OCEN 201
Introduction to Ocean & Coastal Engineering

Renewable Marine Energy (1)

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Why Renewable Energy

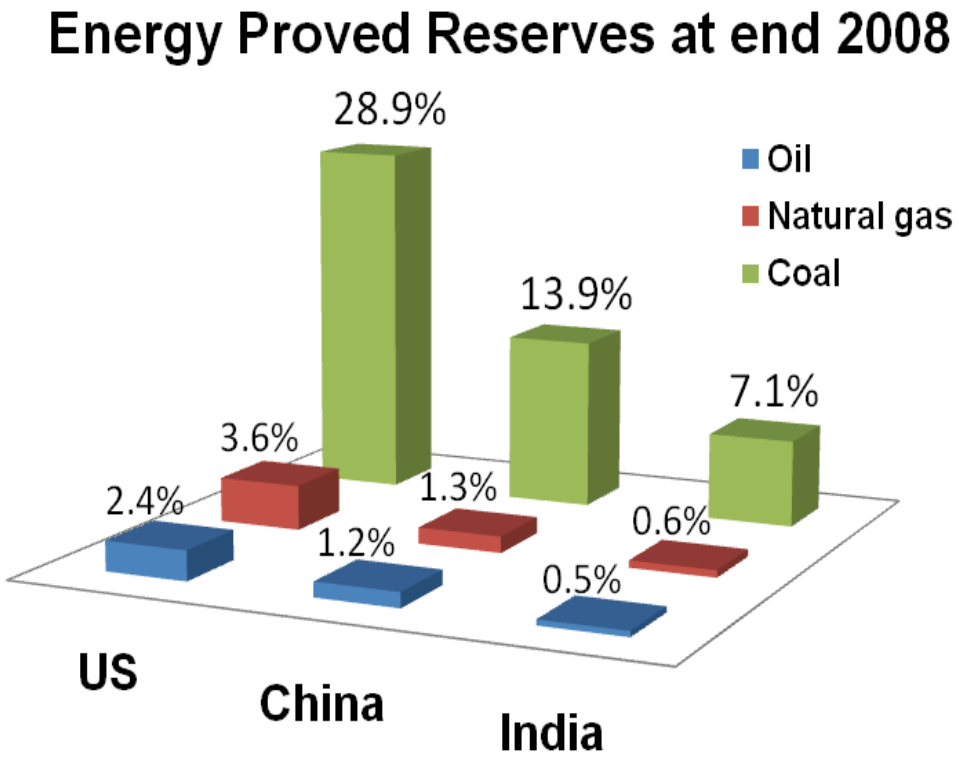
1 Sustainability:

- Limited Sources of Fossil Fuel on the Earth (Oil, Coal and Natural Gas).

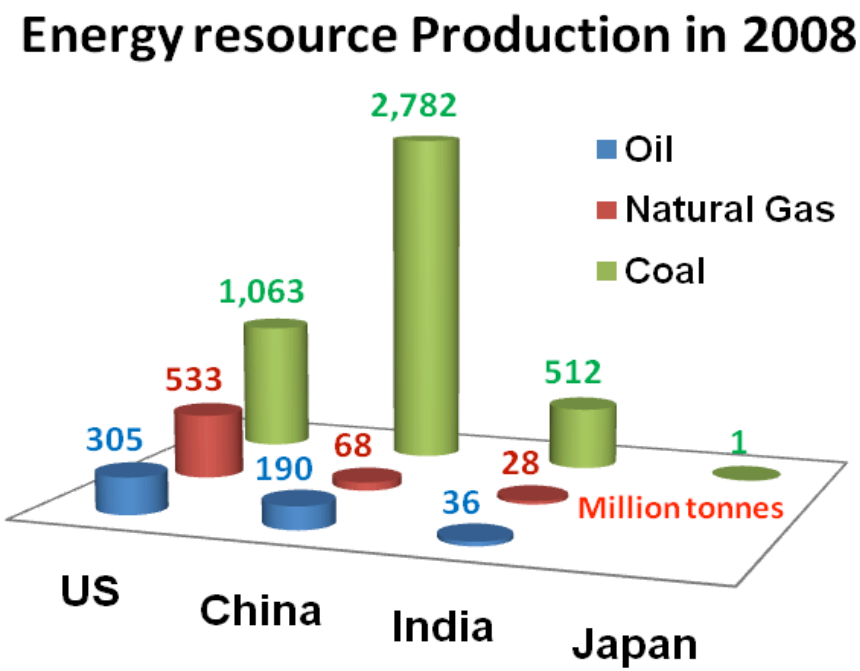
- Increase demanding in Energy All Over the World.

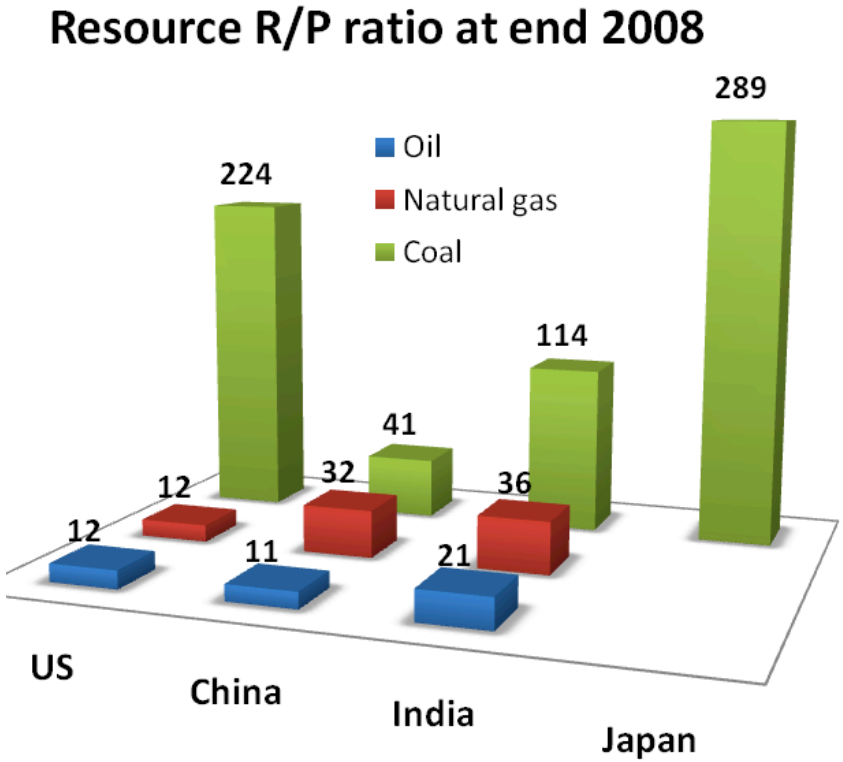
2. Environment Challenges: Pollution & CO2 Emissions

Fossil Energy at end 2008



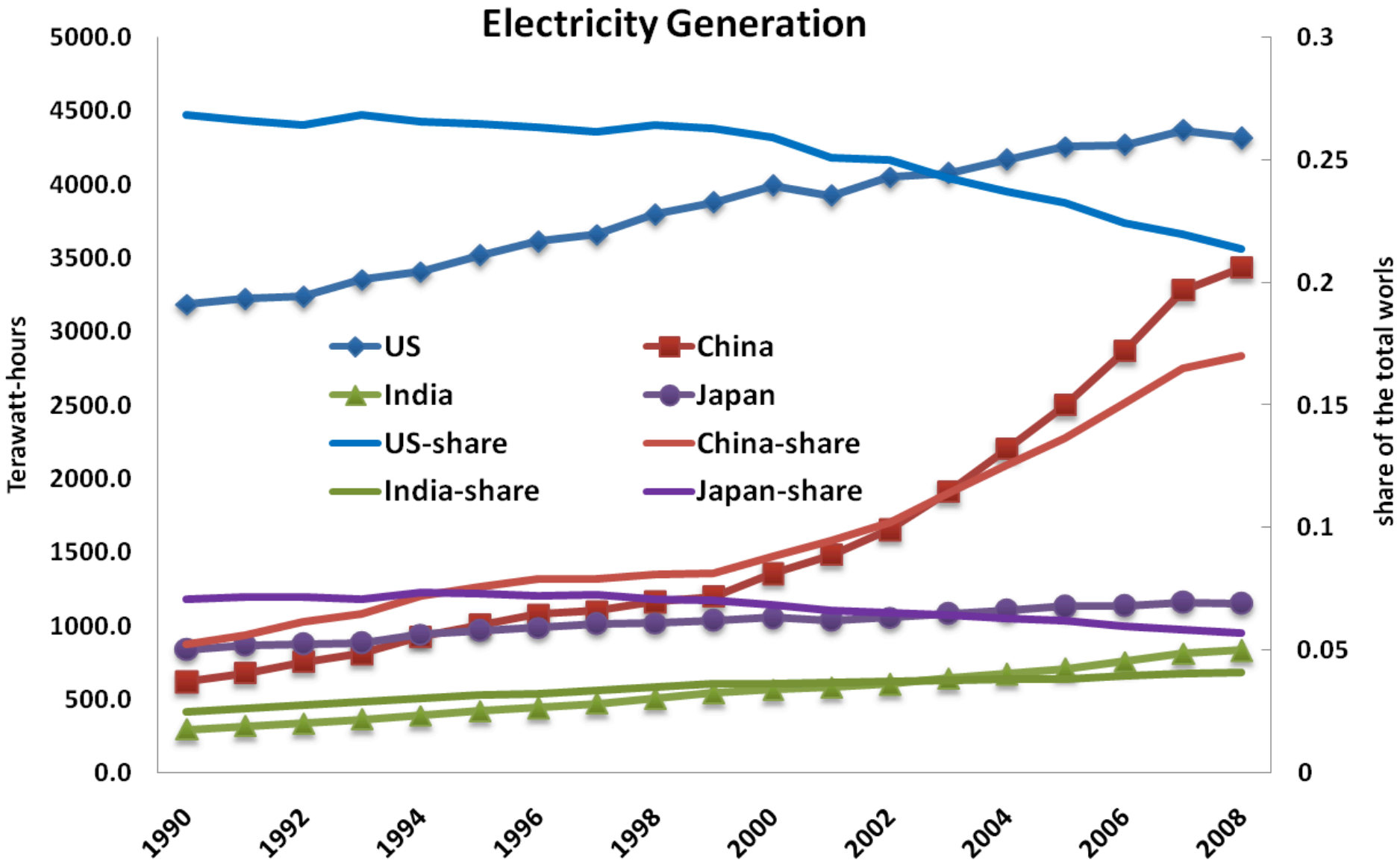
Fossil Energy at end 2008



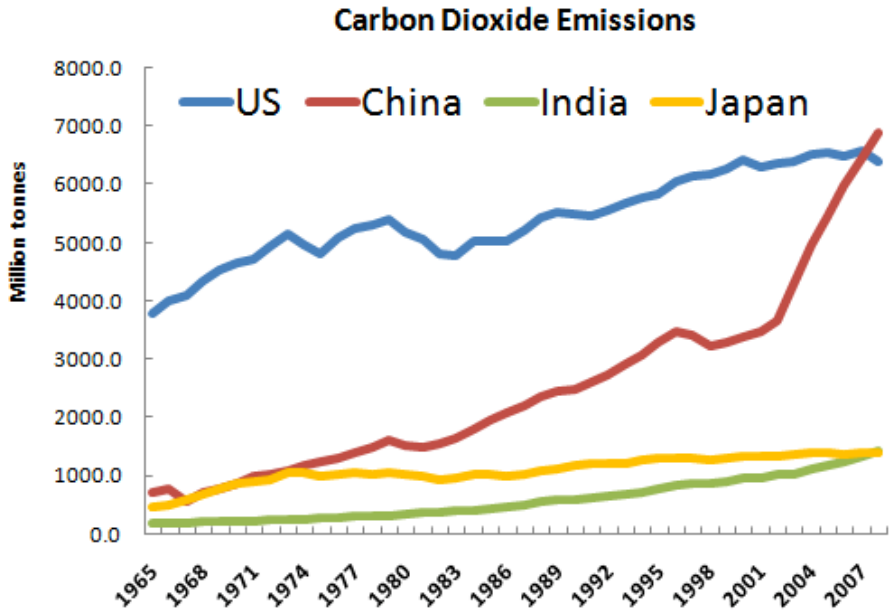


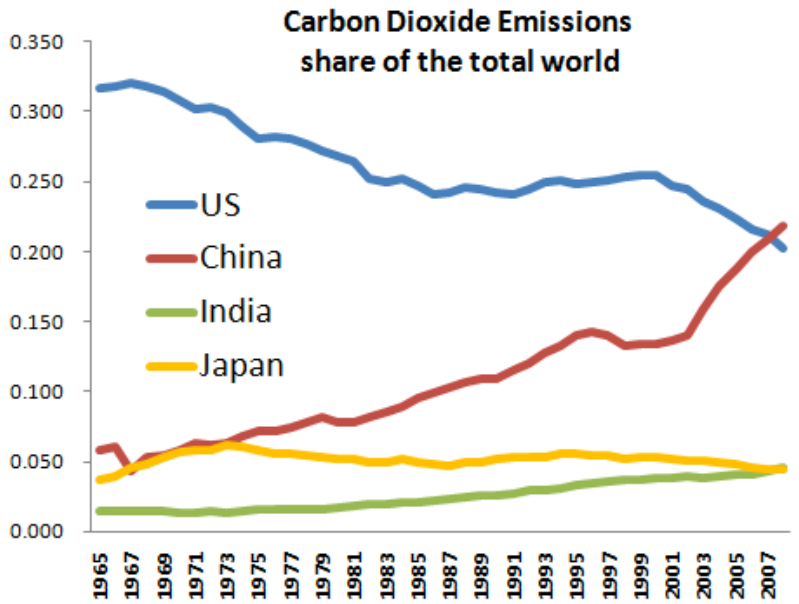
World primary energy demand will grow 45% from 2009 to 2030; 50% of this increase from China and India;
China account for 40% of world coal demand and is expected to increase to 50% by 2030 (IEA World Energy)

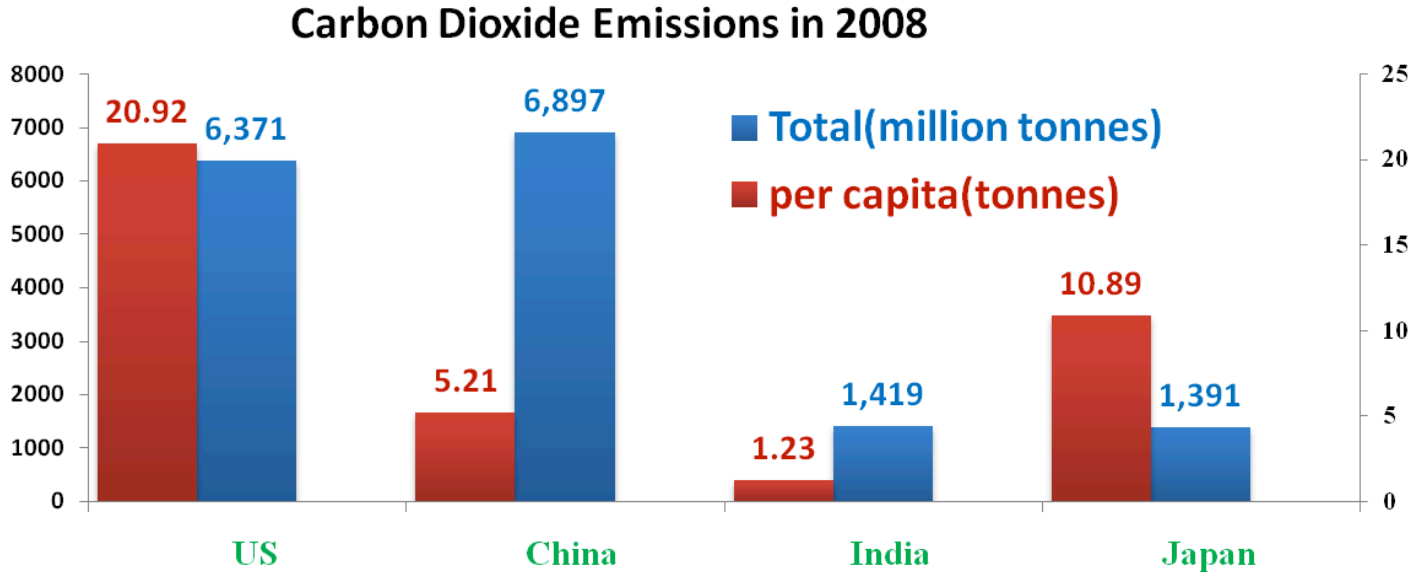
Electricity Production



Carbon Dioxide Emissions



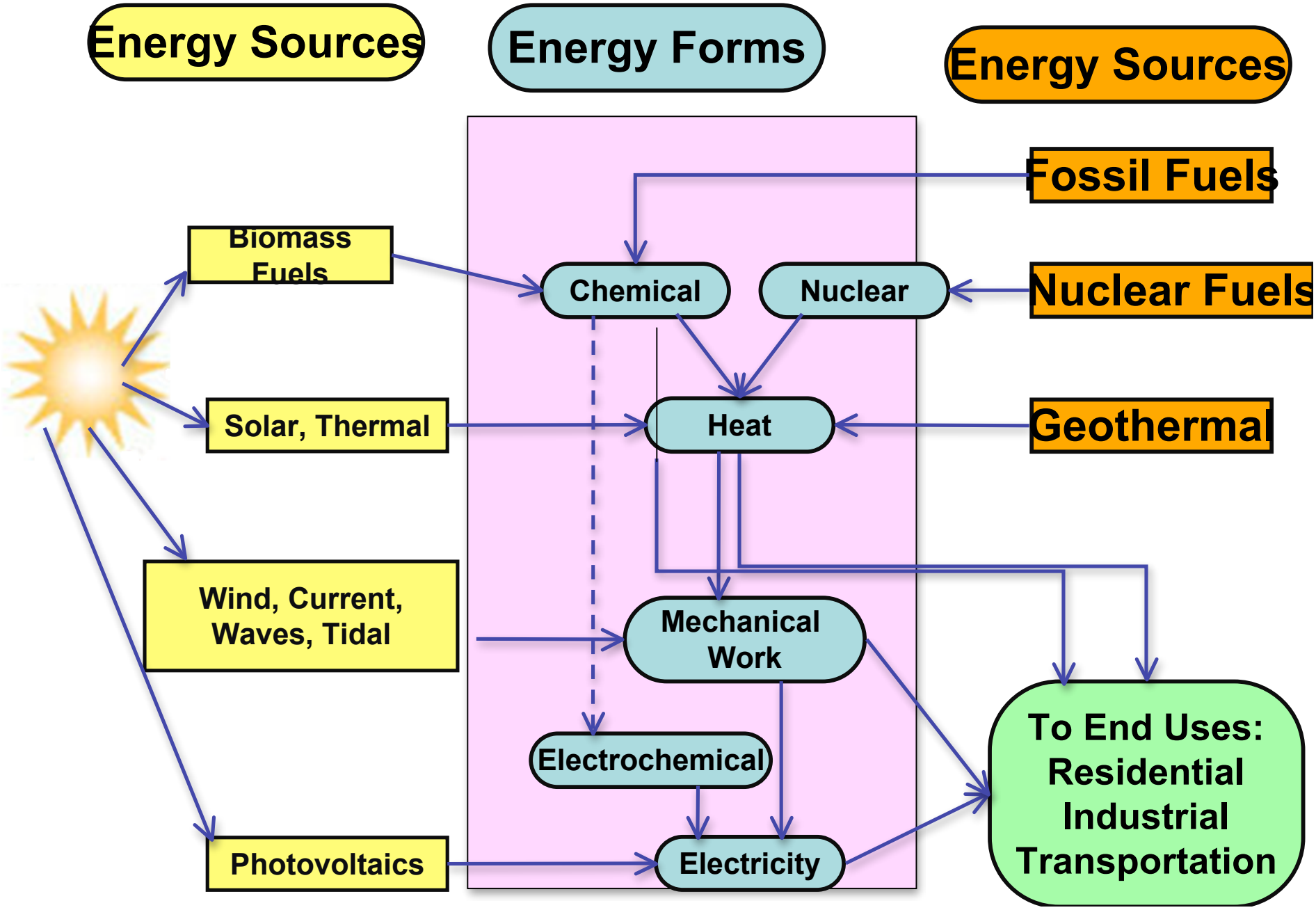




Issues of Sustainability

Challenges: Resources; Energy security; Global climate change; Impact on other dimensions

1) Improvement on energy efficiency and savings
2) Low carbon technology development to address economic, social and environmental issue
3) Development of Renewable Energy


Energy Sources
Energy Forms
Energy Sources
Fossil Fuels
Biomass Fuels
Chemical
Nuclear
Nuclear Fuels
Solar, Thermal
Heat
Geothermal
Wind, Current, Waves, Tidal
Mechanical Work
Electrochemical
To End Uses:
Residential
Industrial
Transportation
Photovoltaics
Electricity

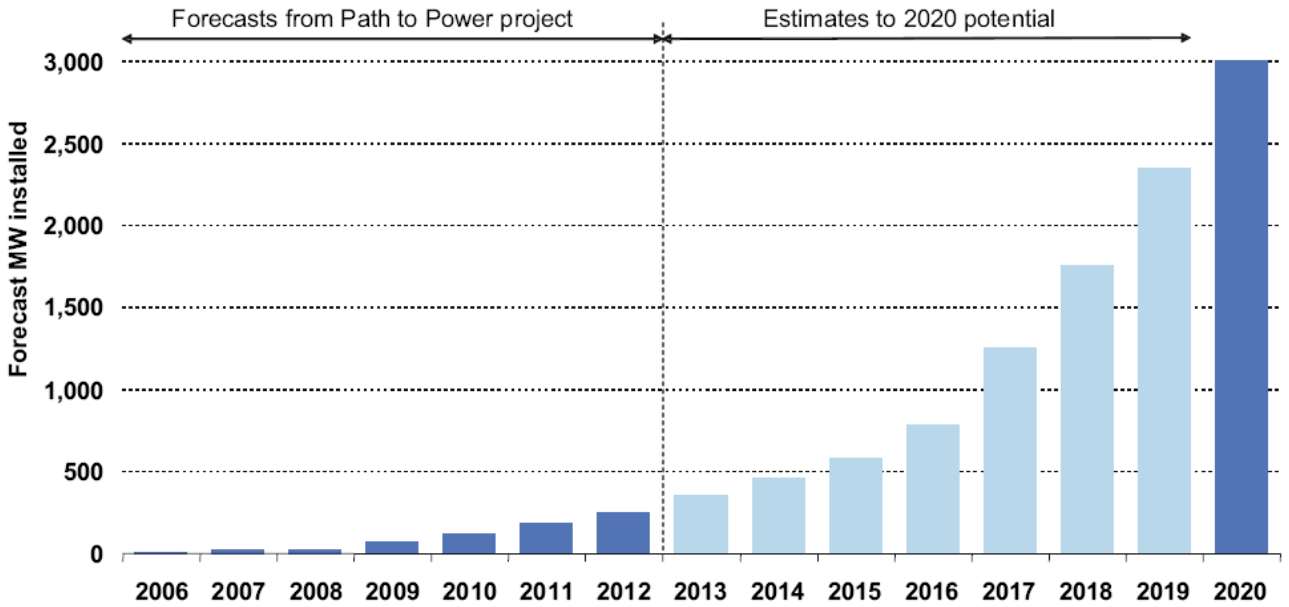
Prospect of Renewable Marine Energy

- Renewable Marine Energy

  - Tidal & Currents
  - Wave
  - Thermal
  - Wind
  - Solar
  - Hydro
  - Others

In the long term marine renewable energy could meet 15 to 20% of current UK electricity demand, with 3% to 5% coming from tidal stream and the remainder from wave energy (Carbon Trust, 2005).

Figure 1: Deployment scenario for wave and tidal energy in the UK to 2020
BWEA (2006) Energy Review submission; Bond Pearce (2005) Path to Power: Stage 1 report; CCC



Global Marine Renewable Energy Resources

OCEAN ENERGY RESOURCE	HOW TO HARNESS THE RESOURCE	THEORETICAL RESOURCE
Tides	Potential energy associated with tides can be harnessed by building barrage or other forms of construction across an estuary.	300+ TWh/year
Waves	Kinetic and potential energy associated with ocean waves can be harnessed using modular technologies.	8,000 to 80,000 TWh/year
Tidal (Marine) Currents	Kinetic energy associated with tidal (marine) currents can be harnessed using modular systems.	800+ TWh/year
Temperature Gradients	Thermal energy due to the temperature gradient between the sea surface and deepwater can be harnessed using different Ocean Thermal Energy Conversion (OTEC) processes.	10,000 TWh/year
Salinity Gradients	At the mouth of rivers where fresh water mixes with salt water, energy associated with the salinity gradient can be harnessed using pressure-retarded reverse osmosis process and associated conversion technologies.	2,000 TWh/year

<IEA-OES Report, 2008>

Marine Renewable Energy Resources

Ocean Tides: Potential energy associated with tides can be harnessed by building barrage or other forms of construction across an estuary.

Ocean Waves: Kinetic & potential energy associated with ocean waves can be harnessed using modular types of technologies.

Marine Current: Kinetic energy associated with tidal/marine currents can be harnessed using modular systems.

Temperature Gradient: Thermal energy due to temperature gradient between sea surface & deep-water can be harnessed using different ocean thermal energy conversion (OTEC) processes.

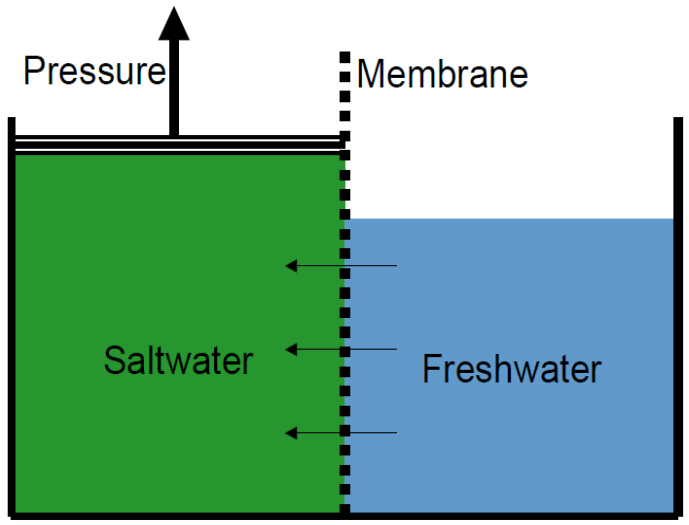
Salinity Gradient: At the mouth of rivers where fresh water mixes with saltwater, energy associated with the salinity gradient can be harnessed using a pressure retarded reverse osmosis process and associated conversion technologies.

Salinity Gradient Energy

Two approaches

1.“**Pressure Retarded Osmosis (PRO)**”:

relies on water molecules moving through a membrane, which is semi-permeable. When salt water is contained on one side of the membrane & fresh water is on its other side, fresh water is osmotically drawn into the salty side. This drives up the pressure in the "salty” chamber,
& the sea water can then be sent through a turbine that generates power.
(*Dr Rolf JarleAaberg*
Statkraft EnergiAS, Norway
2004)



Pressure retarded osmosis (PRO)

Salinity Gradient Energy

2. "**Reverse ElectroDialysis (RED)**":

In RED, a concentrated salt solution & a fresh water are brought into contact through an alternating series of anion exchange membranes (AEM) and cation exchange membranes (CEM)

The difference in chemical potential between both solutions is the driving force for this process. The chemical potential difference generates a voltage over each membrane and the overall potential of the system is the sum of the potential differences over the sum of membranes.

Reference http://mtg.tnw.utwente.nl/teaching/assign/blue/

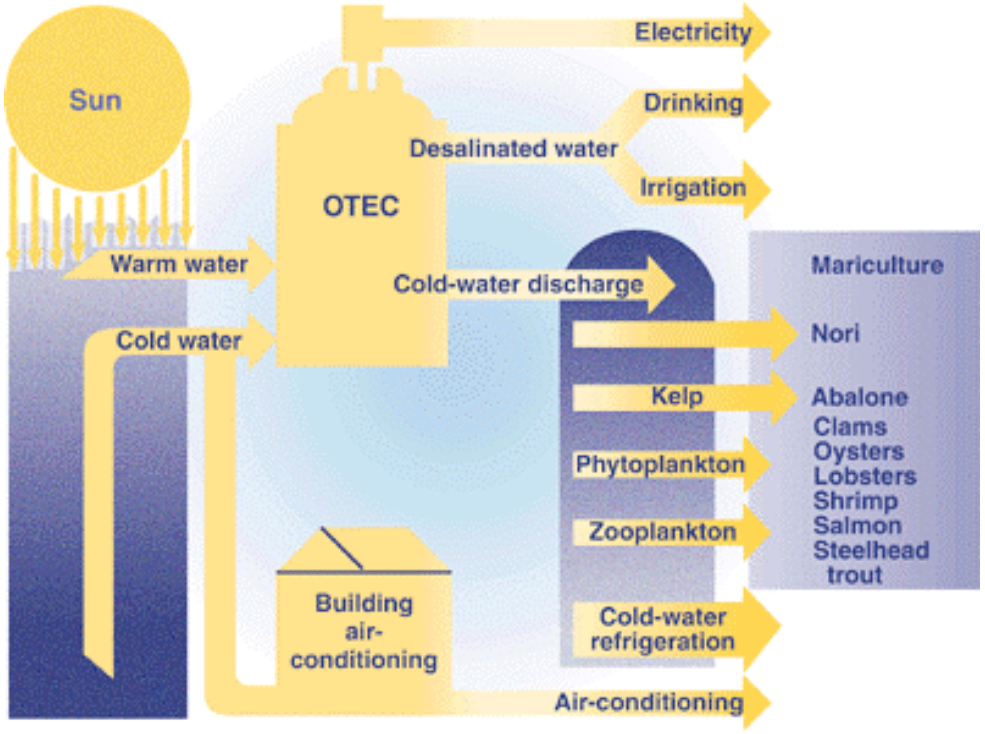
Ocean Thermal Energy Conversion

Applications

Ocean thermal energy conversion (OTEC) systems have many applications or uses. OTEC can be used to generate electricity, desalinate water, support deep-water mariculture, and provide refrigeration and air-conditioning as well as aid in crop growth and mineral extraction.

These complementary products make OTEC systems attractive to industry and island Communities.

http://www.nrel.gov/otec/applications.html

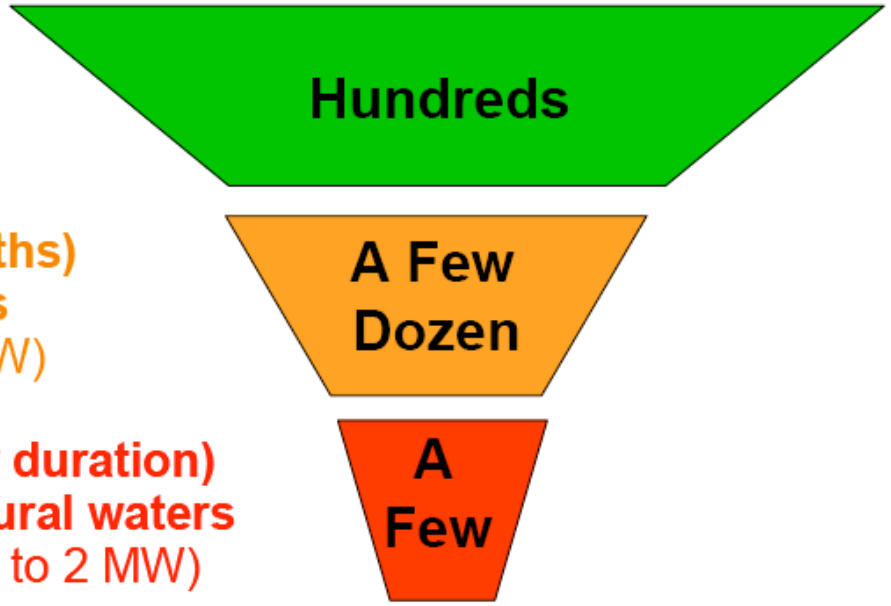


Current Status of Ocean Energy Technologies

Phases in Ocean Energy Technologies

Thousand of concepts and patents on ocean energy conversion technology

Rigorous laboratory tow- or wave-tank physical model tests
(1/50- to 1/5-scale)

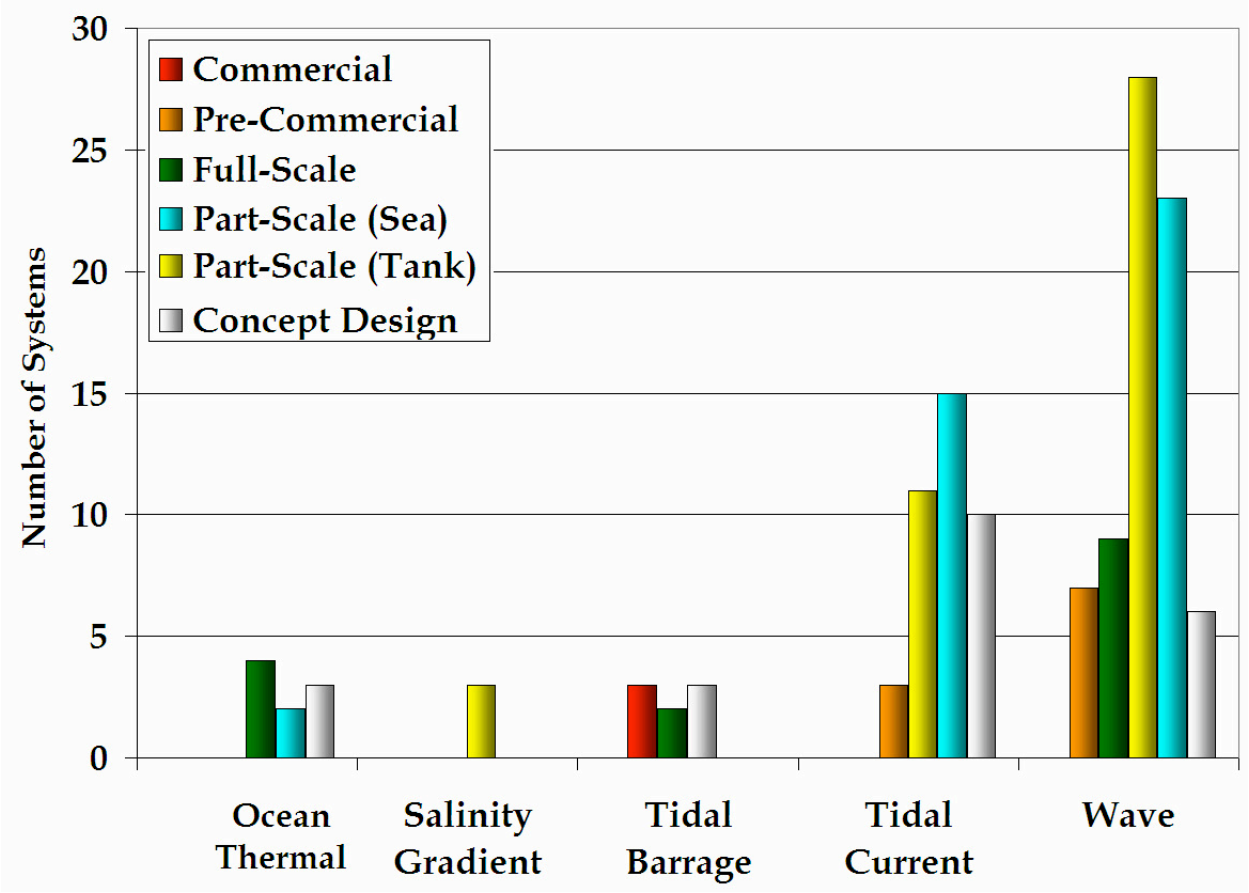


Short-term (days to months) tests in natural waters
(typically 10 kW to 100 kW)

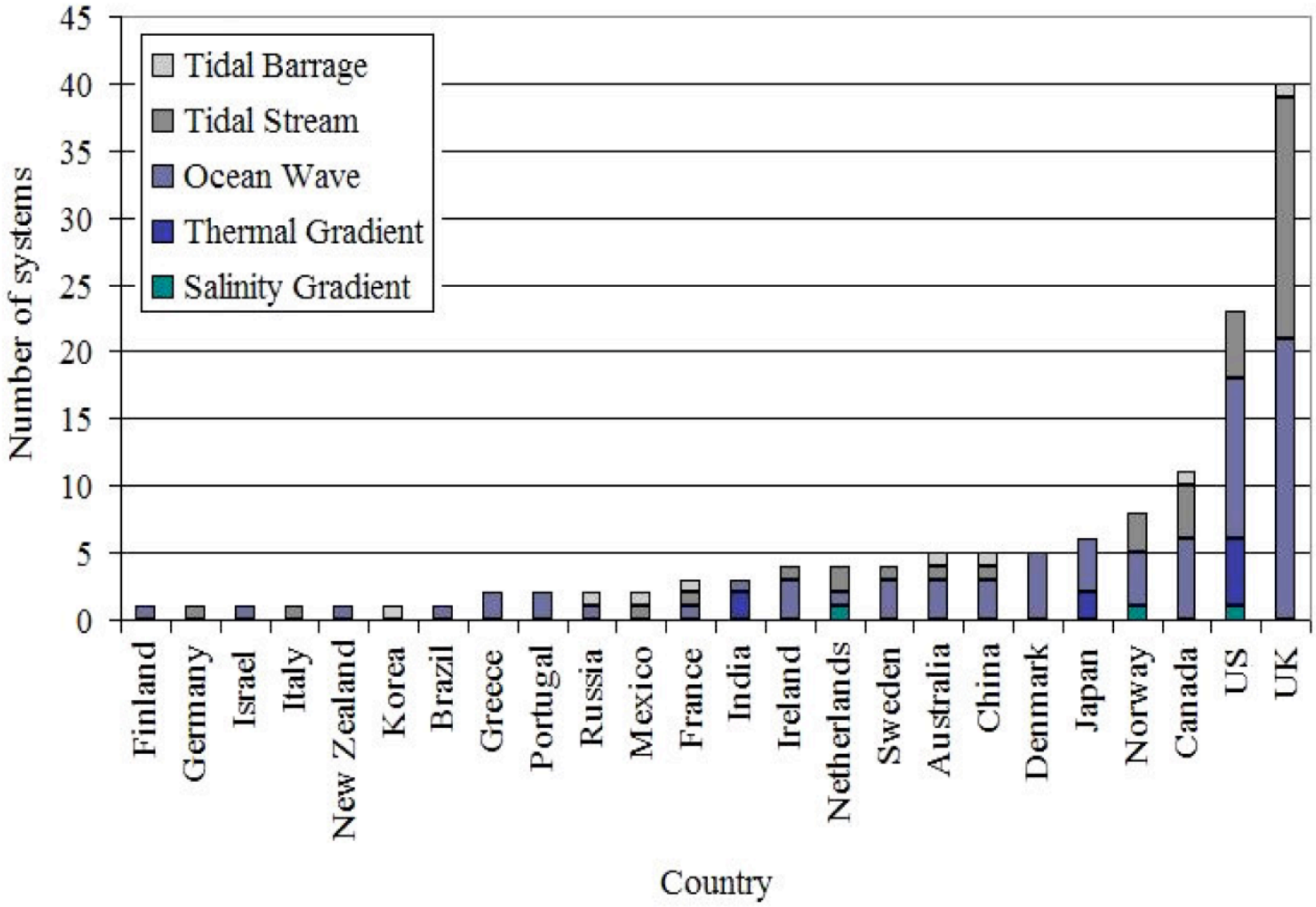
Long-term (>1 yr duration) prototypes in natural waters
(typically 100 kW to 2 MW)

It typically takes 5 to 10 years for a technology to progress from concept-only to deployment of a long-term prototype

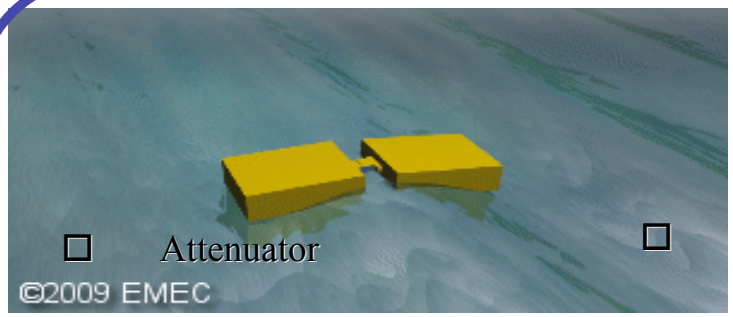
Technology Development Status

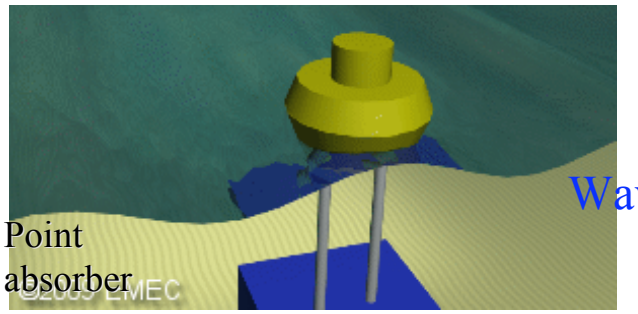


Country Participation in OE Development

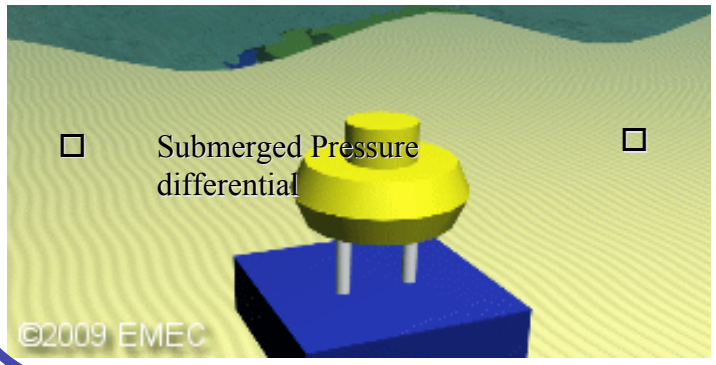


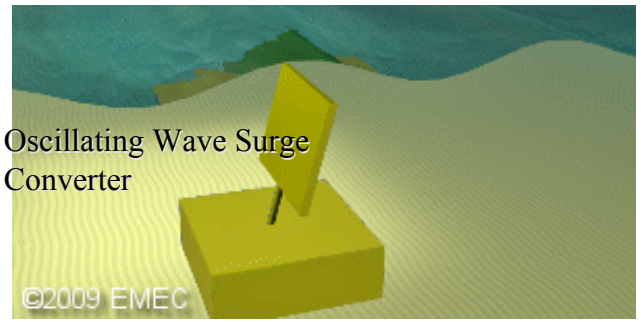
Classification of Wave Energy Conversion Technologies





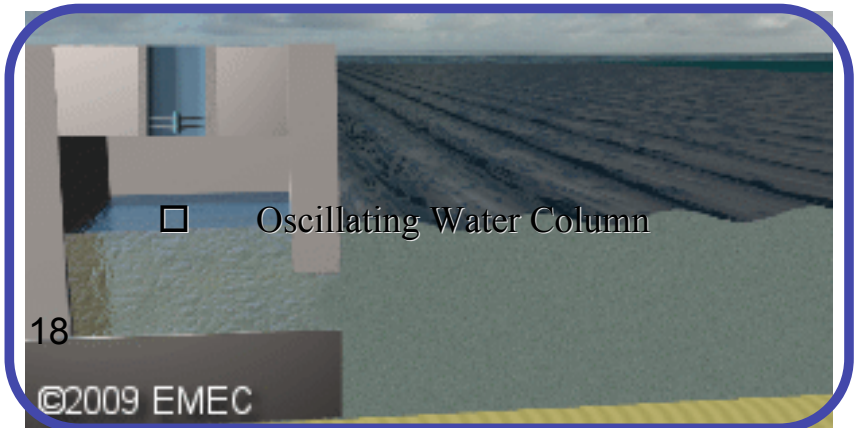
Wave Activated





OWC

Wave Overtopping



Classification of Wave Energy Conversion Technologies

Examples

1. Attenuator ------ Pelamis **Pelamis Offshore Wave Energy in Portugal**
http://www.alternative-energy-news.info/pelamis-offshore-wave-energy-portugal/

2.Point Absorber ------ Power Buoy (OPT)
http://www.oceanpowertechnologies.com/tech.htm

3.Oscillating Wave Surge Converter
http://www.emec.org.uk/wave_energy_devices.asp

4.Oscillating Wave Column (OWC) ----- (compress the air, near the shore line)
http://www.daedalus.gr/OWCsimulation2.html

5.Overtopping Devise ------ Wave Dragon
http://www.wavedragon.net/index.php?option=com_content&task=view&id=6&Itemid=5

Wave Devices in Deployment

Power Buoy, OPT

AWS Ocean Energy

Oyster, Aquamarine Power

Pelamis Wave Power

LIMPET, Wavegen

Wave Dragon

Classification of Wave Energy Conversion Technologies

Examples

6. Aquamarine Power------ Oyster

http://www.aquamarinepower.com/technologies/ http://trendsupdates.com/the-oyster-aquamarine-powers-answer-for-clean-energy-demands/

7. AWS Ocean Energy

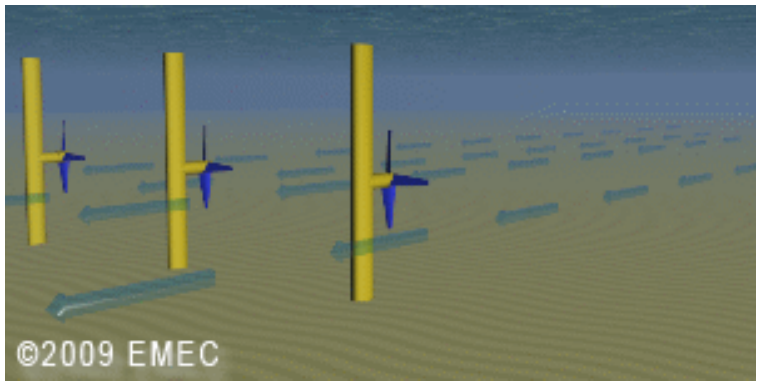
http://www.awsocean.com/PageProducer.aspx

8. Wavegen ----- LIMPET

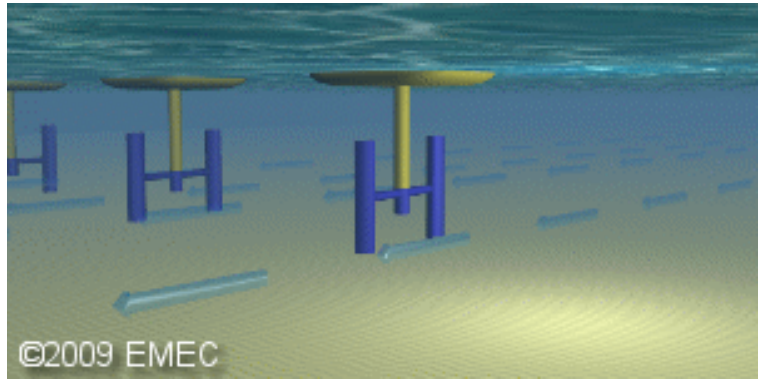
http://www.wavegen.co.uk/what_we_offer_limpet.htm

Classification of Tide Energy Conversion Technologies

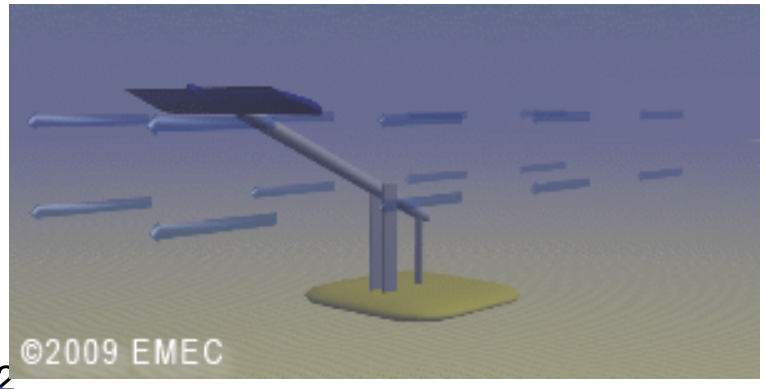
- Horizontal Axis Turbine



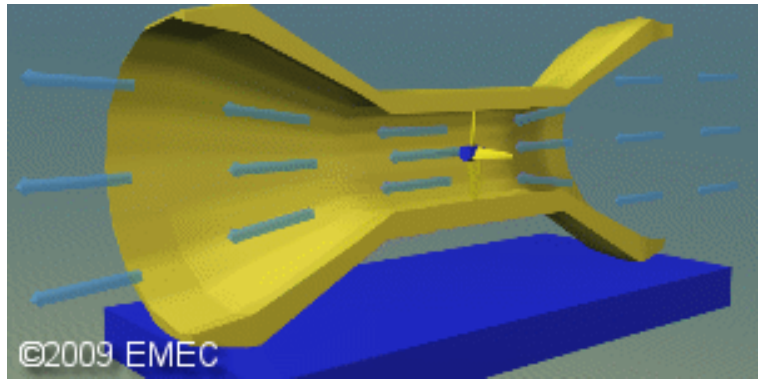
- Vertical Axis Turbine



- Oscillating Hydrofoil



- Venturi Effect



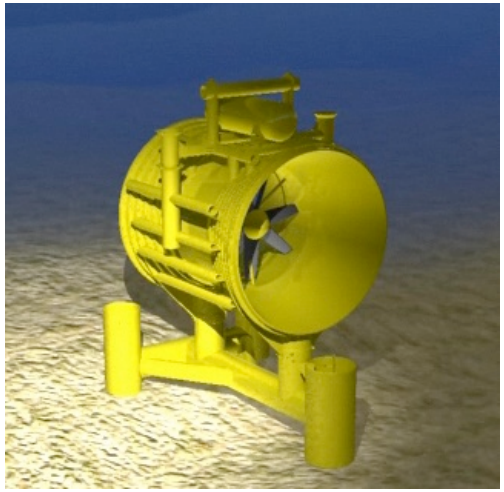
- Others

Tidal Devices in Deployment

SeaGen, MCT Ltd

Uldolmok Helical Turbine, KORDI

Stingray, EB



Lunar Energy

Open Hydro

Classification of Tide Energy Conversion Technologies

1. The European Marine Energy Center Ltd. http://www.emec.org.uk/index.asp

2. Seagen MCT Ltd http://www.alternative-energy-news.info/seagen-tidal-power-installation/

3. Uldolmok Helical Turbine, KORDI (see Korea_tide_energy)

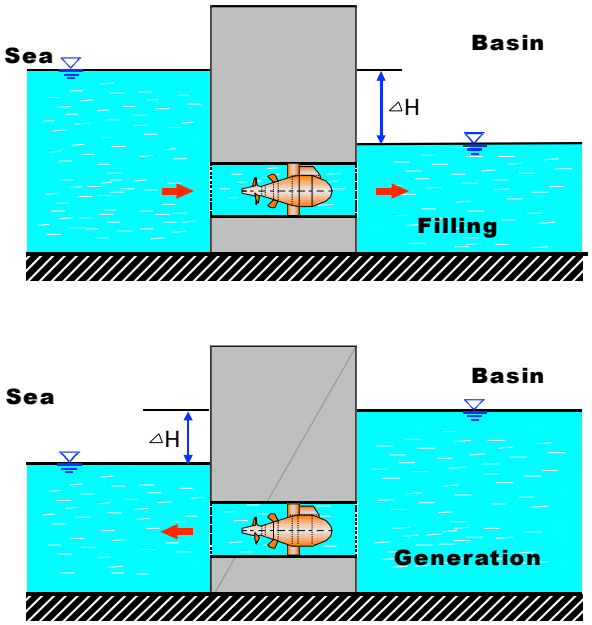
4. Stingray, EB http://www.bwea.com/marine/devices.html

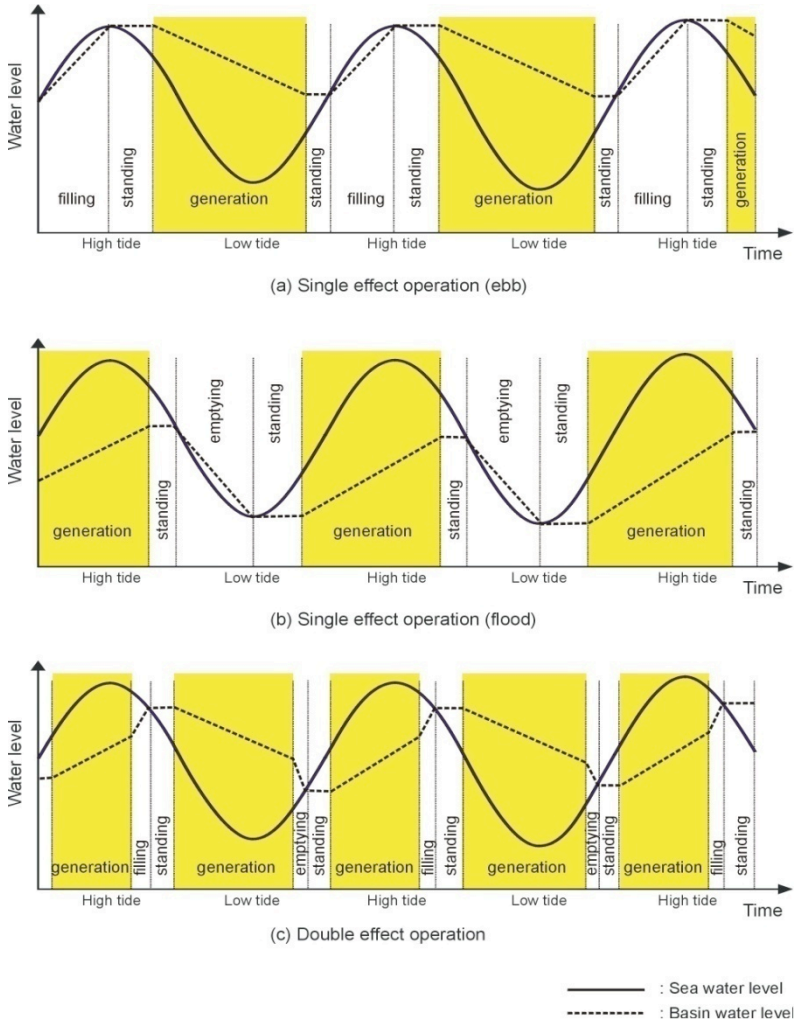
5. Lunar Energy Ltd. http://www.lunarenergy.co.uk/

6. Openhydro Group http://www.snopud.com/PowerSupply/tidal/tidalbg/tidalopenhydro.ashx?p=1511

Tidal Range(Barrage) Energy Technologies

- ✓ Using the water level difference btw inside and outside of the basin
- ✓ Generation methods :
  - 0ne way (ebb, flood)
  - Two way





Sihwa Tidal Barrage Power Plant

➢ Site Conditions

- ✓ Mean tidal range : 5.6m
- ✓ Basin area : 43km2(MSL)
- ✓ Capacity : 254MW
- ✓ Estimated annual output : 553GWh
- ✓ One-way flood generation

➢ Construction History

- ✓ Sea dyke of 12.7km completed in 1994
- ✓ Proposed as a counter measure to lake water pollution in 1997
- ✓ Feasibility study in 2002
- ✓ Plant construction 2004 to 2010

Offshore Fixed Wind Farms (in Coastal Water)

- Typical wind farm made up of several wind turbines.
  - Number can range from as little as one or two to as many as 80.
- Each turbine depending on size and design can produce several Mega watts at peak power output.
- Some wind farms that are in constructions right now are set to produce 500MW of power using as many as 140 turbines.
  - That's enough energy to power 125K average households.

Offshore Fixed Wind Farm

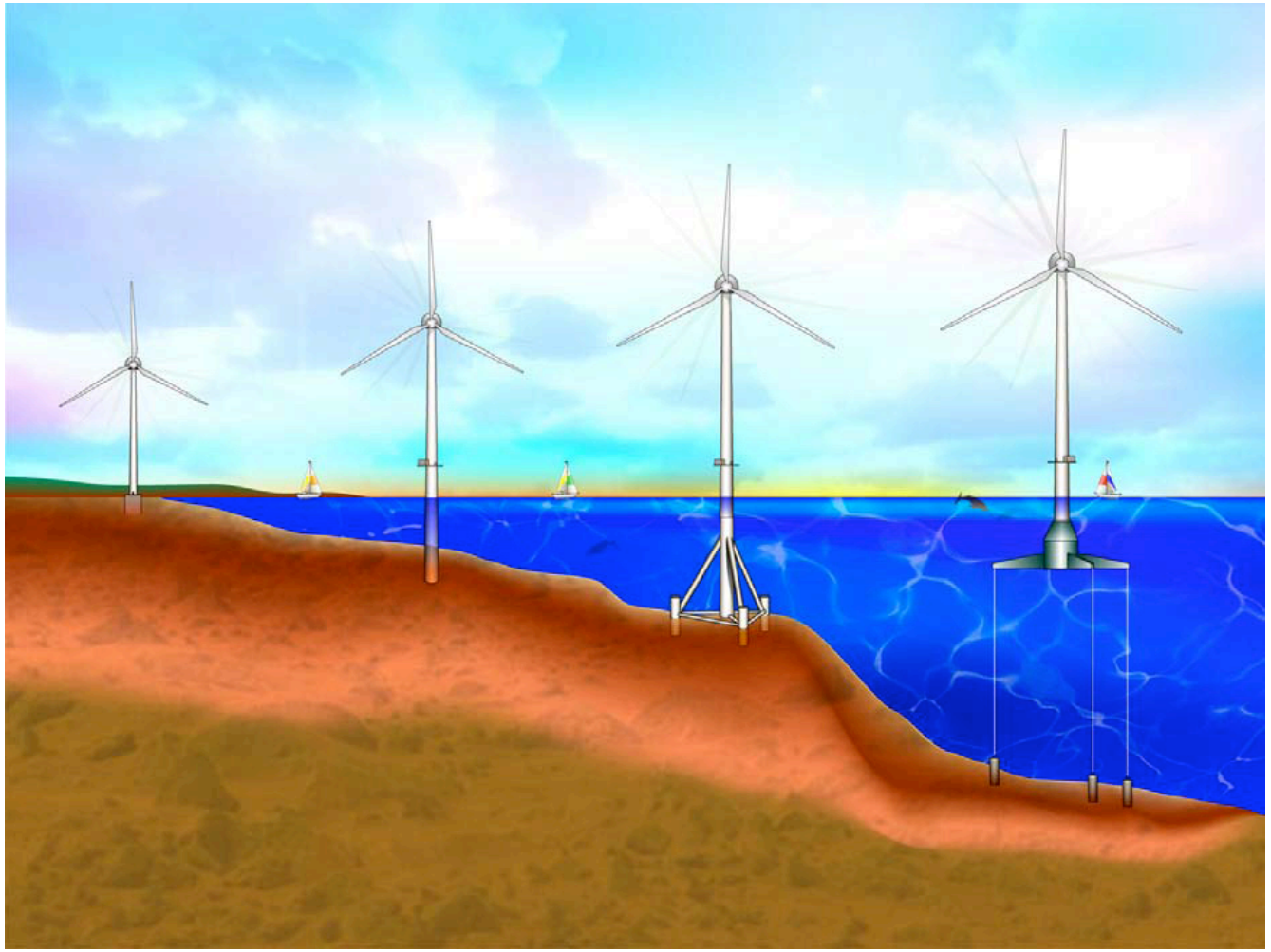
Mostly located in shallow in shallow water areas relatively close to shore. This is because water depth and wave height are two factors that greatly increase the cost of these wind turbines.

Offshore Fixed Wind Farm

OWEC Jacket Foundation at Beatrice Offshore Wind Project

Titan (tripod) Foundation:

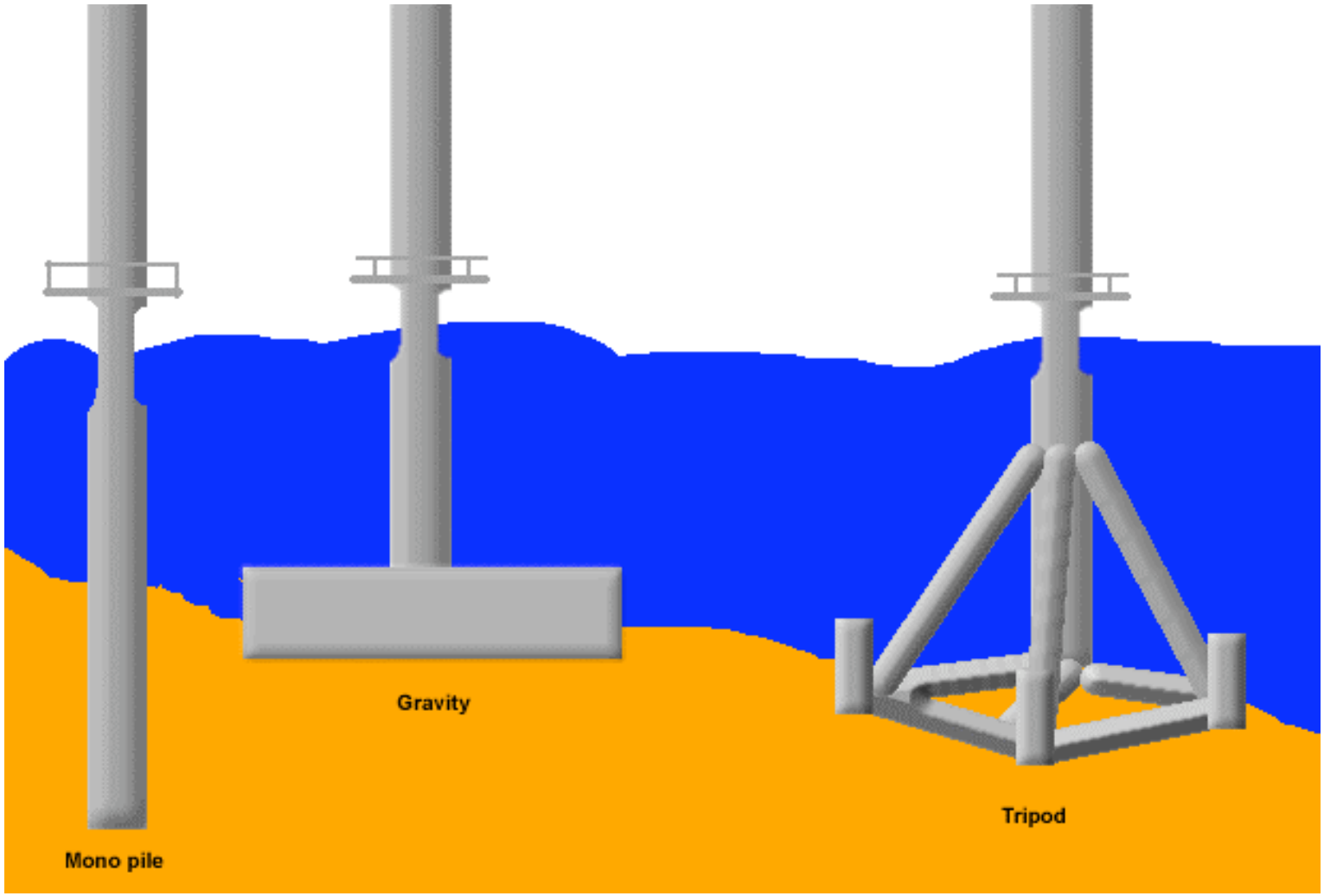
Foundations of Fixed Wind Farm



Loads Analysis of a Floating Offshore Wind Turbine Using Fully Coupled Simulation*

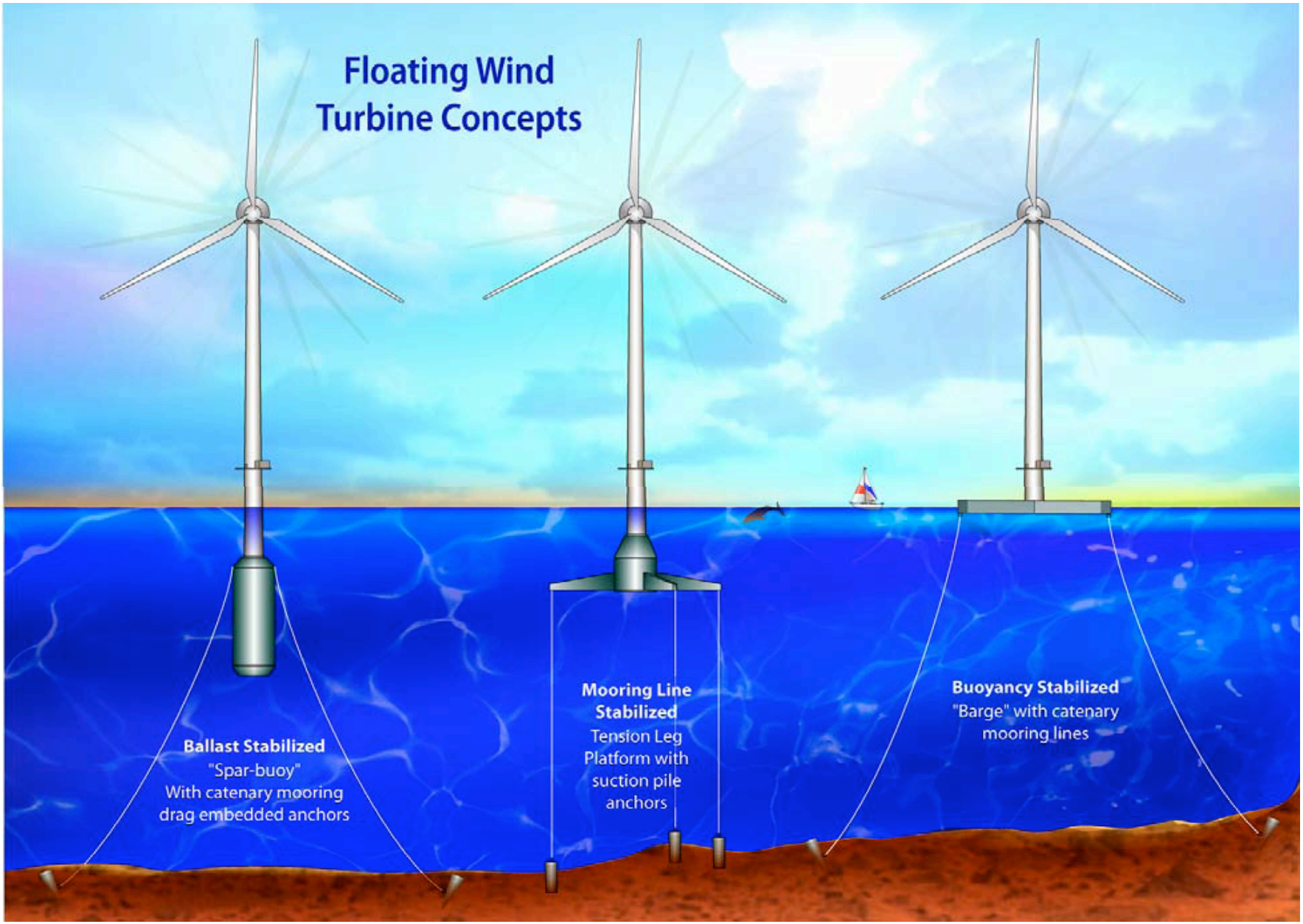
Jason M. Jonkman and Marshall L. Buhl Jr.

Foundations of Fixed Wind Farm

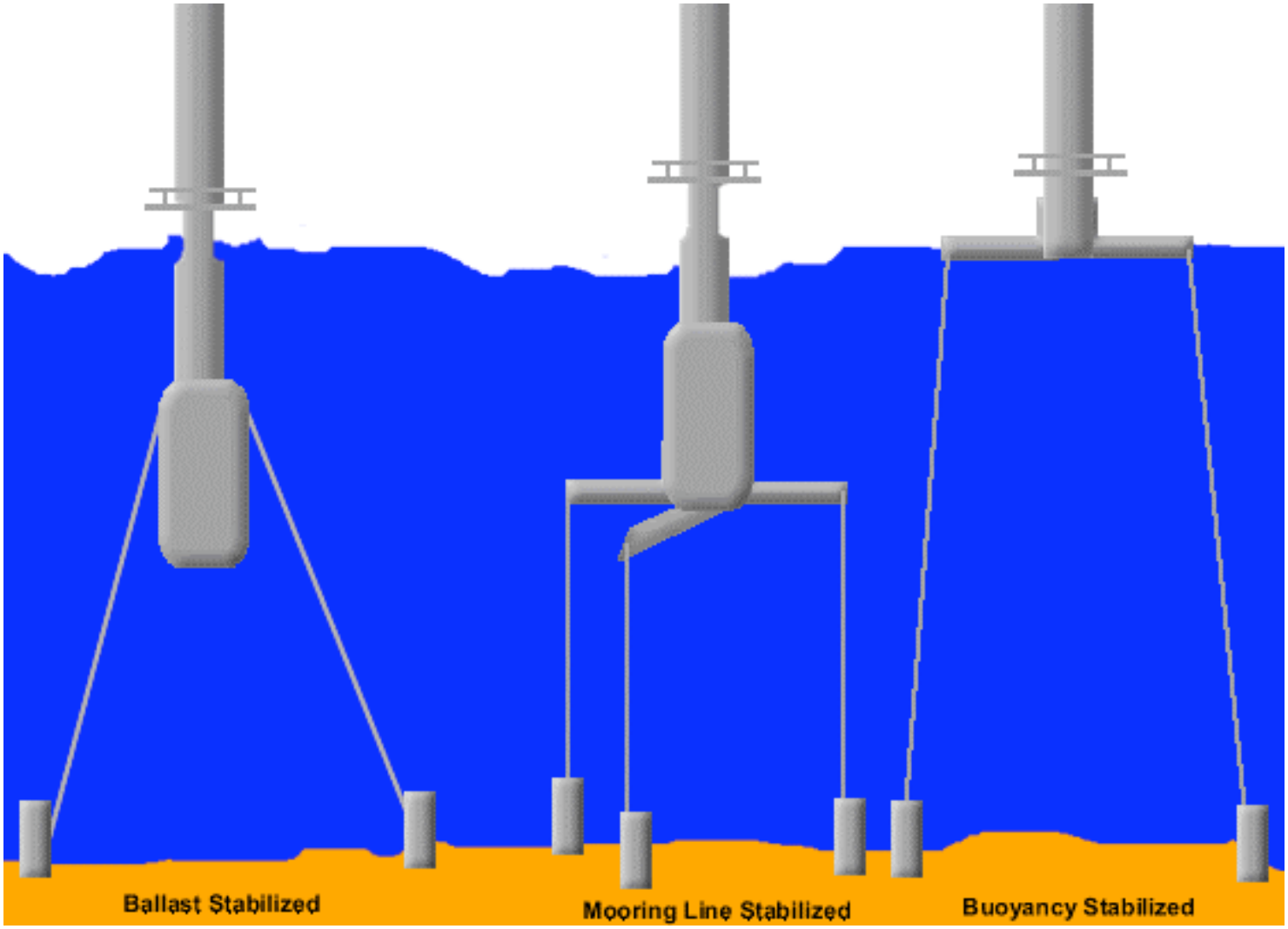


http://www.technologyreview.com/energy/20500/?a=f
http://news.bbc.co.uk/2/hi/8235456.stm

Offshore Floating Wind Farms (far away from shore)



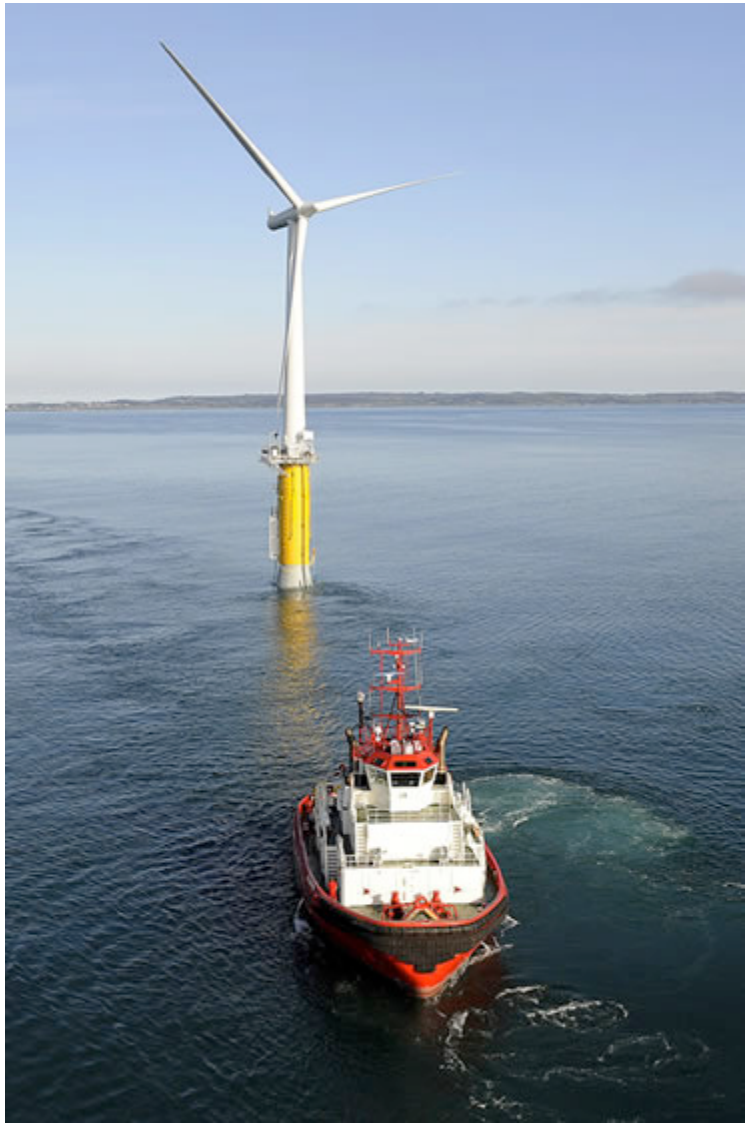
Offshore Floating Wind Farms



Hywind Prototype:Installation:

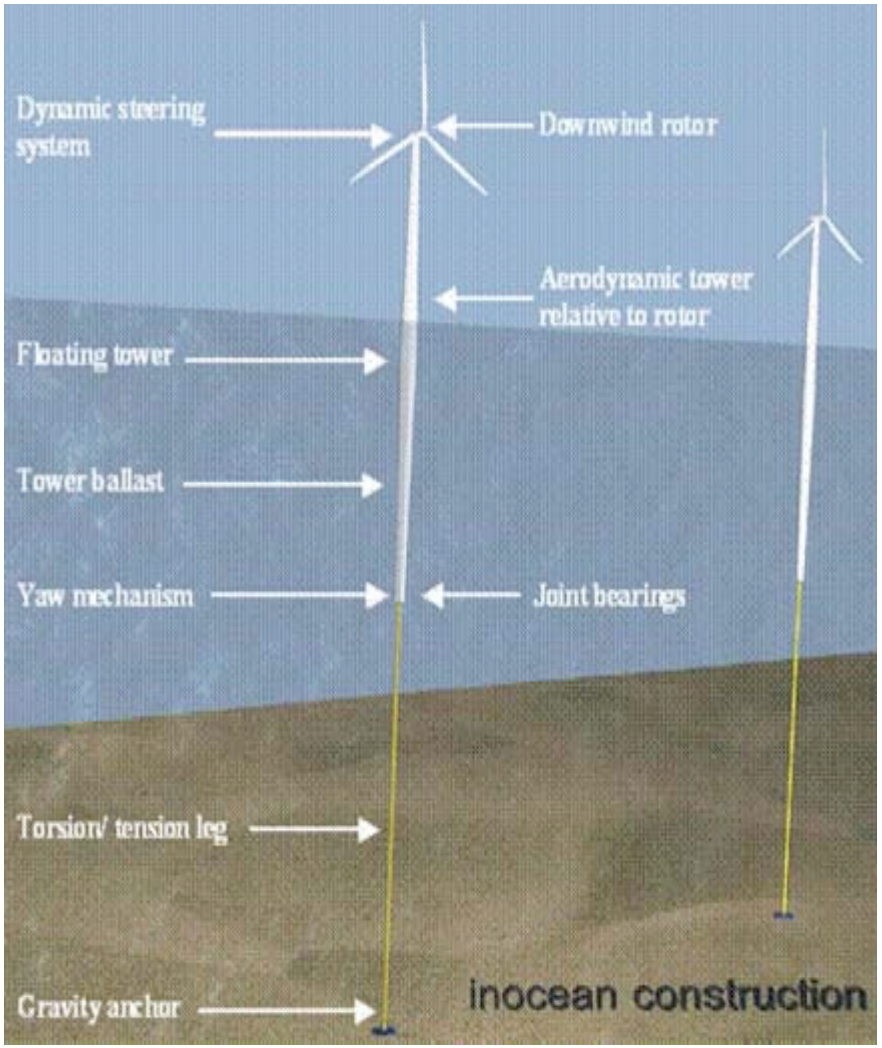
Offshore Floating Wind Farms

Hywind Prototype:



Offshore Floating Wind Farms

WindFloat Schematic:



SWAY Concept (from offshore wind.net)

Offshore Floating Wind Farms

Wind power: the floating wind turbine

Wind power: the floating wind turbine prototype in Brindisi harbour in December 2007