Geothermal Power

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What Is Geothermal Energy?

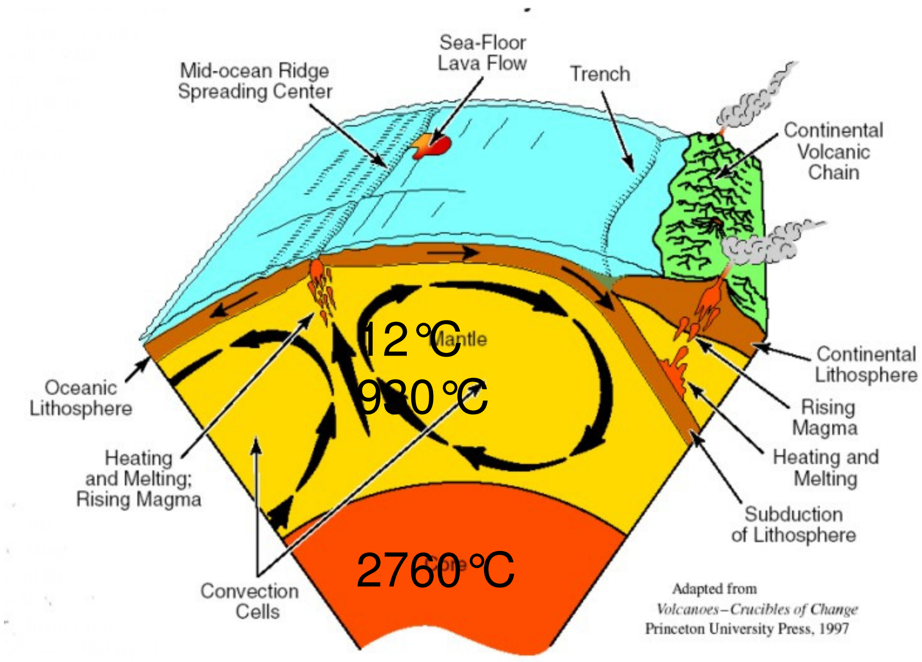
- ‘Geothermal Energy is the energy stored in the form of heat below the surface of the solid earth’

How Hot is it?

- '<u>Geothermal Gradient</u> defines the vertical temperature increase below the earth's surface'

Worldwide Average is

c. 3°C increase per 100m depth



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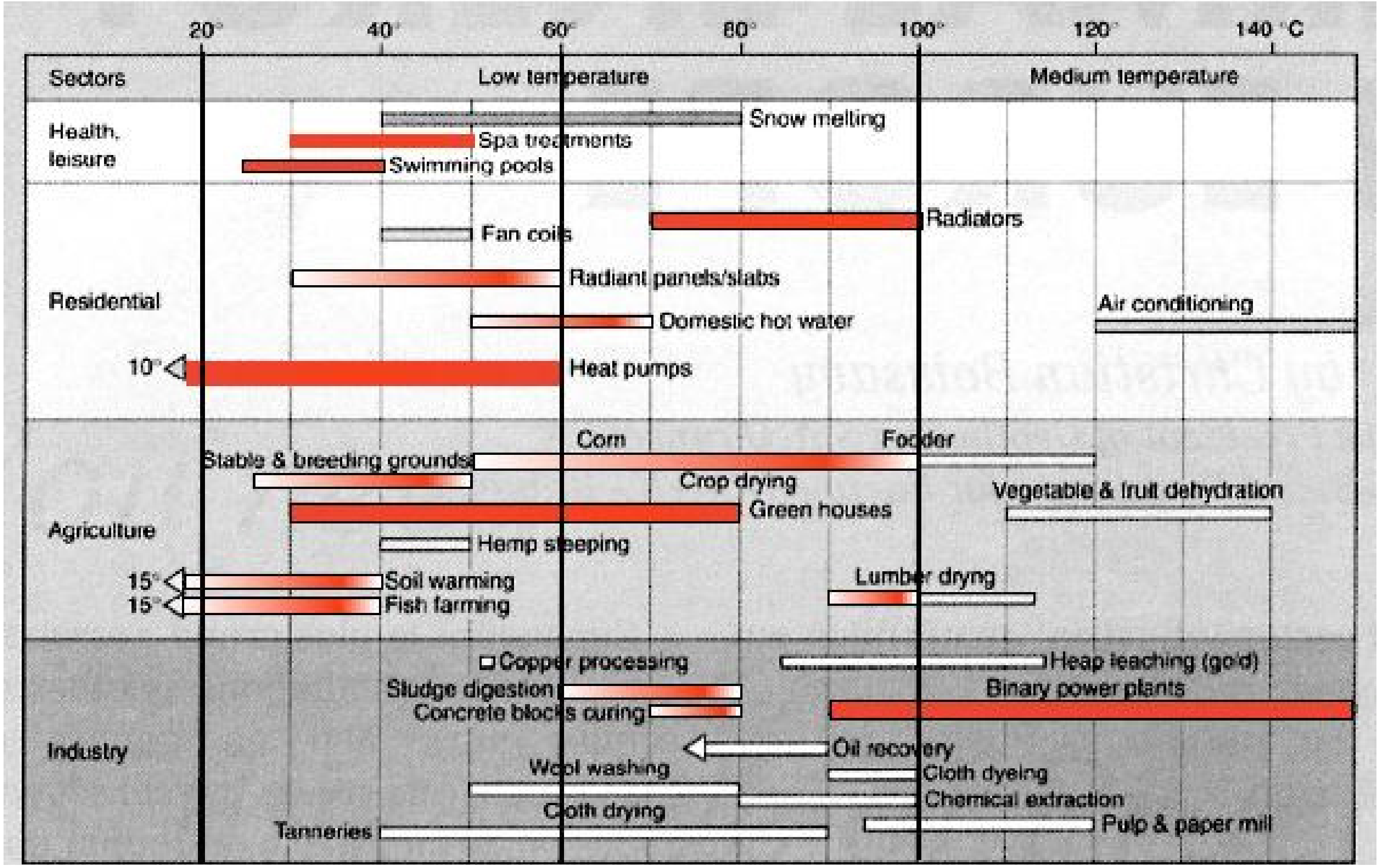
Geothermal Energy Utilisation:

• Soils (Ground Source Heat Pumps)	**9-11℃**
• Surface & Marine Water	**5-15℃**
• Shallow Groundwater Aquifer	**cool, high vol**
• Urban Heat Island	**13-18℃**
• Warm Springs, Shallow Heat	**15-23℃**
• Medium Depth Heat	**25-75℃**
• Deep Heat	**100-150+℃**

Geothermal Energy Utilisation:



Boissavy, 1997, European Geologist 5, after Lindall 1973

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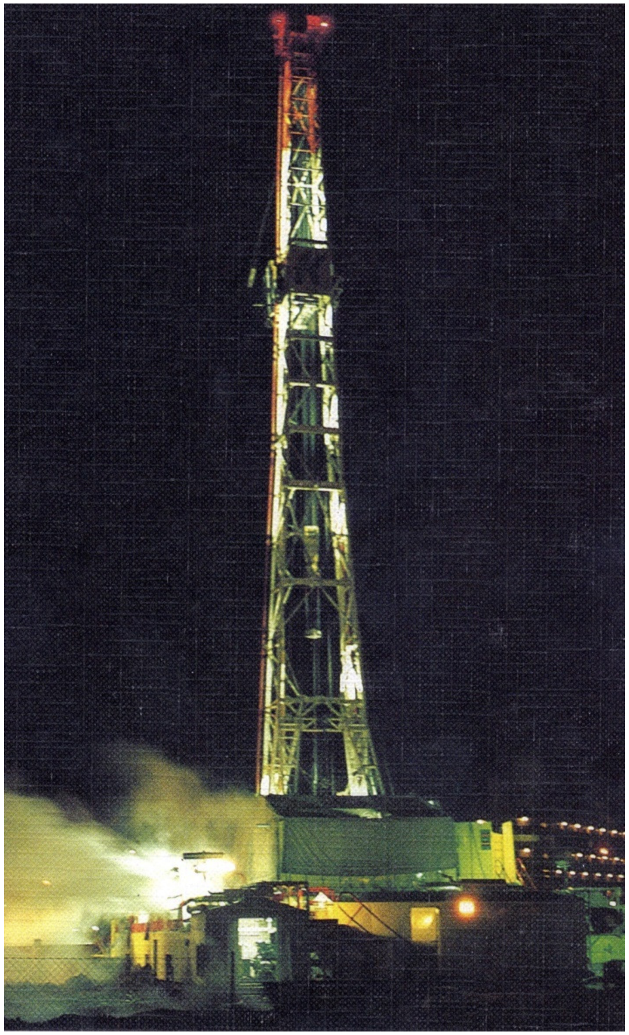

Geothermal Energy in Northern Ireland and Azerbaijan

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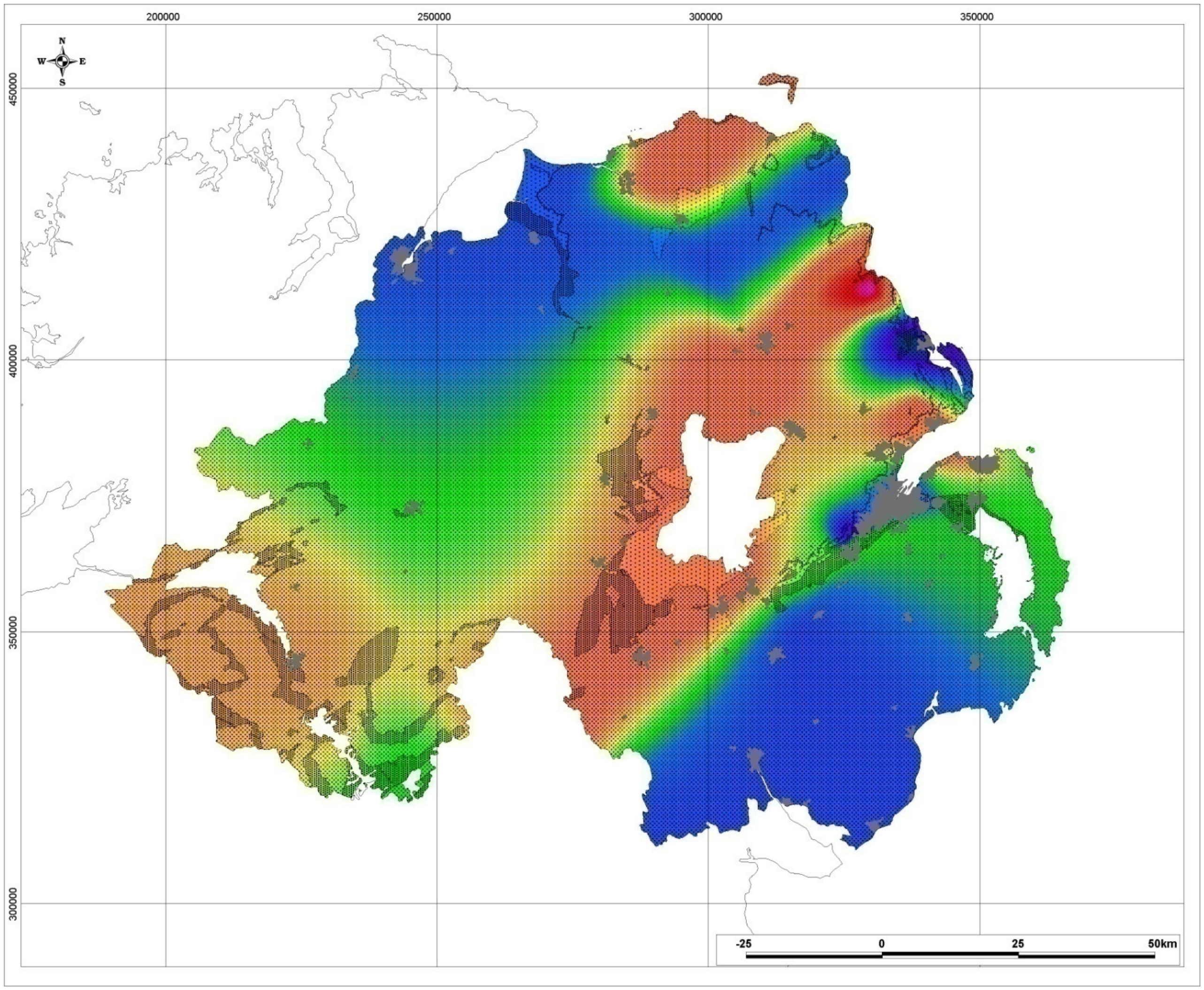
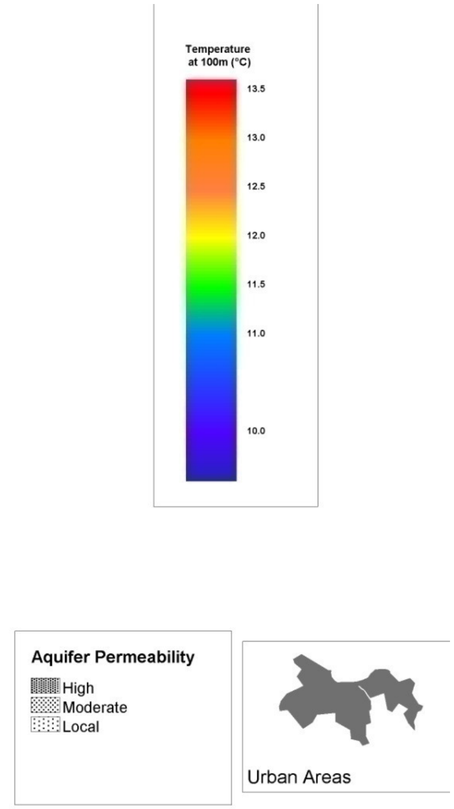
Shallow Geothermal Potential of Northern Ireland

- Defined Temperature Profiles of Northern Ireland Groundwater Aquifers based on existing borehole Measurements

- Results of the study showed a Relationships between Aquifer Permeability and Temperature at 100m where More Permeable Aquifers supply Greater Amounts of Energy to shallow GSHP collectors

Shallow Geothermal Potential

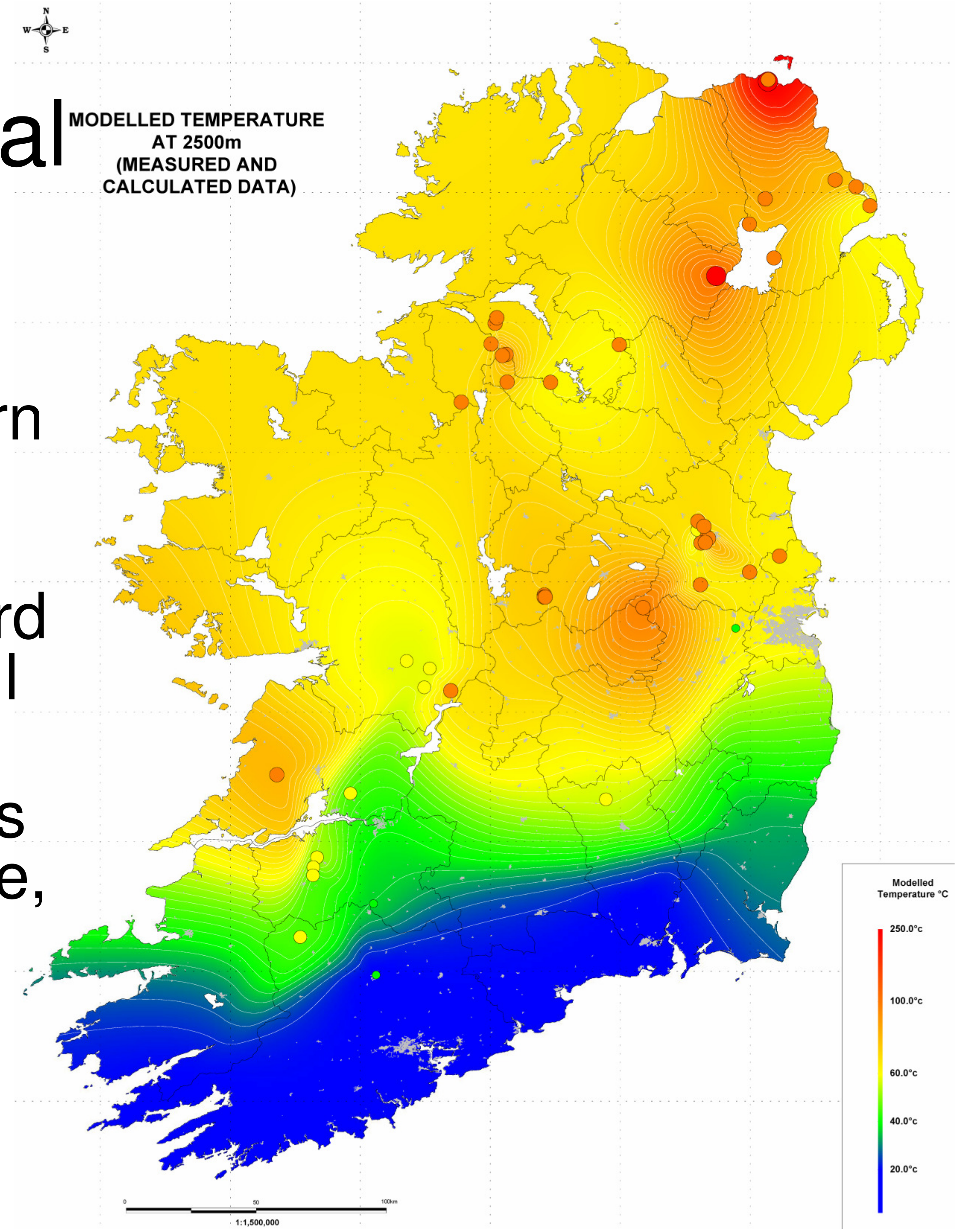




At 100m depth

Deep Geothermal Potential

- Geothermal Potential of Northern Ireland at 2.5km depth
- Temperature Record from Exploration Oil & Gas wells
- Geothermal Targets in the Rathlin, Larne, Lough Neagh and North West basins



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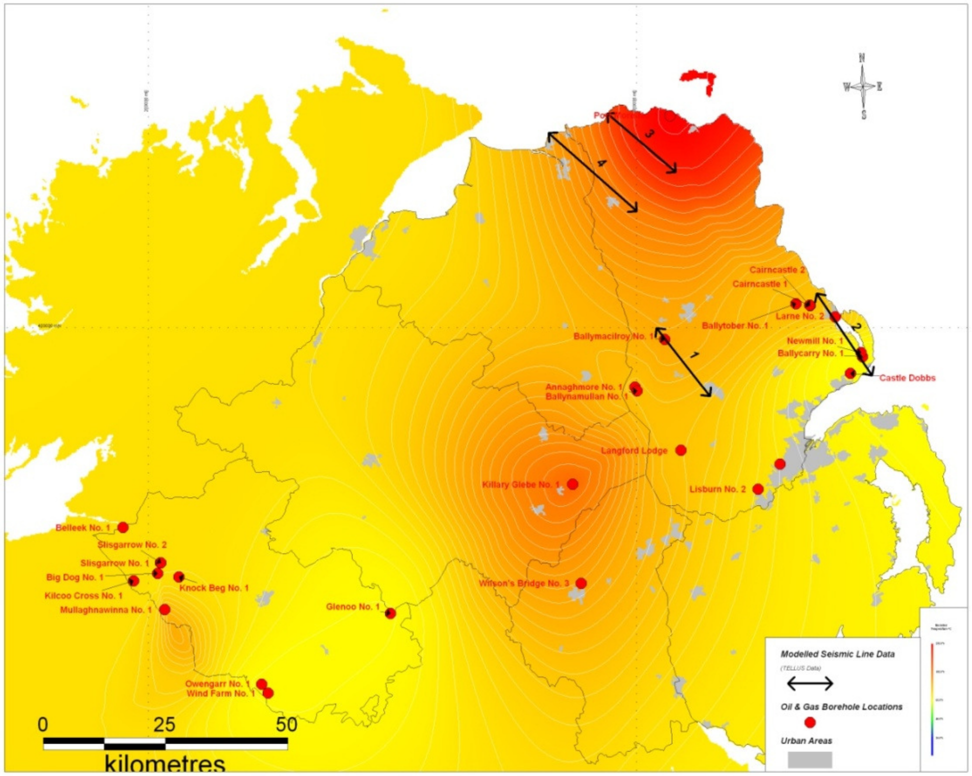
Defining the Potential of Geothermal Targets



Using:

- **Existing Oil & Gas well data** in Northern Ireland
- **Existing Seismic line data**

Define the Thickness, Geometry & Depth of the target reservoirs

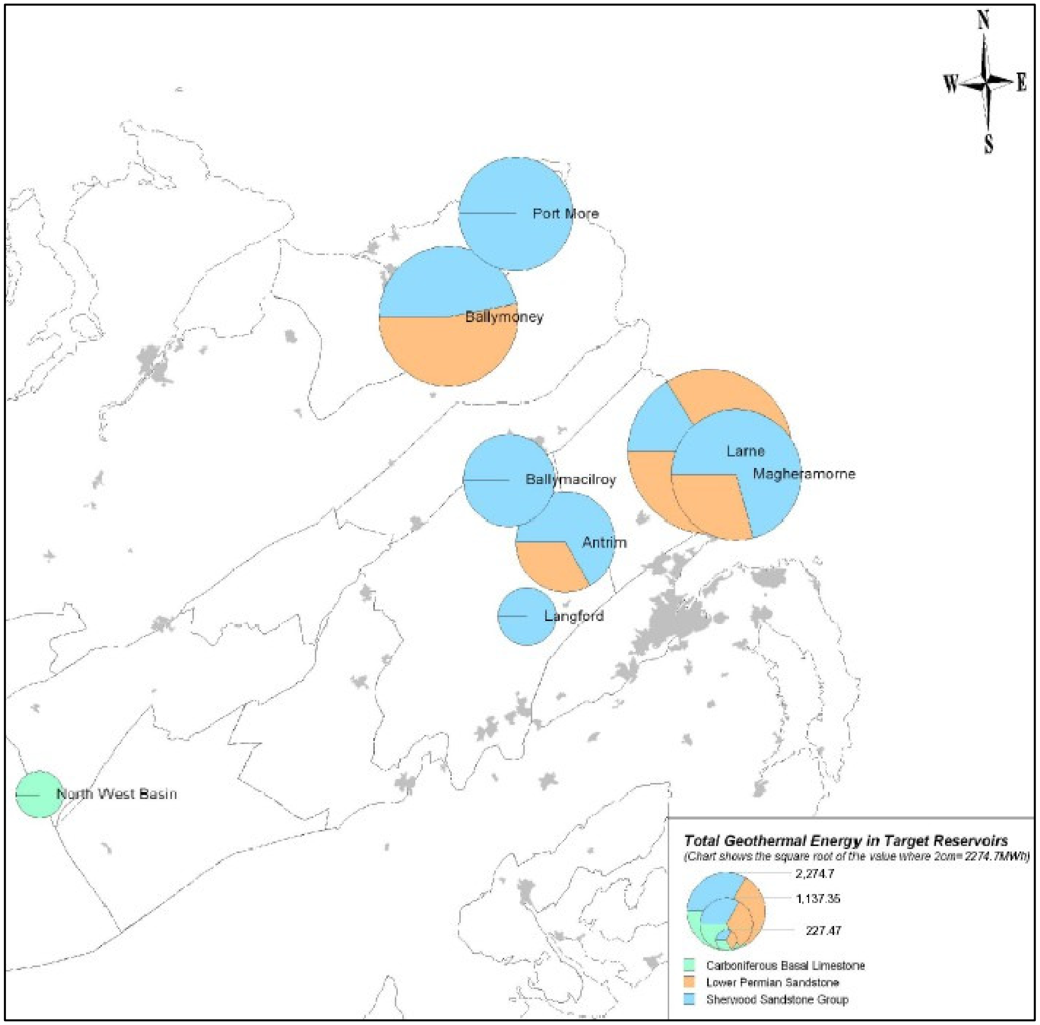
Stored Energy in Northern Ireland Reservoirs

- Deeper, Thicker and Higher Temperature reservoirs contain Higher Quantities of Energy
- Ranked Target Formation - Total Energy in MWh per year

Formation Ranking	Site Location Rank	Site Location	Formation	Reservoir Thickness (m)	Base of Geothermal Target Formation (m)	Volume of Source Rock (*V*) (m^3)	Energy Stored in the Reservoir (kJ_{th})	Total Energy Stored in the Reservoir (MW h)
1	1	Larne	Lwr. Permian Sandstone	900	2800	56250000	8.19E+09	**2274.70**
	2	Ballymoney	Lwr. Permian Sandstone	500	2200	31250000	3.86E+09	**1073.33**
	3	Magheramorne	Lwr Permian Sandstone	250	2200	15625000	1.90E+09	**528.84**
	4	Antrim	Lwr. Permian Sandstone	200	2200	12500000	1.36E+09	**378.22**
2	1	Port More	Sherwood Sandstone	680	1830	42500000	5.24E+09	**1456.08**
	2	Magheramorne	Sherwood Sandstone	650	1600	40625000	4.62E+09	**1281.96**
	3	Ballymacilroy	Sherwood Sandstone	420	1870	26250000	3.54E+09	**983.50**
	4	Ballymoney	Sherwood Sandstone	500	1400	31250000	3.43E+09	**951.69**
	5	Antrim	Sherwood Sandstone	400	1600	25000000	2.74E+09	**761.35**
	6	Langford Lodge	Sherwood Sandstone	270	1515	16875000	1.61E+09	**446.12**
	7	Larne	Sherwood Sandstone	650	1615	14625000	1.58E+09	**439.53**
3	1	North West Basin	Carboniferous Basal Sandstone	150	2000	9375000	1.15E+09	**318.65**

Conservative Estimates

Defining the Potential of Geothermal Targets



- High Geothermal Potential in the Larne, Rathlin, Lough Neagh and North West Basins

How do Northern Ireland Reservoirs Compare to Operating Plants ?

Formation Ranking	Site Location Rank	Site Location	Formation	Reservoir Thickness (m)	Base of Geothermal Target Formation (m)	Total Energy Stored in the Reservoir (MW h)
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	7	Larne	Sherwood Sandstone	650	1615	439.53
3	1	North West Basin	Carboniferous Basal Sandstone	150	2000	318.65
		Unterhaching, DE	Jurassic Malm Limestone	350	3600	1069.29

The Unterhaching Geothermal Power Plant (Southern Germany)

Power Output:
47 MW_{th} – District Heating
4.3 MW_e – Electricity Supply

Stored Annual Energy Calculation:
1069.29 MWh

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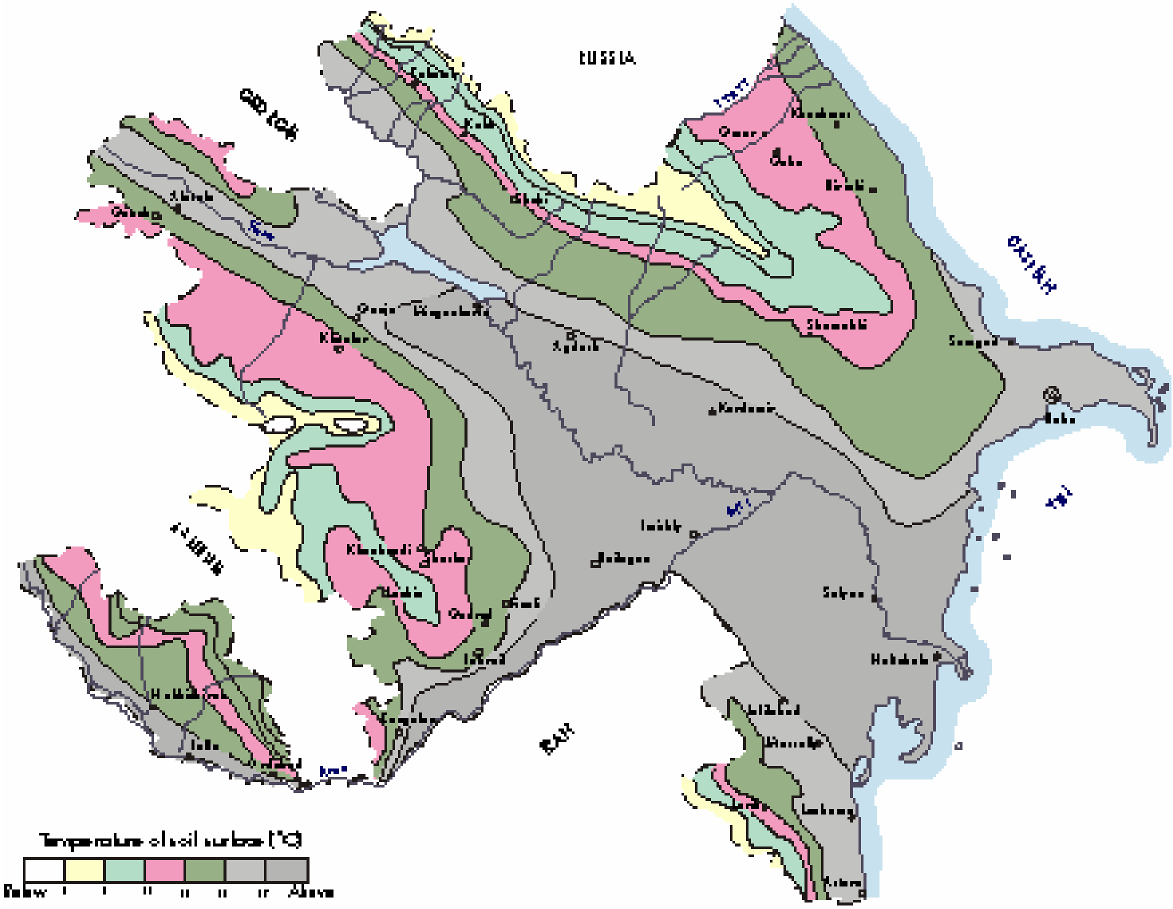
Geothermal Potential of Azerbaijan



Absolute maximum and minimum of temperature of soil surface

Station	Absolute Maximum	Absolute Minimum
Zakataly	[illegible]	[illegible]
Khachmaz	[illegible]	[illegible]
Guba	[illegible]	[illegible]
Shamakhi	[illegible]	[illegible]
Kelbajar	[illegible]	[illegible]
Mashtagi	[illegible]	[illegible]
Kurdamir	[illegible]	[illegible]
Astara	[illegible]	[illegible]
Khankendy	[illegible]	[illegible]
Nakhchevan	[illegible]	[illegible]

Temperature of soil surface on different height above level of sea

Height (m)	Great Caucasus South Slope	Lesser Caucasus	Talysh	Nakhchivan
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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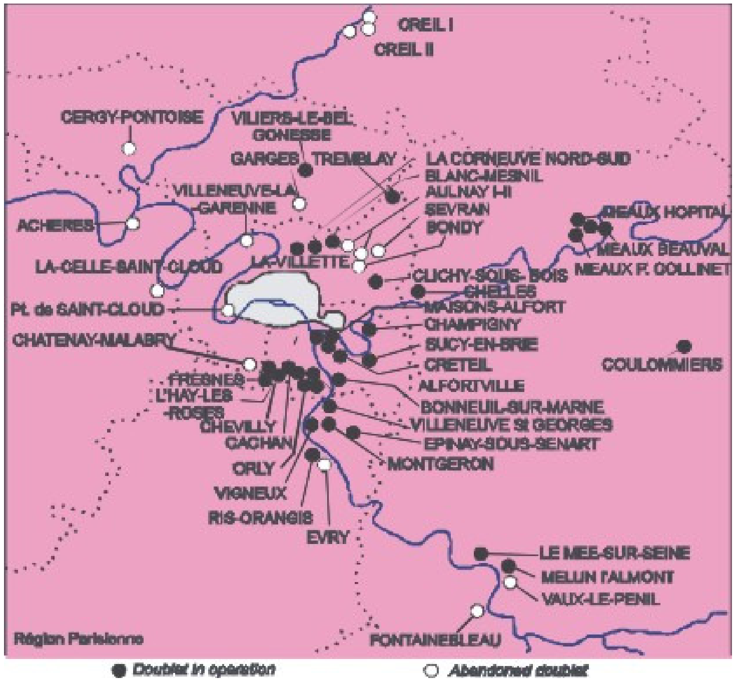
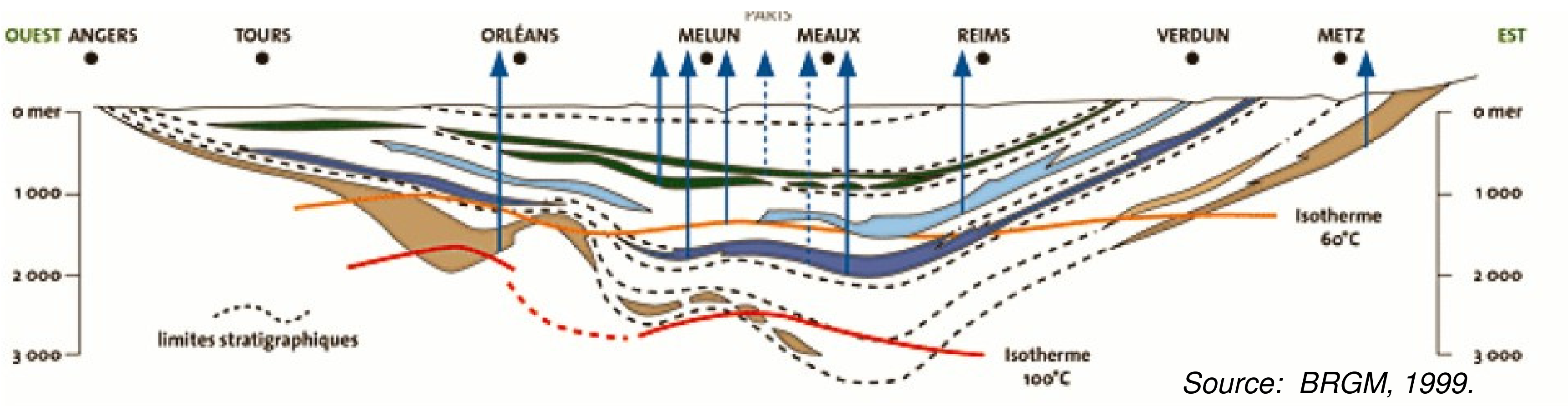
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

- 600oC water was extracted from a well on the Apsheron Peninsula, used for oil exploration
- At lower temperatures, the areas of Lenkoran, Massaly, and Astara have produced 40litres/s of water at 40oC from wells, with an estimated production capacity of 25,000m3 per day
- It is highly likely that significant power generation from deep geothermal resources in Azerbaijan is possible

Geothermal Energy in the Paris Basin since 1961



Source: GPC, 2003.



Source: BRGM, 1999.

- 32 operating well doublets
- 13 abandoned well doublets

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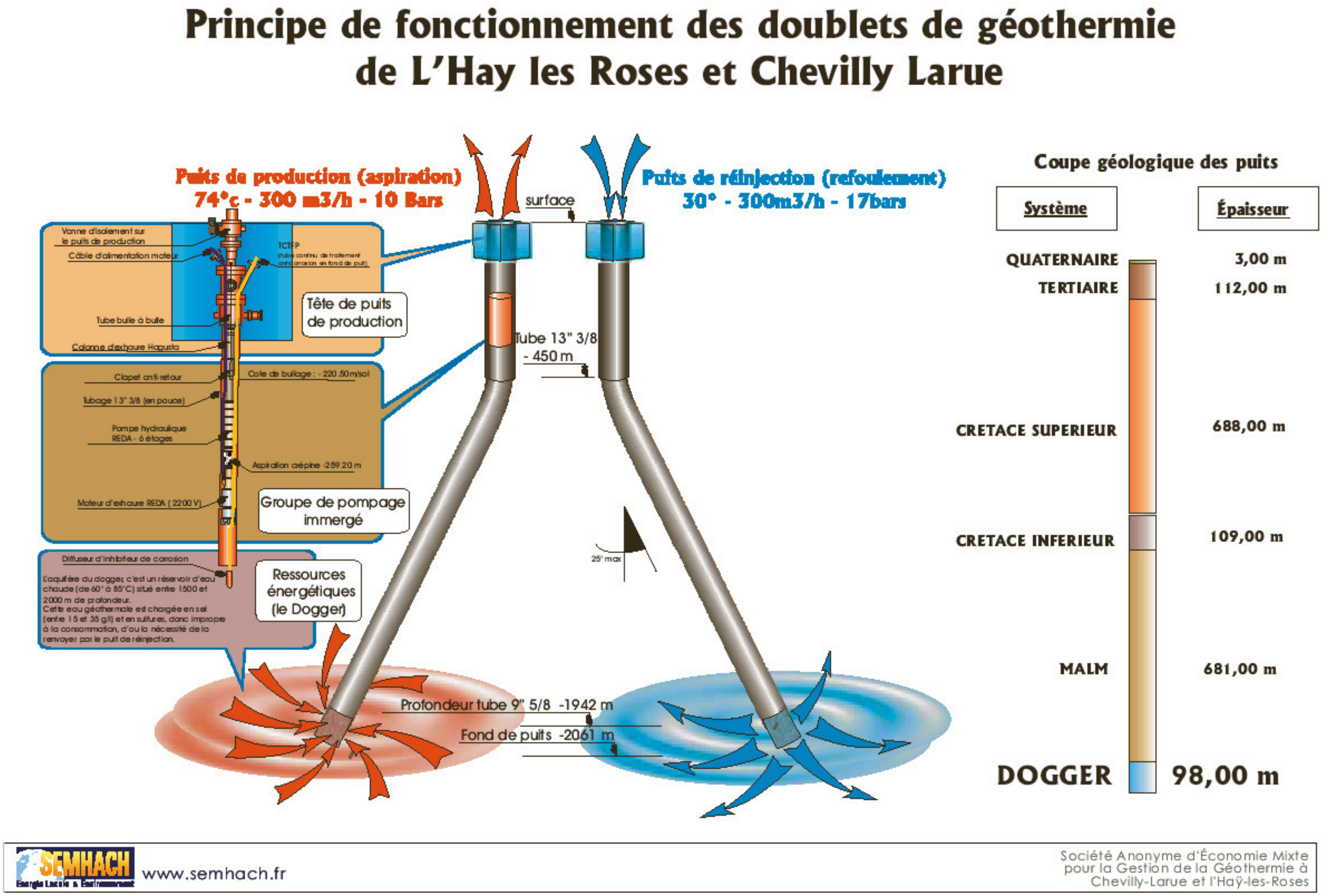
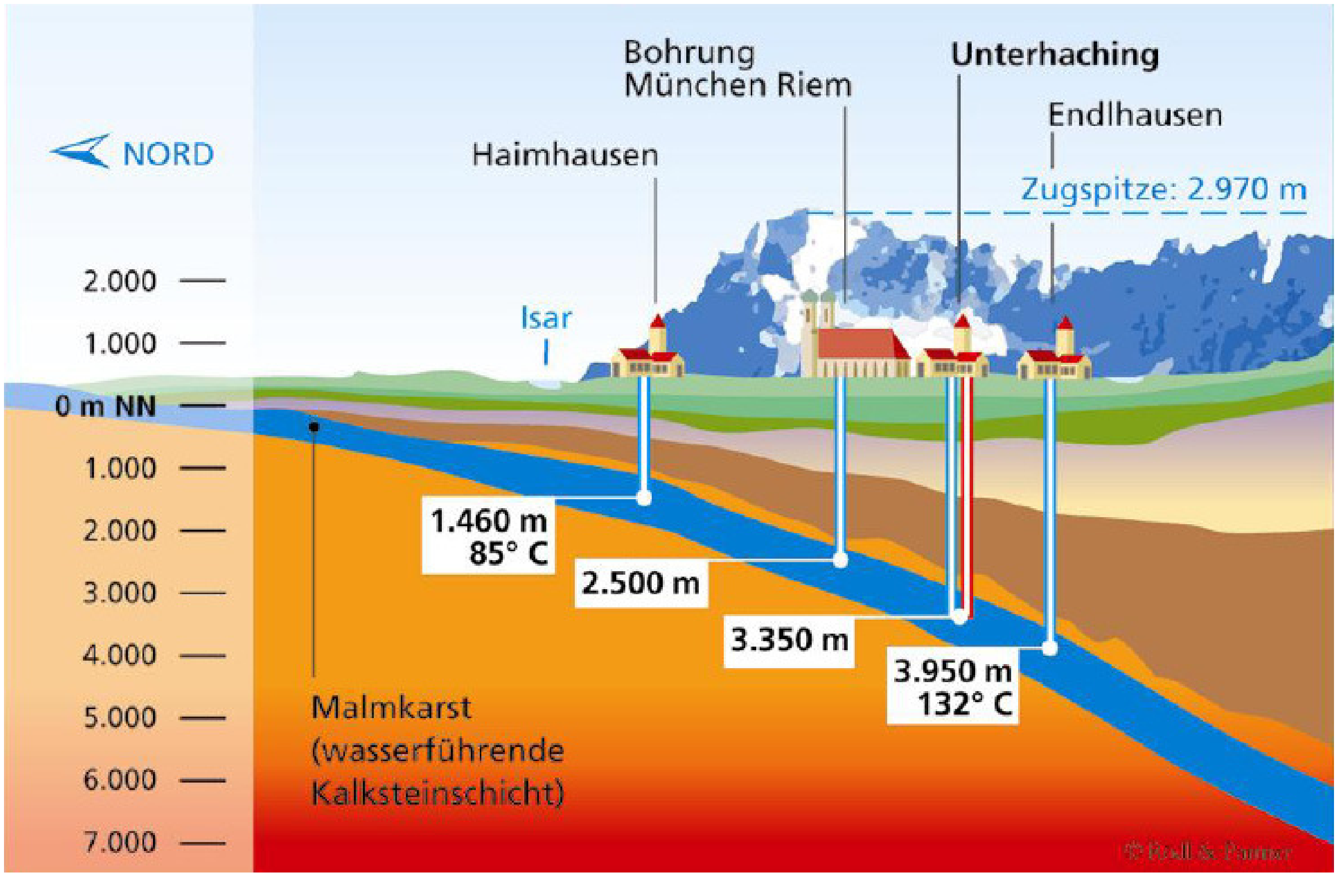
Well Doublet Principles



Unterhaching – Germany
Heat & Electricity



- Malm Limestone at 3,350m depth – Temperature 123^{o}C – Flow rate 150l/s

Steam and Binary Cycle Power Generation

- Most geothermal power plants extract steam or hot water at temperatures of around 180oC and higher. This is then used to turn a steam turbine
- Binary cycle power plants can use water of lower temperatures, and so can be more adaptable
- Binary cycle uses the hot water to evaporate a fluid with low boiling point, the gas of which is then used to turn the turbine

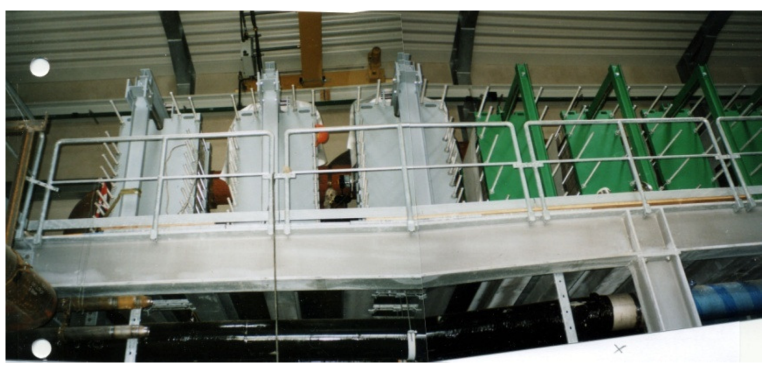
- Geothermal Power Plant in Iceland

Unterhaching – Heat & Electricity

- HEAT: 47MW$_{th}$ – District Heating




- ELECTRICITY: 4.3MW$_{e}$ – Kalina Plant

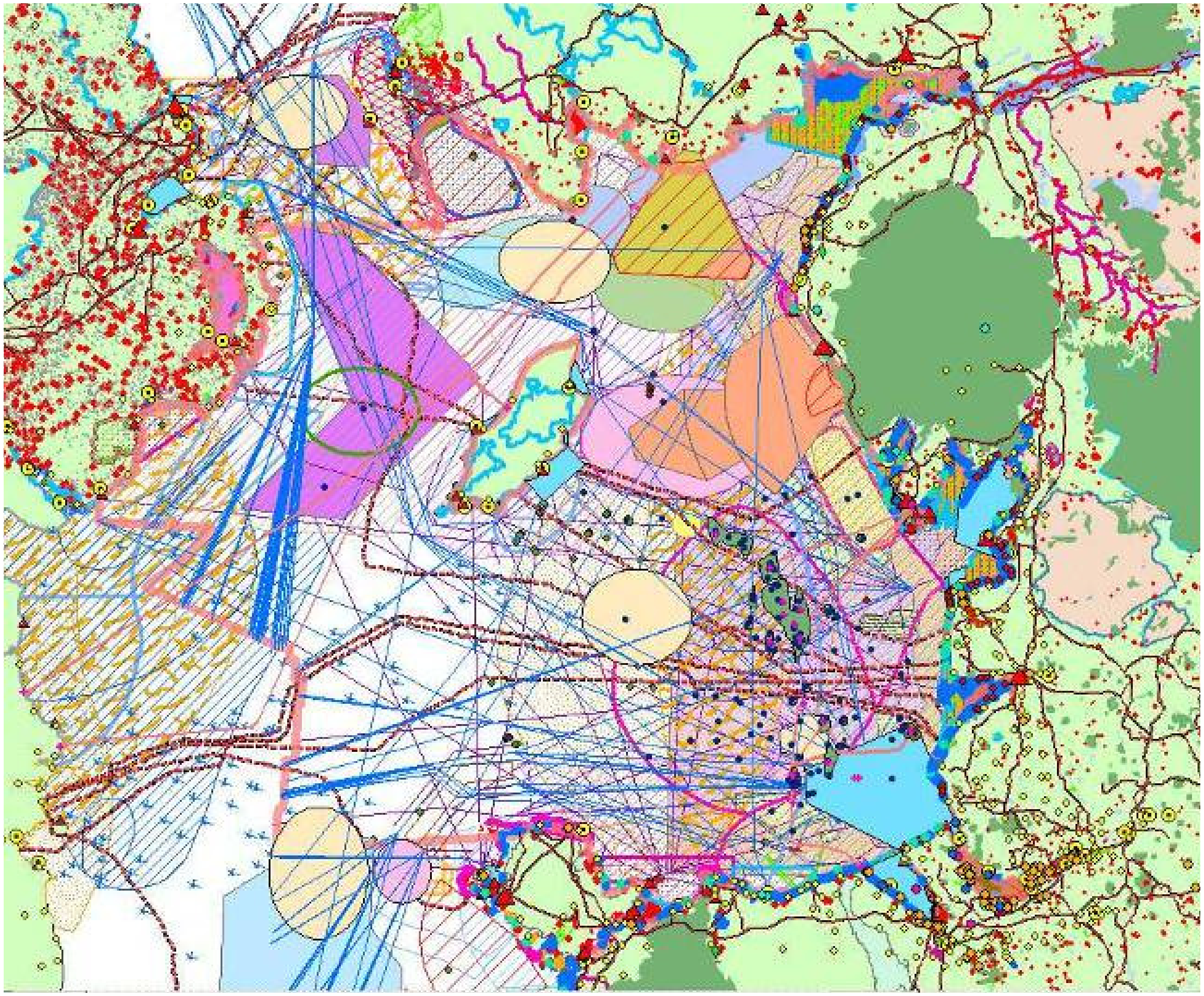



Geothermal Power Summary

- Heat from aquifers can supply district heating and industrial process heat – eg greenhouses
- It is highly likely that electricity generation in Azerbaijan is possible from geothermal resources
- The resource requires detailed mapping
- Evidence suggests that the resource is better than that being exploited in Unterhaching, Germany
- Geothermal energy is not intermittent
- Generation of electricity and heat will free natural gas for export

Marine Power

- Landuse
- Tourism
- Oil &Gas
- Mariculture
- Coastal Defence
- Ports & Navigation
- Military Activities
- Culture
- Conservation
- Dredging & Disposal
- Submarine Cables



- Fishing
- Renewable Energy
- Marine Recreation
- Mineral Extraction

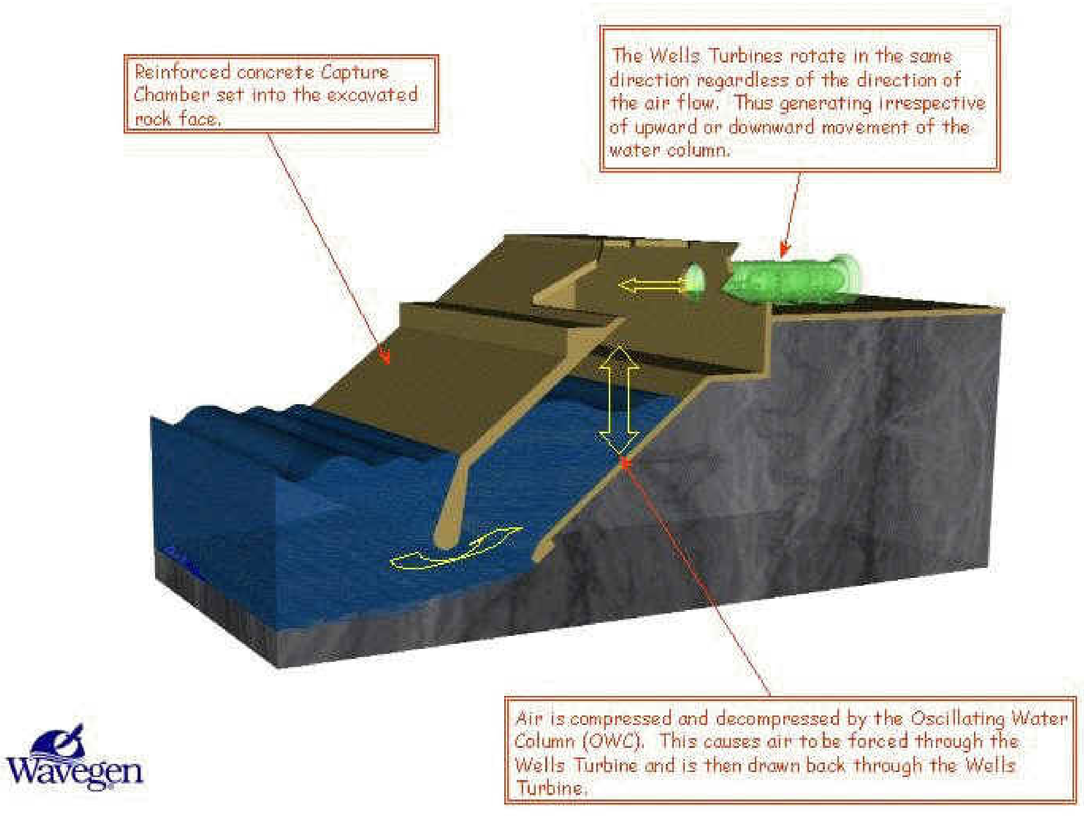
Wave Energy

- Great potential energy is available from the sea as wave energy, where the rise and fall of waves, or their horizontal motion can be captured to generate electricity
- Estimates put the European wave energy resource at 400 TWh – 17% of the EU demand for electricity
- Portugal, France, Ireland, UK and Norway are all best placed to receive the largest waves
- The northern coast of the Apsheron Peninsula may have potential for wave power development

Oscillating Water Columns

- Capturing waves in an enclosed space creates an oscillating water column (OWC)
- The OWC can be used itself to turn a hydroelectric turbine, or it can push air through an air turbine
- The force will flow in two directions, and so the turbine needs to be capable of generating from a bi-directional flow

Shoreline Wave Energy Devices



- Oscillating water column system
- Developed by QUB and Wavegen
- Rising water column pushes and pulls air through the Wells Turbine
- Grid connected on Islay in 2000

Tapered Channels and Overspills

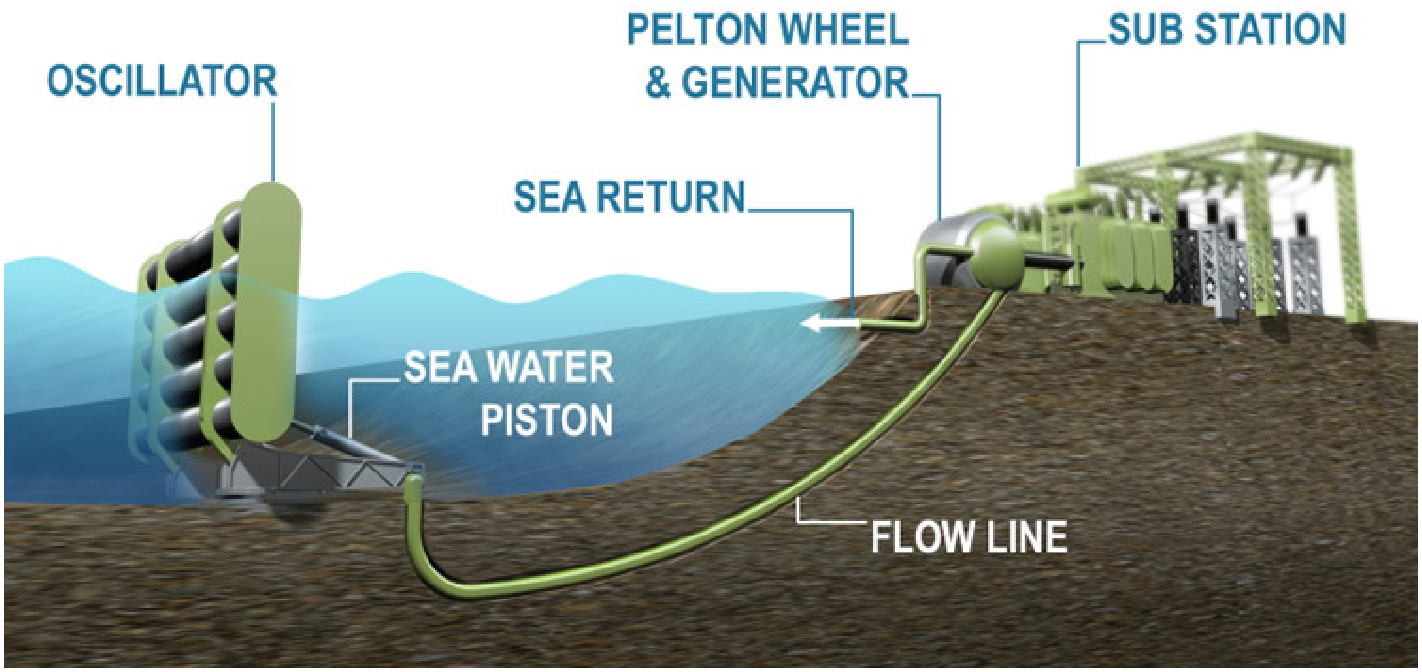
- Seawater can be trapped in a tapered channel, pushing through a turbine
- This requires high pressure
- Has been trialled in Norway
- Overspills a concrete wall which captures seawater as it spills over the top
- Seawater is released at the bottom, passing through turbines

Wavedragon is a type of overspill system

Point absorbers and terminators

- These systems amplify the movement of the waves
- Absorbers can extract energy from multiple directions
- Attenuators are similar but use the force of one section being restrained relative to its neighbour
- The first wave farm is installed in Portugal comprising attenuator type systems, with a total installed capacity of 2.25MW

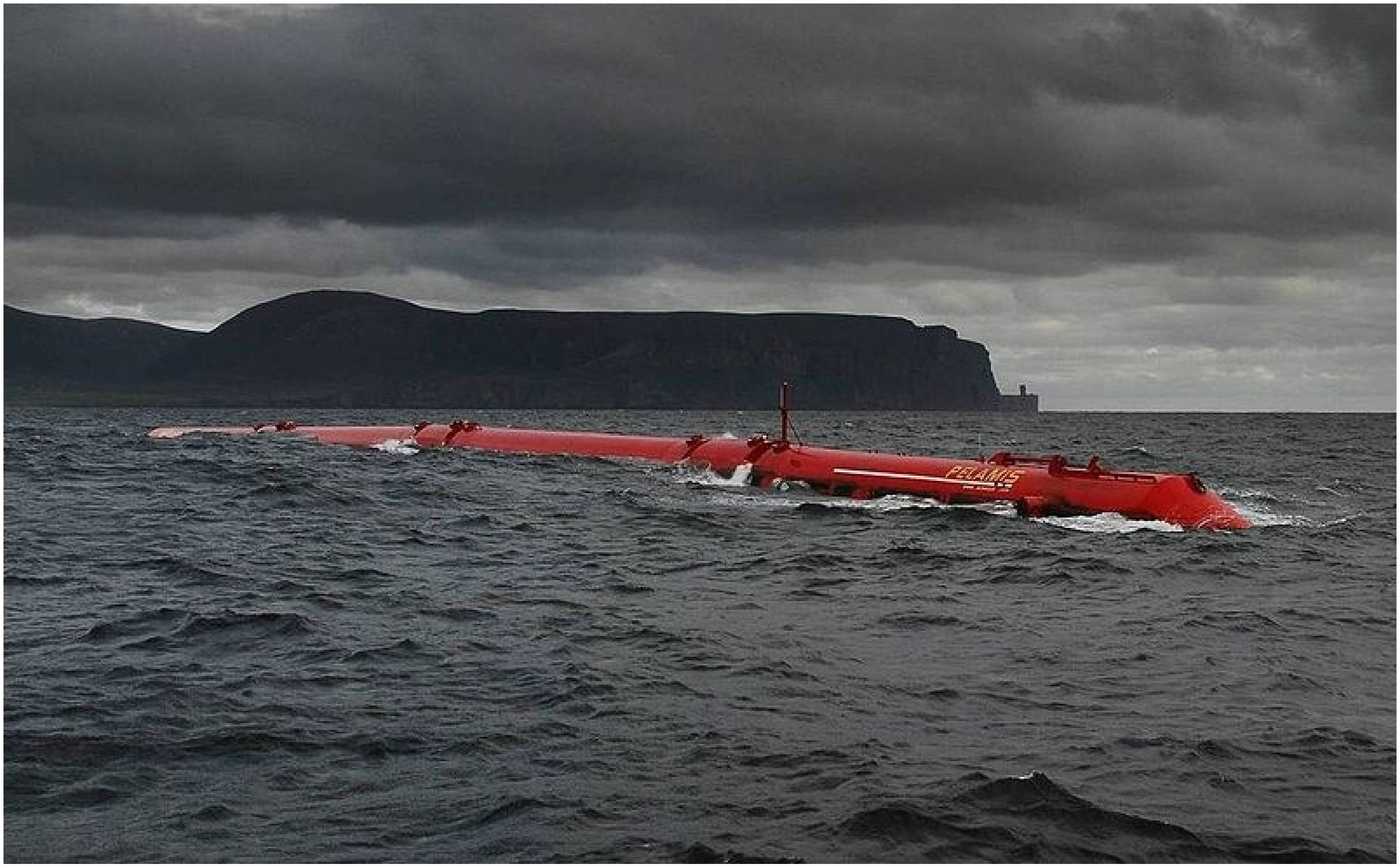
Oyster is a type of absorber system



- Seabed flap device
- "Oyster" concept developed at QUB by Prof. Trevor Whittaker

- Pressurised seawater delivered to the power take off unit
- Designed to extract energy from shallow water surge forces

Pelamis is a type of attenuator system



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Tidal Energy

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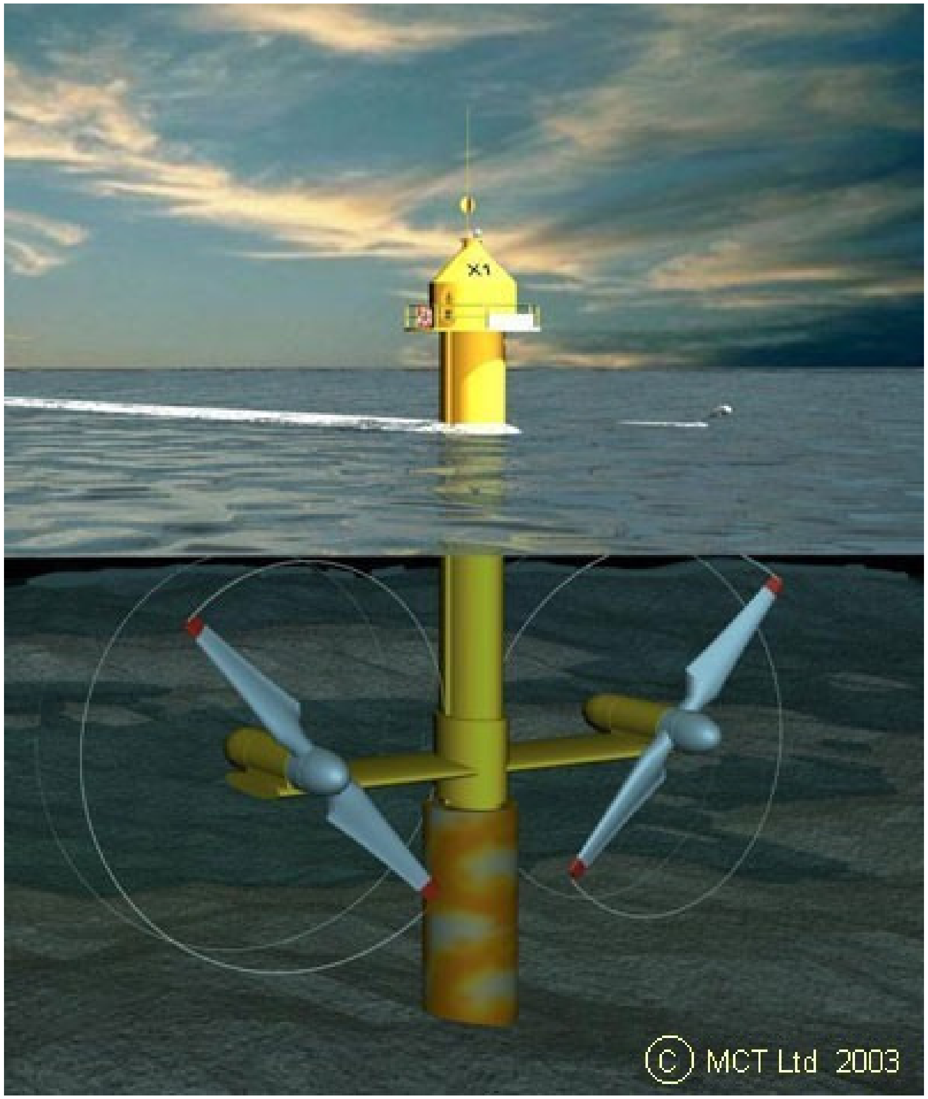
Tidal Energy

- Enormous energy stored far out at sea in the tidal stream
- Seen as greatest long term contributor to renewables
- The technology used to convert this to useful electrical energy is the Marine Current Turbine

Marine Current Turbine

- Same principle as a wind turbine, underwater
- Higher energy intensity than air so 10-20RPM sufficient
- 10 times slower than a ship propeller so little ecological impact
- 11m – 30m blade diameter = 300kW – 1MW
- Water is 40 times denser than air, so tidal stream turbines can be much smaller than wind turbines, or generate much more electricity



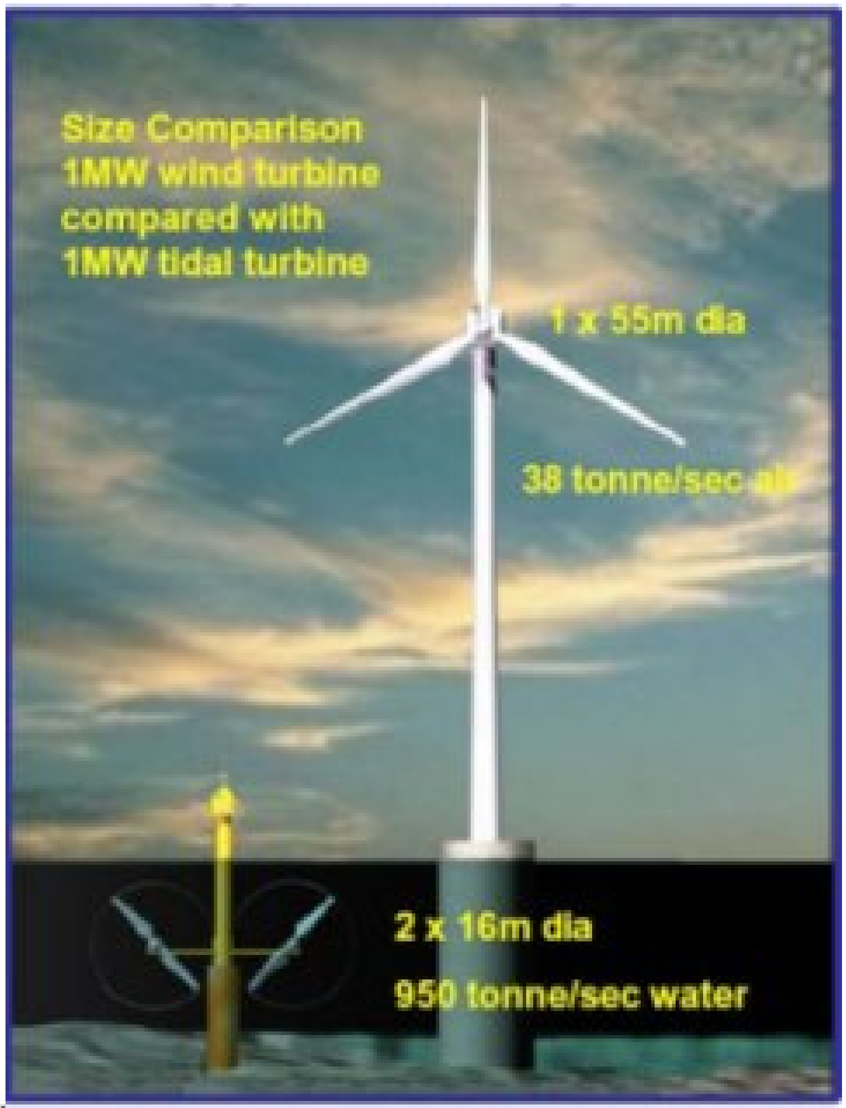
Proposed Marine Current Turbine design

Marine Current Turbines

- Twin power units mounted on winged extensions
- Installed in Strangford Narrows, Northern Ireland in May 2008
- First tidal stream turbine to export electricity to the Grid

- One turbine experienced a computer fault resulting in a damaged blade during commissioning
- Full commissioning now taken place and 1.2MW generated

1MW MCT **Vs** 1MW Off-shore Wind



Open Hydro – showing the venturi shroud

Marine Energy Centre in Orkney, December 2006

- Open centre slow moving rotor
- Permanent magnet in outer rim
- Installed at the European

Evopod

- Floating tethered device
- Plans to test a 1/10th scale prototype
- Can be deployed in waters over 40m depth where greater tidal stream energy is located

Tidal Barrages

- Large dams built across river deltas
- Captures the incoming tide, retains it, and then releases it through tunnels containing turbines
- The largest is on the La Rance Estuary in France
- It has 240 MW peak generating capacity

La Rance tidal barrage

Wave and Tidal Energy Summary

- Could be the second largest supply of renewable electricity in certain countries – Ireland, Scotland, Portugal. 10% of Ireland's electricity could be supplied by wave and tidal by 2020
- Resource requires investigation and detailed mapping
- Offshore wave hub is being installed off the coast of England to allow several systems to connect offshore
- Tidal is highly predictable
- Azerbaijan may have a wave resource, but has no tidal resource