# Tidal Power
# Past, Present and Future Prospects

## North Yorkshire & Cleveland Coastal Forum
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# 1. Renewable Energies



**Kilham East Yorkshire**


Most renewable energy is derived from the sun[7]:

| | | |
|---|---|---|
| 1. | Solar Energy | electricity directly from sunlight or by heating |
| 2. | Biofuels | *via* photosynthesis and burning of plants |
| 3. | Hydroelectric | via the hydrological cycle |
| 4. | Wind | *via* pressure systems |
| 5. | Wave | *via* wind (and hence pressure systems) |
| 6. | Tidal | tides driven by lunar and solar gravity * |
| 7. | Geothermal | Planetary cooling for thermal energy * |

* not derived from the sun

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# 2. A Brief History of Tidal Science



From *The Anlaysis of Tidal Stream Power*, Wiley, 2009
by J.Hardisty

1. Arististotle (384-322 BC) '*ebbings and risings of the sea always come round with the Moon*'
2. Ptolemy (90-168 AD) Earth centred Solar System
3. Kepler (1571-1630) Laws and '*sphere of influence of the Moon*'
4. Galileo (1564-1642) used telescopes to prove the helio-centric Solar System
5. Isaac Newton (1643-1727) introduced *F=ma* and used gravity to prove his equilibrium theory of tides
6. Laplace (1749-1827) derived the dynamic theory of tides and introduced harmonics
7. Lord Kelvin (1824-1907) Developed full harmonic analyses and quantified the tidal species $S_2$, $M_2$, $M_4$ *etc.*.
8. Arthur Doodson (1890-1968) tide prediction machines

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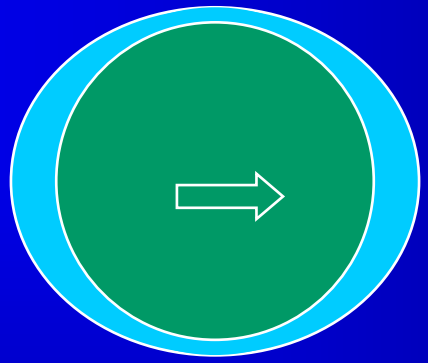
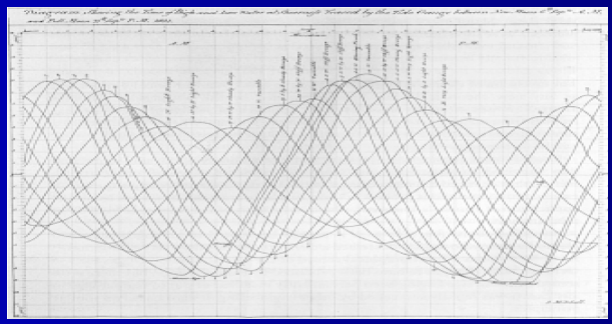
# 3. Tidal Elevations

SLIDE 5



1. The Earth is a sphere surrounded by a film of water
2. The Moon (66% and the Sun 33%) exert gravitational attraction on the water
3. The gravitational attraction generates two bulges
4. The earth spins beneath the bulges giving High Waters and Low Waters
5. The tides also generate ebb and flood flows

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# 4. Power from Tidal Elevations : Barrages



**Potential Energy** of trapped water is:

$$P_E = mgh = \rho W R L g R/2$$

Where $P_E$ energy liberated per semi-cycle

Thus mean Tidal Power:

$$P_T = e P_E/(T/2)$$

Where e is the efficiency
T is the tidal period

For a barrage across the Humber:

R = 6, W = 5,000, L = 40,000, e = 0.75, T = 6.2 x 60 x 60

Thus $P_E$ = 35,300 GJ
$P_T$ = 2,300 MW (2.3 GW)
about 4 nuclear power stations

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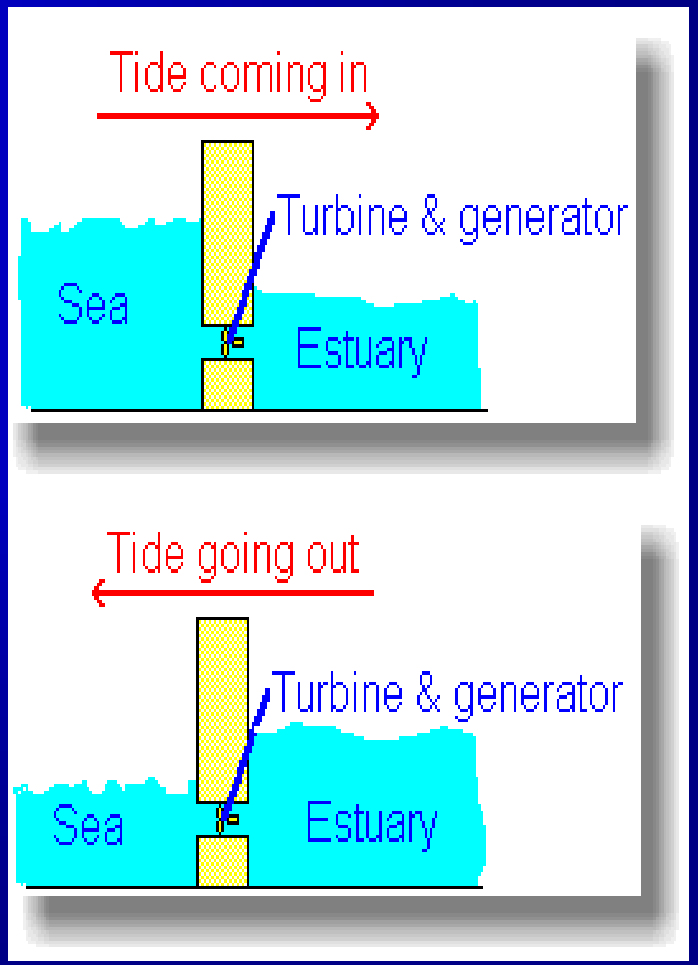

# 5. The Tidal Barrage Resource



1. NW Europe
2. White Sea
3. Bay of Fundy
4. New Zealand
5. Bass Strait
6. Arafura Sea
7. Falkland Islands
8. NW North America

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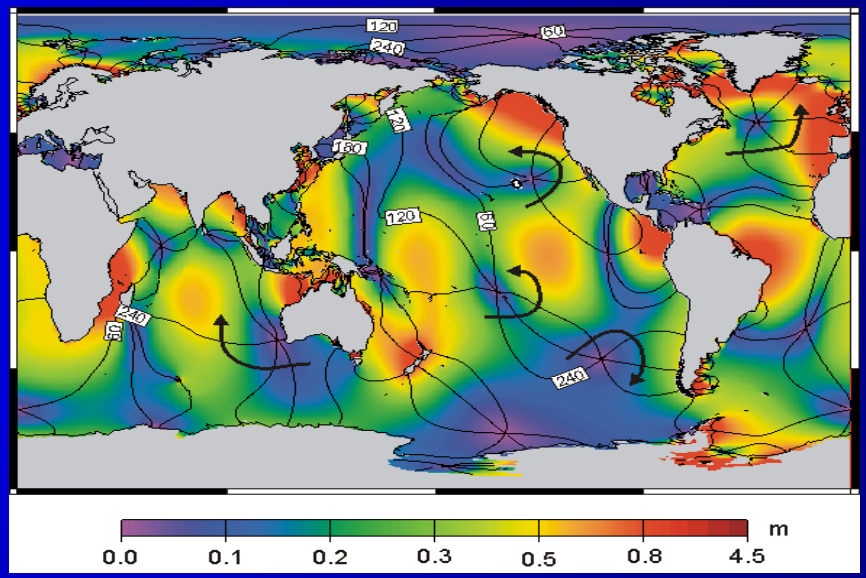



# 6. Tidal Currents



http://tidesandcurrents.noaa.gov/nyports/nyports.shtml?port=ny

Harmonic analysis gives the tidal current speed:

$$U = (R/2)\sqrt{(g/h)}\cos(2\pi t/T)$$

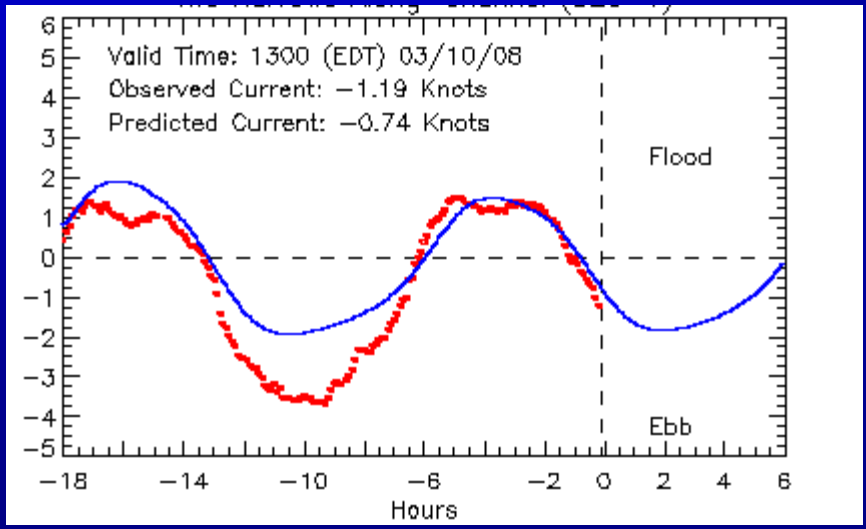
Where U is the current speed at time t (m/s)

R is the tidal range (m)

h is the water depth (m)

T is the tidal period (semi-diurnal = 12.4 hrs) hrs

The result is a sinusoid varying from low water slack, through flood, high water slack and ebb

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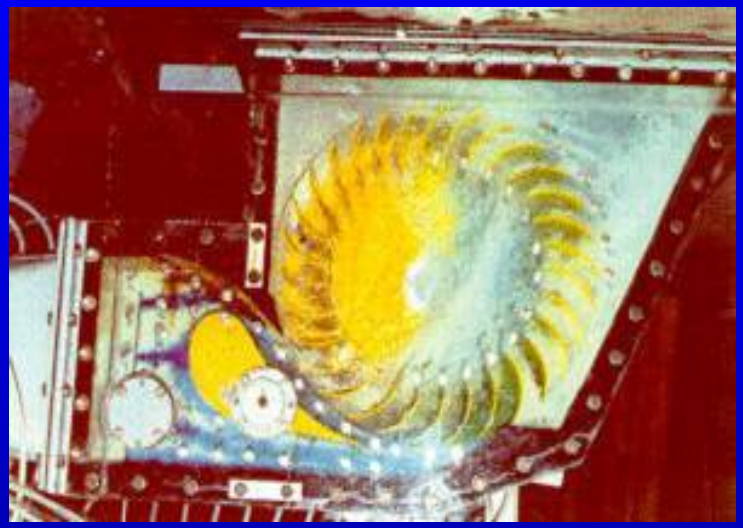
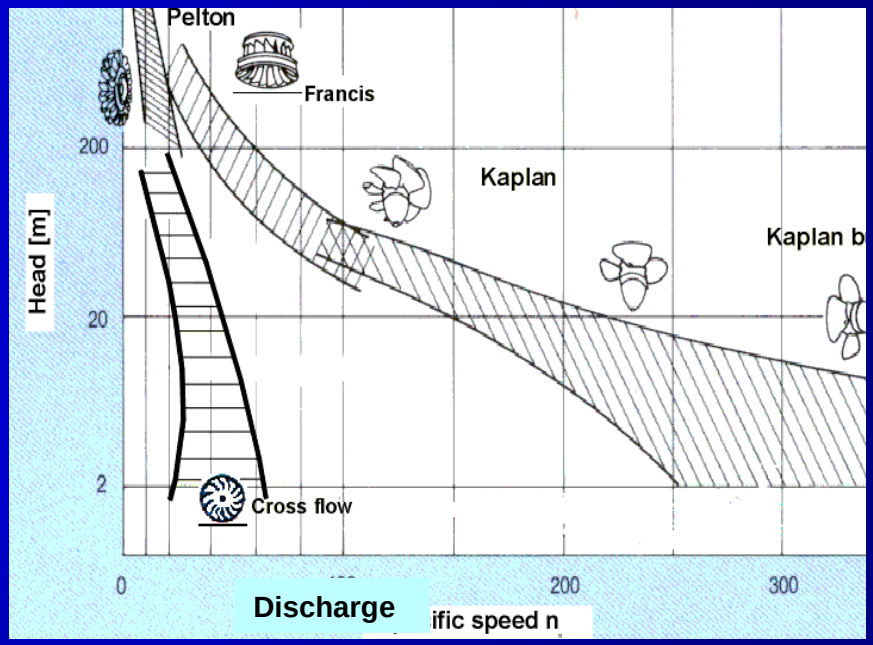
# 7. Power from Tidal Currents : Turbines








**Four hydroelectric turbine technologies:**

1. **Pelton** — **Very large head 500-2,000 m**
2. **Francis** — **Large head 200-500 m**
3. **Kaplan** — **Head 10-200 m**
4. **Crossflow** — **Small head 1-20 m**

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# 7. Power from Tidal Currents : Turbines



The power in the tide is the kinetic energy of the water mass passing through the blades each second:

$$P = \tfrac{1}{2} m V^2$$

Horizontal axis $P \sim 1500 V^3 R^2$

Vertical axis $P \sim 500 V^3 h w$

Typically for 50% efficiency:

$P_E = 750 V^3 R^2$ (horizontal) = $500 V^3 h w$ (vertical)

Thus
10 m horizontal axis in 2 $ms^{-1}$ = 150 kW
20m vertical axis in 3 $ms^{-1}$ = 2.7 MW

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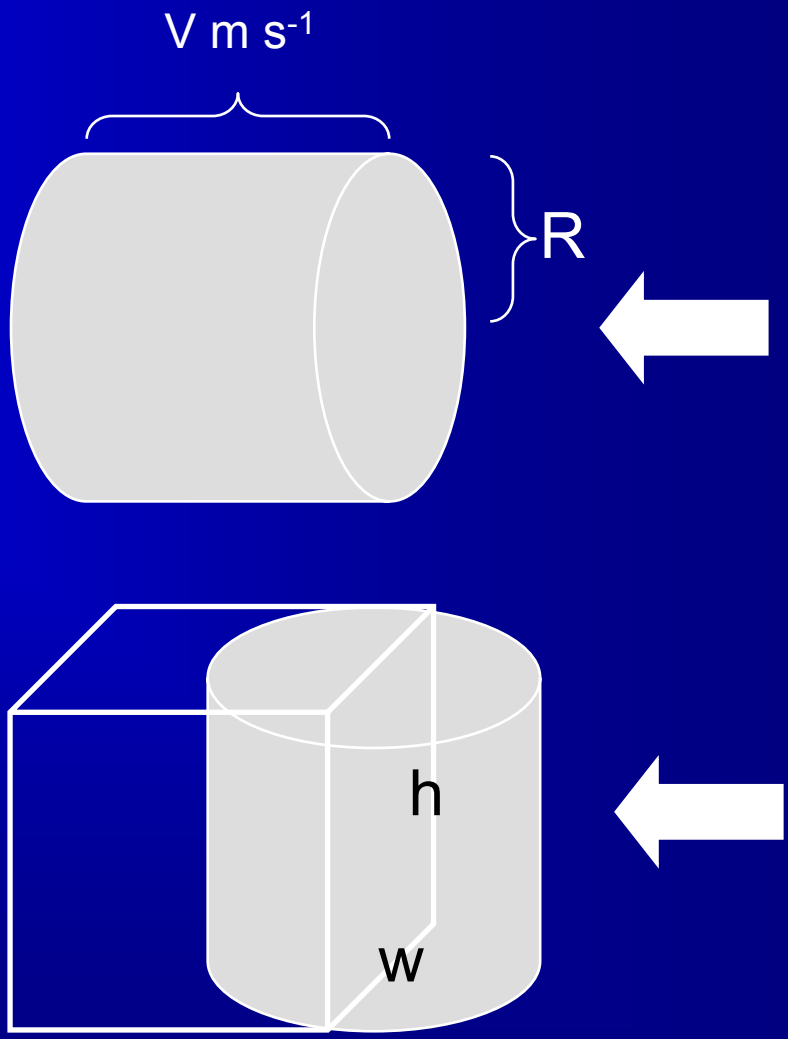


# 7. Power from Tidal Currents : Turbines



**TIDAL TURBINES**

Four types of tidal turbines:

**a. Horizontal Axis Lift Rotor (Kaplan)**

http://www.marineturbines.com/home.htm

**b. Horizontal Axis Drag Rotor**

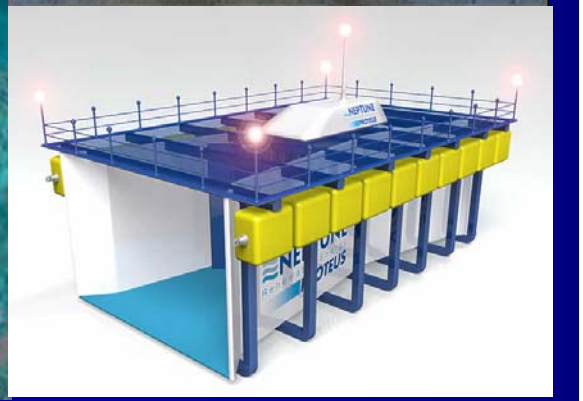
http://www.openhydro.com

**c. Vertical Axis Lift Rotor**

www.bluenergy.com

**d. Vertical Axis Drag Rotor (Crossflow)**

http://www.neptunerenewableenergy.co.uk

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# 8. The Tidal Current Resource



1. NW Europe
2. East Coast North America
3. West Coast North America
4. Australia
5. New Zealand
6. East  Arabian Sea
7. Yellow Sea
8. South Korea

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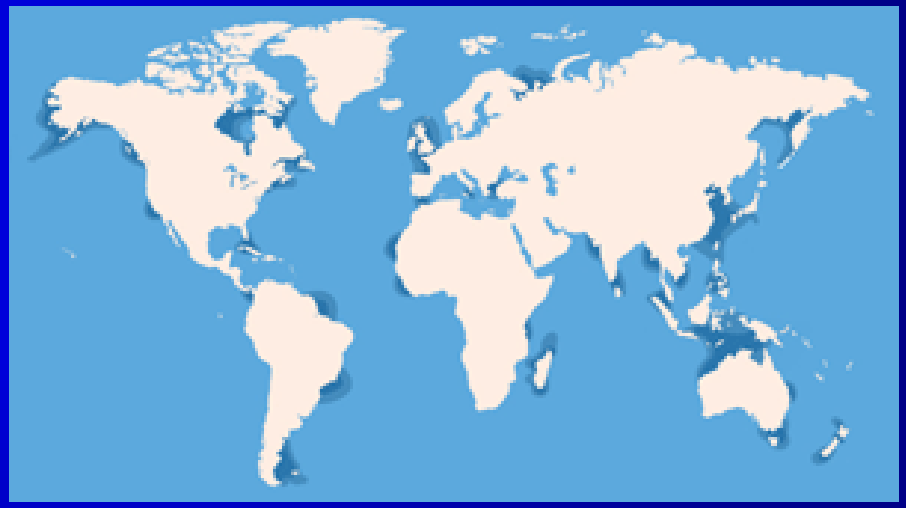
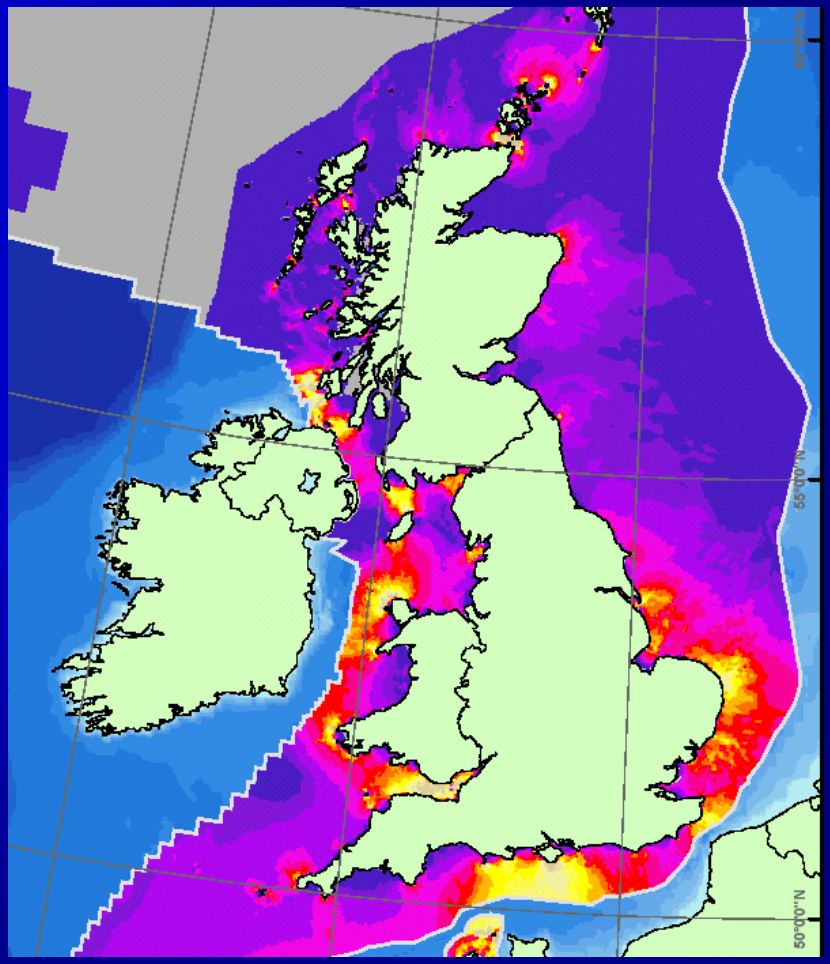


# 8. The Tidal Current Resource



i. Orkneys (OpenHydro)
ii. Pentland Firth
iii. Humber (Neptune)
iv. Norfolk
v. Dover
vi. Isle of White
vii. Portland
viii. Channel Islands
ix. Severn Estuary
x. Pembroke (Lunar)
xi. Anglesey (MCT)
xii. Mersey (Neptune)
xiii. Isle of Man
xiv. North Channel

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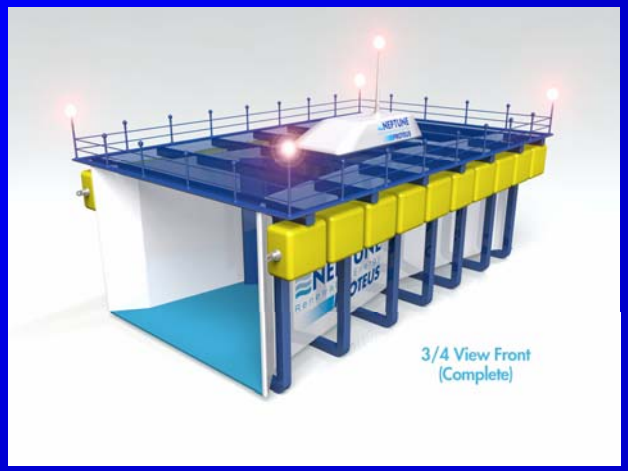
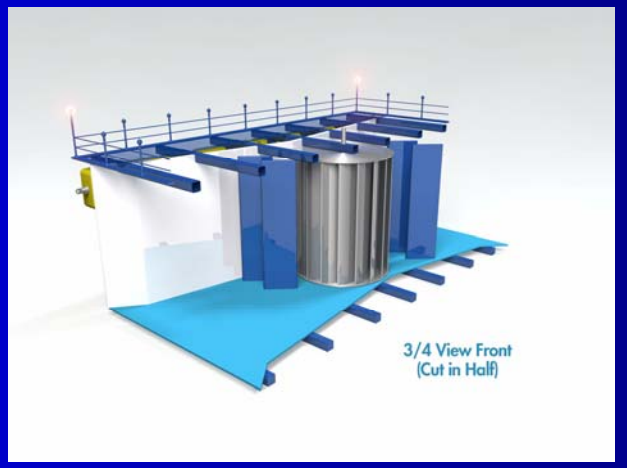
# 9. The Neptune Hull Roads Project






i. 20.0 LOA x 14.0 beam x 6.50 OD, floating Balmorel buoyancy device with low cost exo-skeletal framework

ii. Moored in estuarine locations to minimise structural, maintenance, cabling and O&M costs

iii. Vertical axis crossflow rotor significantly reduces capital and O&M costs as all electrical systems are above water

iv. Turbine drives 2 x David Brown G19 gearboxes into 2 x Brook Crompton DC Generators and 2 x Sprint Thyristor drives producing 3 ph 450 V, mains synchronised output up to 500kW

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# 9. The Neptune Hull Roads Project



1. Demonstrator under construction at MMS Shiprepairs, Alexandra Dock, Hull
2. Launch January 2009 to supply KHCC
3. ‘Iconic’ location off The Deep in support of KHCC regeneration objectives of Healthcare, Port Logistics and Renewable Energy
4. Humber I array (10-15,000 MWh/yr) completed March 2010
5. Humber II (January 2011) then Mersey I and II by November 2011 and September 2012

**TP, PP&FP**
**Thank you for your attention**