Marine renewable energy

Sources of energy
technological barriers
foresight

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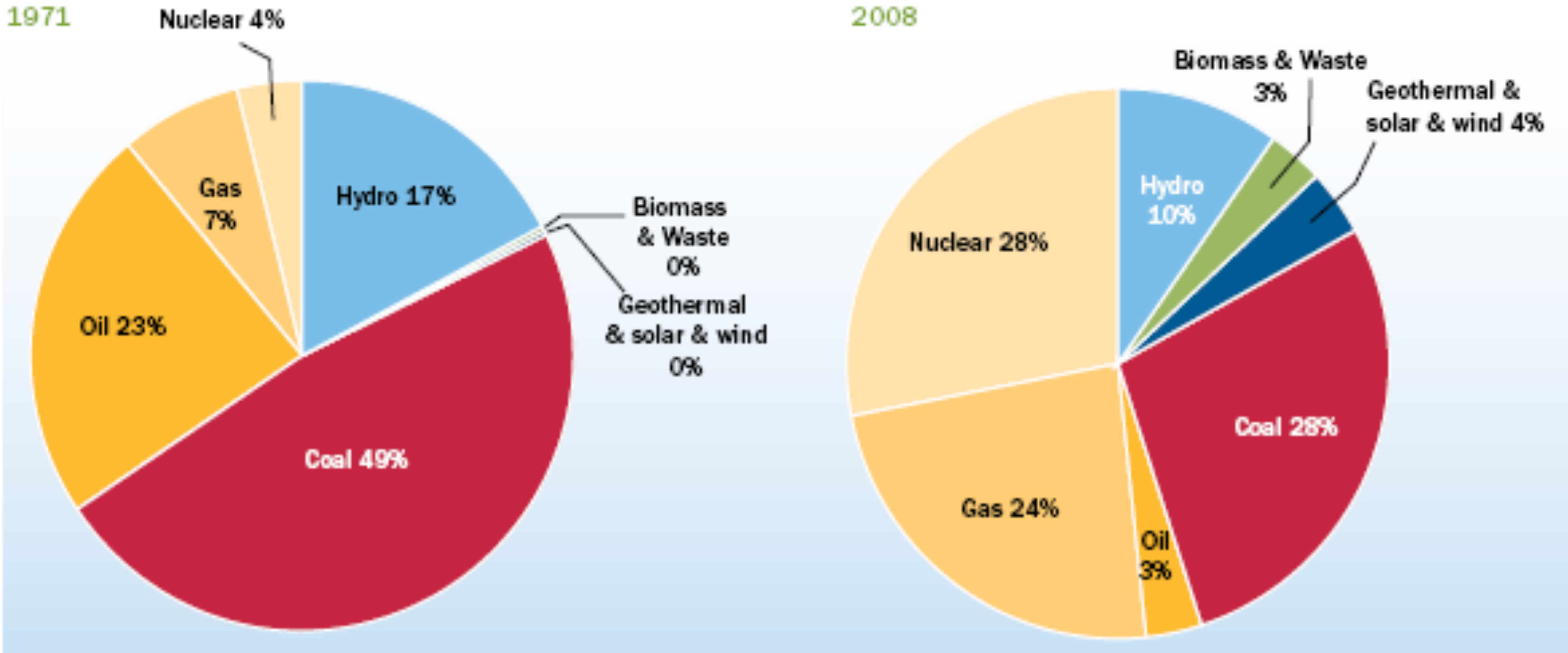
Energy for the future

FIG 1: EU27'S EVOLVING ENERGY MIX (% OF ELECTRICITY CONSUMPTION)

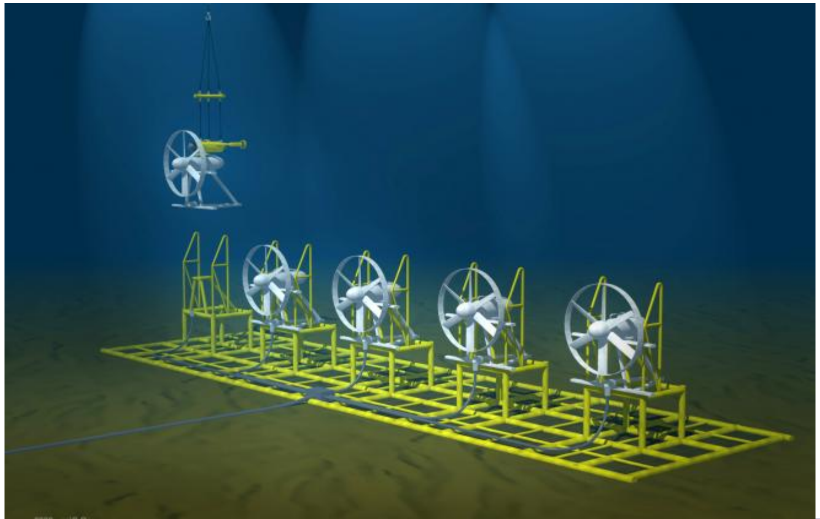


1971 Calculations provided by 3E using the following sources: IEA Electricity Information (2010 Edition); IEA Energy statistics of non-OECD countries (2010 Edition); IEA CO_2 emissions from fuel combustion - Annual historical series (1971-2008); US Energy Information administration (EIA, www.eia.doe.gov, installed capacity non OECD) 1971 (TWh 1,376).
2008 Ibid 2008 (TWh 3,341)

Renewable sources of marine energy

They are based on the conversion of the energy of :

- Offshore wind
- Currents
- Tide
- Wave
- Ocean thermal content



Key figures

Annual electricity production

- **World 20 000 Twh**
- **Europe 3 300 Twh**
- **France 500 Twh**

Price France : producer cost 4 c€/kwh

Final user around 4 to7 c€/kwh

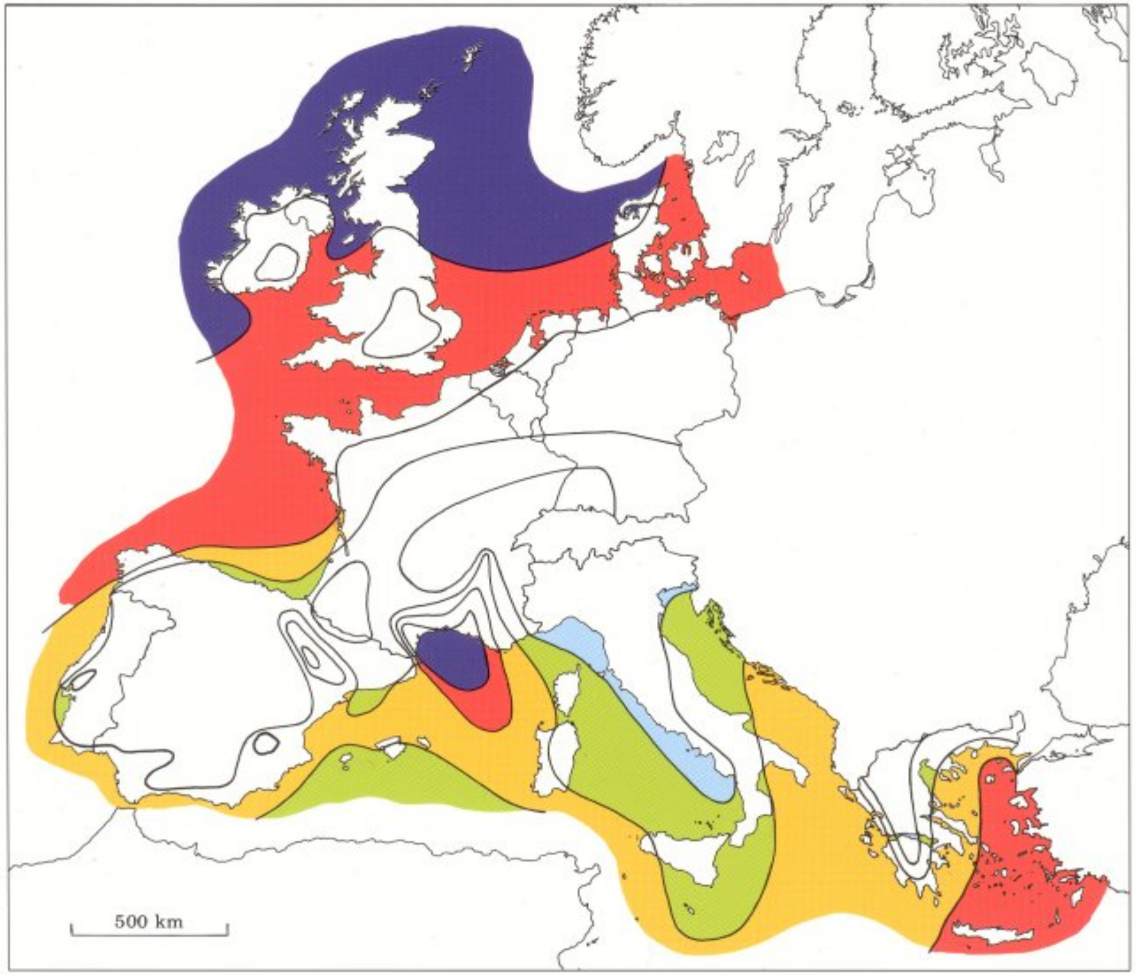
Price comparisons are difficult due to different way of regulation by the different governments (infrastructure, research, waste processing....)

Offshore wind energy

Stronger and more regular wind at sea

Potentially less use conflict between activities (visual impact, noise, human activities...)

Large areas available



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

Offshore wind energy
An industrial reality

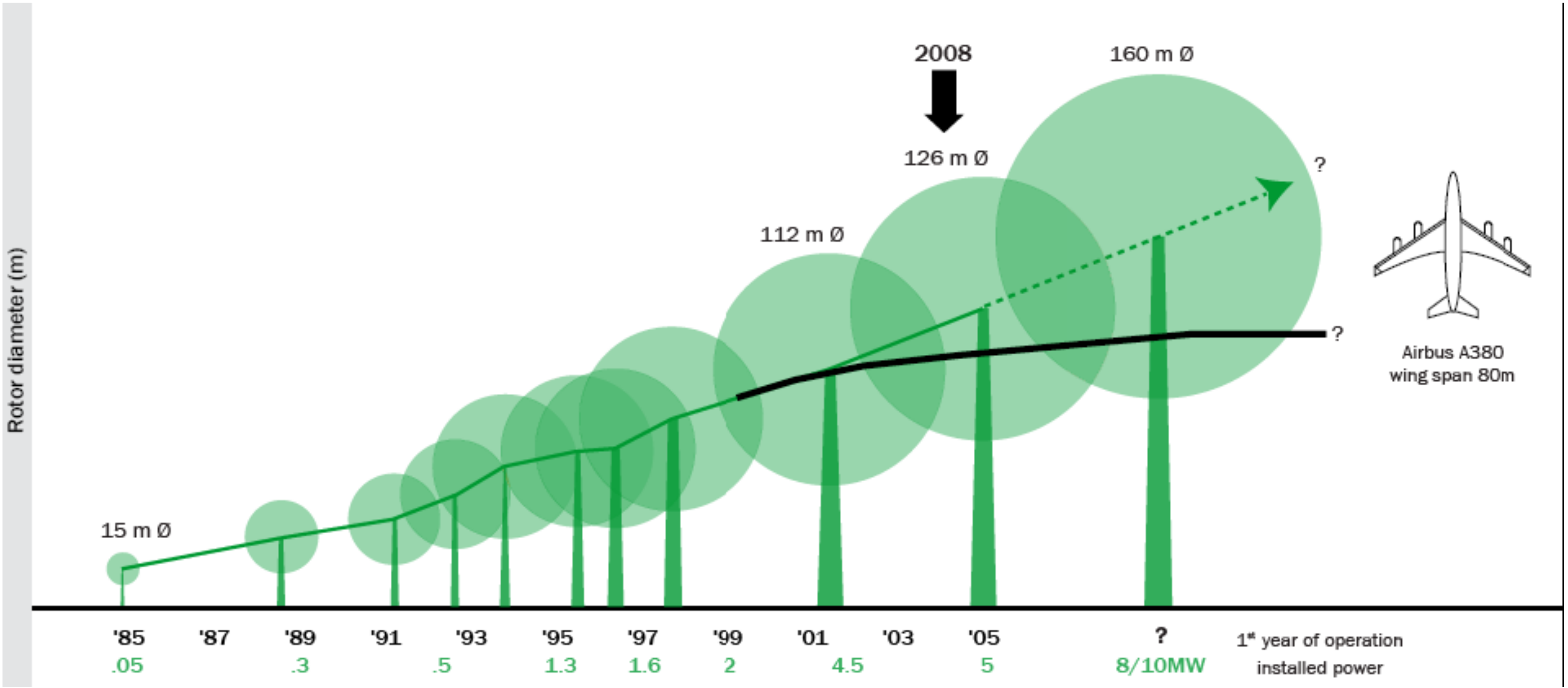
2 technologies :

Build up on the sea bed (waterdepth < 50m).

- Operational systems. More than 30 farms in EU.
- 2 Gw installed
- 4 Gw under construction (Denmark, Germany)
- 6 GW in project (France 2020)

Offshore wind energy

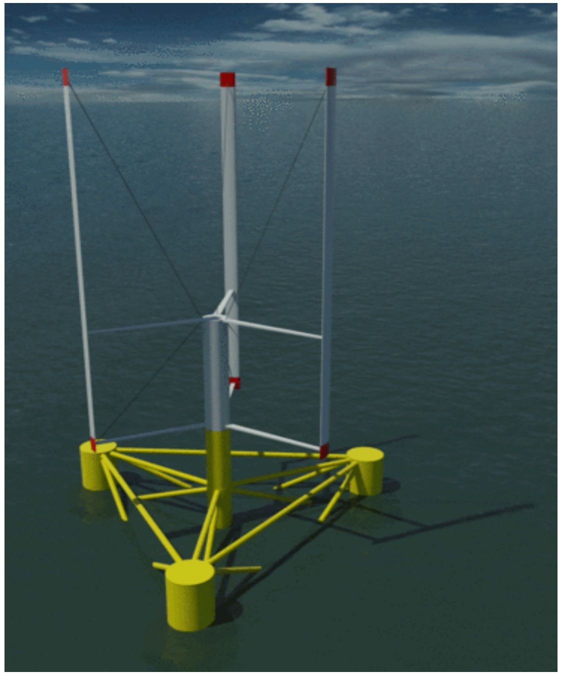
- Race gigantism !
  - Example : Enercon 126 mast 135 m, rotor dia. 126 m, power 6MW

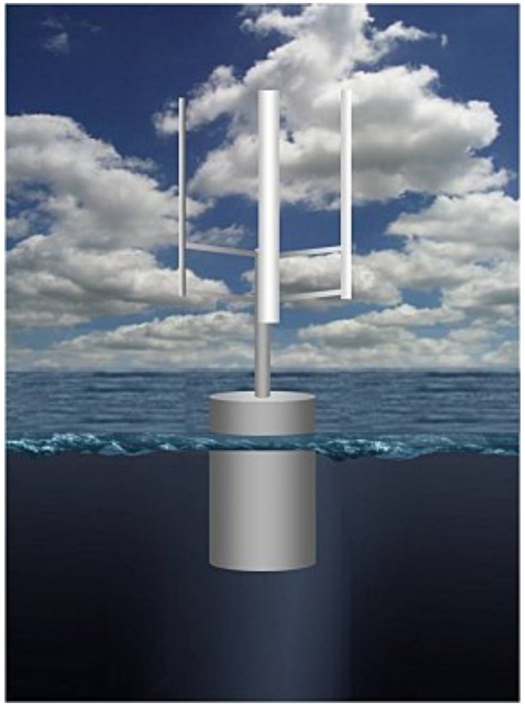


Offshore wind energy

Projects of Floating systems to avoid bathymetric limitation.

Active research to progress: anchoring systems, coupling of the efforts of the wind and float,





Offshore wind energy

Rentability threshold : 8 to 12 c€ / Kwh depending on the water depth, the distance to the shore, to the grid connection...

According to PriceWaterHouse Cooper 2010 :

- +20%/year until 2035
- offshore W production > terrestrial W production in 2026 (Europe)

Current

Predictible resource

- Great oceanic current (ie gulf stream)
- Tidal current

No visual impact and no perturbation for the shipping

Available energy 450TWh

80% of the UE resource is in UK, F

Current

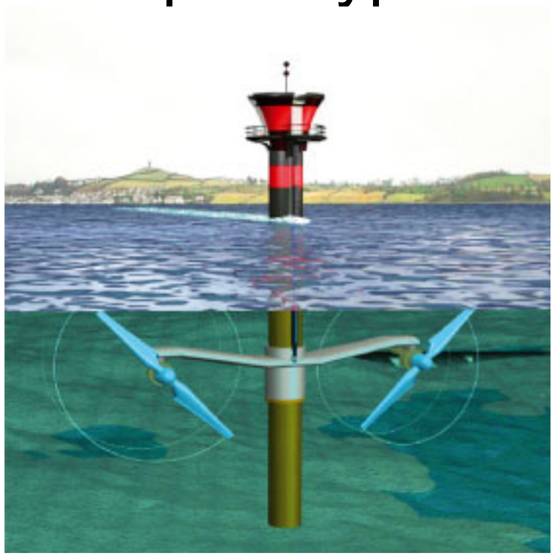
- More than 50 prototypes. Very few experimented at sea

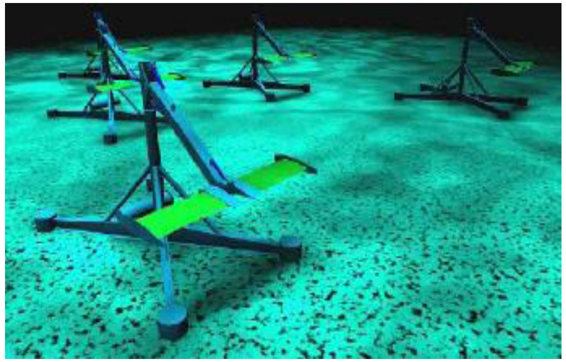
Seagen

1,2 Mw

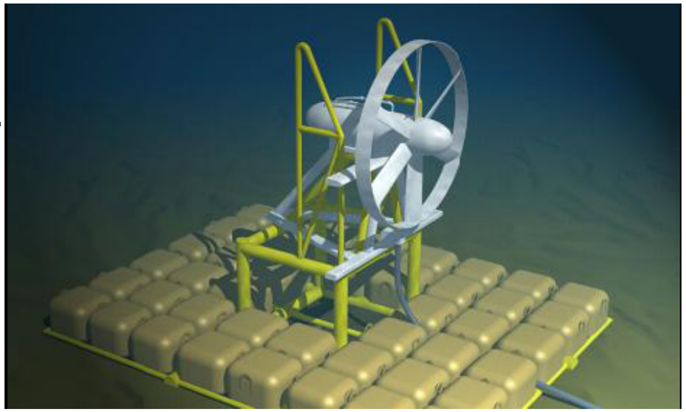
Installed

in ireland





Sabella F



Current

Simple concepts which need to be improved

Research axes :

Reduce the installation and maintenance expenses (offshore technology, teleoperation, anchoring system, connection to the grid, etc)

fouling and corrosion problems

Price objective less than 4c€/kwh

Tide

La Rance France 1967 240 Mw

sihwa Korea 2010 254Mw

Smaller plants running in Canada, USA. Projects in India, Korea, etc

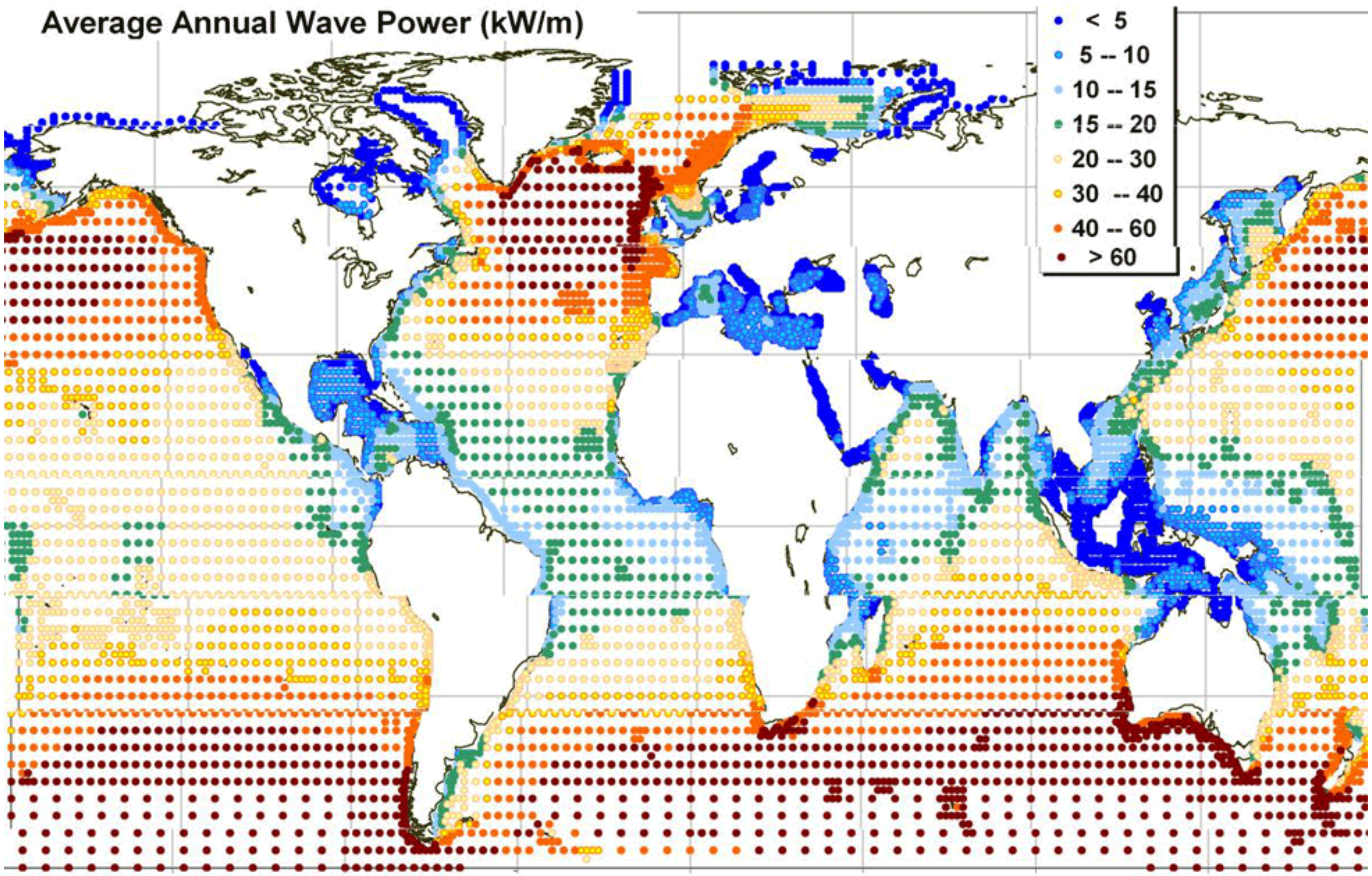
Regular and predictible ressource

Environmental impact still unsolved (artificial lake changing the biodiversity)

Waves

Theoretical available energy : World 1400 Twh Europe 100 Twh

random energy source



Waves

More than 100 patented systems. Few expérimentations. No system has demonstrated its technical and economical viability

4 main principles :

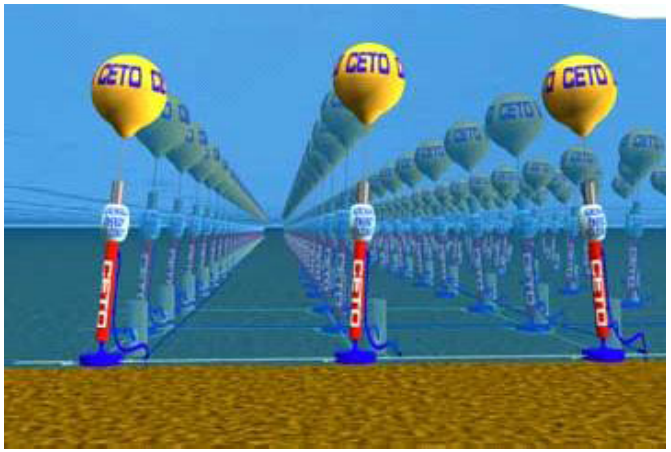
- Oscillating water column compressing water (protypes in Scotland, Norway)
- Articulated floating systems converting the twisting of the system
- Oscillating floats converting the movements of an inertia mass
- Subsurface oscillators

Waves

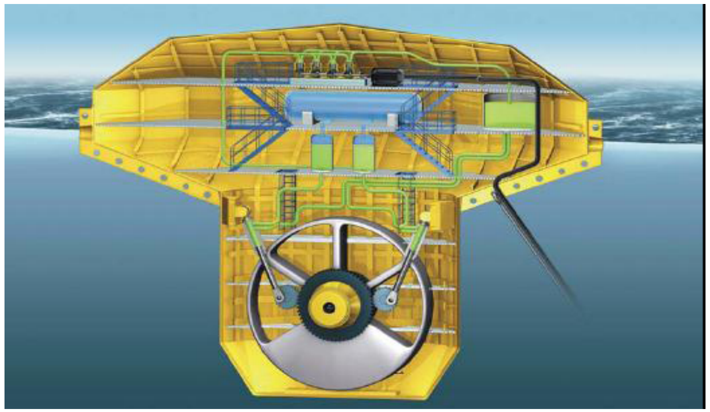
Pelamis, articulated system 140 m,
350 tonnes ,
750 kW 3 systems tested offshore Portugal

Limpet, Islay, scotland 500 kW, oscillating water column

CETO, système de subsurface avec pompe hydraulique (Australia)



Searev 25 m de long, 15 m de tirant d'eau 1000 tonnes, 500 kW (EC Nantes) France



Waves

Heavy and complex systems which have to be designed to resist storms

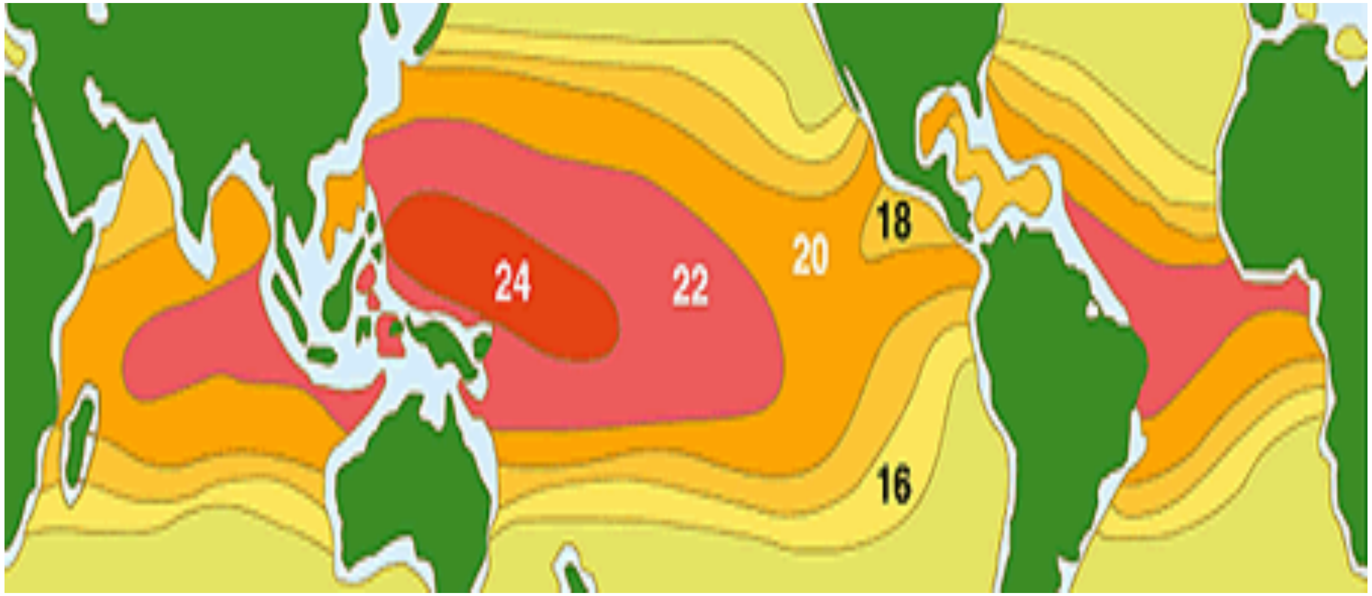
High manufacturing costs and maintenance

Experimentation needed to select the concepts that have a future

Ocean thermal energy conversion

Principle : use the temperature difference between the warmer sea surface and the cooler deep water to run a heat engine

map of DT between surface and 1000 m depth



Sustained energy but only available in Equatorial zone

Experiments in France, Japan and USA proving the feasibility.

(low power < 250Kw)

OTEC

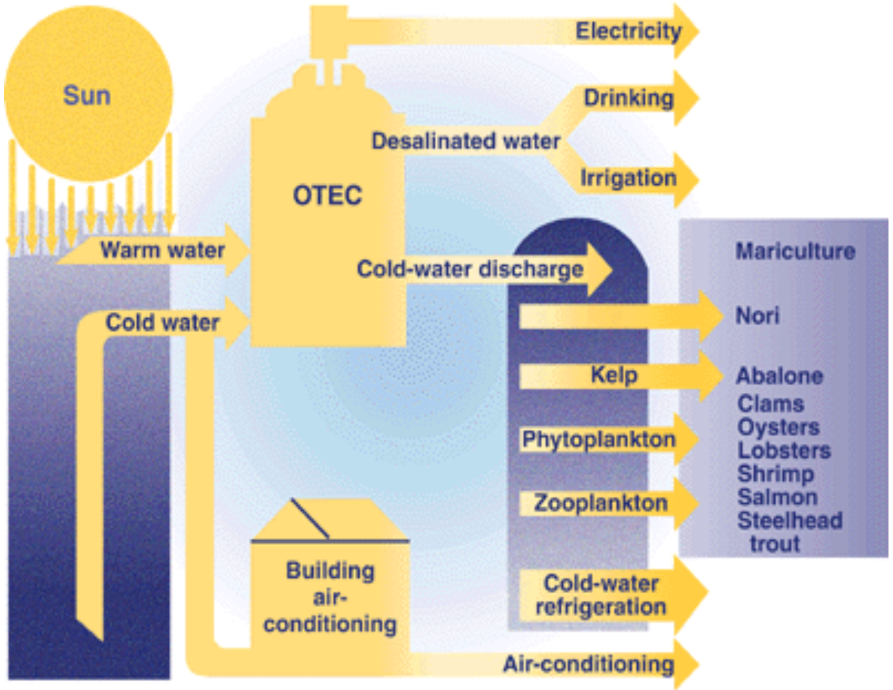
Technological barriers :

•High flow of water have consequences on the pipes diameter (10 m for 50 Mw, 15 m for 150 Mw)

•Materials for the exchanger (biofouling...)

•environmental impact (cold water discharge, chemical in case of close cycle problem...)

Exploitation of the coldwater discharge (aquaculture...) to optimise the economical balance



Conditions for the development of marine energies

Stimulate the R&D by funding research projects including realistic experimentation with private companies to improve and select the right concepts

Adapt the grid or develop energy storage for this mainly make and break energy. Could be a key problem wih the increase of random energys sources in the mix of electricity production.

Create a stable administratif and financial framework (price of the Kwh is not enough)

Comprehensive energy policy to balance the efficiency of the production by the environmental impact (Co2, Nox, waste,...), and by the jobs

Table 1 ESTIMATED BENEFITS OF DEVELOPING A WORLD LEADING EUROPEAN OCEAN ENERGY INDUSTRY

Installed Capacity / GW	Direct Jobs[1]	Total Jobs (Direct & Indirect)[2]	CO_2 avoided Mt/year[3]	Investment €m.[4]
3.6 (in 2020)	26,000	40,000	2.61	8,544
188 (in 2050)	314,213	471,320	136.3	451,104

European Ocean Energy Association. Roadmap 2010-2050