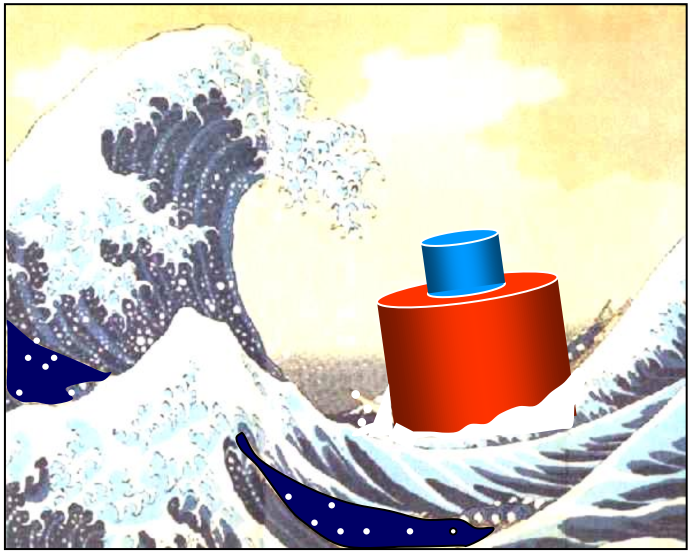
Università degli Studi di Firenze, 18-19 April 2012



WAVE ENERGY UTILIZATION

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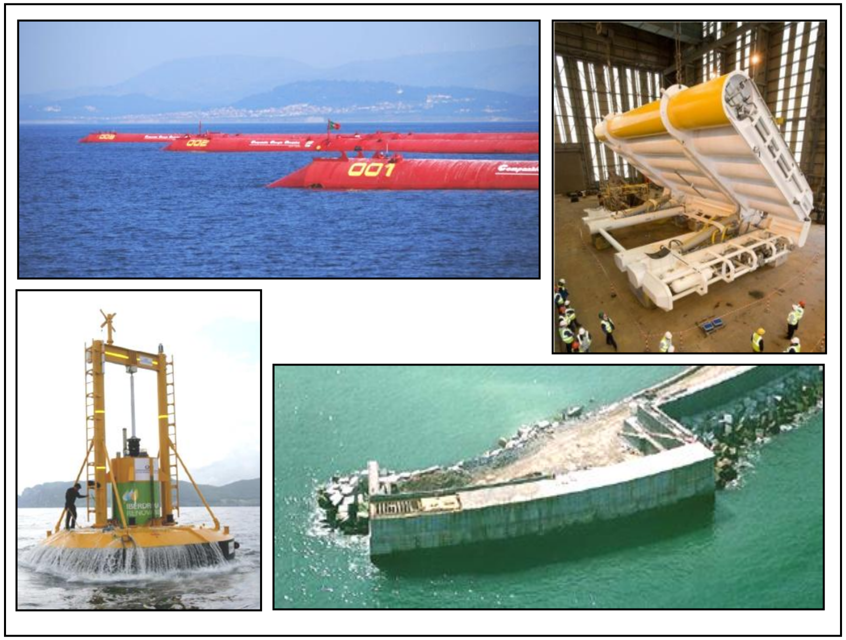
Part 5
Wave Energy Situation and Perspectives

- **The Present Situation.**
- **Costs.**
- **Challenges, Risks and Barriers.**
- **Public Policies.**



Present Situation

A few basic concepts:

- **Oscillating water column (OWC)**
- **“point absorber”**
- **large oscillating-body (multi-body)**
- **run-up device, ...**

A large number of designs (>50) of which a few (≈15 ?) reached (or are close to) the prototype stage.

Slow convergence to a small number of basic designs.

The extensive exploitation of the wave energy resource by large farms of offshore devices.

Present Situation

The technology is more difficult than wind.

From the develpment and economic point of view, the situation is similar to wind in the 1980s ?

Except for a few shoreline OWCs (Pico 1999, Islay 2000), there is little or no experience of maintenance, reliability and survival (under extreme conditions) in real open-ocean, for more than a few months.

Scarce reliable information on costs and economics.

Often, what is advertised by develpment teams is based on scenarios and projections assuming cost reductions.

Present Situation

For most technologies, the **capacity factor**: annual-averaged power divided by rated power, is similar to wind (~0.3) (possibly larger in the **southern hemisphere** due to smaller seasonal variations).

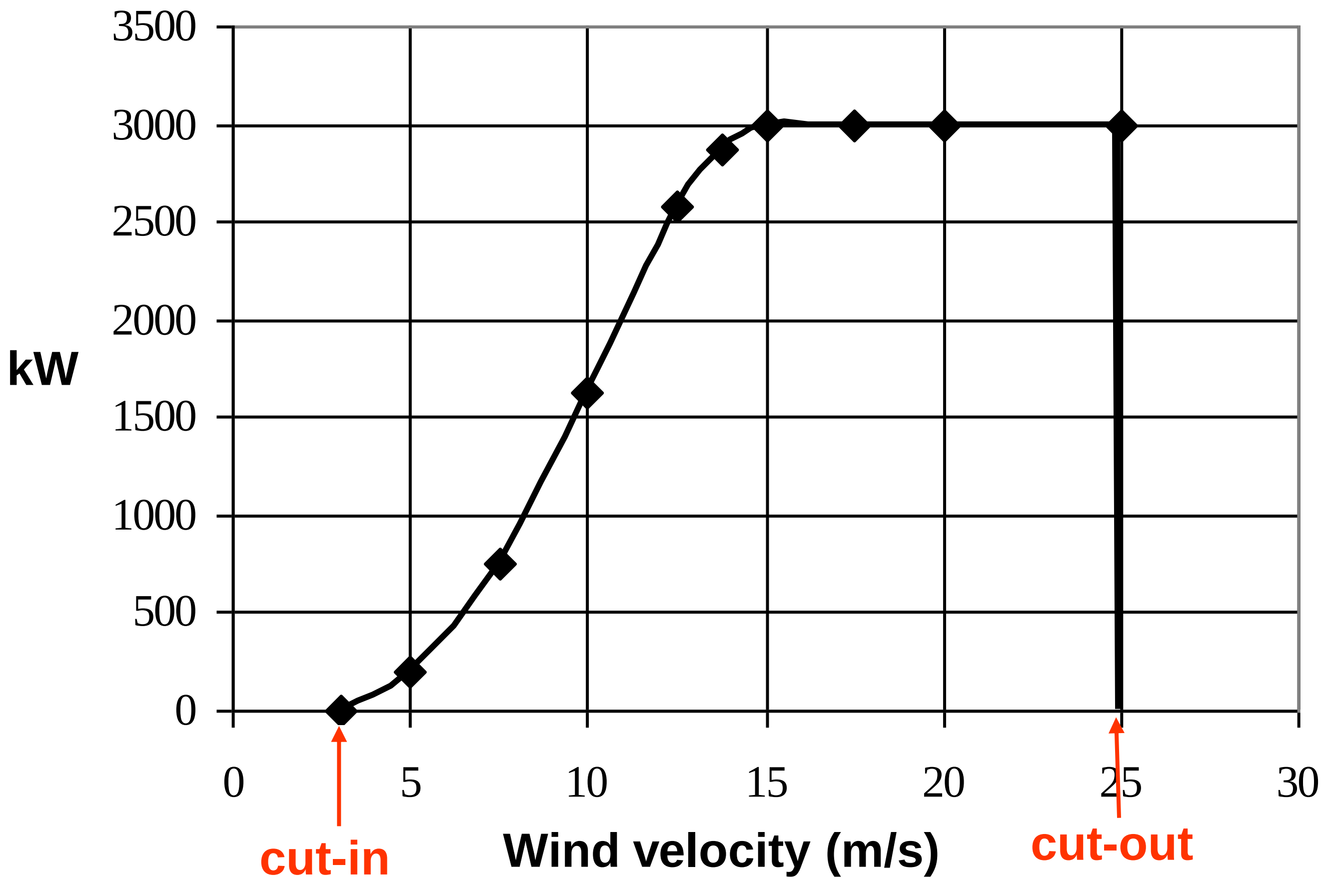
At the present stage of technology development, the unit cost of electricity from waves ranges **between wind and large photovoltaics.**

In order to be competitive with onshore wind, a cost reduction factor of about 3 will be required for the best designs (2 or less if compared with offshore wind).

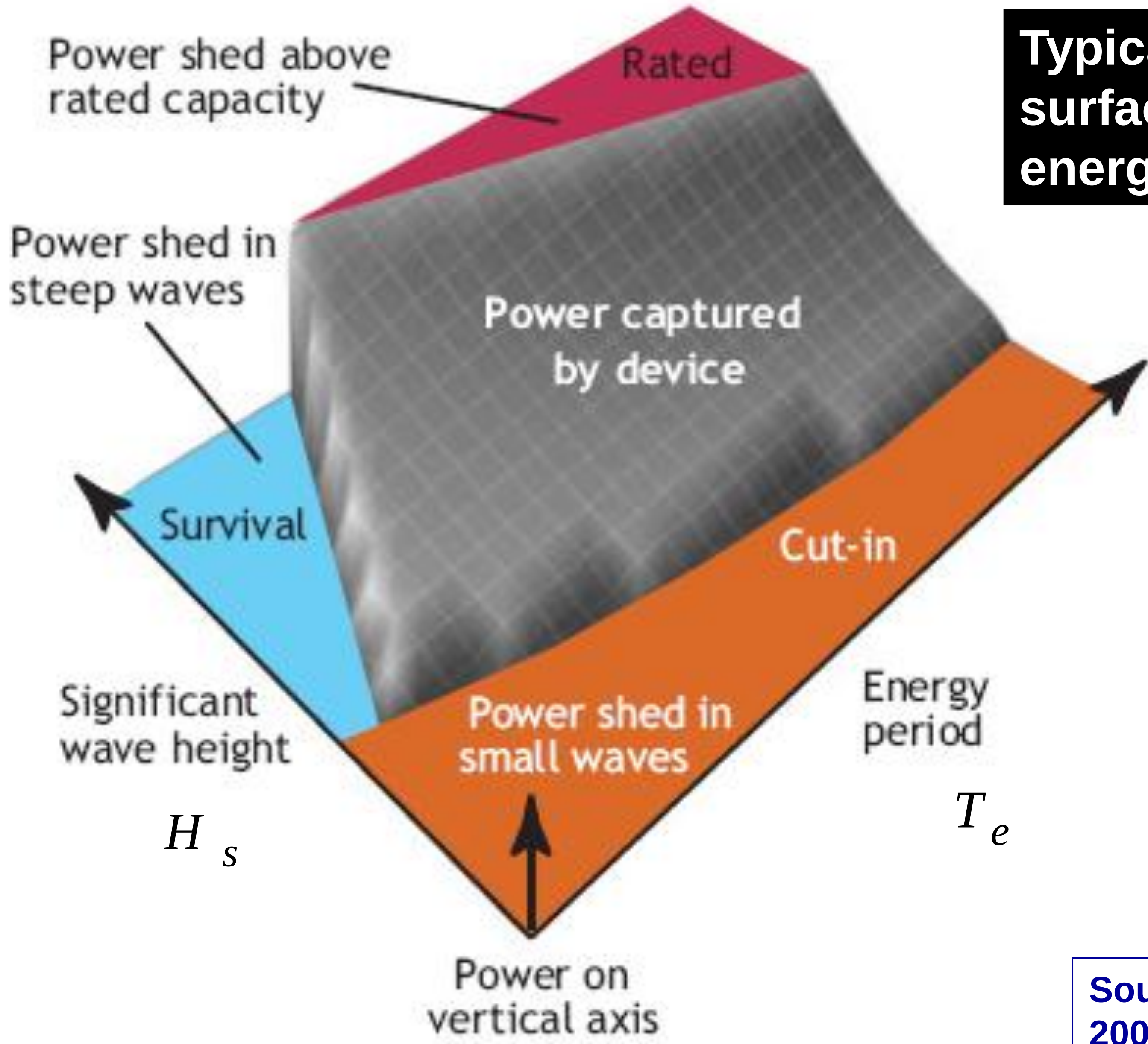
The relatively large investments from private companies in wave technology (especially in Europe) indicate that such cost reductions are believed to be feasible (within 10+ years?).

Present Situation

Typical power curve of a large wind turbine



Typical power surface of a wave energy converter

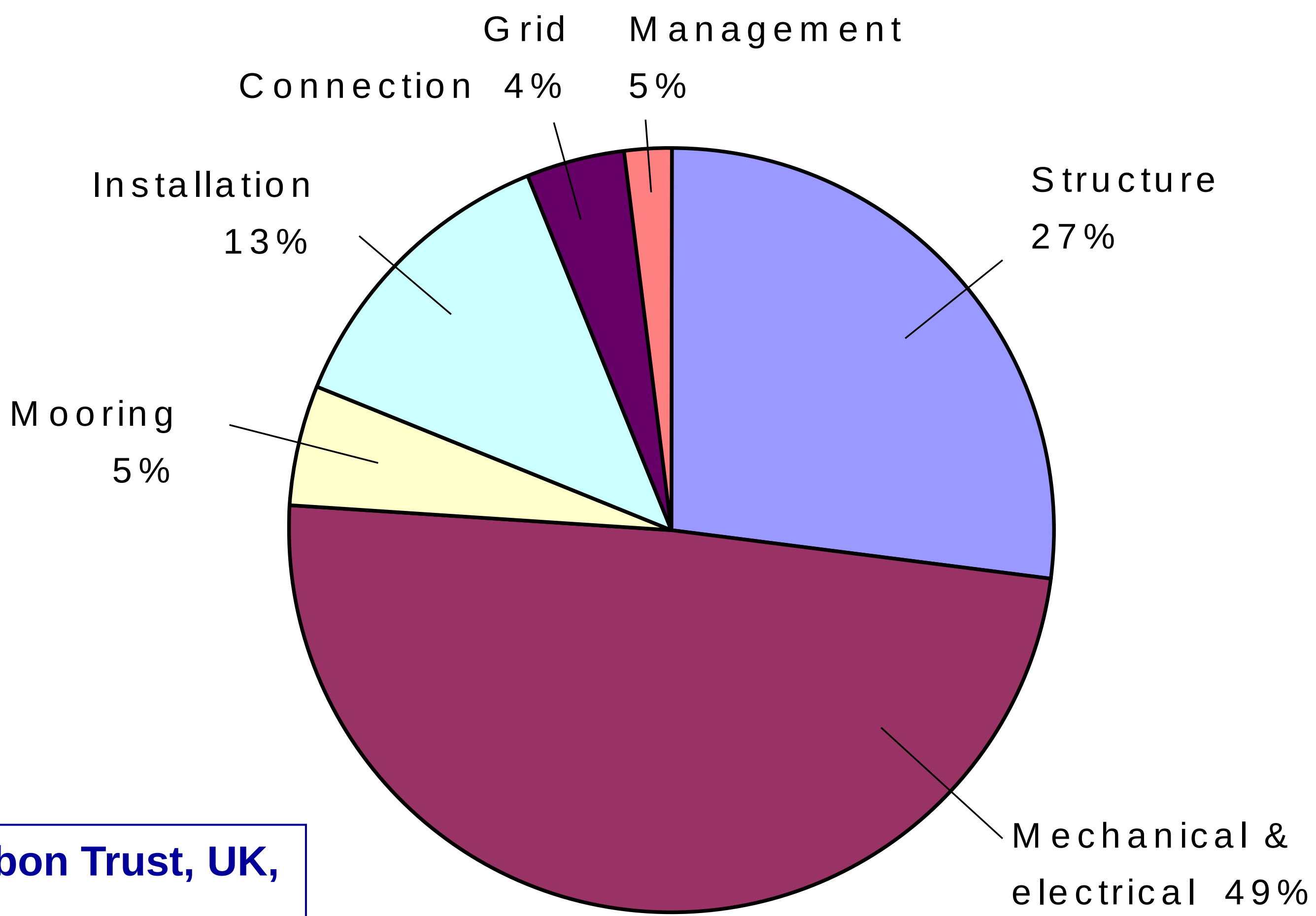


H_s T_e

Source: Carbon Trust, UK, 2006

Costs

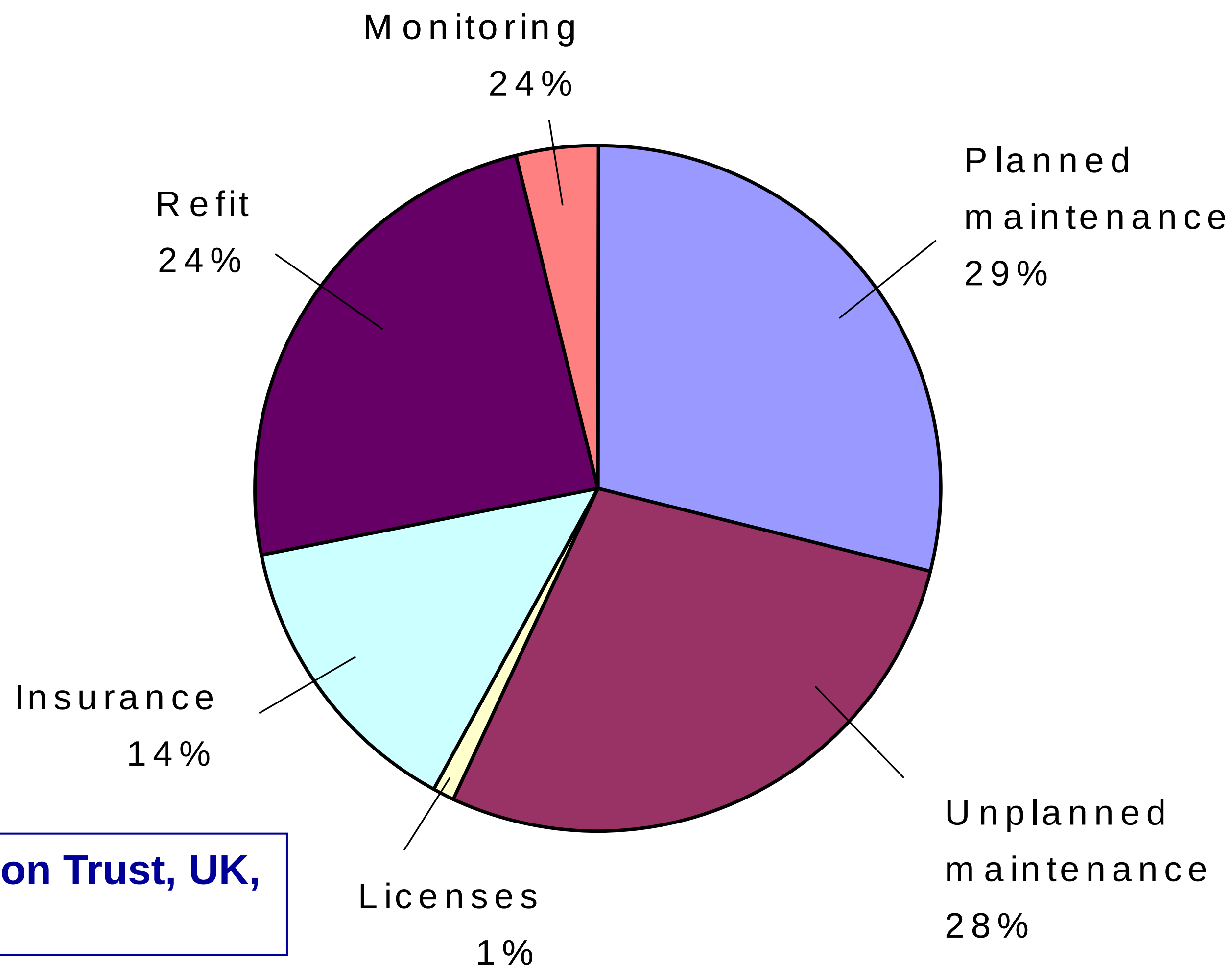
Typical breakdown of capital costs for a wave farm



Source: Carbon Trust, UK, 2006

Costs

Typical breakdown of operation & maintenance costs for a wave farm



Source: Carbon Trust, UK, 2006

Costs

Capital costs of first prototypes and first production models

First prototype: 6 – 13 k€/kW

First production model: 2 – 6 k€/kW

Cost of energy at present stage of development, small farms up to 10 MW, rate of return 15%

Range of estimates 0.20 – 0.60 €/kWh

Central estimates 0.32 – 0.36 €/kWh

Lowest costs for shoreline and nearshore OWCs (possibly in breakwaters) ?

Source: Carbon Trust, UK, 2006

Costs

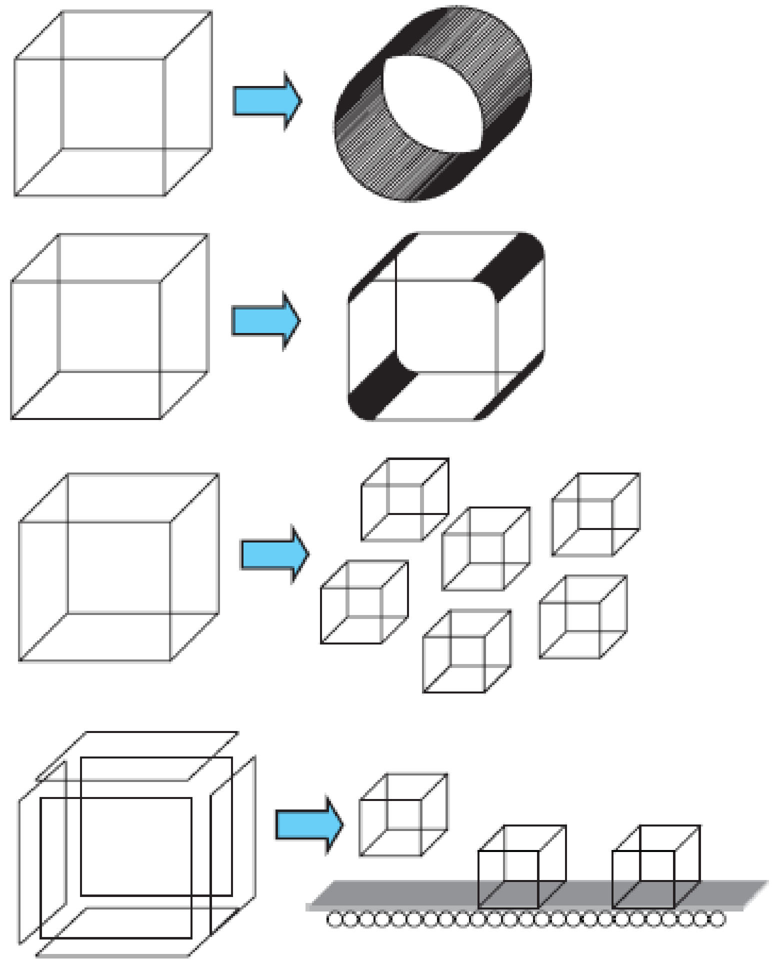
How to reduce costs of energy from waves

Concept design developments

Detailed design optimizations

Economies of scale

Learning in production, installation, operation & maintenance



(Source: Carbon Trust, UK, 2006)

Costs

Scenarios for cost reductions

(based on the evolution of other technologies)

Based on :

- **Initial unit cost of produced electrical energy (€/kWh).**
- **Learning rate: percentage decrease in cost each time installed power capacity is doubled.**

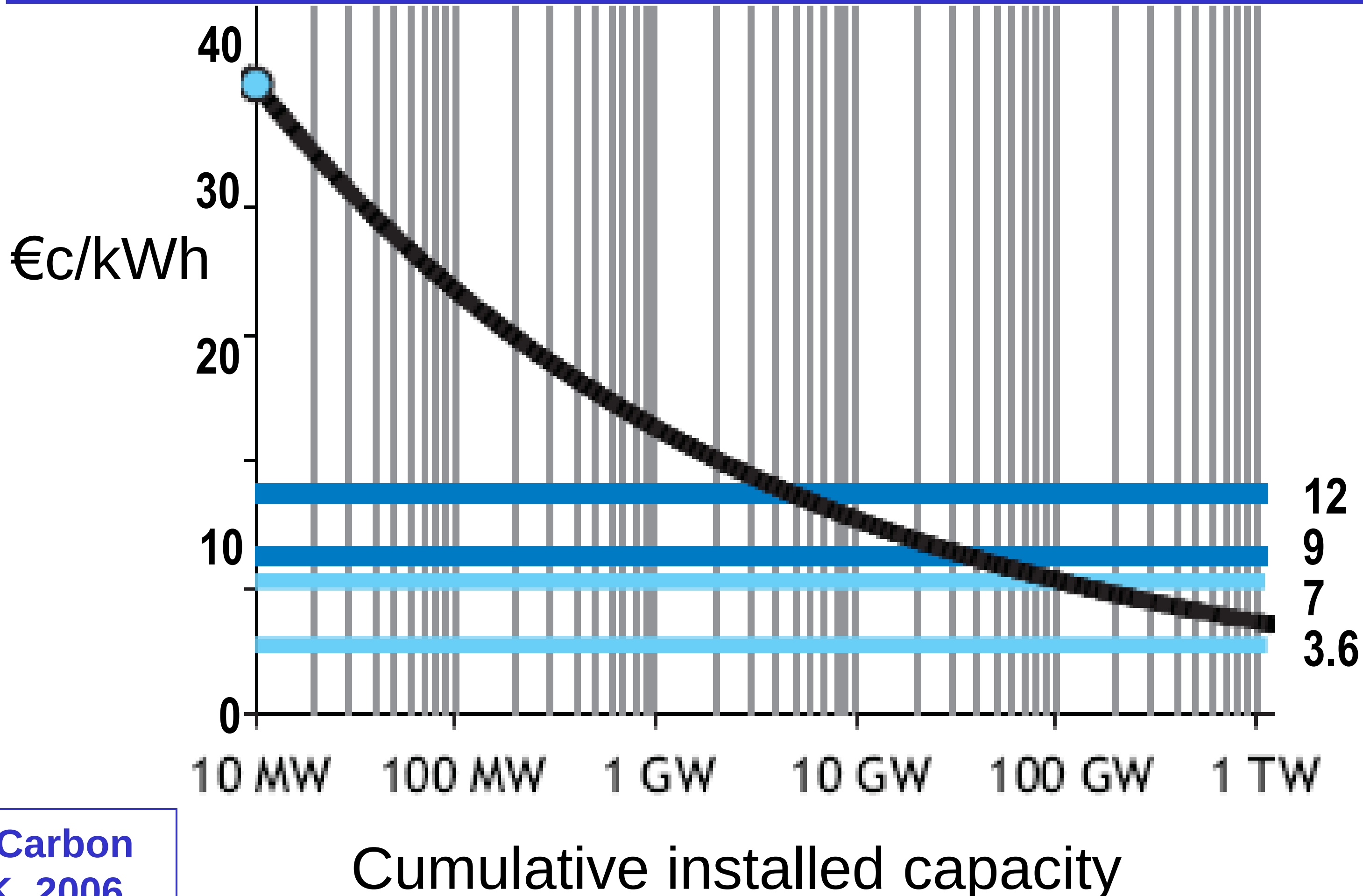
Scenario A "pessimistic": initial 0.36 €/kWh
learning rate 10%

Scenario B "optimistic": initial 0.31 €/kWh
learning rate 15%

Costs

Offshore wave energy cost reduction scenarios

A – 0.36 €/kWh starting point, 10% learning rate

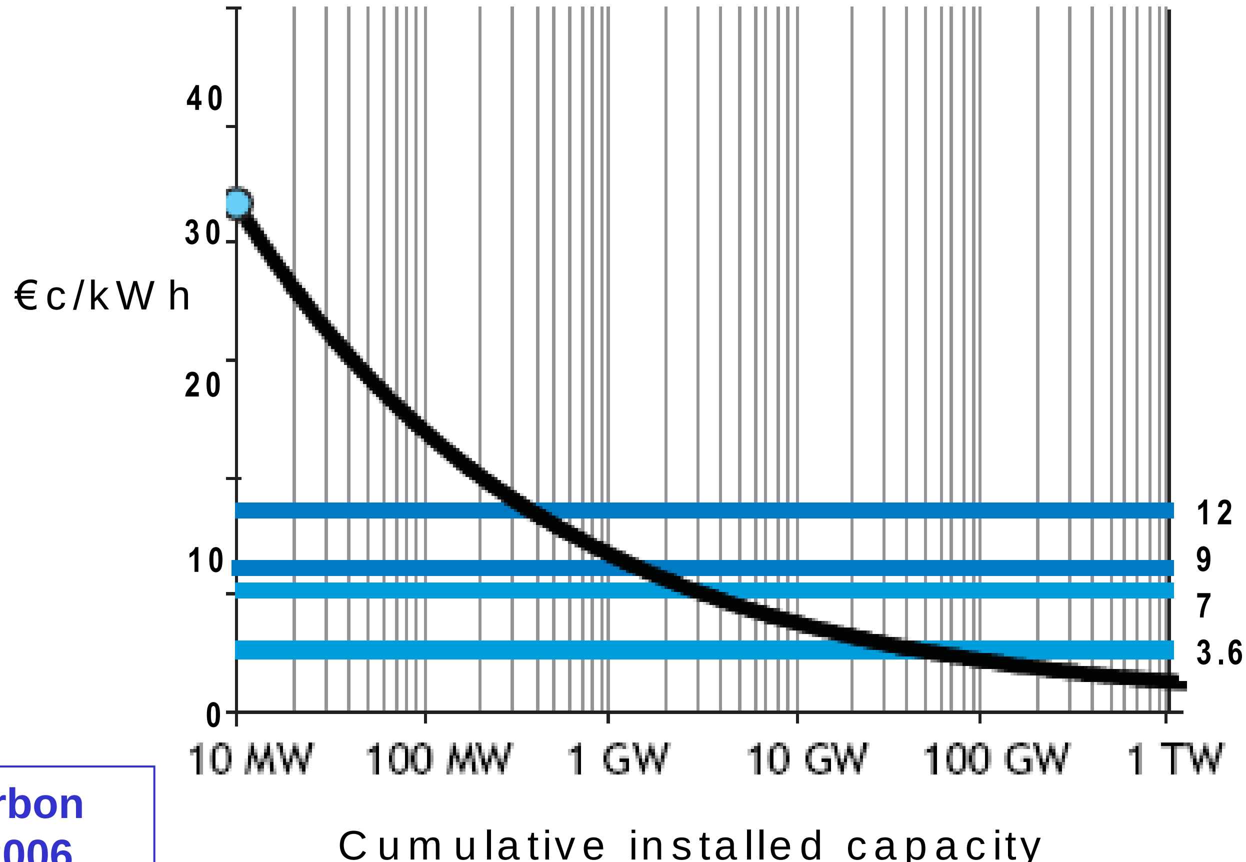


Source: Carbon Trust, UK, 2006

Costs

Offshore wave energy cost reduction scenarios

B – 0.31 €/kWh starting point, 15% learning rate



Source: Carbon Trust, UK, 2006

Challenges, risks and barriers

Challenge:

- **Develop robust and competitive technologies supported by standards and best practices.**

Risks:

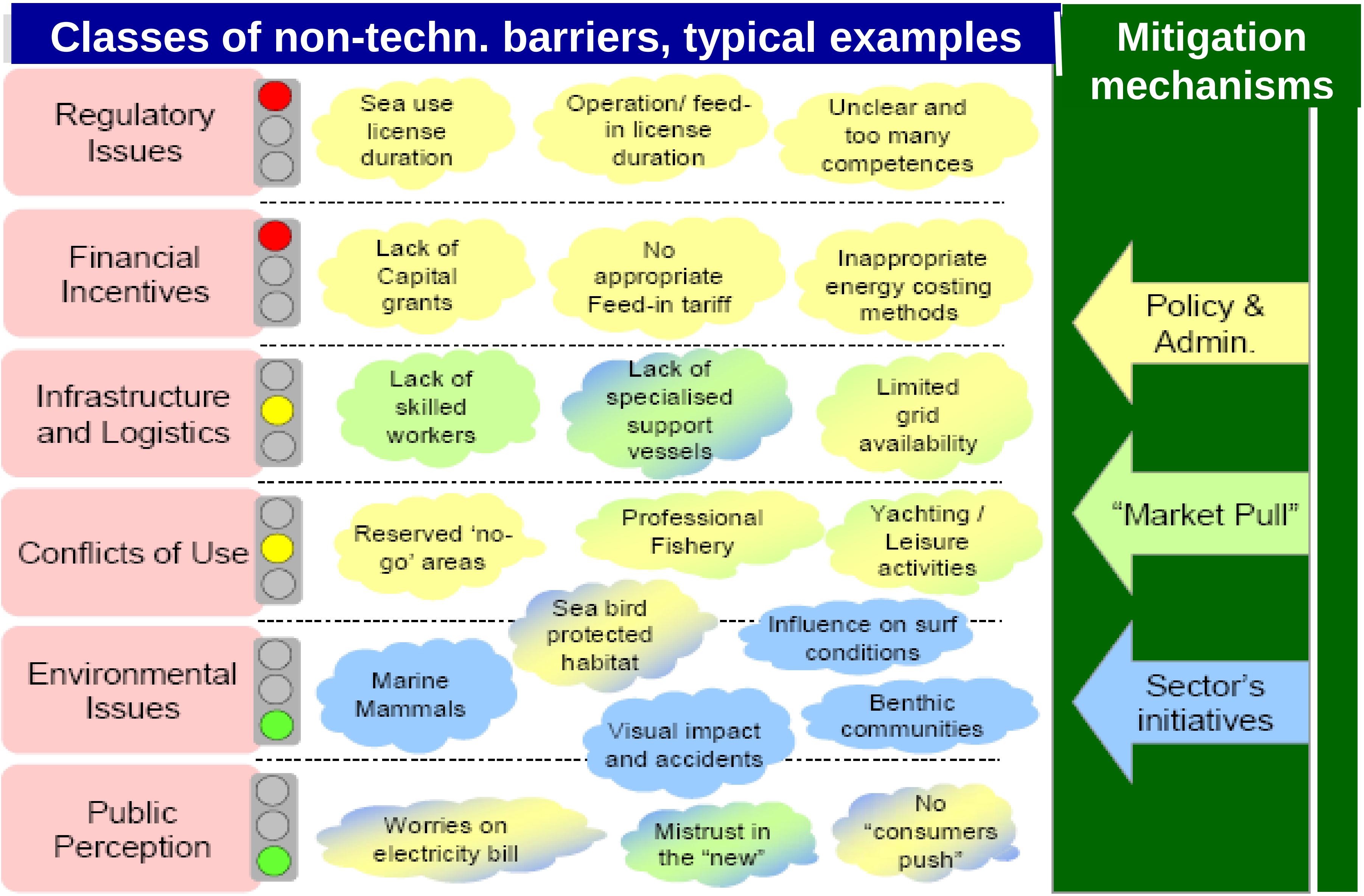
- **Higher than expected development, capital and operational & maintenance costs.**
- **Less energy production or lower energy tariff.**
- **Negative environmental impact and conflicts of uses higher than expected at very large scale utilization.**

Challenges, risks and barriers

Barriers:

- **No electrical grid access.**
- **No room in the energy mix.**
- **Administrative processes long and UNPREDICTABLE (Licensing, Grid Access, Public Funds, Tariffs).**
- **No or limited access to relevant data (waves, winds, currents, type of bottom…) in a proper format.**

Challenges, risks and barriers



Public Policies

Define targets and clear strategies.

Infrastructures and logistics.

Financial incentives.

Simplification of licensing procedures.

Access to the electrical grid.

Access to field data.

Promote internal market:

- **Feed-in tariff**
- **Define internal market (% of energy mix)**

Public Policies

Targets

- Act as a motor for other policies that could favour/be necessary to achieve the established target.
- Give confidence for technology developement and investements.

Country	Energy	2010	2020
Ireland	Ocean energy	-	500 MW
UK (Scotland)	Ocean energy	-	700 MW
Spain (Basque Country)	Wave energy	5 MW	-
Portugal	Wave energy	50 MW (?)	200 MW

Public Policies

Clear strategies

Largely different strategies among European countries

Country	Strategy	Main tools
Portugal	Attract investors. Develop national market. Develop natl technologies.	Portuguese Pilot Zone. Feed-in tariff.
Ireland	Develop national devices.	4-step strategy
UK	Develop national devices.	EMEC – WaveHub. Supergen, Marine Energy Challence. Others.
Spain	Develop national devices.	PSE-MAR, BIMEP.
France	In construction	Tariff and Pilot Zone.

Public Policies

Financial incentives: feed-in tariffs in Europe

Country	Tariff (€/kWh)	
Portugal	0.26 -0.07	
France	0.15	
Spain	first 20 years	0.0689(+0.0384)
	next	0.0651(+0.060)
Denmark	first 10 years	0.08
	next	0.053
Germany	0.1 to 0.07	
UK	market price + ROC	
Ireland	0,2 *	
Norway	-	

Public Policies

Infrastrutures and logistics: initiatives in Europe for facilitating prototypes and demonstration

Country	Test Infrastructure	Max. Capacity (MW)
Portugal	Pilot Zone	80 → 250
UK	EMEC	20
	Wave Hub	20
Ireland	Galway Bay	*
Denmark	Nissum Bredning	**
France	SEMREV	2
Spain	BIMEP	20
Norway	Runde	**

* Not grid connected ** not specified

Situation and Perspectives

Regulatory issues

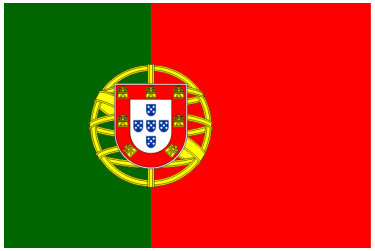
- **Licensing** is expensive, long and very laborious process
- Enormous differences among countries in time/expenses
- Ideal process: **ONE STOP SHOP**

Test sites for wave and tidal energy systems in Europe

Source: EQUIMAR – Draft report on the state of ocean energy in Europe: technologies, test sites, and joint projects, 2011

Public Policies

Portuguese Public Policies



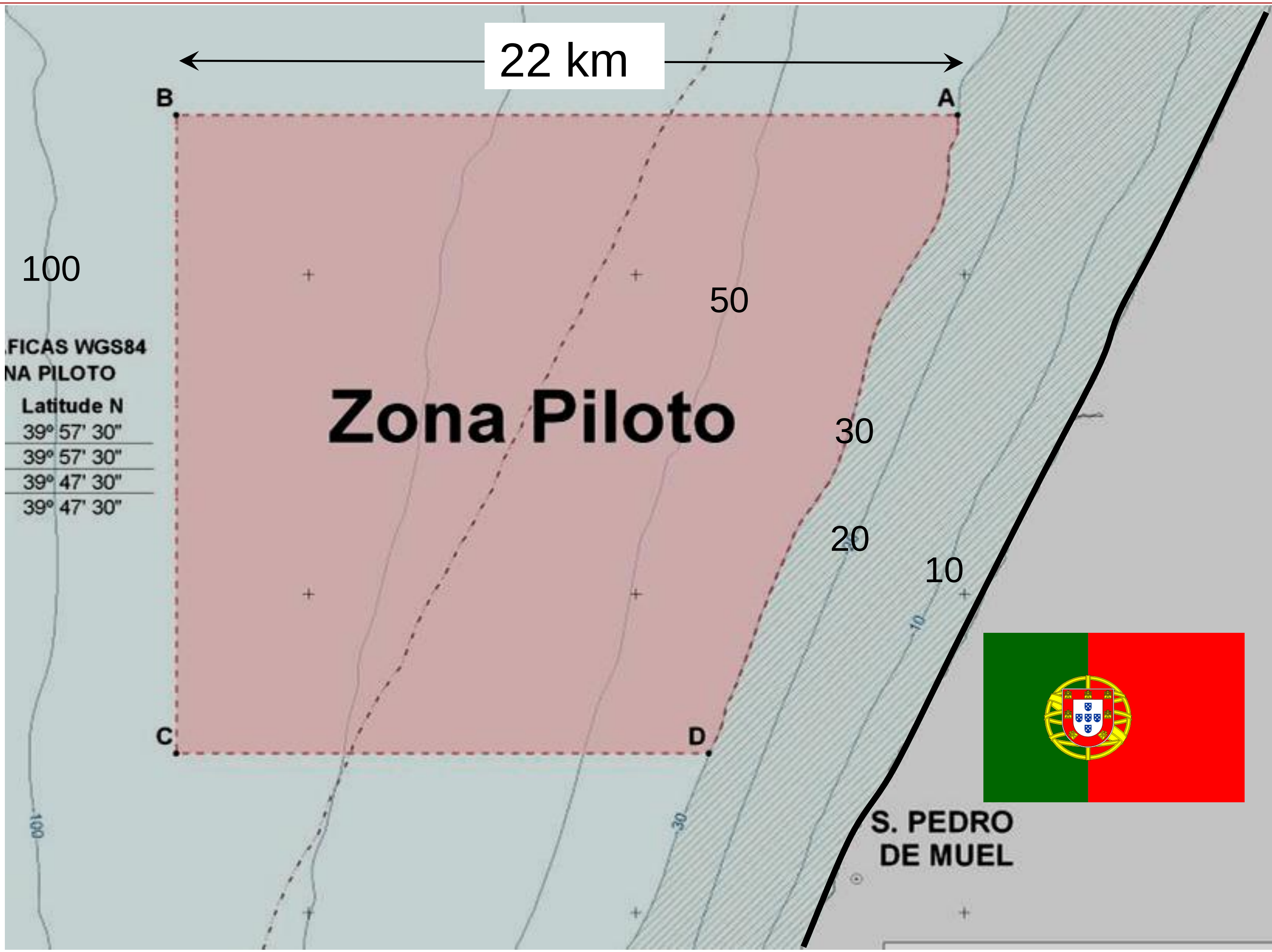
Pilot Zone:

- **Simplified and fast licensing through a Managing Company for demonstration, pre-commercial and commercial phases**
- **80 MW (medium voltage) + 250 MW (high voltage) connection**
- **GIS with relevant data**
- **Infrastructures promoted by the Managing Company**

(laws published in 2008, 2009, 2010)

Public Policies

Pilot zone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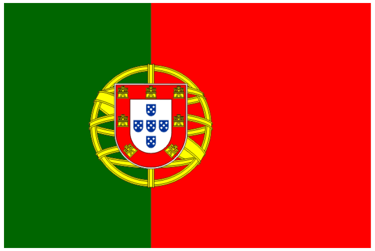
Public Policies

Portuguese Public Policies

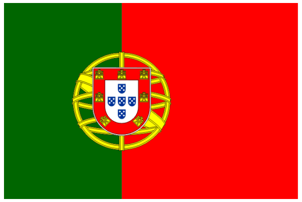


Feed-in tariff:

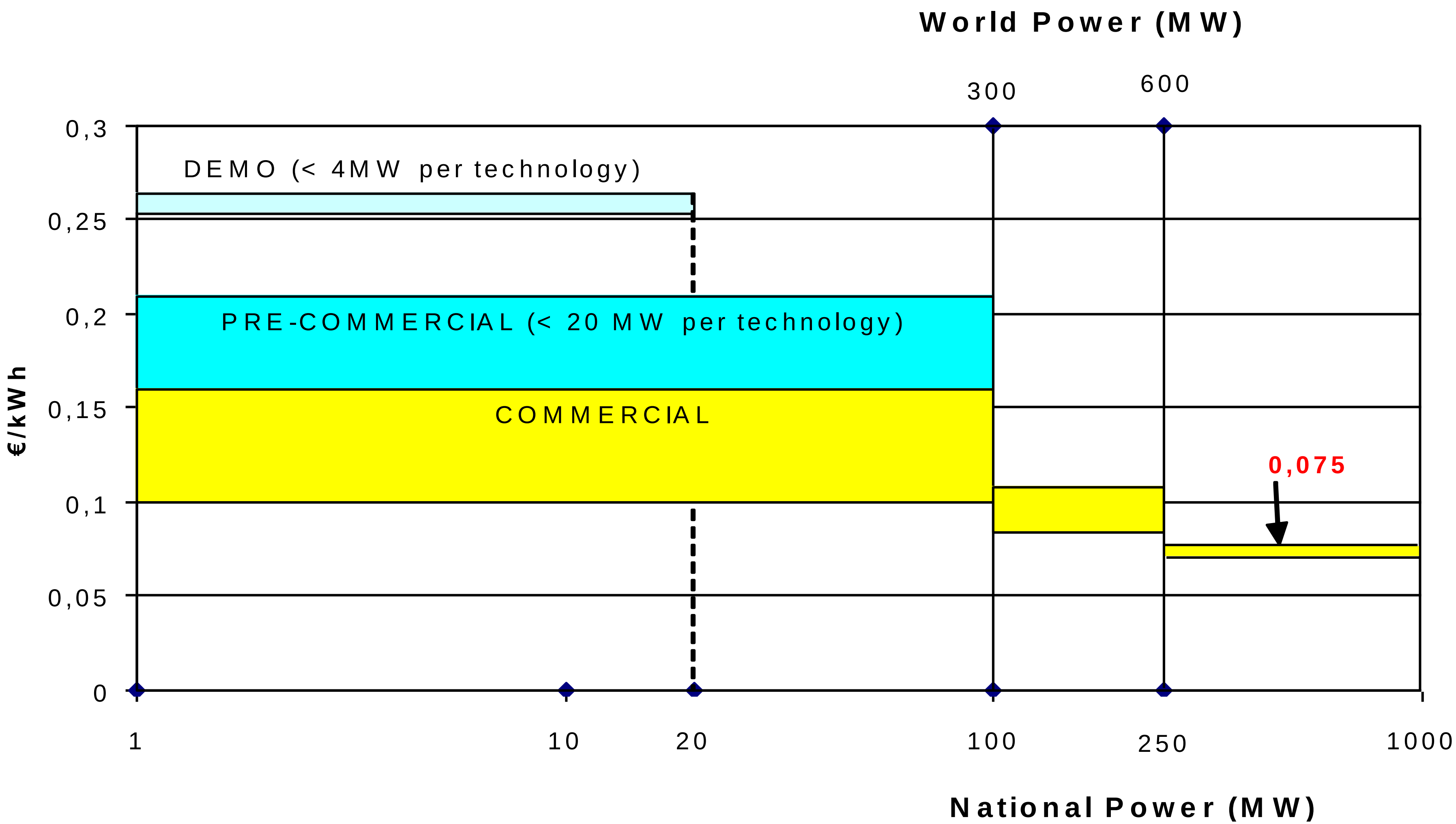
- **0.26 €/kWh for demonstration.**
- **0.16 - 0.21 €/kWh for pre-commercial.**
- **0.075 - 0.16 €/MWh for commercial.**

Tariff depends on installed power per technology in Portugal and elsewhere and quality of the technology & project.

Public Policies



Portuguese Public Policies



Public Policies

Financial incentives: capital and other economic governmental support

Funding in Ireland

Phase	Year	Task	Cost (M€)
1	2007	Prototype development (scale ¼)	4.9
2	2008-10	Pre-commercial devices (full scale)	6.9-10.5
3	2011-15	Pre-commercial array (full scale)	10.1-11.15
4	Onwards	Further market development	To be decided

Public Policies
Ireland

Funding schemes

Work Type		Feasibility	Research and Development			Prototype
Stage		Concept	Validation Model	Lab Design Model	Process Model	Prototype
Industry Project		up to 45%	up to 45%	up to 45%	up to 45%	up to 40%
Collaboration Project	**3rd Level**	up to 75%	up to 75%	up to 75%	up to 75%	N/A
	Industry	up to 45%	up to 45%	up to 45%	up to 45%	N/A
Typical Duration		2 months	4 months	4 months	12 months	12 – 18 months
Indicative Funding		<€15,000	€30,000 – €45,000	€50,000 – €100,000	100,000 – €250,000	Indicative €1,000,000
Examples of Work type undertaken		Desk study Patent / Paper search	Numerical model Small scale testing	Medium scale test Survival Moorings	Real Ocean testing Motions Control	Full Scale testing Grid connection Control Optimisation
Assessment		Expert Review			Review and Negotiation	

Public Policies

Public Policies

Nissun Brending Test Site, Northern Denmark

Scales 1/10 – 1/4

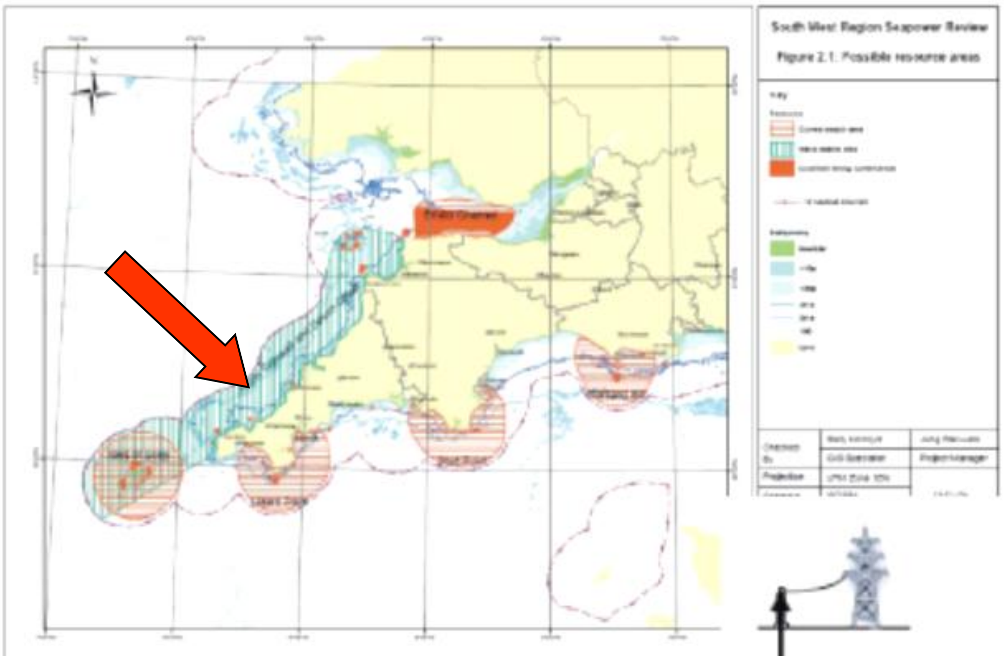
Tested devices:
- Wave Dragon
- Wave Star
- others

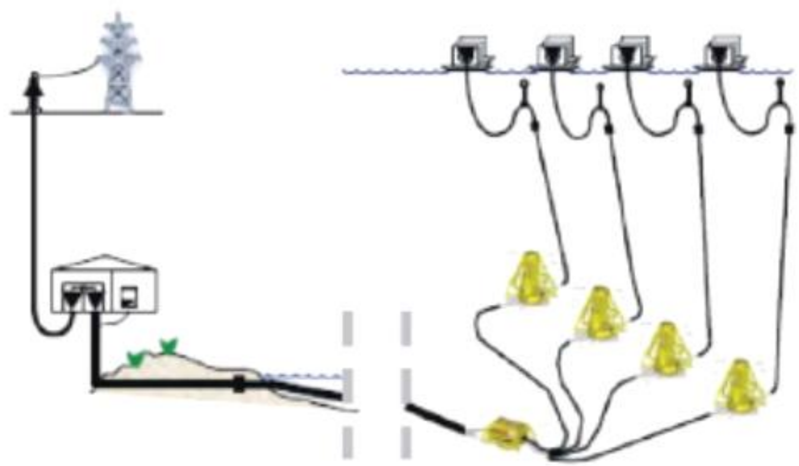
Public Policies

EMEC, Orkney, Scotland, UK

Public Policies

WAVE HUB, Cornwall, SW England, UK





Pre-commercial wave farms

Public Policies
European Commission

Funding of Ocean Energy Projects, 1990-2008

Framework Programme	Number of Projects	Total Eligible Cost (M€)	Total EC Contribution (M€)
FP2 (JOULE I)	2	0.52	0.52
FP3 (JOULE II)	8	6.36	3.05
FP4 (JOULE III)	11	12.14	6.91
FP5	4	7.47	4.54
FP6	4	26.1	7.3
FP7*	2	9.9	7.5
Total	**31**	**62.49**	**29.82**

* First Call 2007 only

Public Policies
European Commission

Funding of Ocean Energy Projects in 2008

Project Acronym	Duration (Months)	EC Funding for the Whole Duration
WAVE DRAGON MW	36	2.431.000 €
SEEWEC	42	2.299.755 €
WAVE SSG	30	1.000.000 €
CORES	36	3.449.588 €
EQUIMAR	36	3.990.024 €

WAVE ENERGY

Public Policies

IEA | OES
Ocean Energy Systems

International Energy Agency

Implementing Agreement on Ocean Energy Systems

Vision

To realise, by 2020, the use of cost-competitive, environmentally sound ocean energy on a sustainable basis.

Mission

To facilitate and co-ordinate ocean energy research, development and demonstration through international co-operation and information exchange.

Public Policies Objectives

IEA | OES Ocean Energy Systems

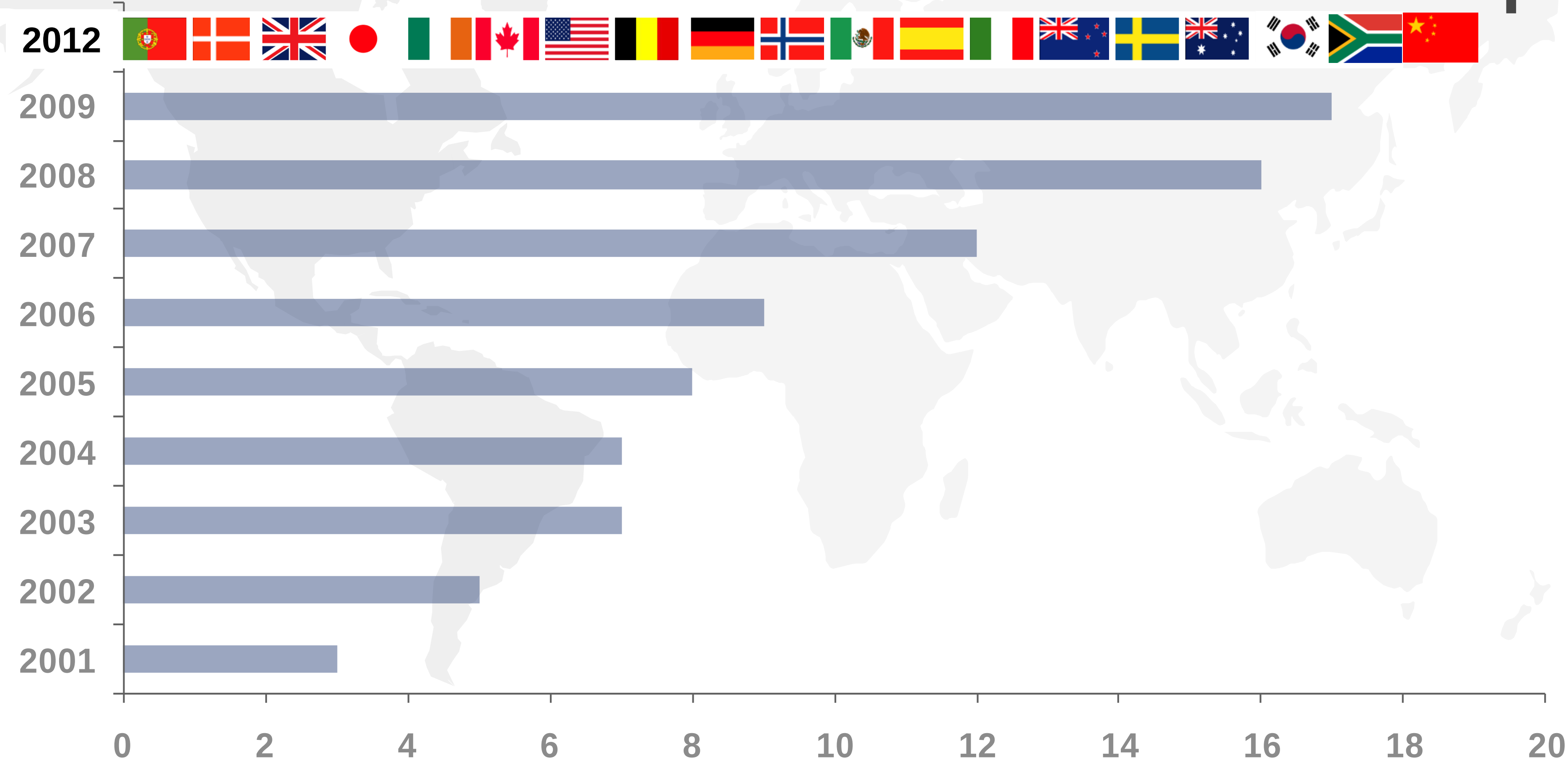
5 Year Strategic Plan (2007 – 2011)

1. To actively encourage and support the development of networks of participants involved in R, D & D, prototype testing and deployment, policy development and facilitate networking opportunities
2. To promote and facilitate collaborative research, development, and demonstration to identify and address barriers to, and opportunities for, the development and deployment of ocean energy technologies
3. To promote the harmonization of standards, methodologies, terminologies, and procedures, where such harmonization will facilitate the development of ocean energy
4. To become a trusted source of objective information and be effective in disseminating such information to ocean energy stakeholders, policymakers and the public
5. To promote policies and procedures consistent with sustainable development

Public Policies

IEA | OES Ocean Energy Systems

Present Membership



END OF PART 5
WAVE ENERGY SITUATION AND PERSPECTIVES