# Ocean Energy in View of the IPCC Report with an Emphasis on Brazilian Activities

**Segen F. Estefen**
**Professor of Ocean Structures**
**COPPE - Federal University of Rio de Janeiro**
**Brazil**

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INTERGOVERNMENTAL PANEL ON climate change

Working Group III - Mitigation of Climate Change

# Special Report on Renewable Energy Sources and Climate Change Mitigation

## Chapter 6: Ocean Energy

# Ocean Energy

**Coordinating Lead Authors:**
Anthony Lewis (Ireland) and Segen Estefen (Brazil)

**Lead Authors:**
John Huckerby (New Zealand), Kwang Soo Lee (Rep.of Korea),
Walter Musial (USA), Teresa Pontes (Portugal),
Julio Torres - Martinez (Cuba)

**Contributing Authors:**
Desikan Bharathan (USA), Howard Hanson (USA),
Garvin Heath (USA), Frederic Louis (France),
Sandvik Øystein Scråmestø (Norway)

**Review Editors:**
Amjad Abdulla (Republic of Maldives), José M. Moreno (Spain),
Yage You (China)

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## Special Report on Renewable Energy Sources and Climate Change Mitigation

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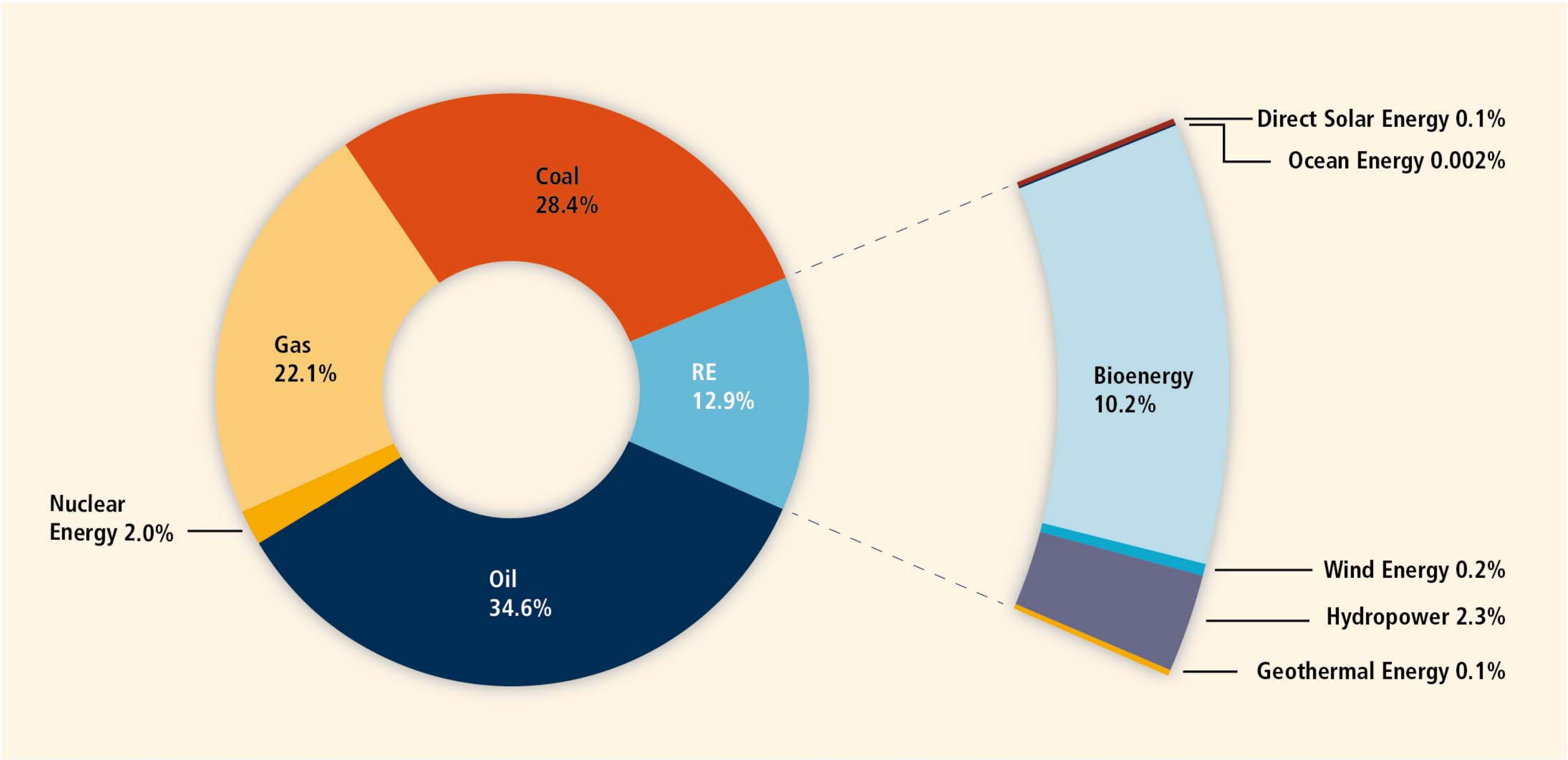
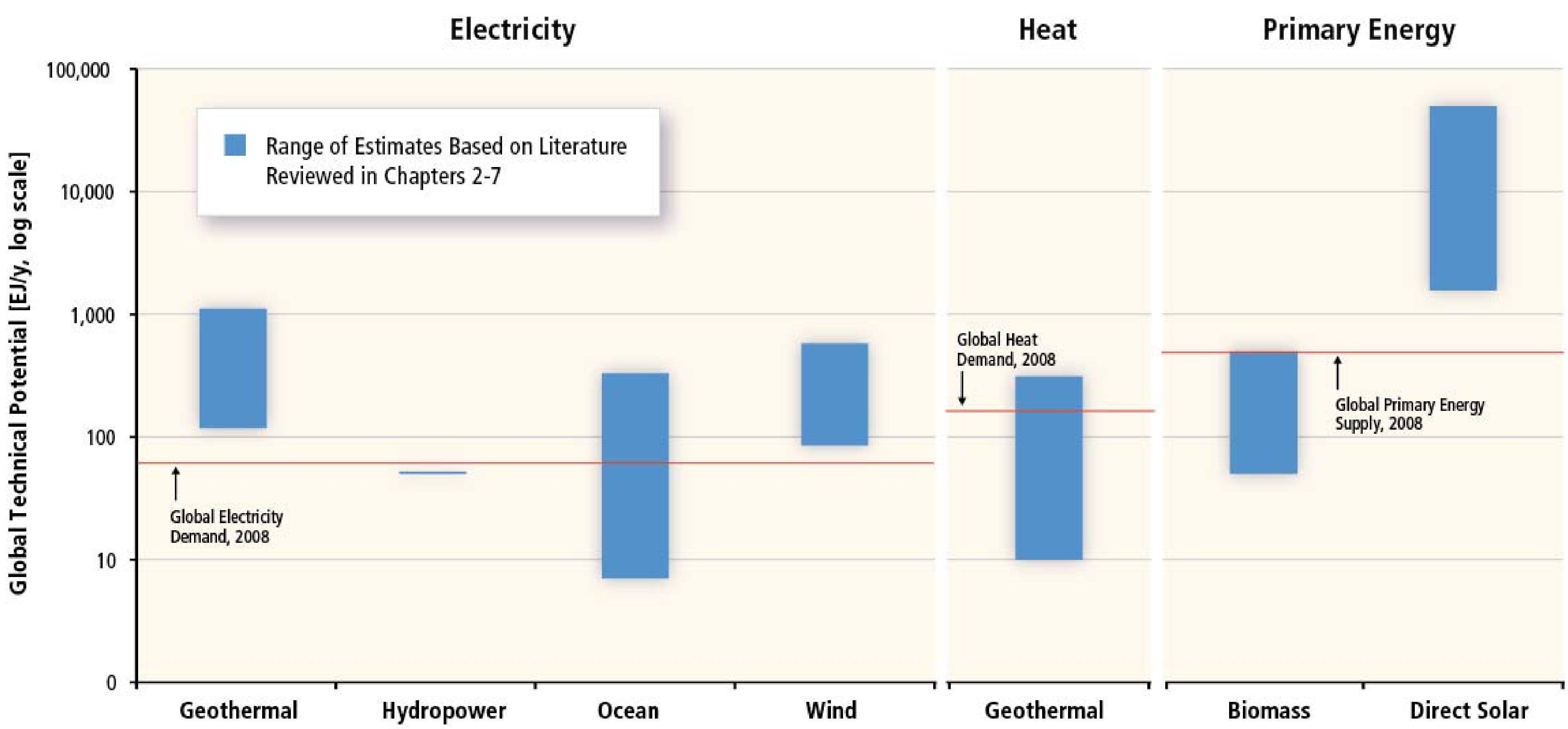
**http://srren.ipcc-wg3/report**

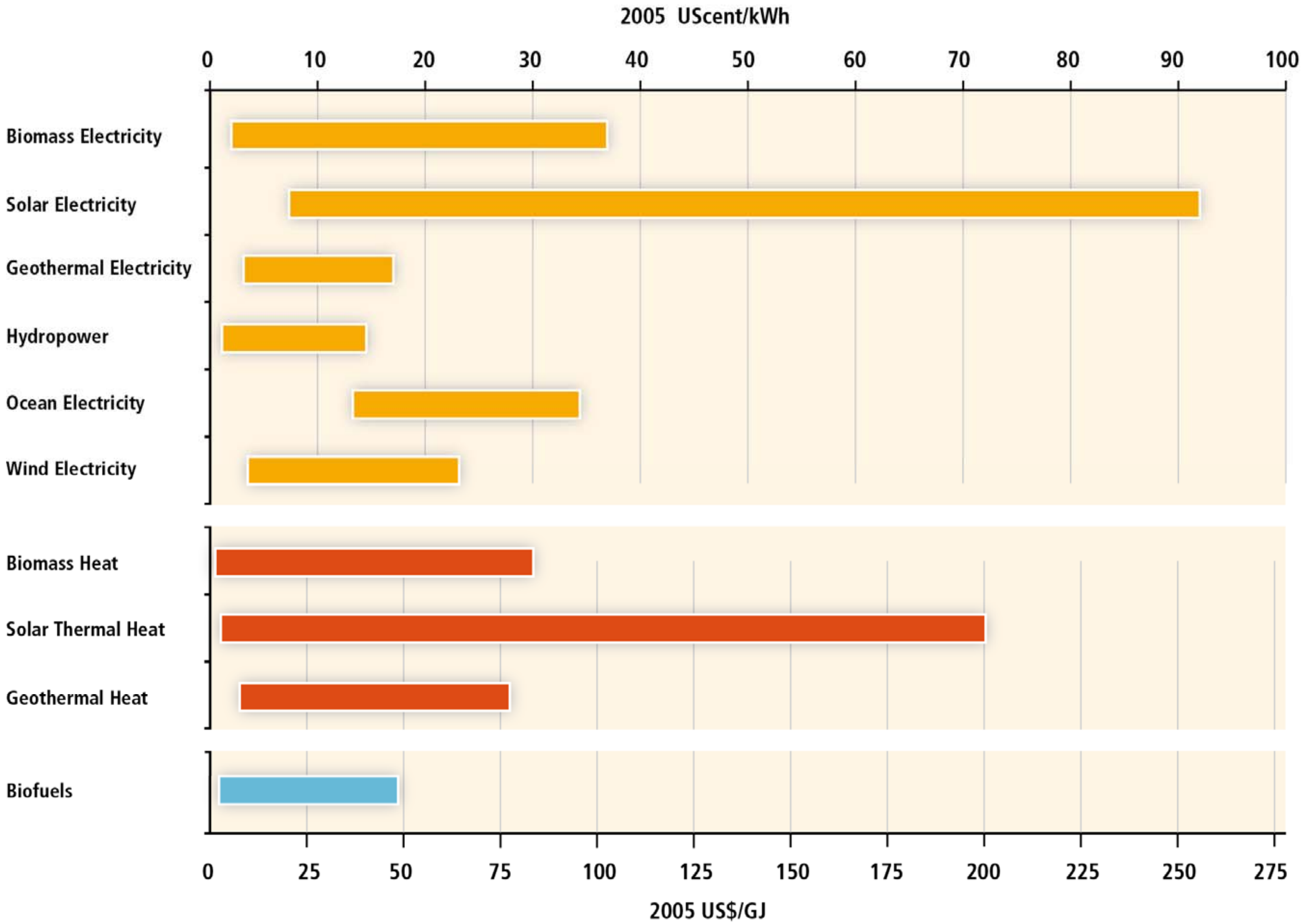
# Global total primary energy supply (2008)



# Range of global technical potentials



# Cost of energy



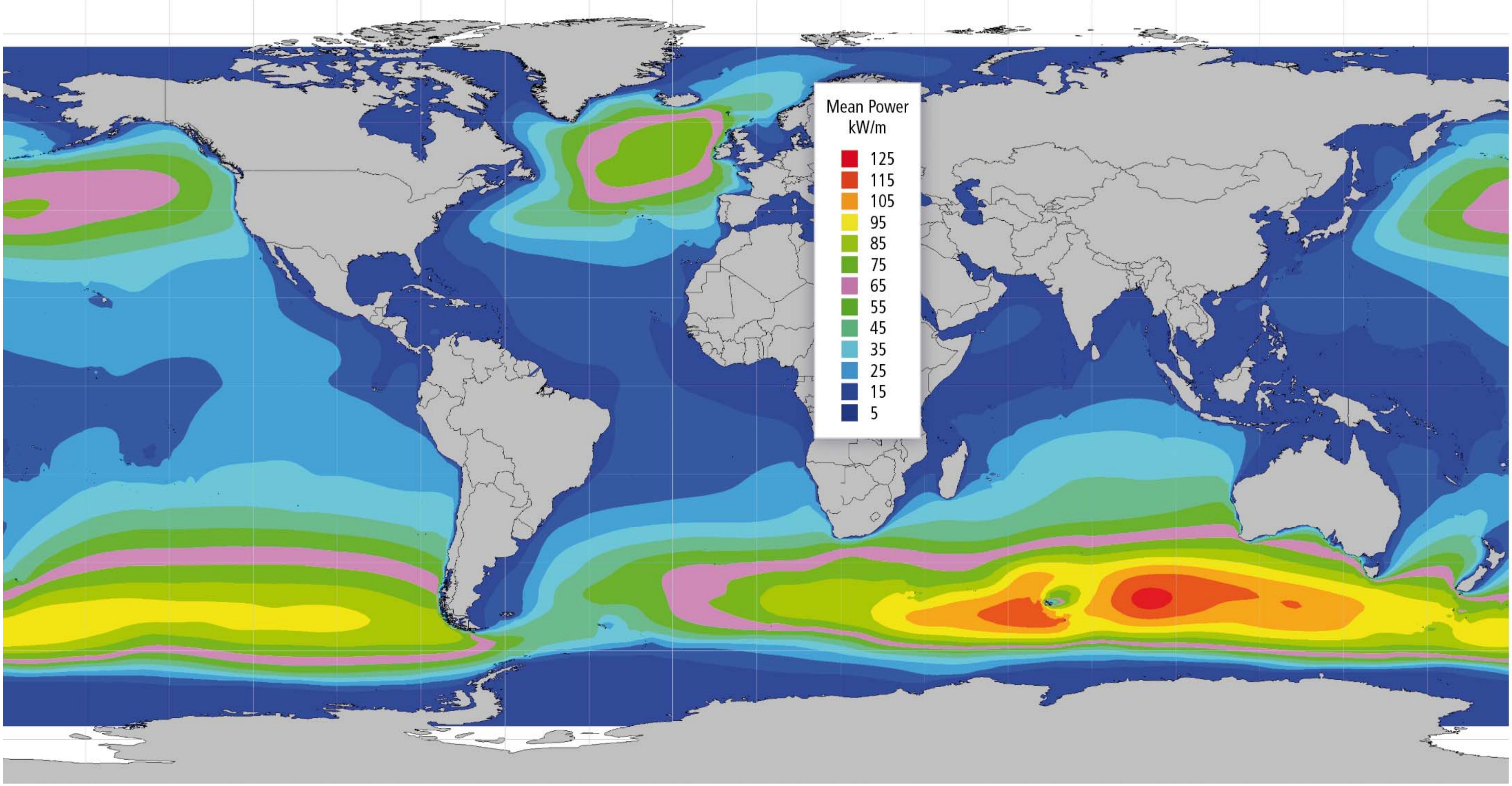
# Ocean Energy

Ocean energy can be defined as energy derived from technologies that utilize seawater as their motive power or harness the water's chemical or heat potential.

The RE resource in the ocean comes from six distinct sources, each with different origins and requiring different technologies for conversion.

<u>Sources</u>: Wave, Tidal range, Tidal current, Ocean current
Thermal gradient, Salinity gradient

**Wave energy** derived from the transfer of the kinetic energy of the wind to the upper surface of the ocean. Theoretical wave energy resource is estimated in 32,000 TWh/yr (115 EJ/yr), higher than the global electricity supply in 2008.



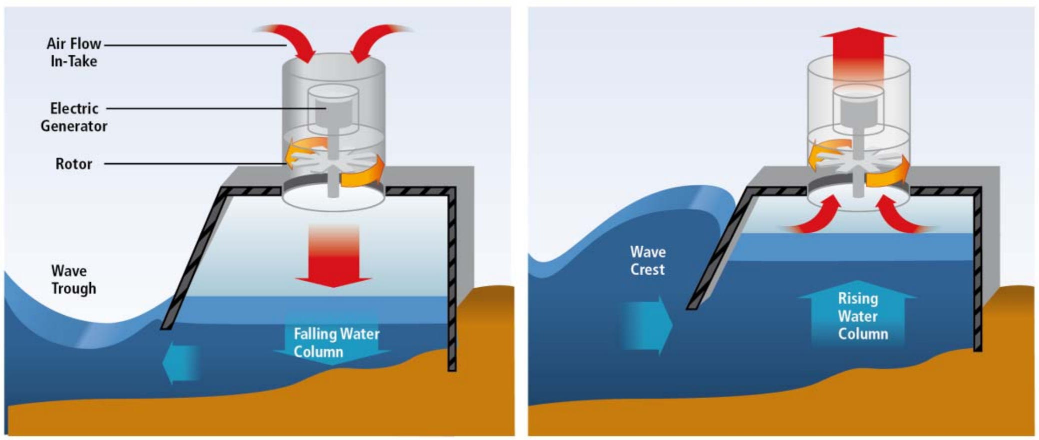
## Regional theoretical potential of wave energy (TWh/yr)

Western and Northern Europe.......................... 2,800
Mediterranean Sea and Atlantic Archipelagos.... 1,300
North America and Greenland........................... 4,000
Central America................................................. 1,500
South America ....................................................4,600
Africa .................................................................3,500
Asia.................................................................... 6,200
Australia, New Zealand and Pacific Islands.......... 5,600

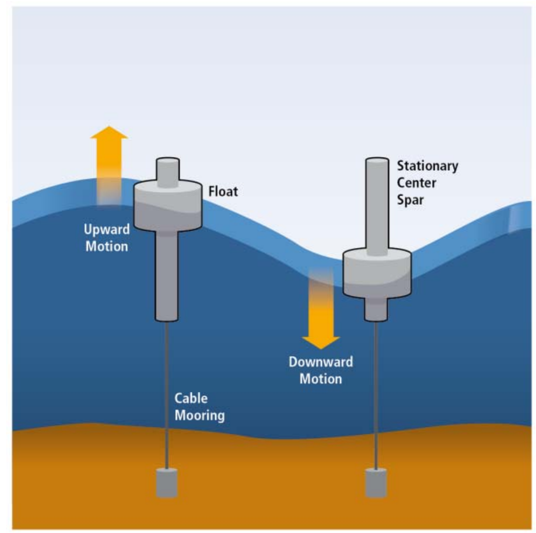
The regional distribution of the annual wave energy incident on the coasts of countries / regions has been obtained for areas where theoretical wave power $P \geq 5$ kW/m and latitude $\leq 66.5$º.

# Wave Energy Technologies

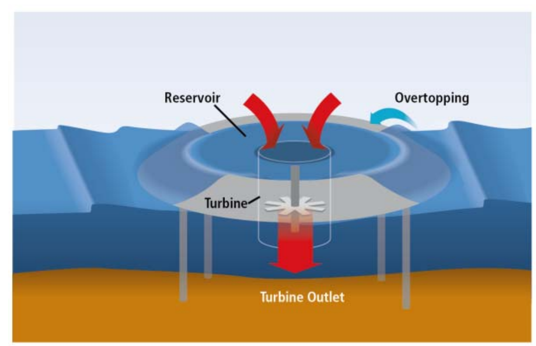
## Oscillating Water Column (OWC)



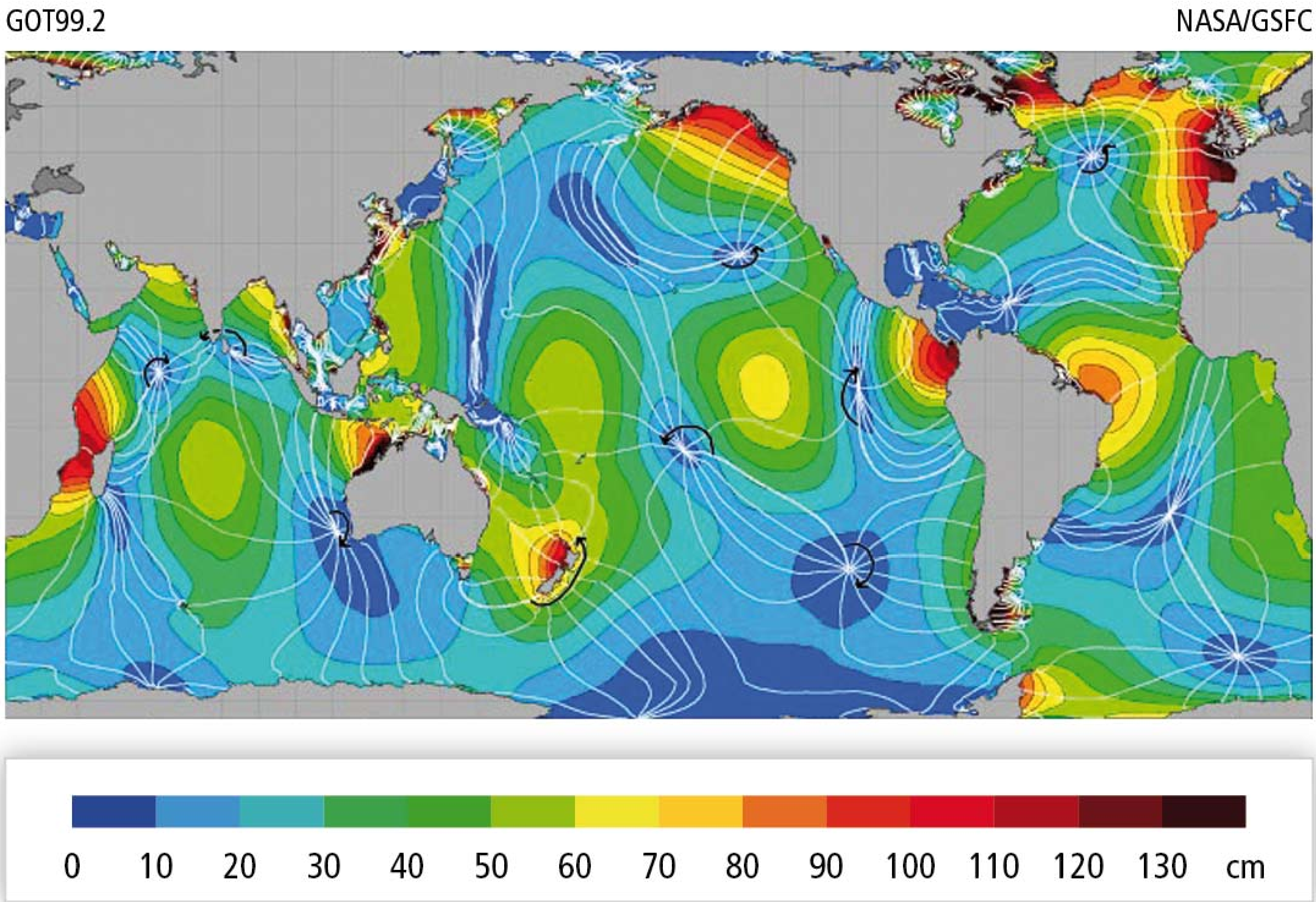

## Oscillating Body (OB)

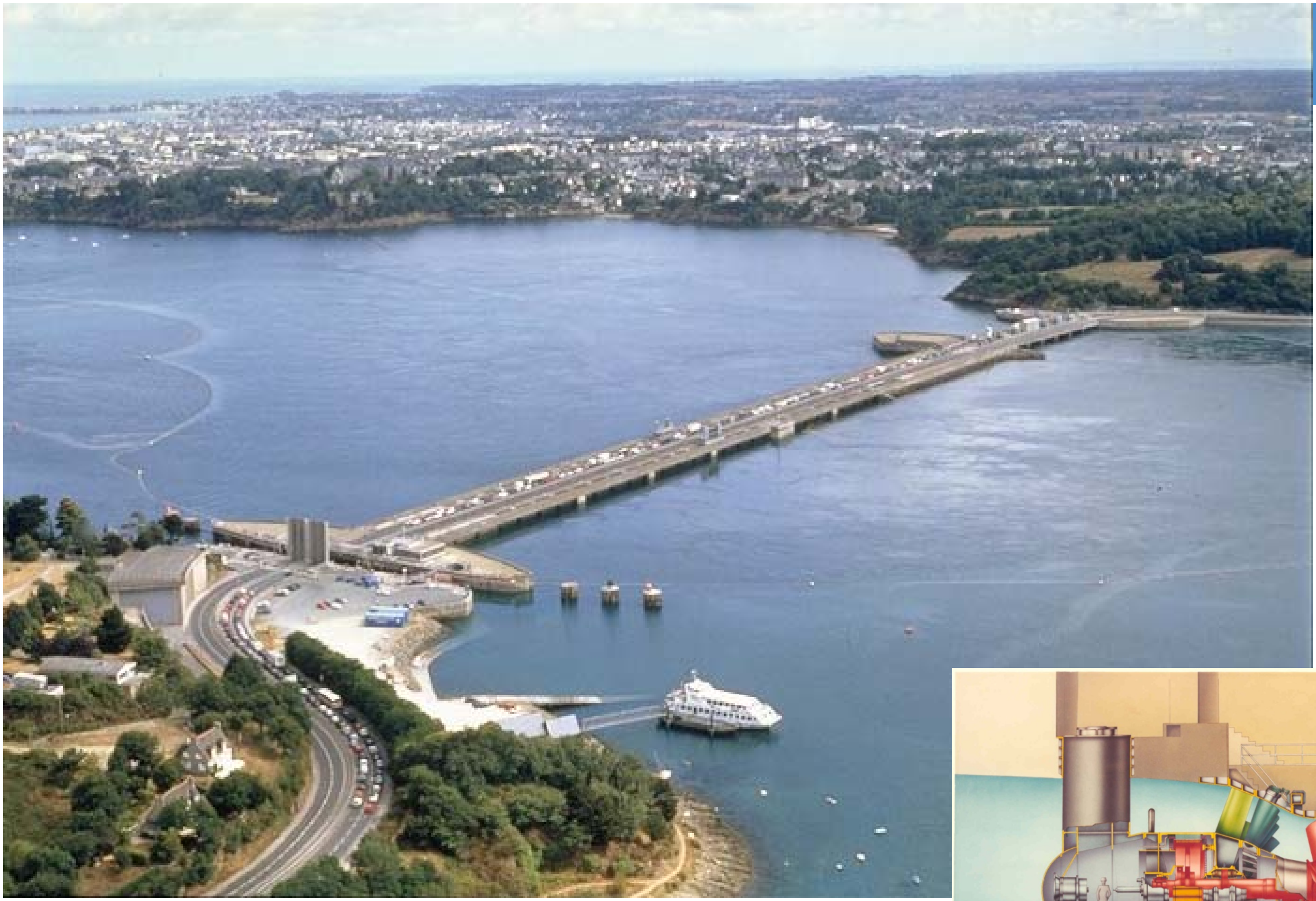



## Overtopping

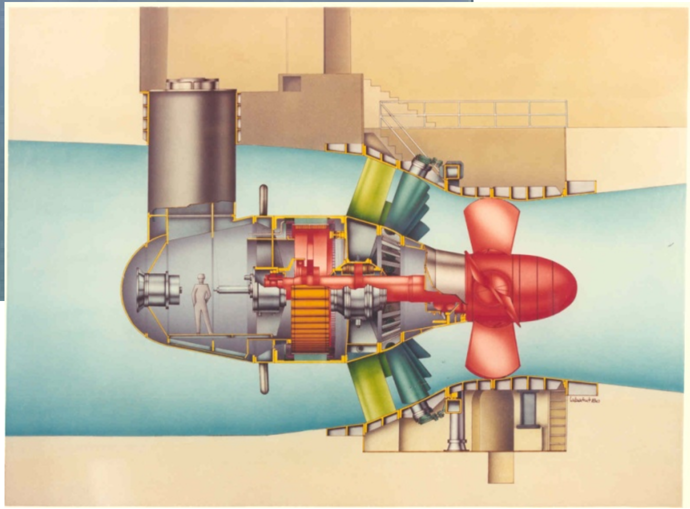


**Tidal range (tidal rise and fall)** derived from gravitational forces of the Earth-Moon-Sun system. Theoretical tidal power potential is in the range of 1 to 3 TW.





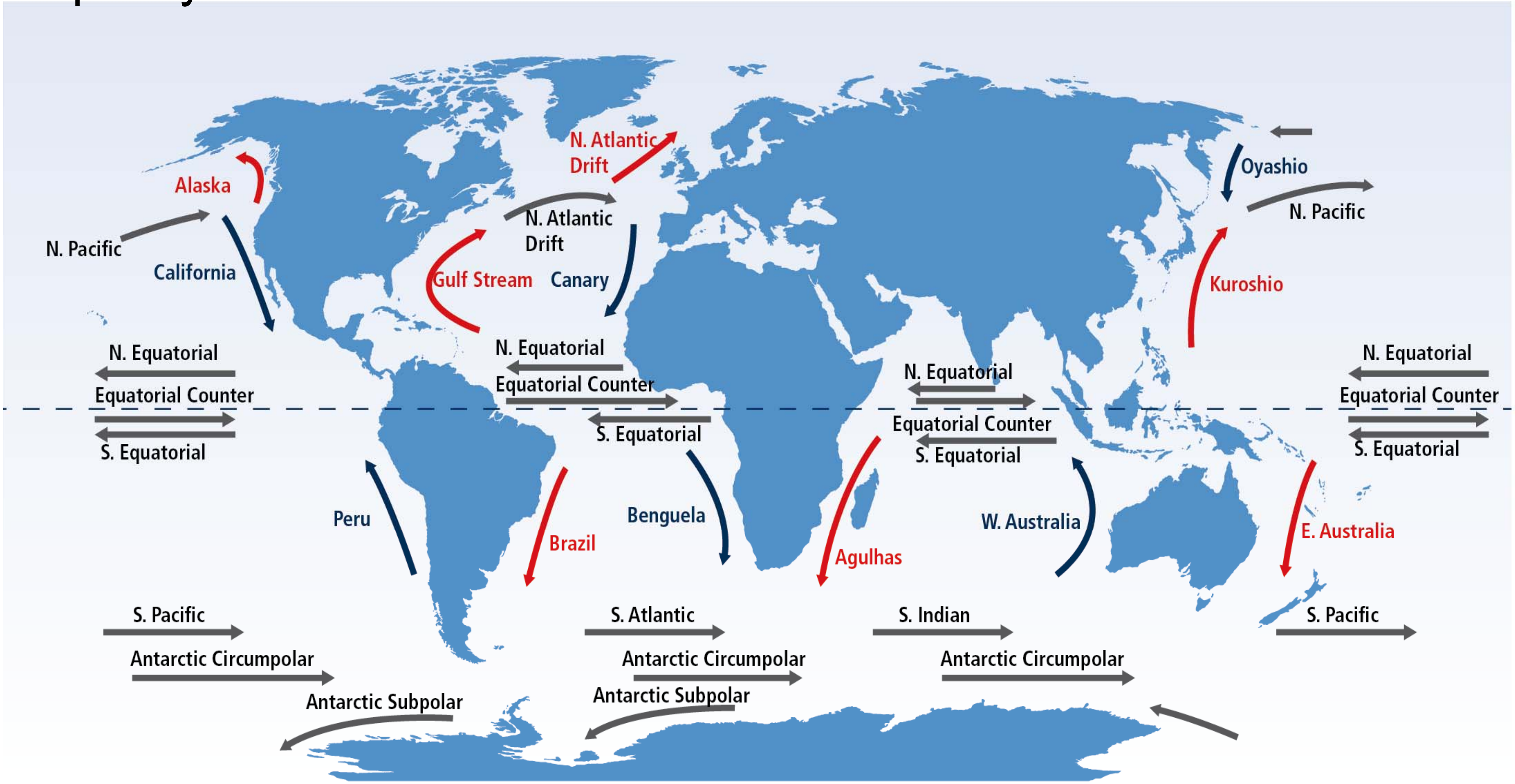
La Rance - 240 MW



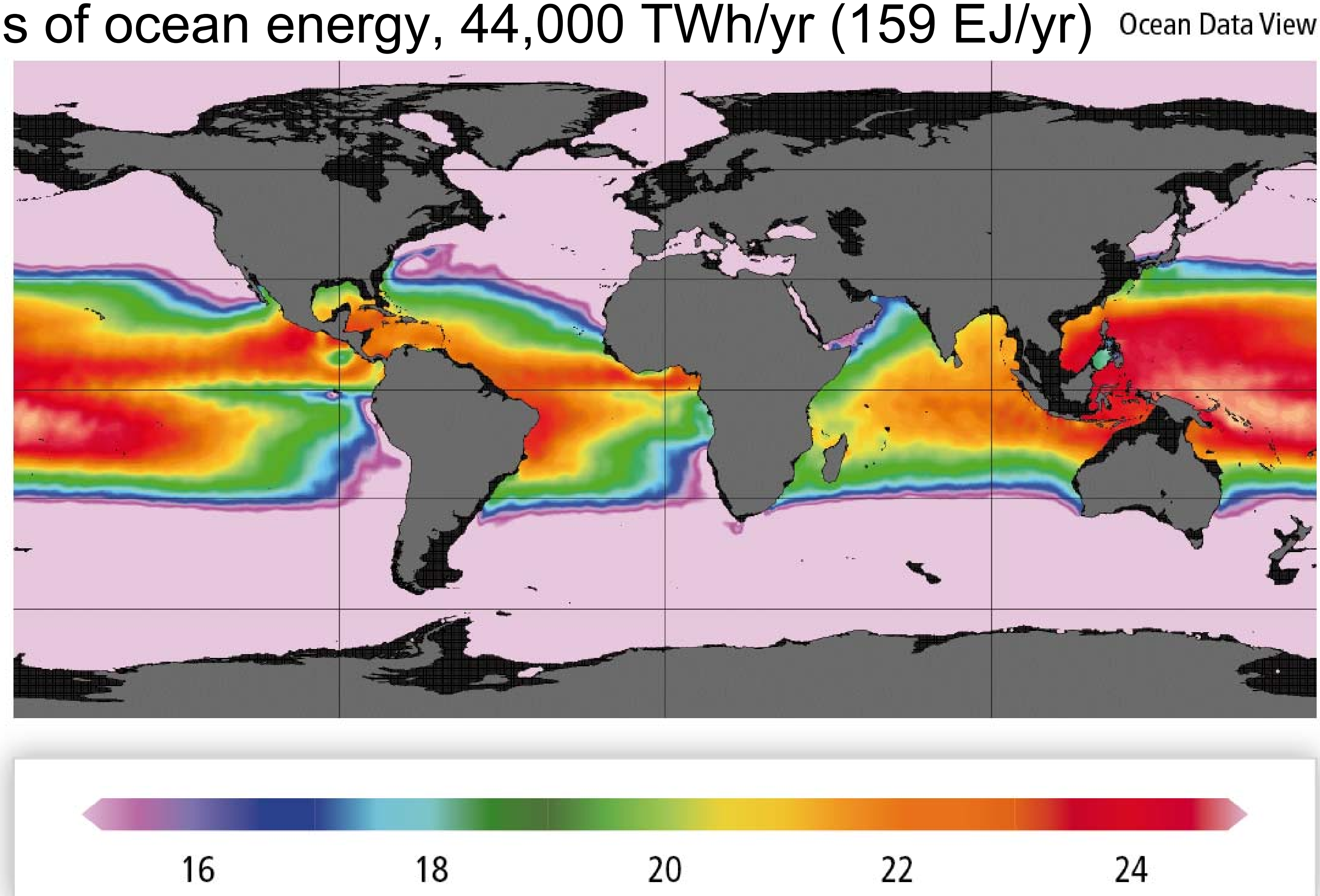
Bulb Turbine

**Tidal currents** derived from water flow that results from the filling and emptying of coastal regions associated with tides. Commercially attractive sites have been identified in Europe, Korea, Canada, Japan, China, New Zealand and South America.

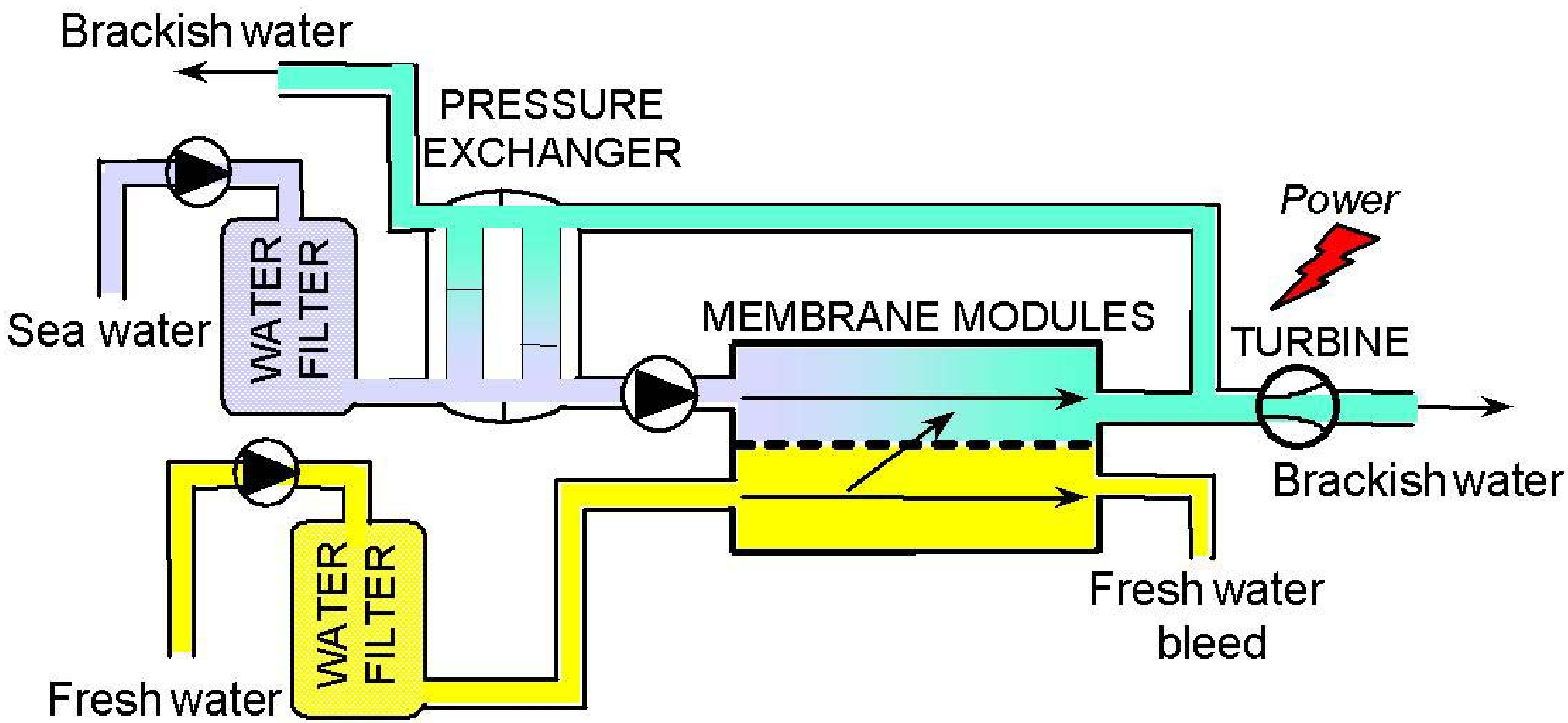
**Ocean currents** derived from wind-driven and thermohaline ocean circulation. The best-characterized system of ocean currents is the Gulf Stream in North America, where the Florida Current has a technical potential for 25 GW of electricity capacity.



**Ocean thermal energy** derived from temperature differences arising from solar energy stored as heat in upper ocean layers and colder seawater, generally below 1,000 m. The overall resource potential is much larger than for other forms of ocean energy, 44,000 TWh/yr (159 EJ/yr)



**Salinity gradients (osmotic power)** derived from salinity differences between fresh and ocean water at river mouths. The theoretical potential of salinity gradients is estimated at 1,650 TWh/yr (6 EJ/yr).



# Market and Industry Development

Presently, the only full-size and operational ocean energy technology available is the tidal barrage:

- 240 MW, La Rance, France, 1966
- 254 MW, Sihwa Barrage, Republic of Korea, 2011

Technologies to develop other ocean energy sources including OTEC, salinity gradients and ocean currents are still at the conceptual, R&D or prototype stages.

Currently, more than 100 different ocean energy technologies are under development in over 30 countries.

# Cost

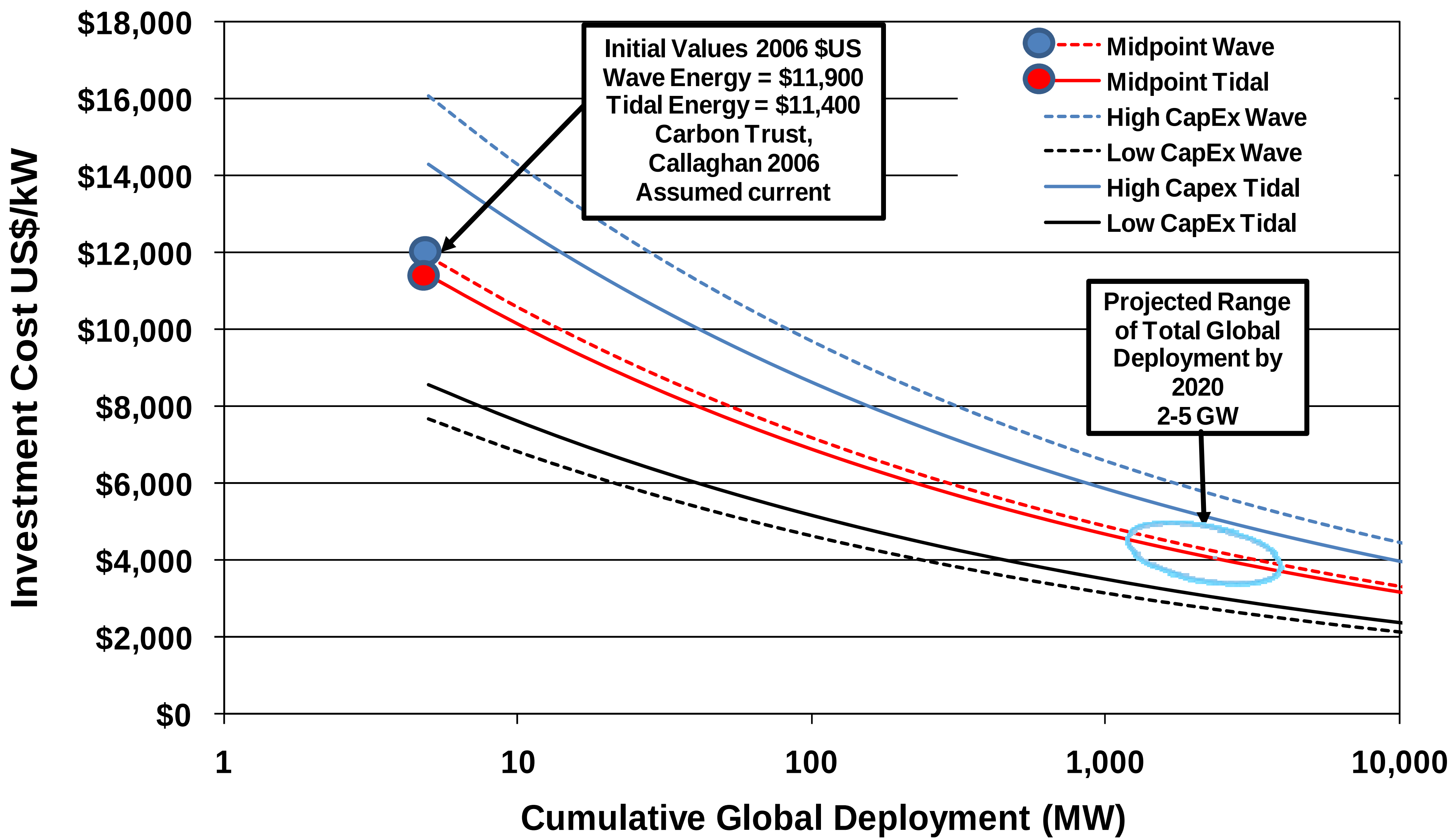
Commercial markets are not yet driving marine energy technology development.

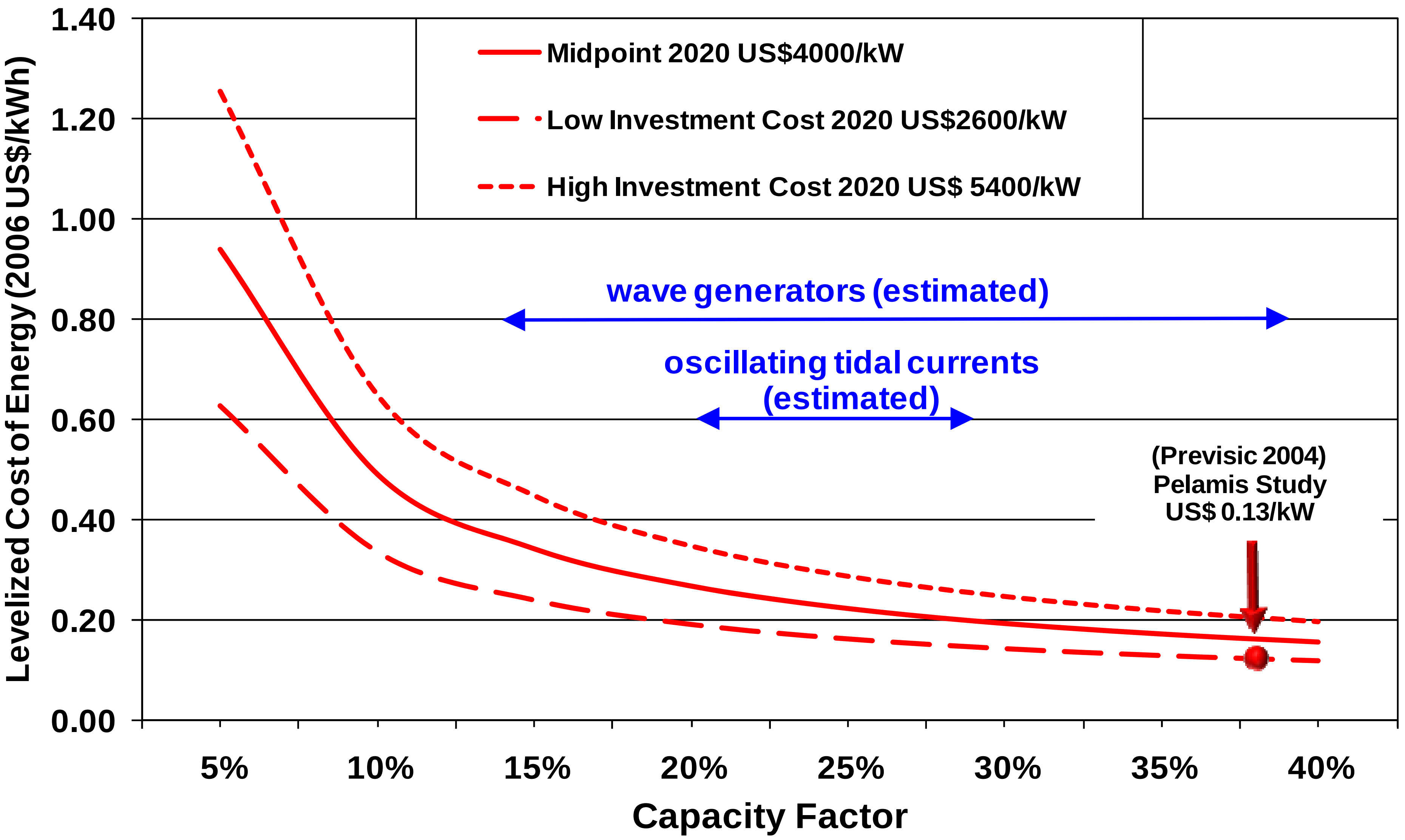
Government-supported R&D and national policy incentives are the key motivation for most technology development and deployment.

The cost of most ocean energy technologies is therefore difficult to assess, because very little fabrication and deployment experience is available for validation of cost assumptions.

# Summary of cost and performance parameters for all ocean energy technologies

| Ocean Energy Technology | Investment costs ($USD_{2005}$/kW) | Annual O&M Costs ($USD_{2005}$/kW) | Capacity Factor (CF) (%) | Design Life (years) |
|---|---|---|---|---|
| Wave | 6,200–16,100 | 180 | 25–40 | 20 |
| Tidal Range | 4,500–5,000 | 100 | 22.5–28.5 | 40 |
| Tidal Current | 5,400–14,300 | 140 | 26–40 | 20 |
| Ocean Current | NA | NA | NA | 20 |
| Ocean Thermal | 4,200–12,300 | NA | NA | 20 |
| Salinity Gradient | NA | NA | NA | 20 |


Initial Values 2006 $US
Wave Energy = $11,900
Tidal Energy = $11,400
Carbon Trust,
Callaghan 2006
Assumed current
Midpoint Wave
Midpoint Tidal
High CapEx Wave
Low CapEx Wave
High Capex Tidal
Low CapEx Tidal
Projected Range
of Total Global
Deployment by
2020
2-5 GW
$18,000
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
Investment Cost US$/kW
1
10
100
1,000
10,000
Cumulative Global Deployment (MW)



1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Levelized Cost of Energy (2006 US$/kWh)
Midpoint 2020 US$4000/kW
Low Investment Cost 2020 US$2600/kW
High Investment Cost 2020 US$ 5400/kW
wave generators (estimated)
oscillating tidal currents (estimated)
(Previsic 2004) Pelamis Study US$ 0.13/kW
5%
10%
15%
20%
25%
30%
35%
40%
Capacity Factor

# Resource Potential

• Assessments for ocean energy present the highest estimates for long-term (2050).

• Ocean energy supply (7 EJ/yr) presented before are well within the theoretical and technical potential for the resource, suggesting that on a global basis, technical potential is unlikely to be a limiting factor to ocean energy deployment.

• OTEC may have the highest technical potential of the available ocean energy options.

• The impact of climate change on the technical potential for ocean energy is anticipated to be modest.

# Technology and Economics

- All ocean energy technologies, except tidal barrages, are conceptual, undergoing R&D, or are in the pre-commercial prototype and demonstration stage.

- The technical performance of ocean energy technologies is anticipated to improve steadily over time as experience is gained and new technologies are able to access poorer quality resources.

- Technical improvements can reduce capital costs, enhance efficiency, reduce O&M requirements and enhance capacity factors.

- Sinnergy with the oil&gas offshore industry may also contribute to increase deployment of ocean technologies.

# Carbon emissions reductions and low environmental impacts

- Ocean energy technologies do not generate GHGs in operation and have low lifecycle GHG emissions.

- Utility-scale deployments with transmission grid connections can be used to displace carbon-emitting energy supplies, while smaller-scale developments may supply electricity and/or drinking water to remote communities.

- The local social and environmental impacts of ocean energy projects are being evaluated as actual deployments multiply, but can be estimated based on the experience of other maritime and offshore industries. Environmental risks from ocean energy technologies appear to be relatively low.

# Deployment

Scenarios for ocean energy deployment are considered in only three major sources:

- Energy [R]evolution (E[R]) 2010
- IEA World Energy Outlook (WEO) 2009
- Energy Technology Perspectives (ETP) 2010.

- Ocean energy has the potential to help mitigate long-term climate change by offsetting GHG emissions.

- Projected deployments: electricity delivery in the range of 25 TWh/yr (0.9 EJ/yr) to 1,943 TWh/yr (7 EJ/yr) by 2050.

# Conclusions

• All ocean energy technologies, except tidal barrages, are conceptual, undergoing research and development (R&D), or are in the pre-commercial prototype and demonstration stage. Technical advances may progress rapidly given the number of technology demonstrations.

• Theoretical potential for ocean energy easily exceeds present human energy requirements.

• Ocean energy has the potential to deliver long-term carbon emissions reductions and appears to have low environmental impacts.

• Successful deployment will lead to cost reductions.

# Ocean Energy:

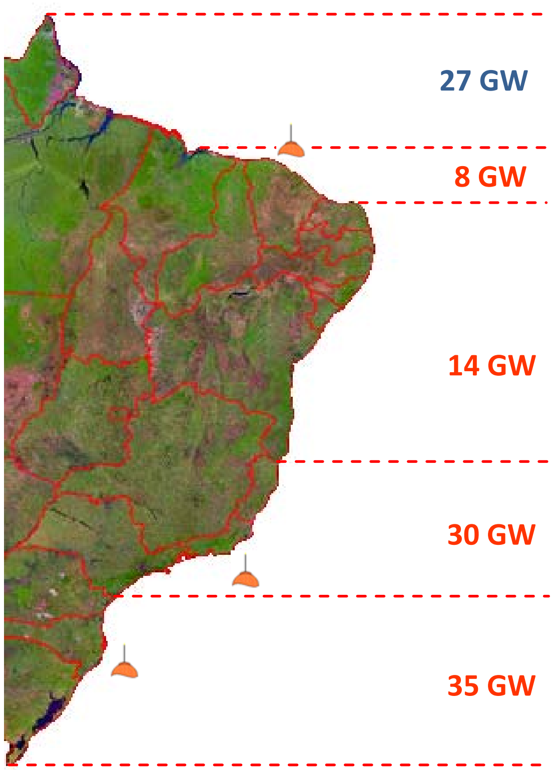
# Activities in Brazil

# Ocean Energy in Brazil

- Availability of resources associated with all ocean sources.
- Need of monitoring technical potentials.
- Increase prototype deployments.
- Establishment of test centers to facilitate prototype evaluation.
- Legislation to induce commercial deployments.
- Advantage due to the experience in deepwater technology for the oil&gas industry.

# Theoretical Potential – Brazilian Coast

- Tides in the North Region: 5 to 11 m
- Waves: $H_s$ = 1,2 to 3 m  T = 5 to 12 s




| Region | Theoretical Potential (GW) |
|---|---|
| North (tides) | 27 |
| Northeast (waves) | 22 |
| Southeast | 30 |
| South | 35 |
| **Brazilian Potential** | **114** |

# Program for Renewable Ocean Energy

- Knowledge to provide solutions for the exploitation of the potential ocean energy resources based on R, D & I.

- **OBJECTIVES**

1. Mapping the energy resources from the Brazilian EEZ.

**Program 1 - Ocean Energy Resources**

2. Research, Development and Innovation for the implementation of devices to generate electricity.

**Program 2 - Convertion Devices**

## Research Projects in Progress

- Tidal range barrage (COPPE & UFMA, CNPq)
- Tidal current (COPPE & UFPA, CNPq)
- Wave energy, prototype 100kW
  (COPPE & Tractebel Energia, ANEEL)
- Control Techniques applied to wave energy converters (DSc)

## Research Projects Concluded

- Tidal current turbine
  (COPPE & ENDESA, ANEEL)
- Experiments on onshore wave converter
  (COPPE & ELETROBRÁS - COPPE & ELETROSUL, ANEEL)
- Experimental evaluation of offshore wave converter
  (COPPE & PETROBRAS)

**Spin-off Company:** Seahorse Wave Energy

# Laboratorial Tests – Scale 1:10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