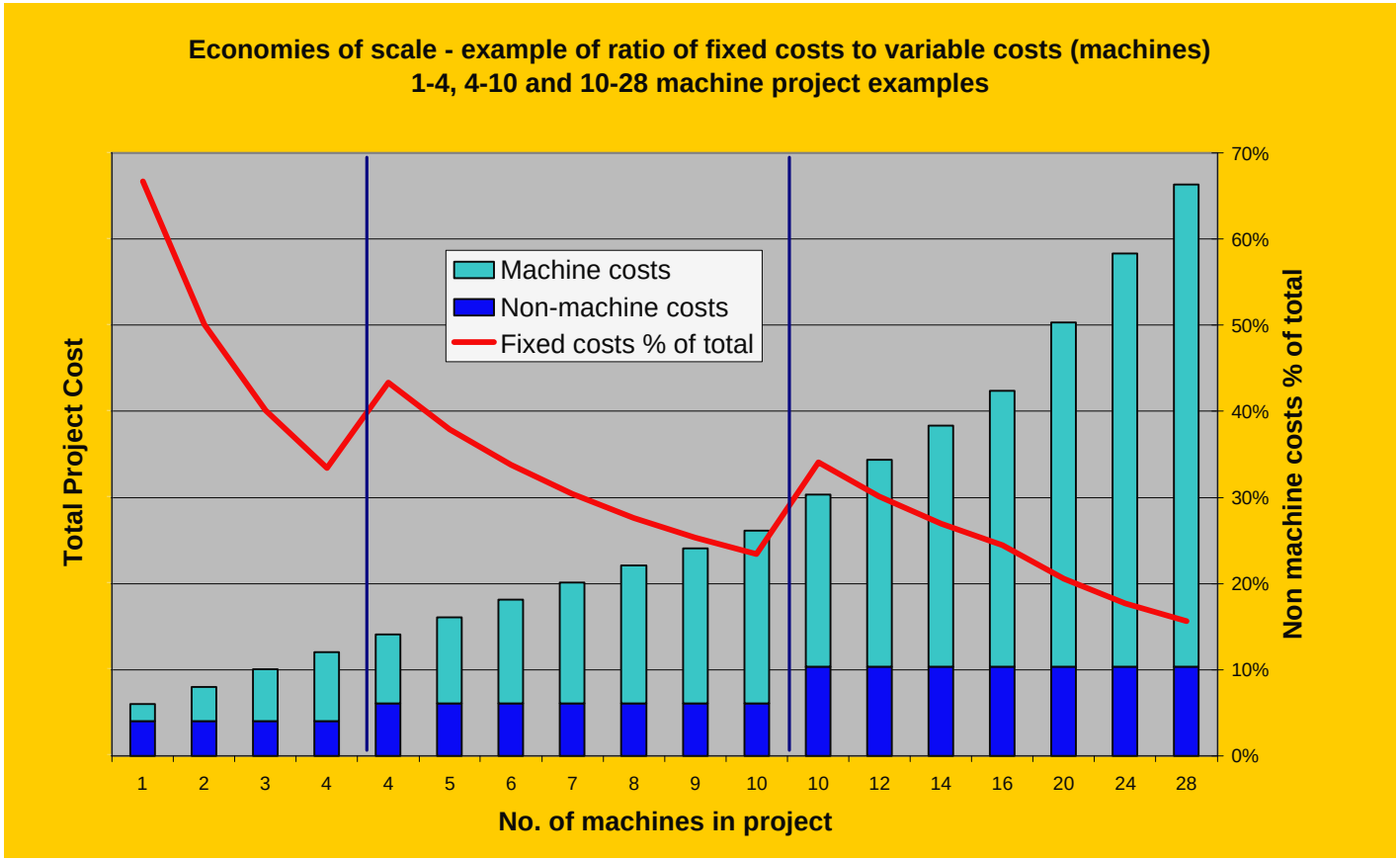
Influenced by:

- Risks during project development
- Risks during construction/installation
- Risks during operation (technical & political)
- Availability of debt
- Project length
- Due diligence costs
- Bankable warranties
- Future uncertainty

ECONOMIES OF SCALE

- Planning
  - Onshore costs, Env. Impacts, Seabed survey, Resource assessment and measurement
- Construction
  - Cable costs, Cable lay costs, Grid connection, Machine installation
- Machine
  - Bulk ordering of components, Tooling costs, Plant overhead, Verification costs
- Operation
  - Insurance, Maintenance, Spares

ECONOMIES OF SCALE



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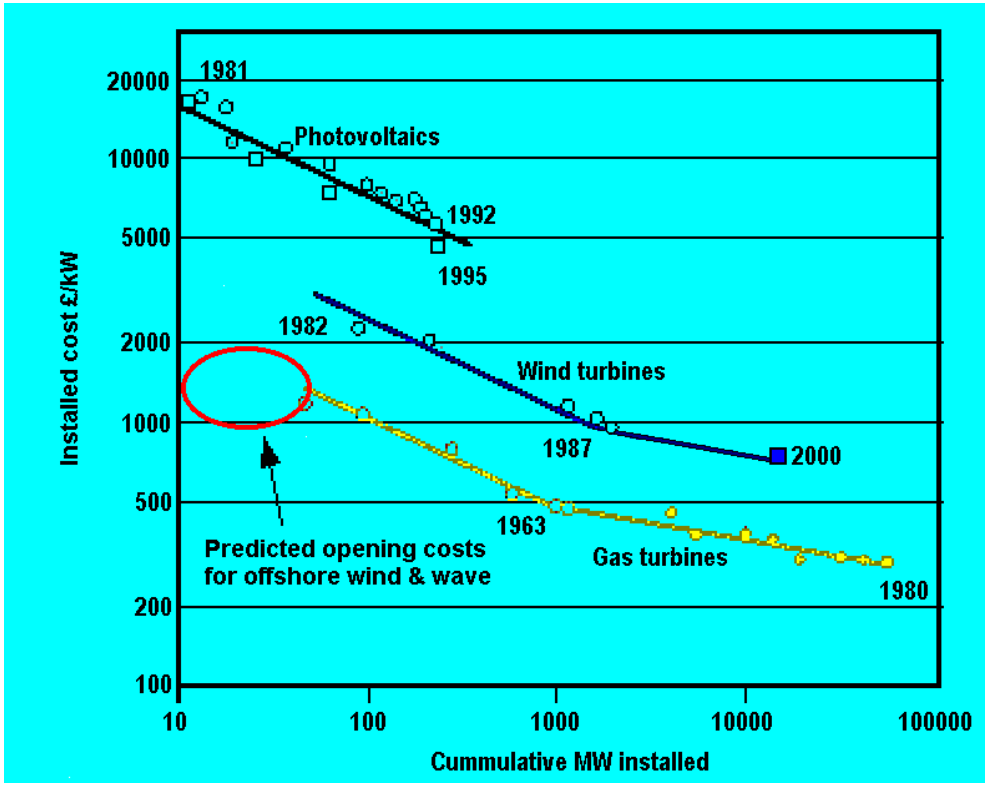
EXPERIENCE & TECHNOLOGICAL IMPROVEMENT

- Project capital costs
  - Machine cost – components
  - Prototype – Batch – Series production
  - Development costs (EIA etc)
- Project operation
  - Improvements in energy capture
  - Insurance costs
  - O&M costs

BRIDGING THE GAP

- High initial costs...
- High initial risks...
- High initial opportunities…



- Costs fall as a result of technical refinement
- Costs fall in line with installed capacity
- Costs fall as a result of investor confidence

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THE OPPORTUNITY

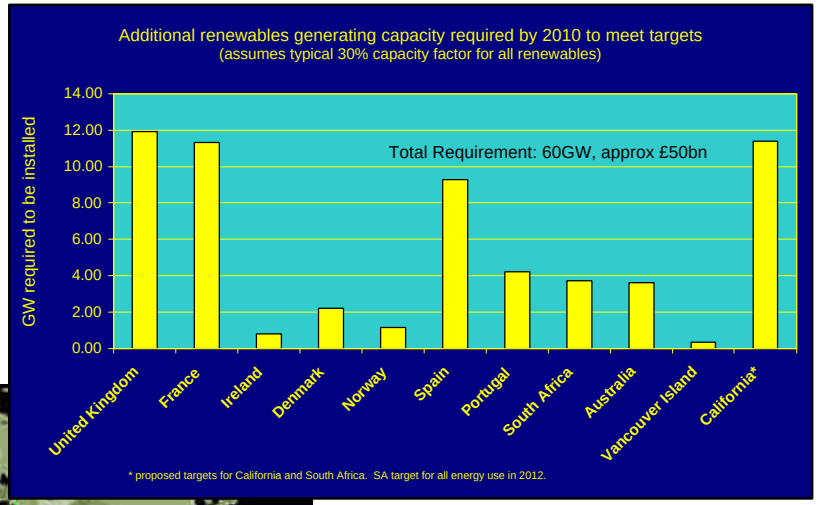
OPD
Manufacture and supply wave energy converters

Developer
Plan, permit, finance and install wave farms

Operator
Own and operate wave farms, sell electricity generated

- First projects: attractive returns, through market enablement mechanisms (eg: UK: Renewable Obligation + Capital grants; Portugal €c23/kWh)

- Strategic: Accessible global market size >£50bn by 2010, unlimited by resource



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