What is the truth about climate change?

John E Midwinter FRS FREng
john.midwinter@btopenworld.com

Copies of my slides can be seen on
www.greatbealings.co.uk
under Parish Council

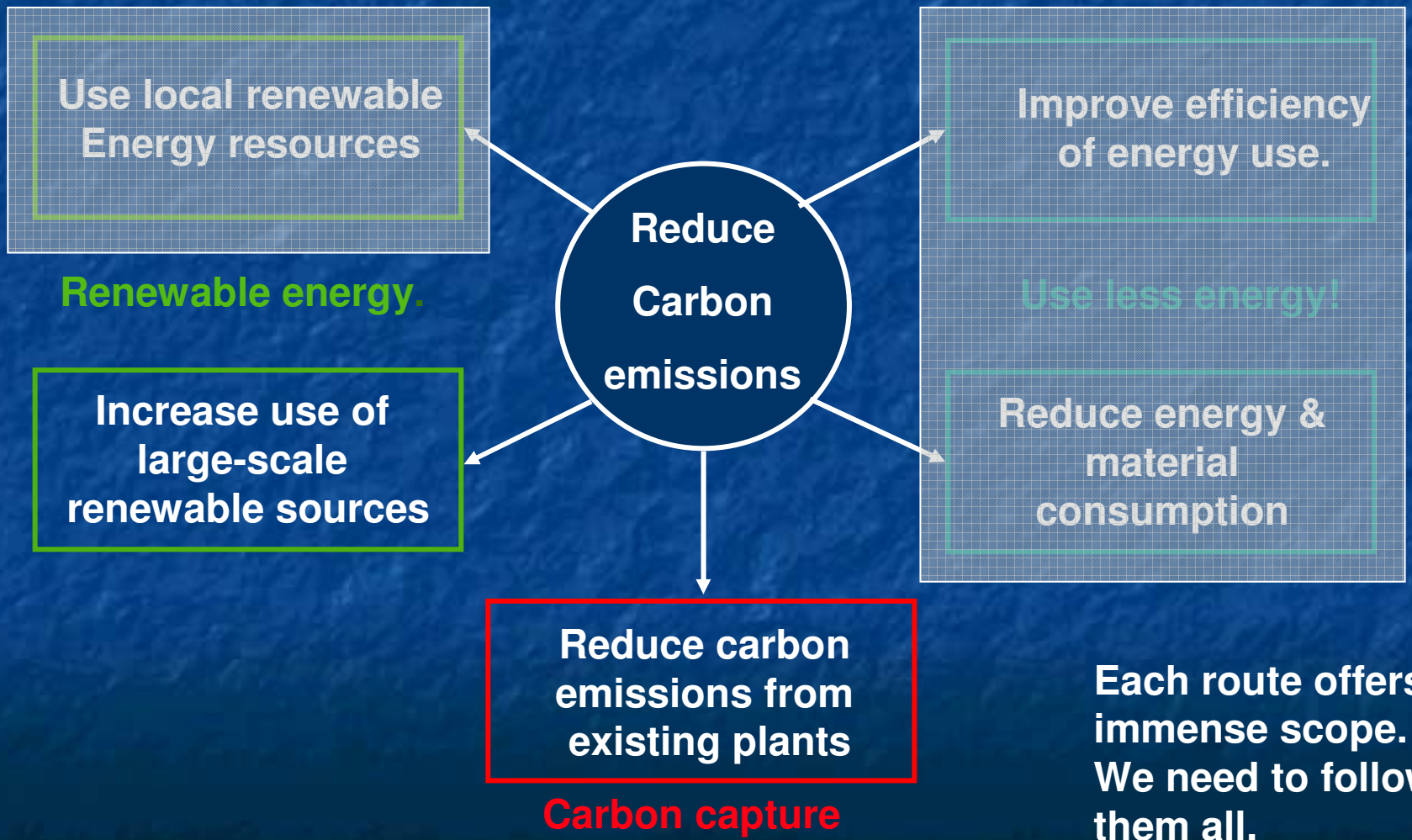
Lecture 4

What can be done about it at the National/ International level?

Bealings Village Hall

27 February 2008

Routes forward continued!



Each route offers immense scope. We need to follow them all.

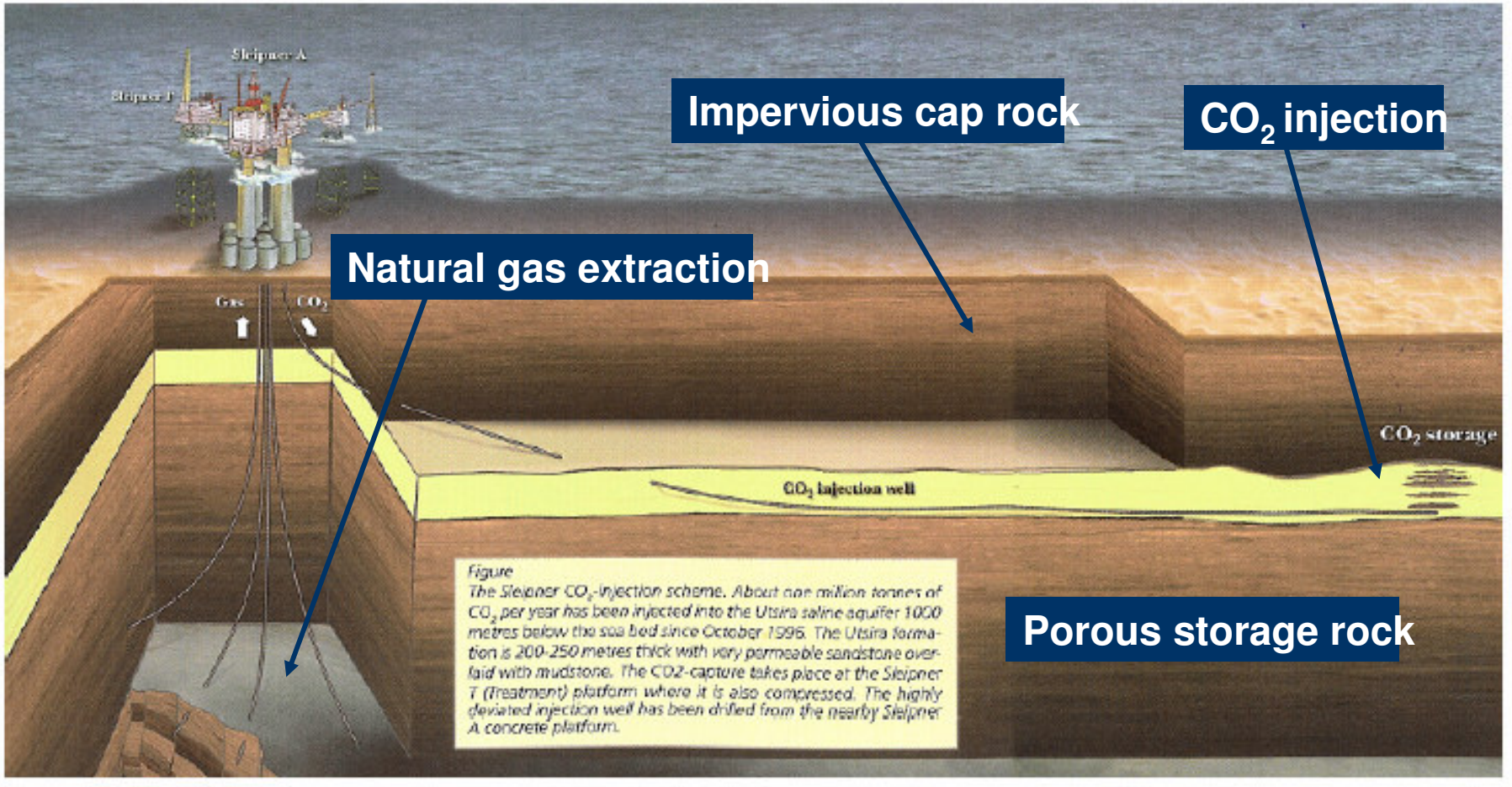
Carbon Capture & Storage

Statoil/Shell 860-MW gas fired Power Station at Tjeldbergodden, Norway.

Up to 2.5 million tons of CO_2 injected annually.

Carbon Capture & Storage

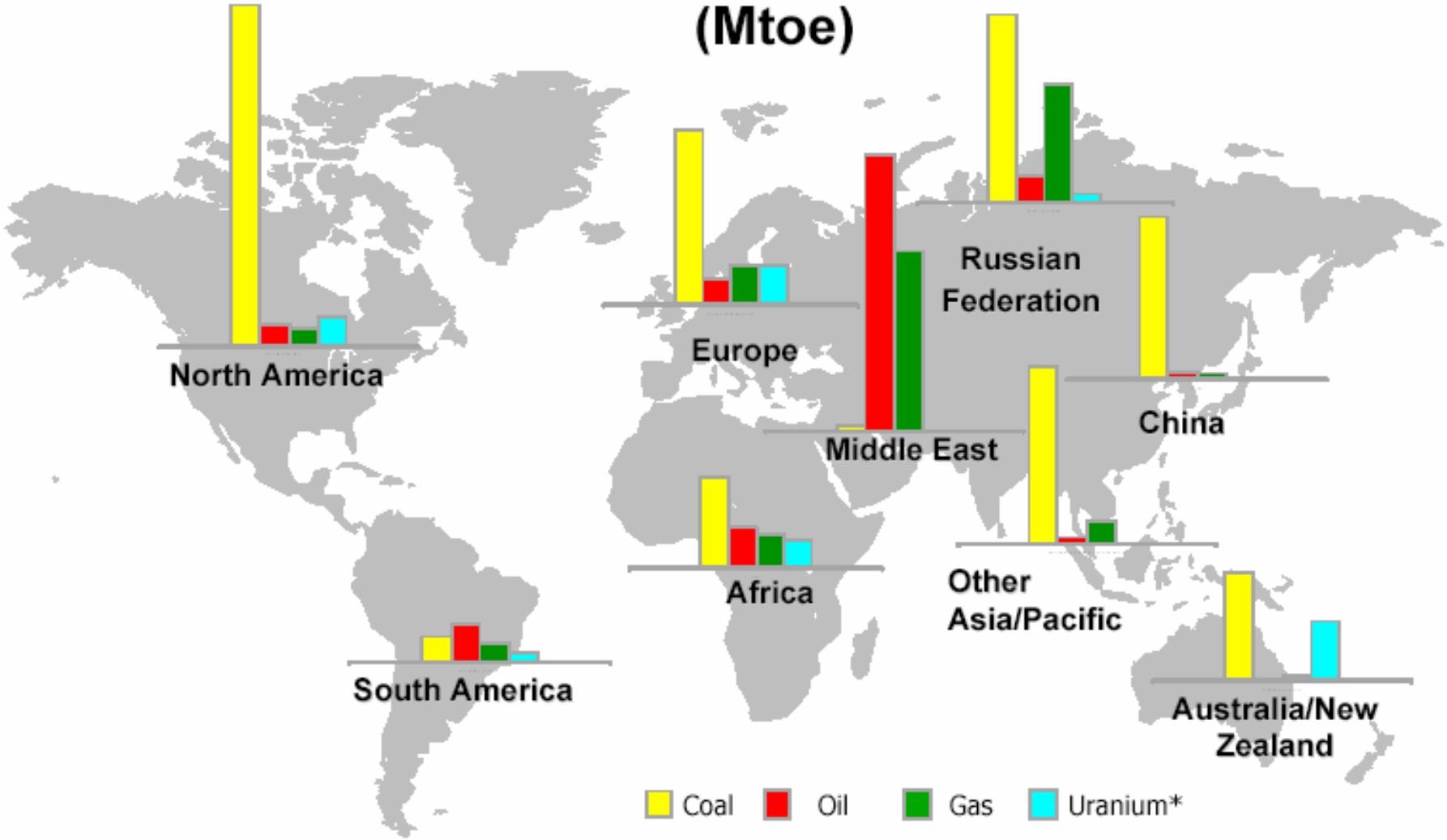
Sleipner (Oil & Gas Field) - Norway



Carbon Capture & Sequestration

- Critically important technology for climate-change minimisation
- Coal WILL be a key energy source for the foreseeable future (see next slide).
  - Because there is a huge amount
  - And nuclear fission won't meet global need
- But it imposes a cost on generation (5-10%)

World Energy Reserves 2004 (Mtoe)



Sources: BP Statistical Review 2005; WEC Survey of Energy Resources 2001; Reasonably Assured Sources plus inferred resources to US$80/kg U 1/1/03 from OECD NEA & IAEA Uranium 2003; Resources, Production & Demand updated 2005; *energy equivalence of uranium assumed to be ~20,000 times that of coal

Large Scale Renewables

- Wind Farm
- Tidal Barrage
- Tidal Stream
- Wavepower
- Solar Photo-Voltaic

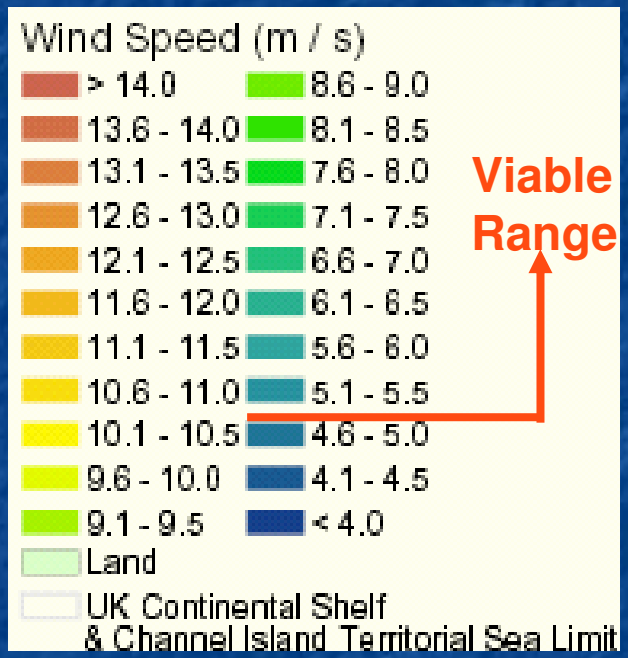
Dynamic Renewables - Use them or lose them

- Deep Geothermal
- Ground Source Heat Pump
- Biomass power station.
- Biomass Road Transport Fuel
- Hydro-electricity

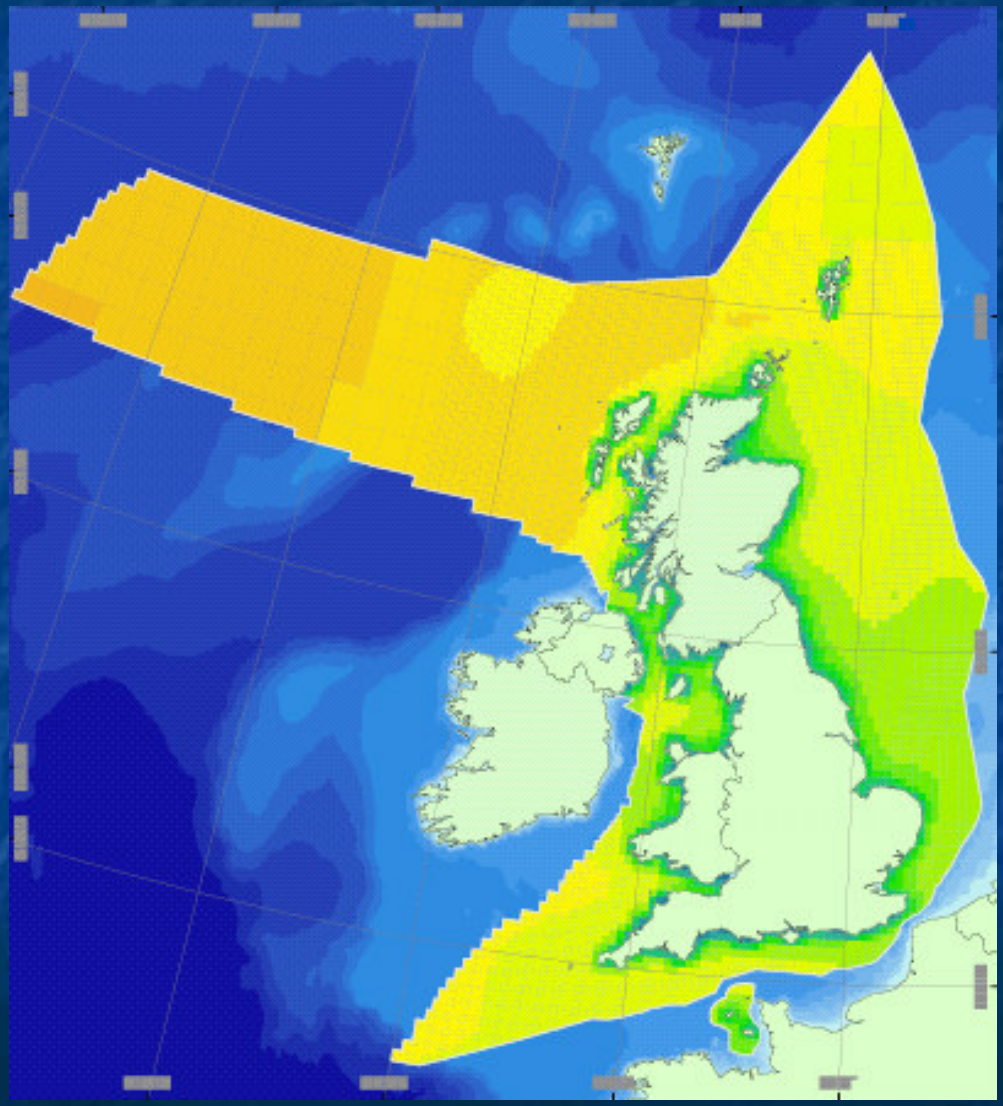
Continuous Renewables Use when needed.

Wind Farm

UK Offshore Average Wind-speed

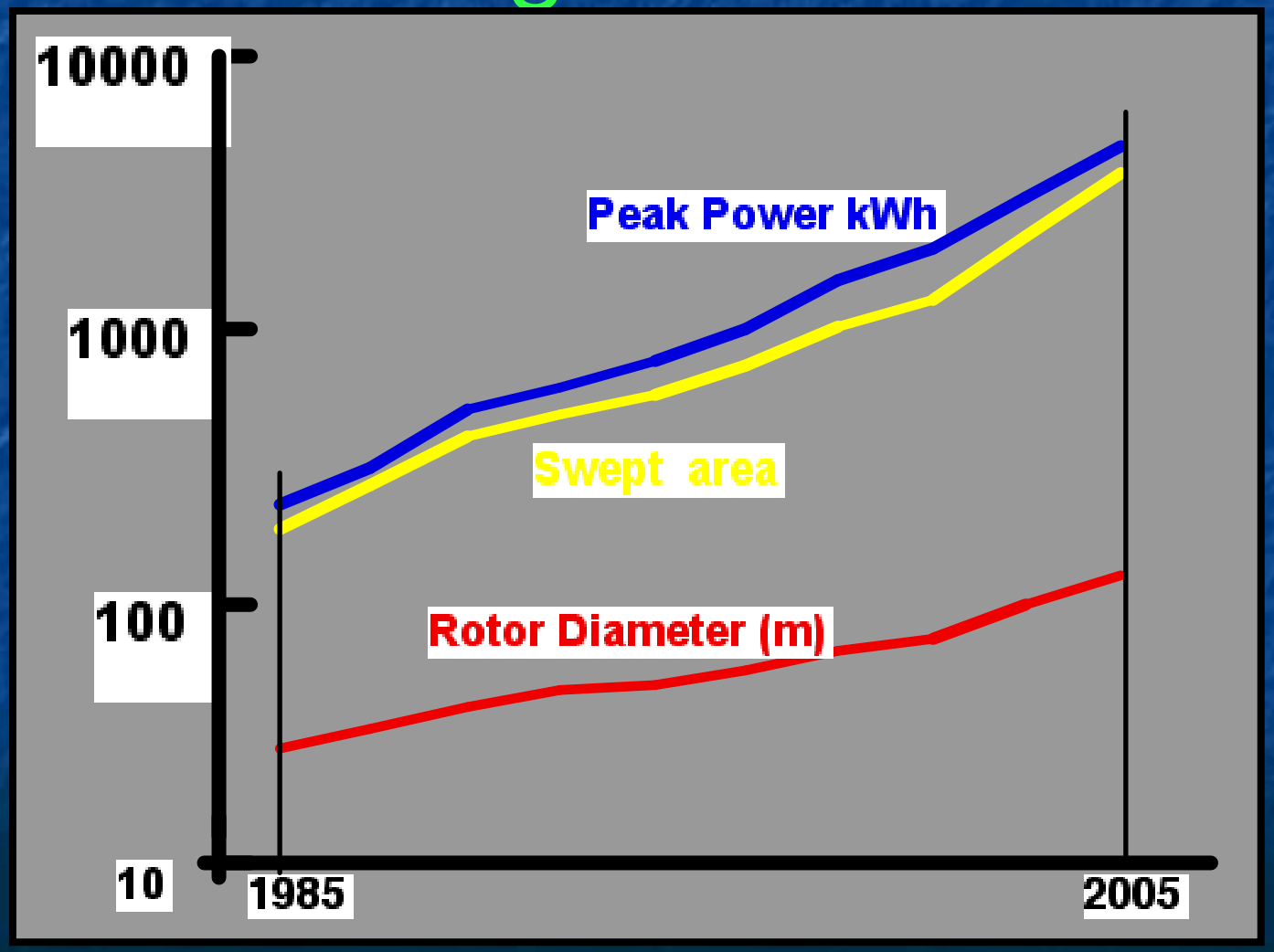


UK is the best place in Europe for wind power! (Which is why we are nor leading the way??)



From DTI Renewables Database.
www.dti.gov.uk/renewables/

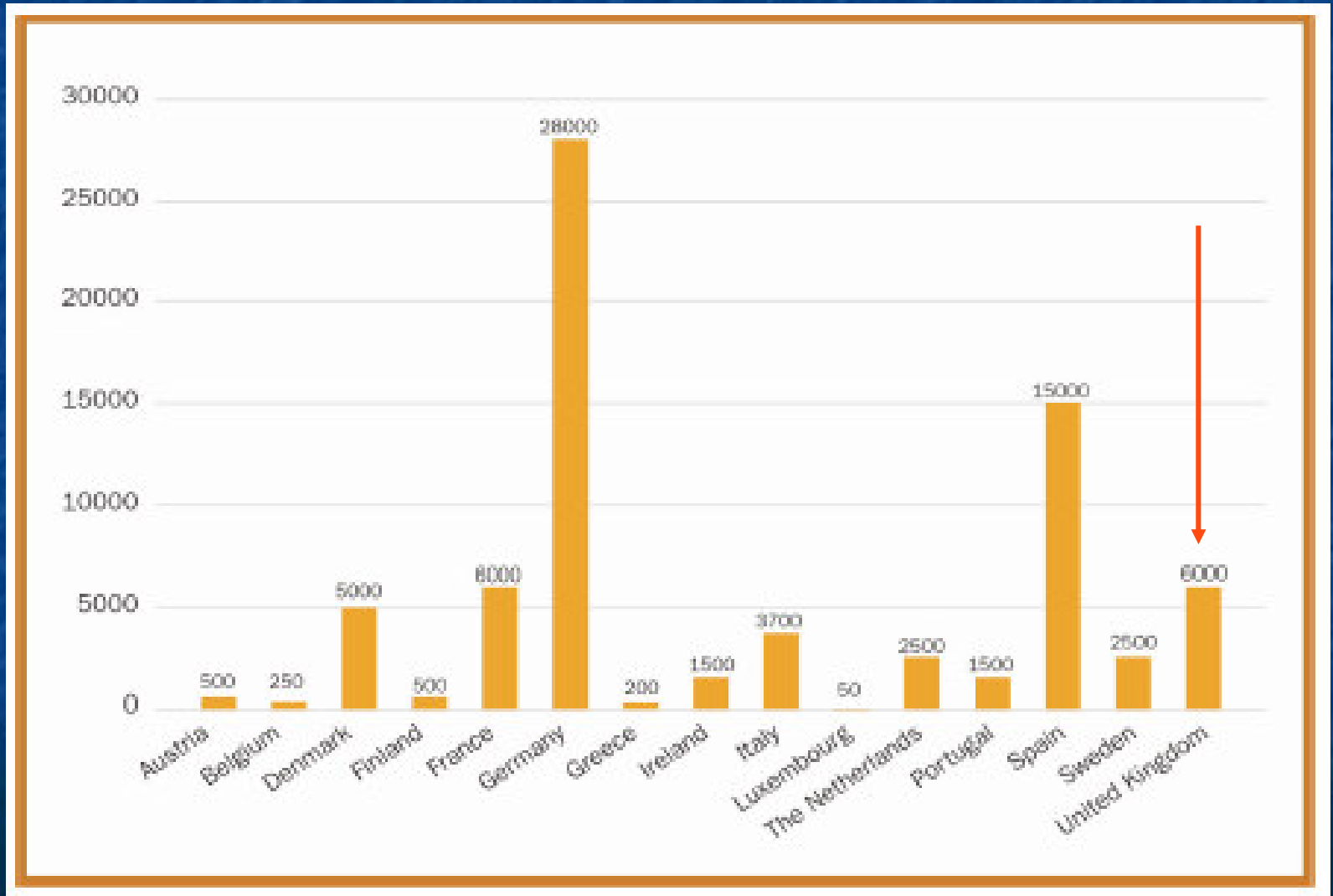
Wind Farm - growth in size of largest machines.



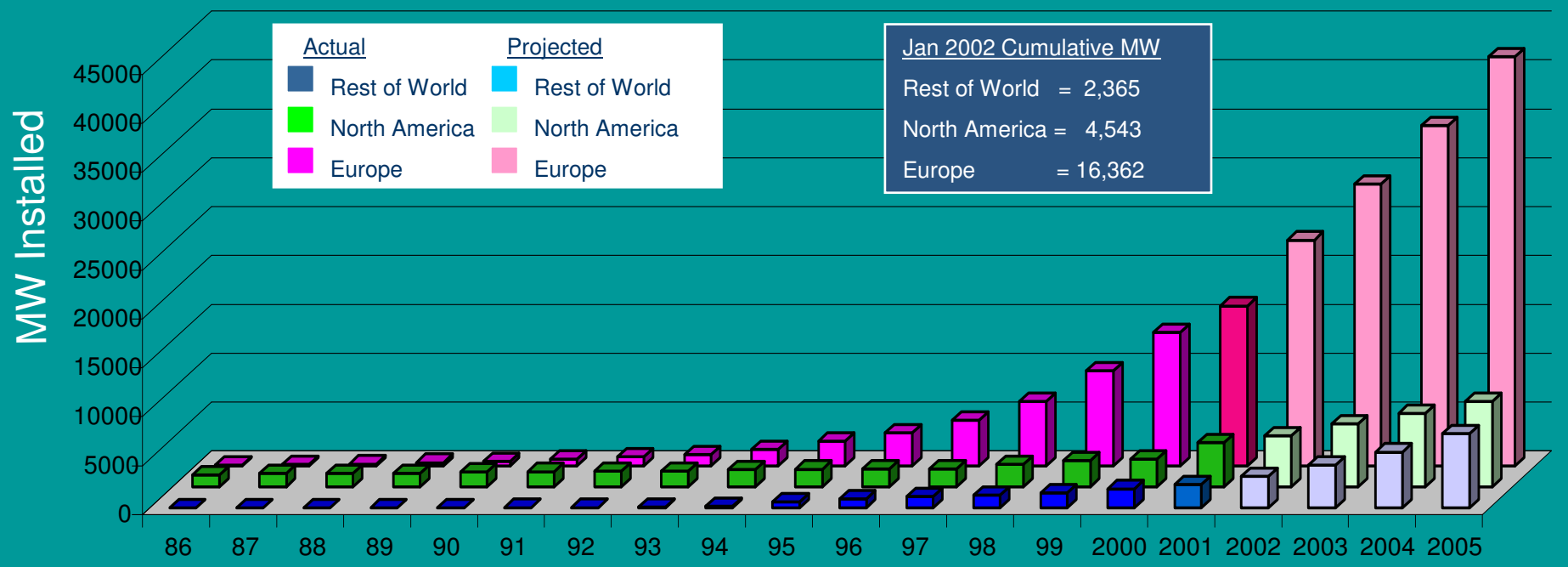
NOTE - Peak power varies as swept area or diameter squared.

Wind Farm - capacities by 2010

(MWp - in Europe).



Growth of Wind Energy Capacity Worldwide



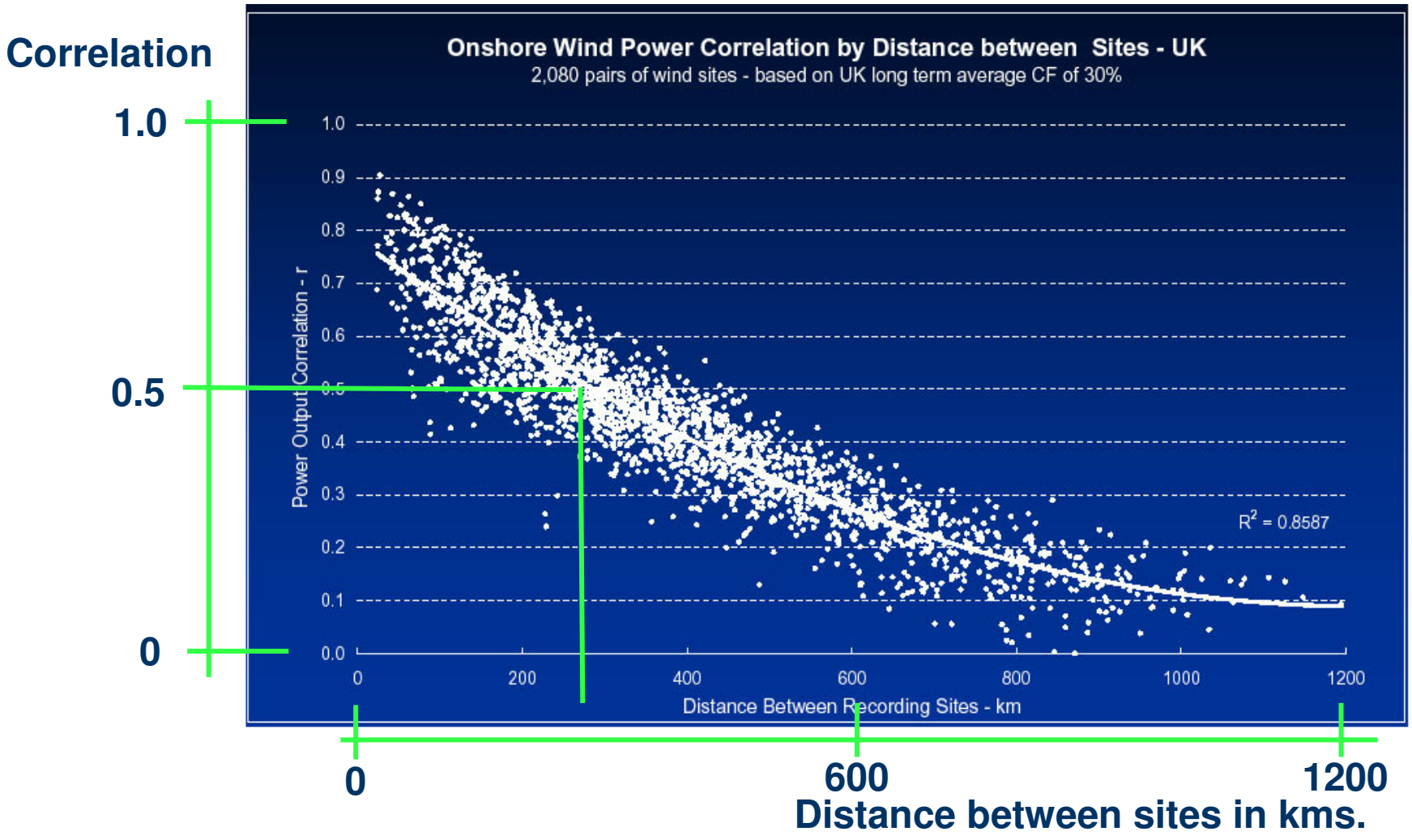
Source - NREL

Wind Farm - land-based scale!

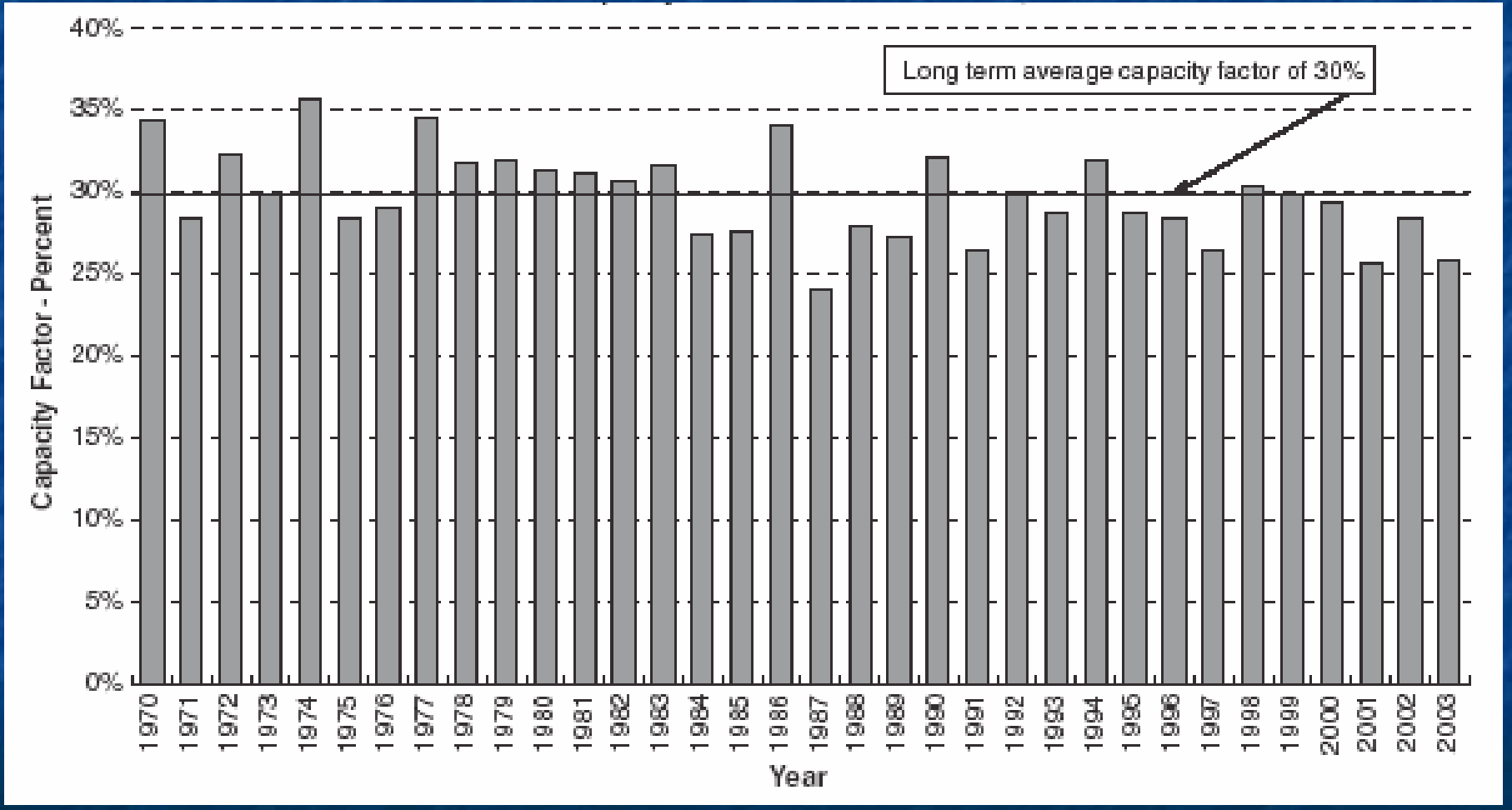
Wind Farm - ocean-based scale!

Correlation between wind-farm sites.

Source - Graham Sinden, ECI-Oxford



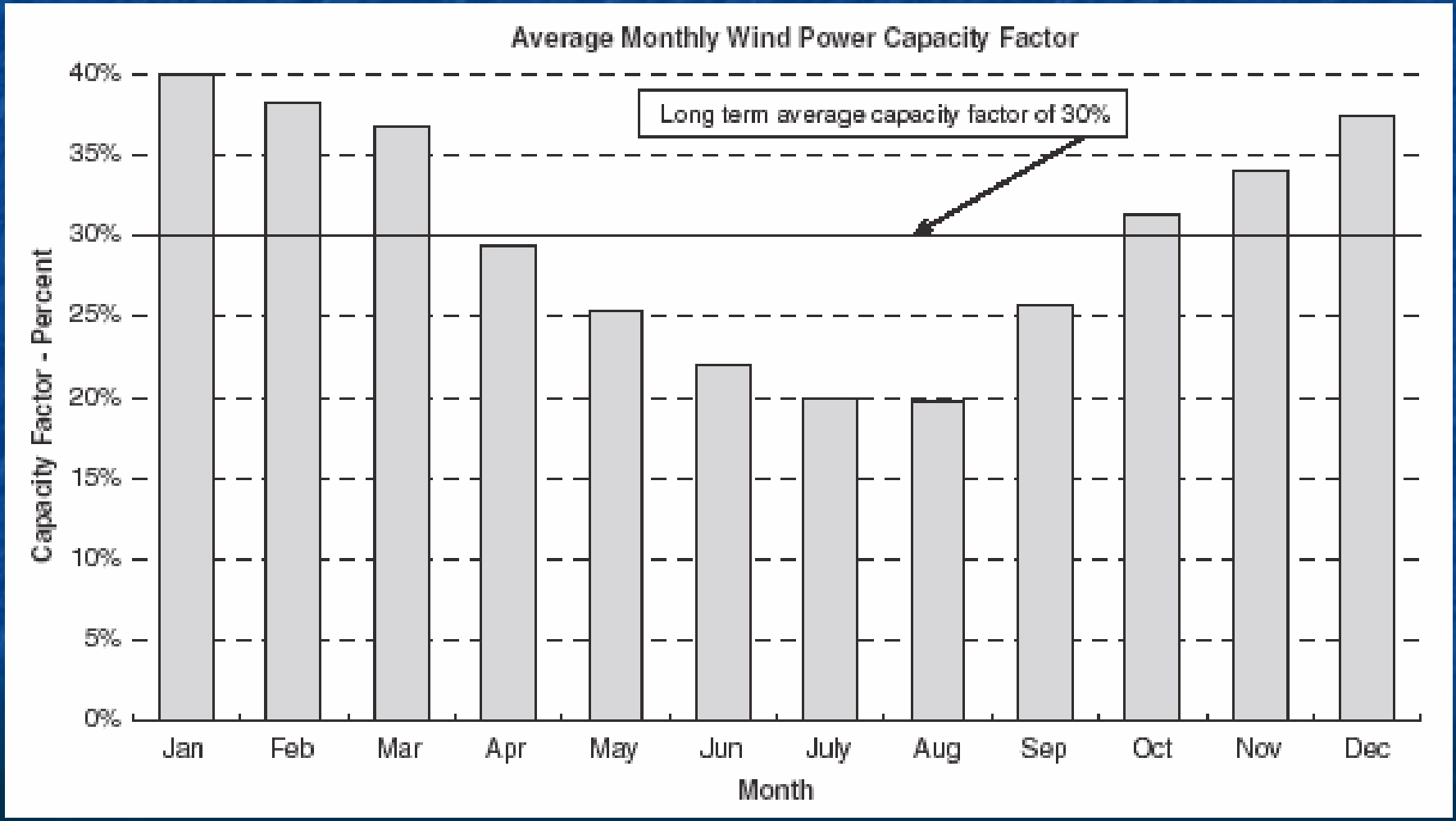
Wind Capacity Factor



Source - Graham Sinden - ECI-Oxford

Annual variation of wind energy.

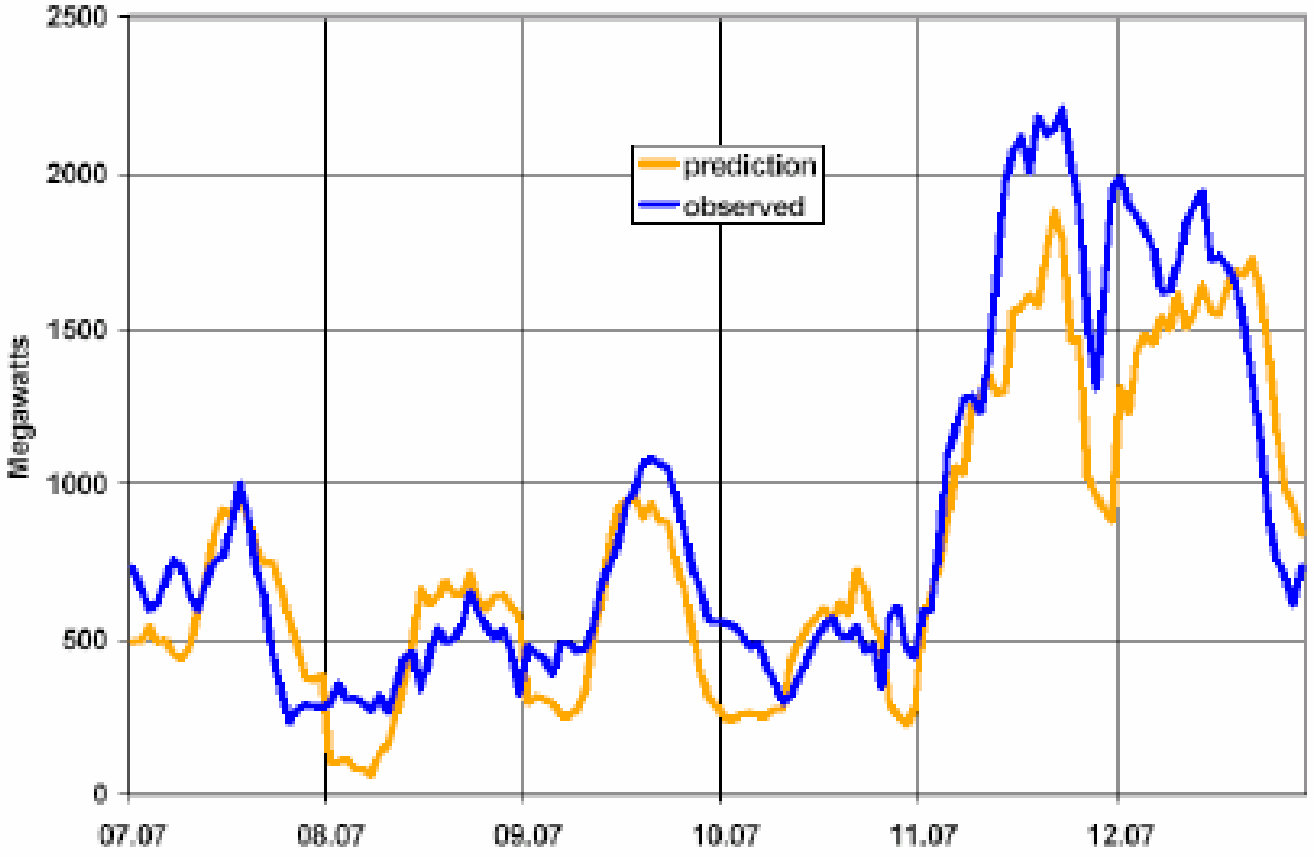
Wind tends to blow when you want extra power!



Source - Graham Sinden ECI-Oxford

Wind-power Prediction

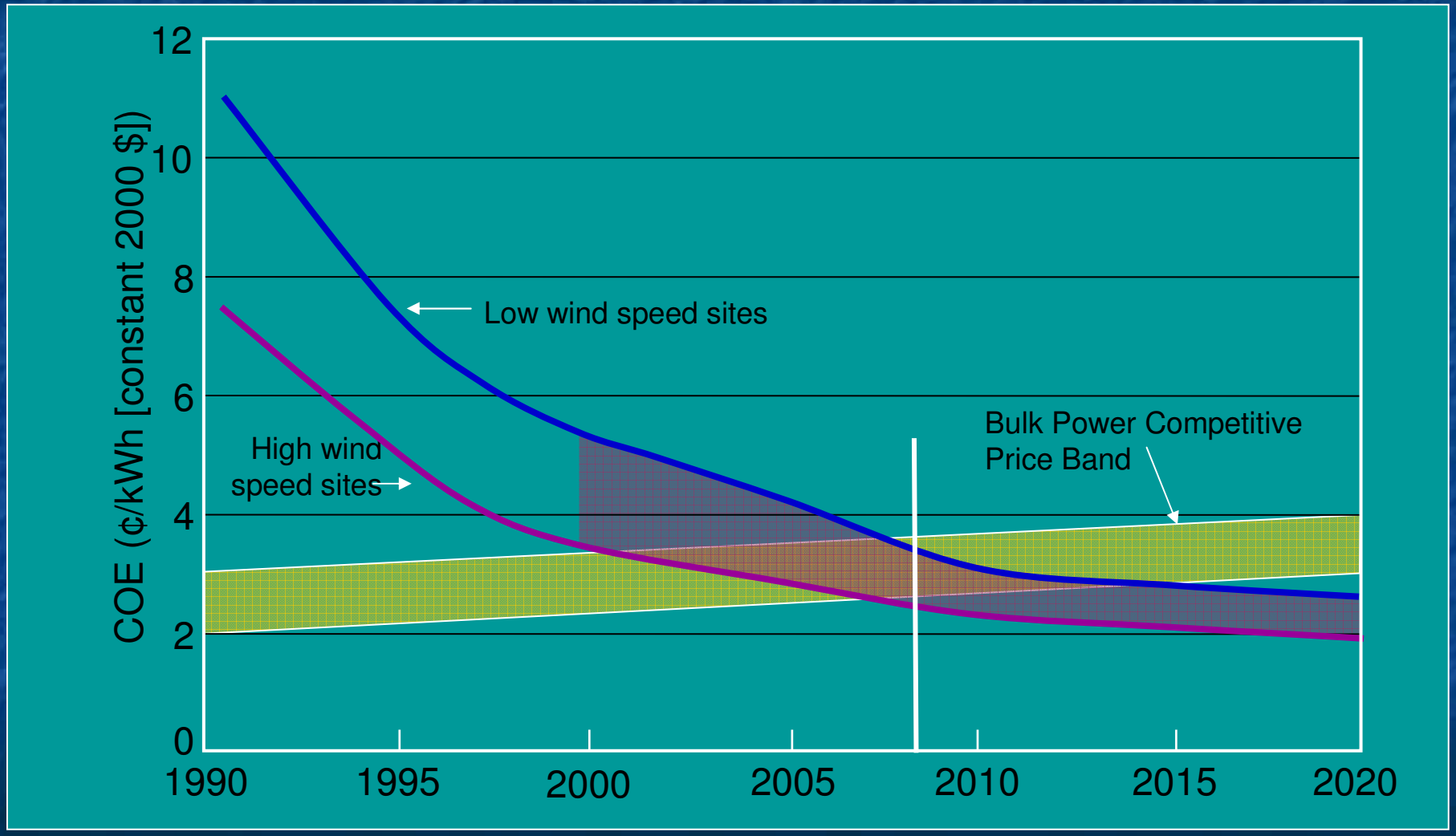
With modern forecasting - pretty good!



Predicted and observed wind power (ISET)

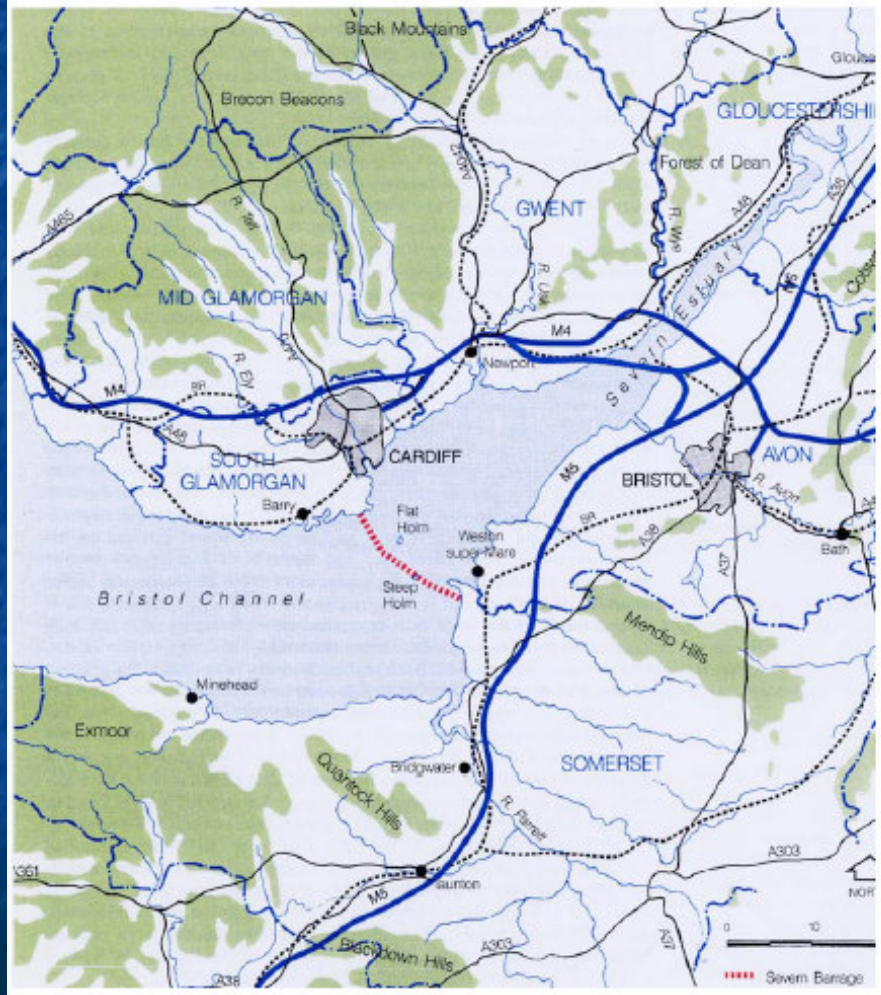
D Lindley: Energy 2100. 08.05.06

Cost of wind energy.



Source - NREL

Tidal Barrage

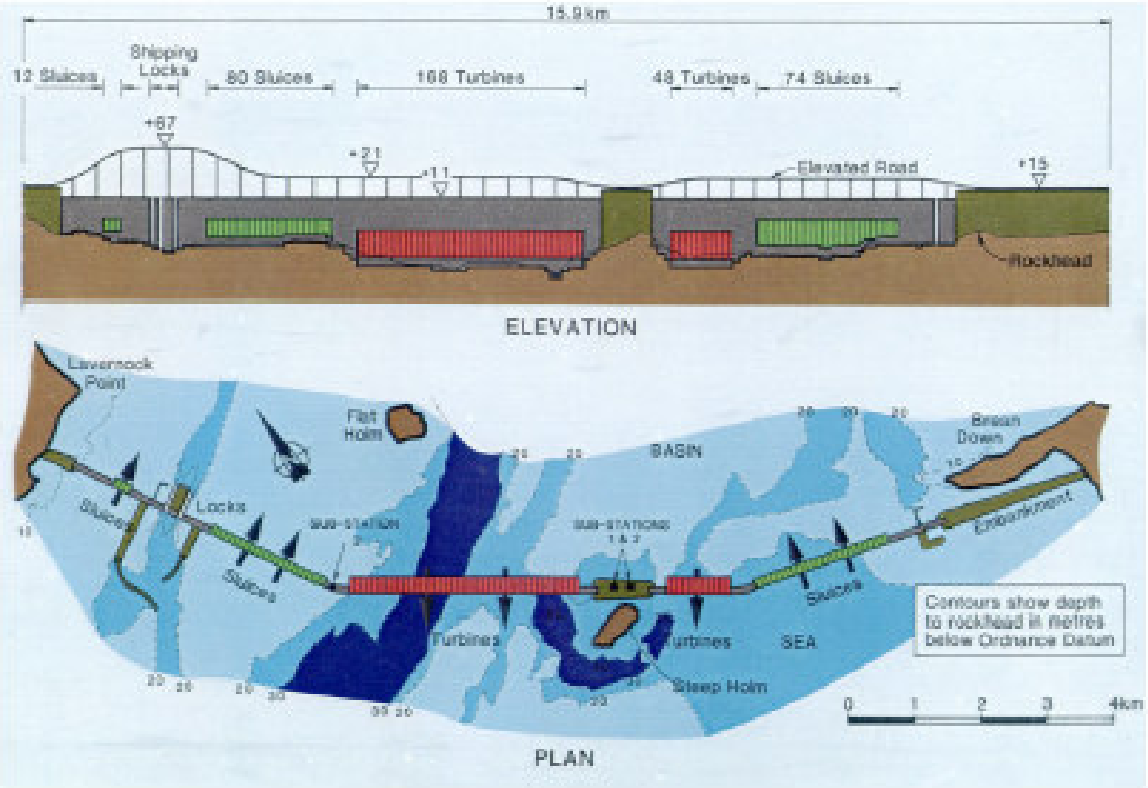


Severn Tidal Barrage

- UK potential mainly from Severn Estuary
- 17TWh = 5% of UK electricity supply
- Rated at 8640MW
- 7p/kWh (incl. financing & grid upgrade)
- Estimated capital cost =£14 billion (2006)
- Constraints
  - Project financing
  - Environmental issues

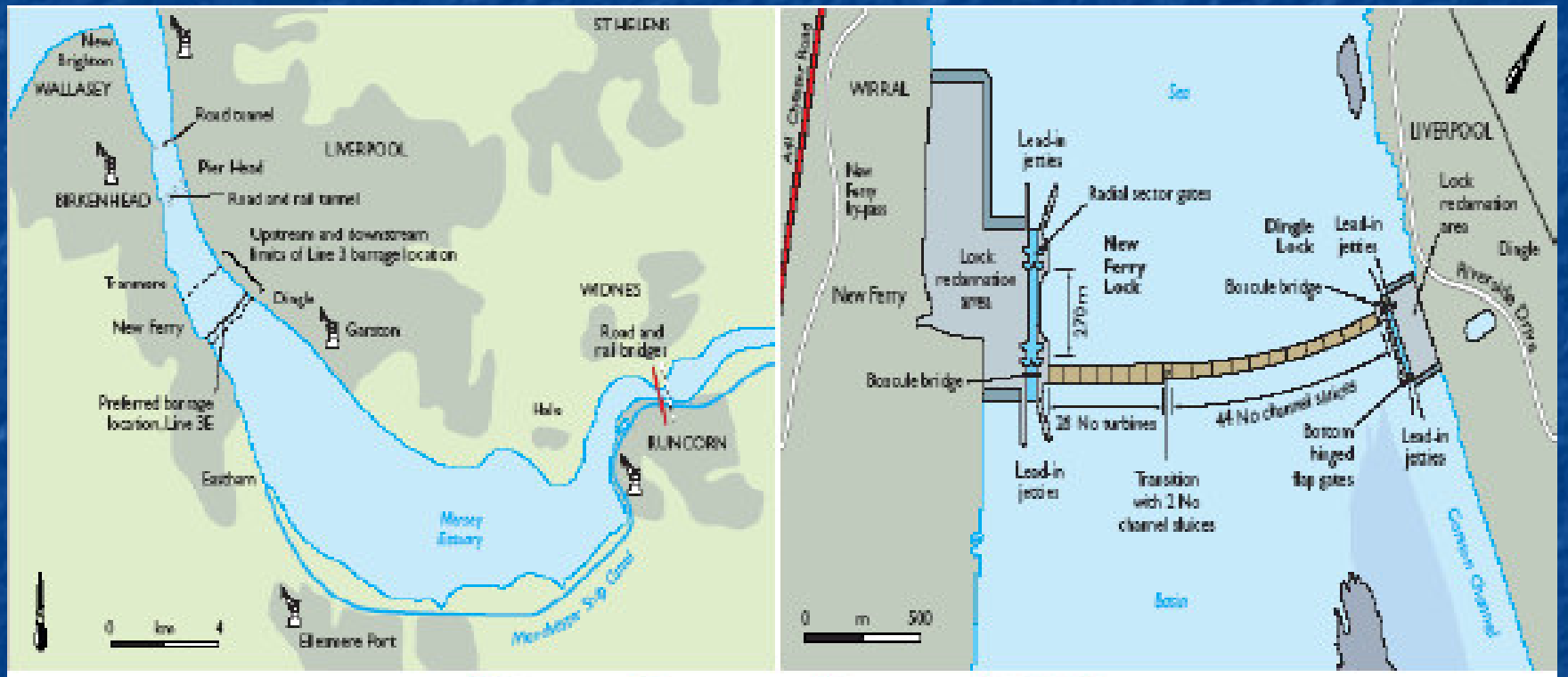
Tidal Barrage

Severn Barrage Layout (1989 report)



- 216 turbines (40MW each)
- 166 sluices
- Ship locks
- Small locks
- Public Road
- Railway (possibly)

Tidal Barrage



Mersey Barrage Proposal 1992

700 MW capacity & 1.45 TWh/year output

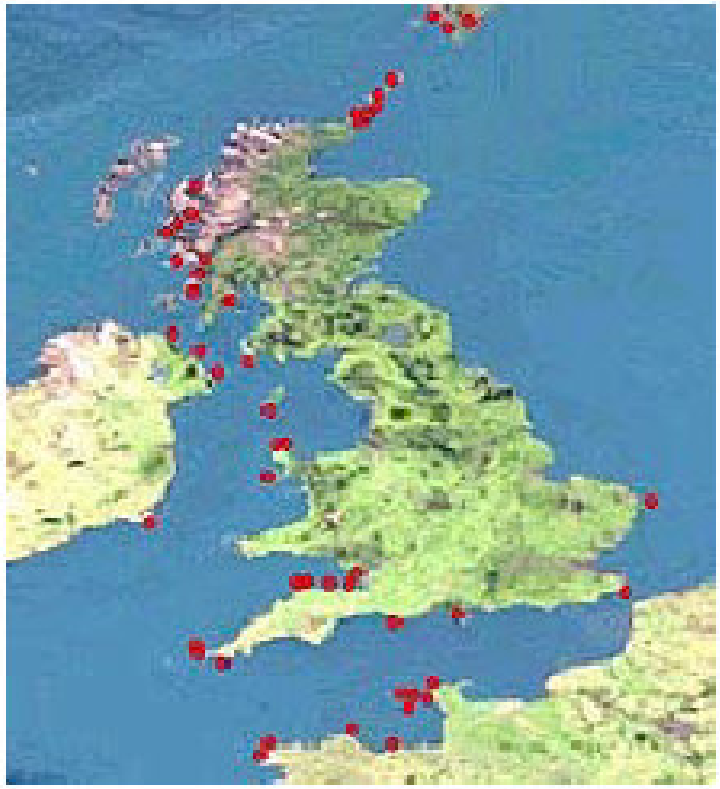
Estimated Capital cost (1992) = £900 million

Tidal Stream
(using the tidal current offshore)

Tidal Stream Resource
(Black & Veitch - for Carbon Trust - 2004-5)

Location	Total TWh/year	Extractable TWh/year	Economic TWh/year
UK	90	18	~12
Europe (excl. UK)	90	17	?
Worldwide (remainder)	600 ?	120 ?	?

Tidal Stream potential sites



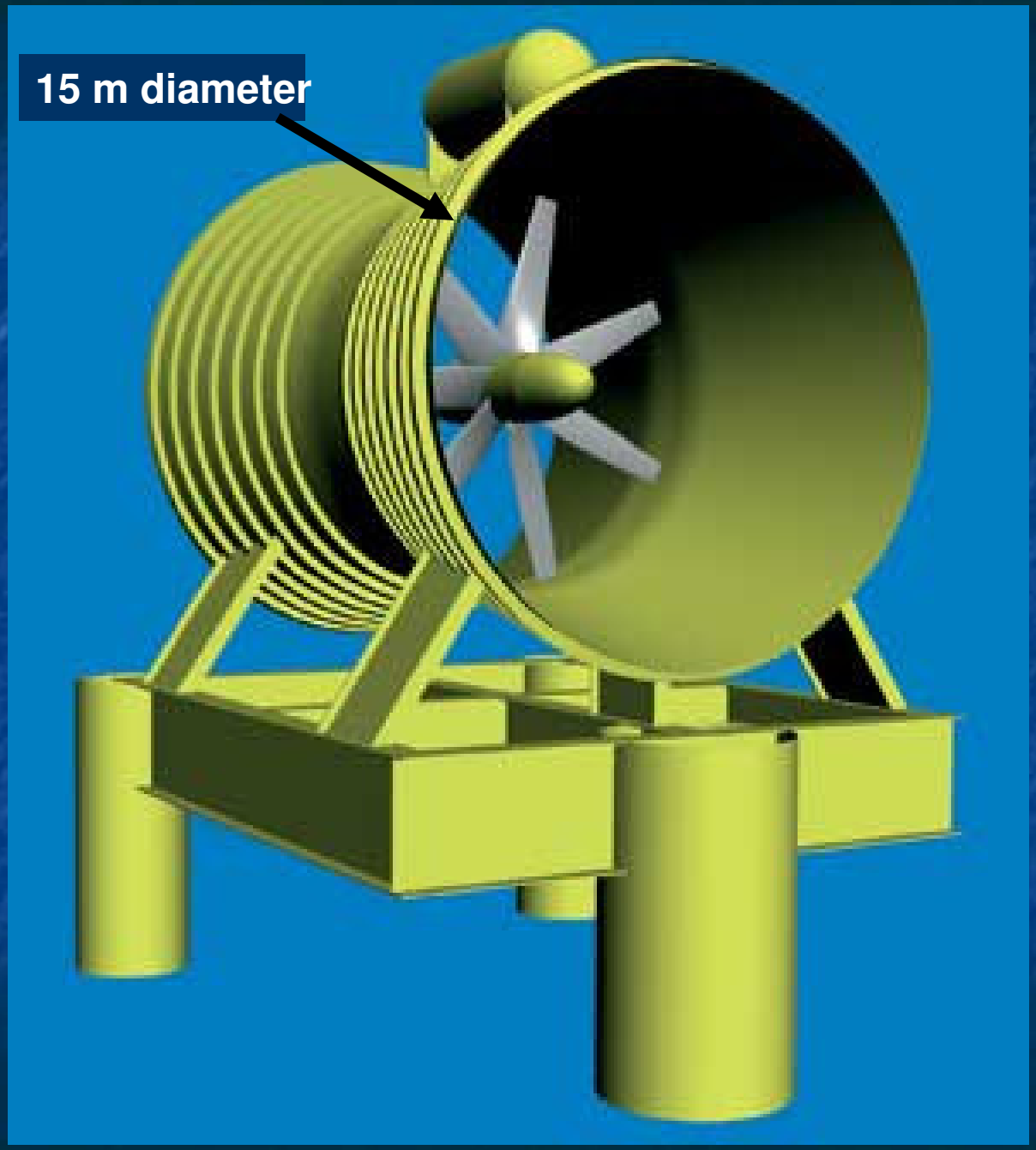
- Tidal Streams around the UK with Spring Tide > 2 m/s
- Water 800 times denser than air
- Water flow of 1m/s carries the same energy density as a wind flow of 9m/s
- Constraints
  - Technology at an early stage
  - Best sites are remote (e.g Orkneys and Channel Isles)
  - Costs uncertain at present

  >9p/KWh for first farms

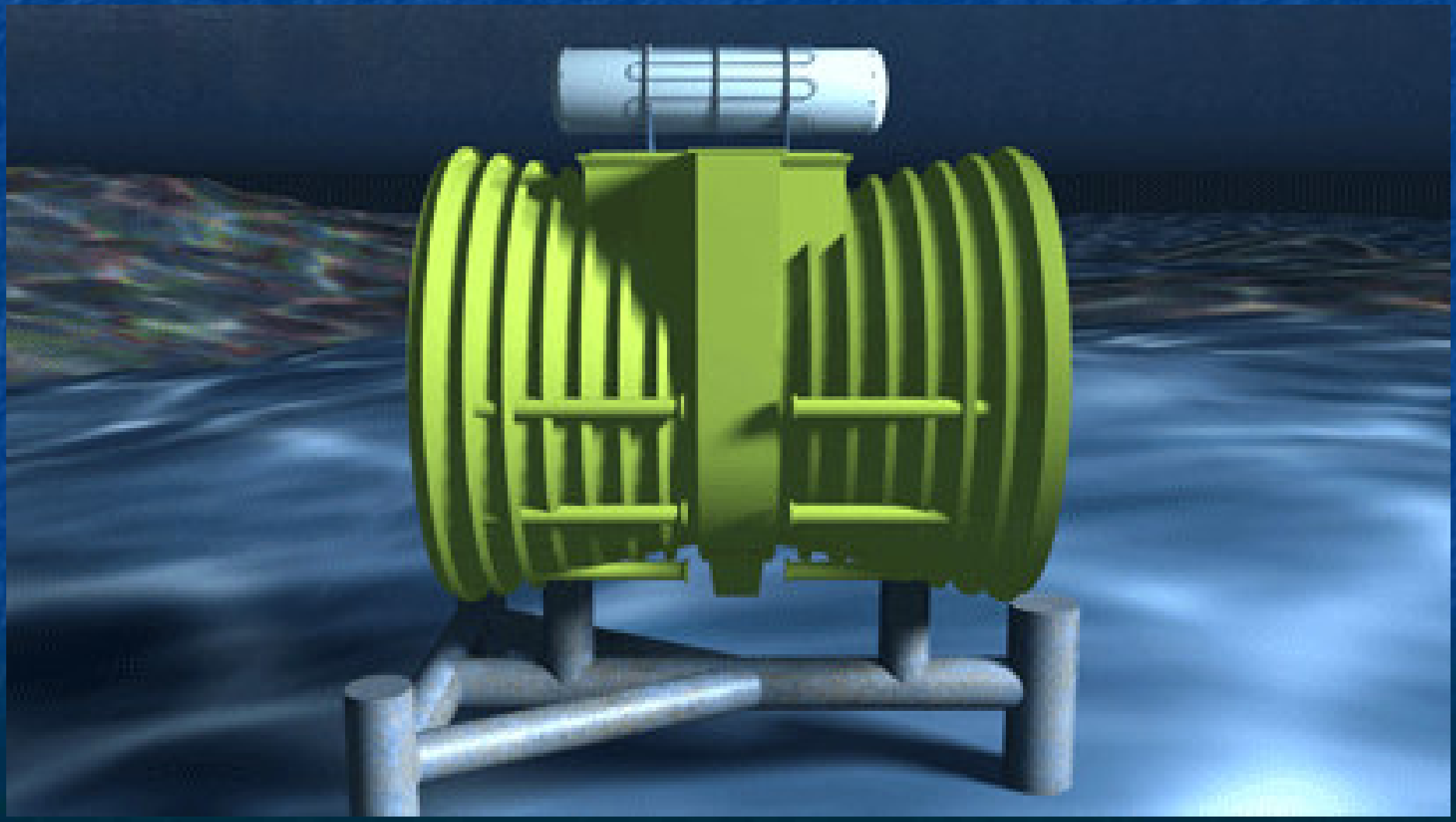
A Tidal Stream machine

Seagen - 1MW device Operating in Strangford Lough, Norhern Ireland.

Another Tidal Stream machine - Lunar Energy Co.



Side view of system.



Lunar Generator Specifications

- 1 MW peak power output
- Duct diameter 15 m
- Duct length 19.2 m
- Turbine diameter 11.5 m
- Operates at depths down to 40 m
  - This covers 63% of potential sites in UK
- Being installed by E-ON in SW Wales.

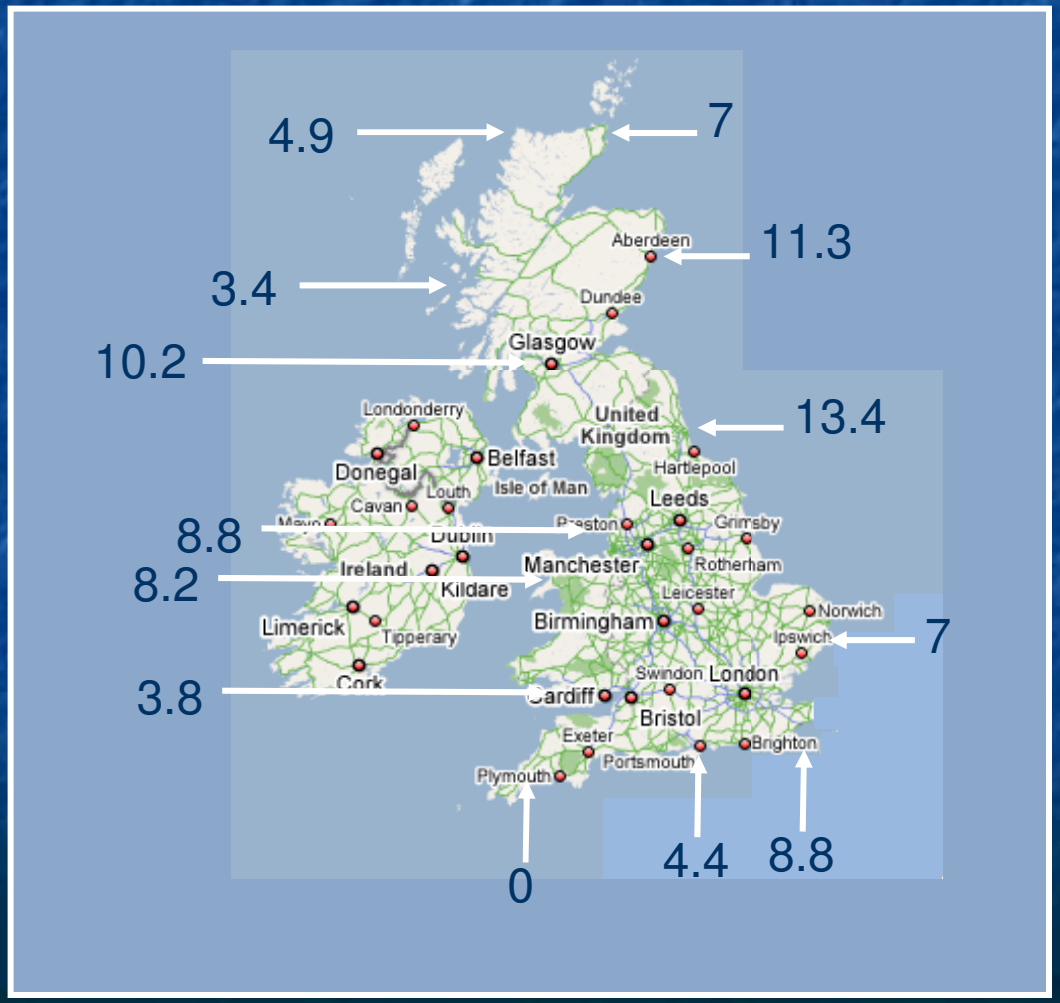
Tidal Stream and Barrage Generation

Obviously they can generate power for a maximum of two periods per day with dead periods in between -

BUT -

Tidal delays relative to Falmouth (in hours)

Generators at different sites will generate power at different times.



Wave Power - Pelamis

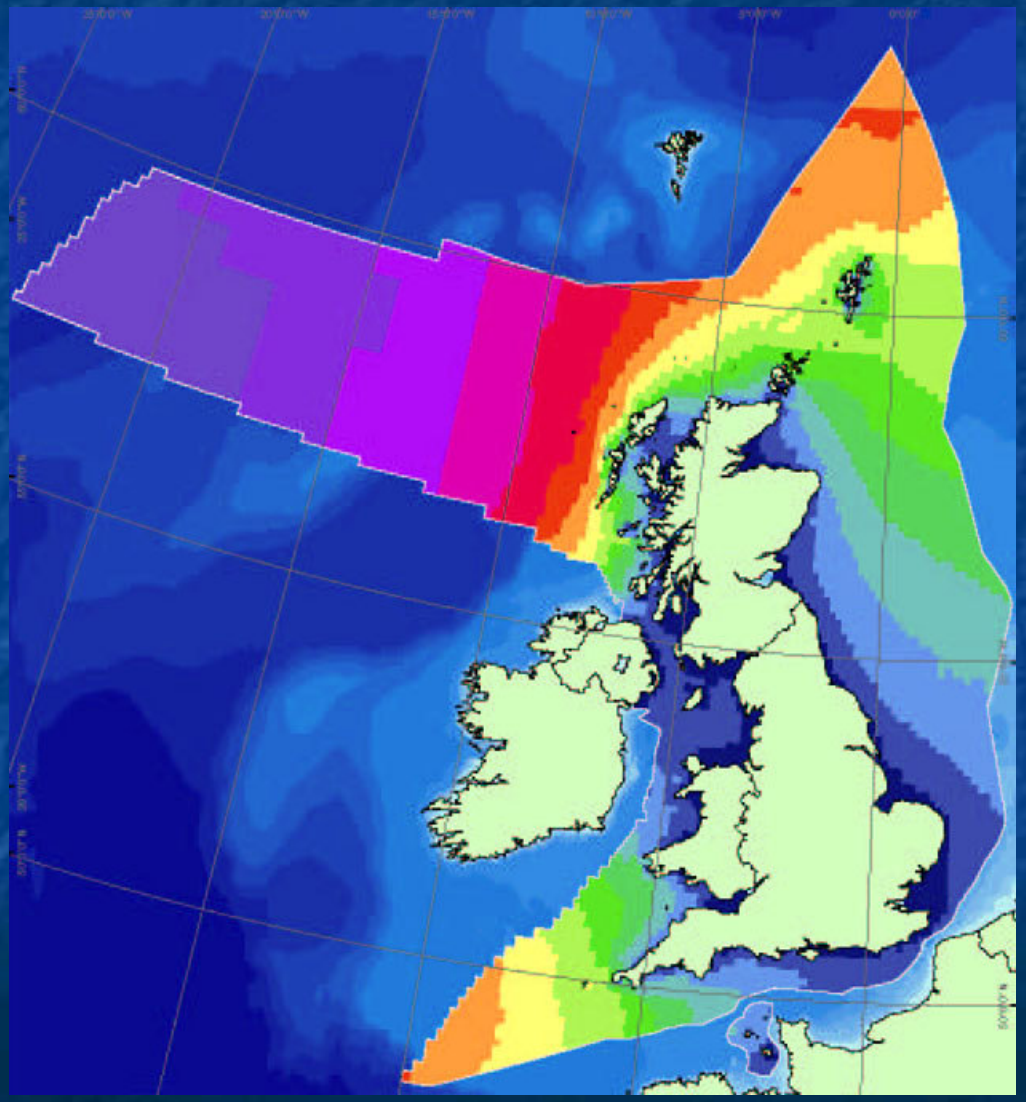
UK Offshore Average Wave Power

Mean Wave Power
(kW / m of wave crest)

> 70	36 - 40
66 - 70	31 - 35
61 - 65	26 - 30
56 - 60	21 - 25
51 - 55	16 - 20
46 - 50	11 - 15
41 - 45	6 - 10
	0 - 5

Land

UK Continental Shelf
& Channel Island
Territorial Sea Limit



UK again one of the best places in Europe.

From DTI Renewables Database.
www.dti.gov.uk/renewables/

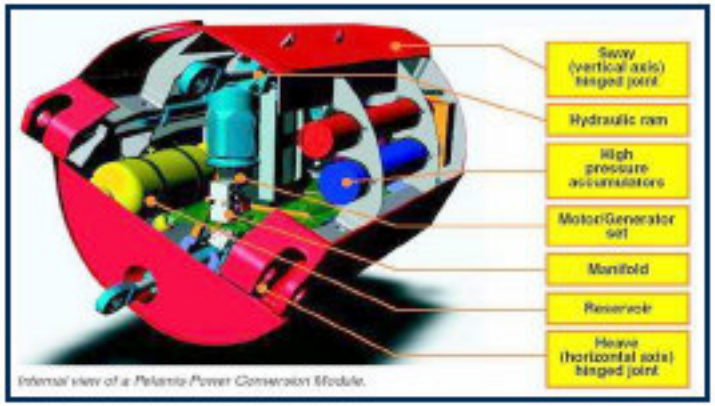
Wave Power - Pelamis Power Module

PELAMIS WEC

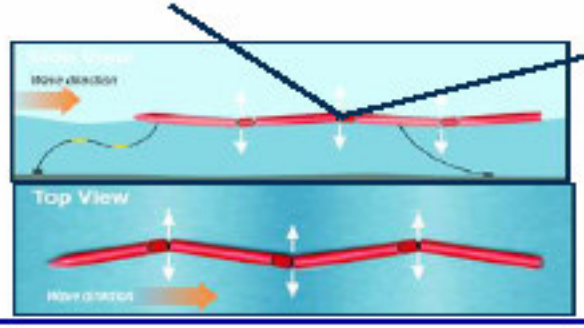
Concept
- Articulated cylinder
- Self-referenced
- Slack moored
- Head-on to incident waves

Power Conversion Module
- 4 x hydraulic rams (2 heave, 2 sway)
- 2 x 125kW motor/generator sets
- 250kW rating

Complete machine
- ~ 150m length
- 3.5m diameter
- 750kW rating
- 2.7GWh p.a.



Internal view of a Pelamis Power Conversion Module.



Wave Power - Pelamis construction

Wave Power - Pelamis deployment

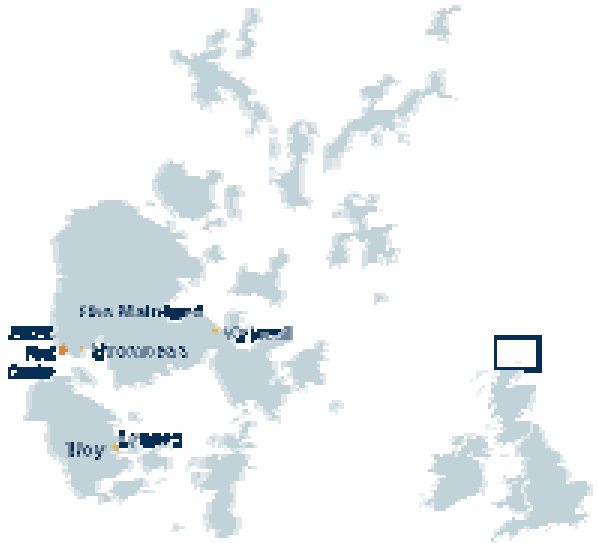
Project #2 – Scottish Power, UK

Phase 1

- Five Pelamis P-1A 750kW machines
- 3.75MW
- Sited at EMEC, Orkney
- **Project approved September 2007.**

Phase 2 expansion

- Expand project to 22.5MW
- Move to permanent site (Orkney)
- Grid connection application submitted
- Consenting process started



ScottishPower

OCEAN POWER DELIVERY LTD

A large installation for SW Cornwall also approved September 2007

Intermittent vs Predictable

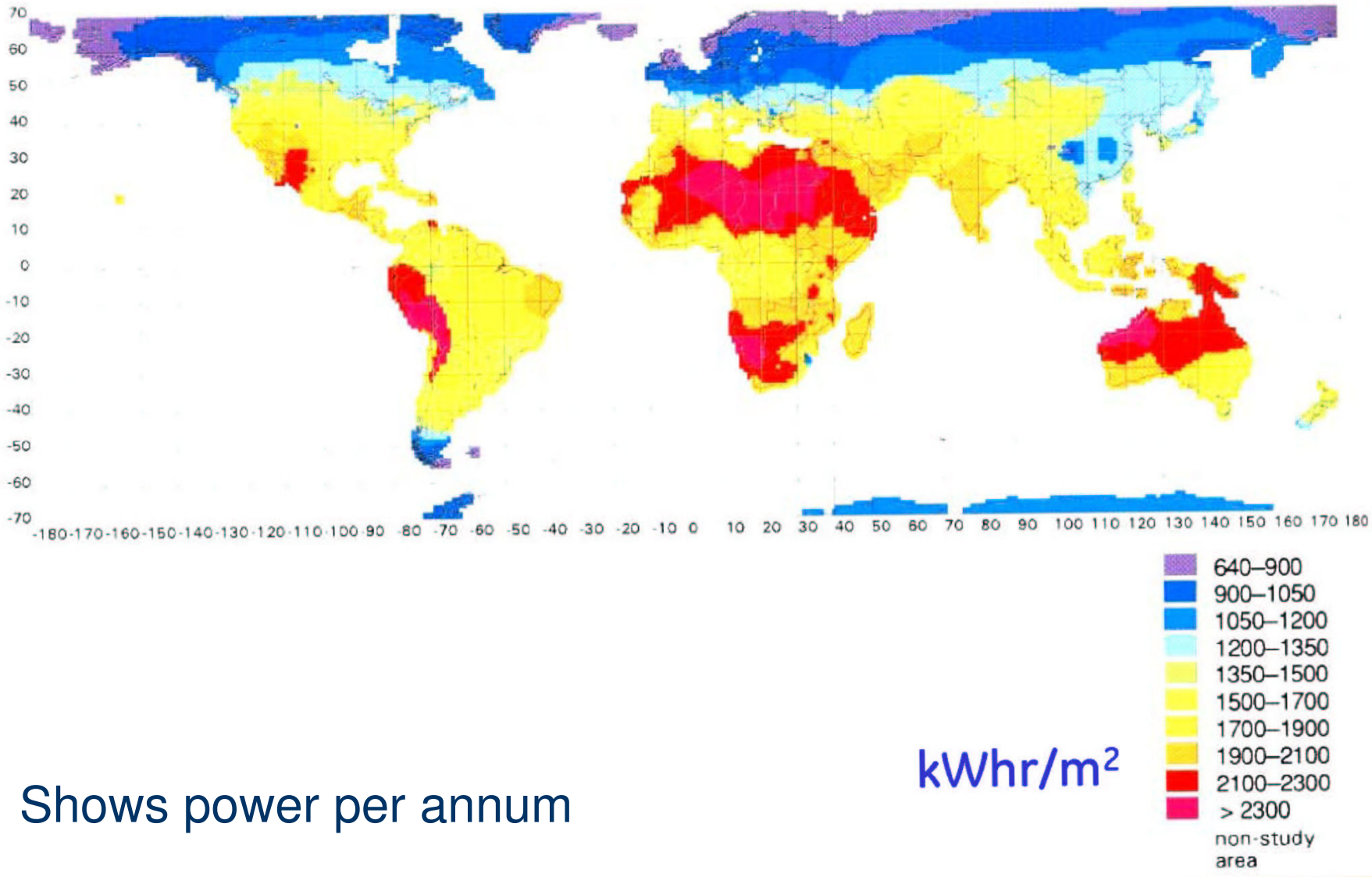
- Tidal energy is intermittent but entirely predictable for months ahead.
- Tidal flows peak at different times around our coasts

- Wind and Wave power are not predictable long term but are predictable a few days ahead
  - - e.g. short term weather forecasts.
- Multiple wind generators and sites smooth short term fluctuations and improve overall reliability.

Solar Photo-Voltaic Power

- Uses huge arrays of solar cells
- Converts sunlight directly to DC electrical power
- Slowly becoming cost effective
- Power available about 0.9 MWh/m^2.annum
- Efficiency 15-20%
- So generate ~ 200 kWh/m^2.annum
  - my home would need about 25 m^2 collectors
- So uses large area of land.

Global solar resource

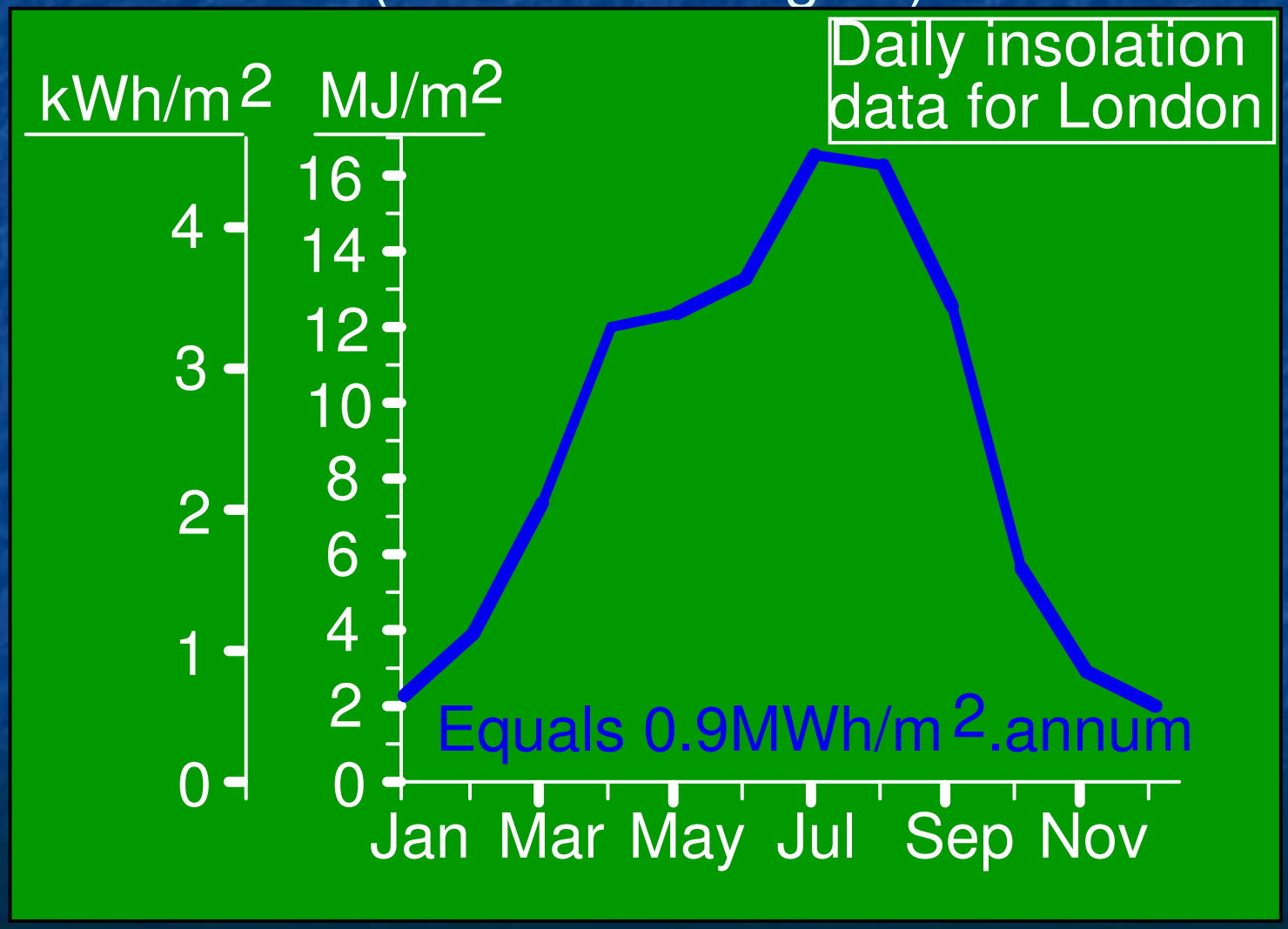


kWhr/m²

Shows power per annum

Solar radiation arriving in UK

(at all wavelengths)



Solar Photo-Voltaic Power

With cost reductions currently promised by some manufacturers, could become a reality especially in sunny climes!

Large Scale Renewables

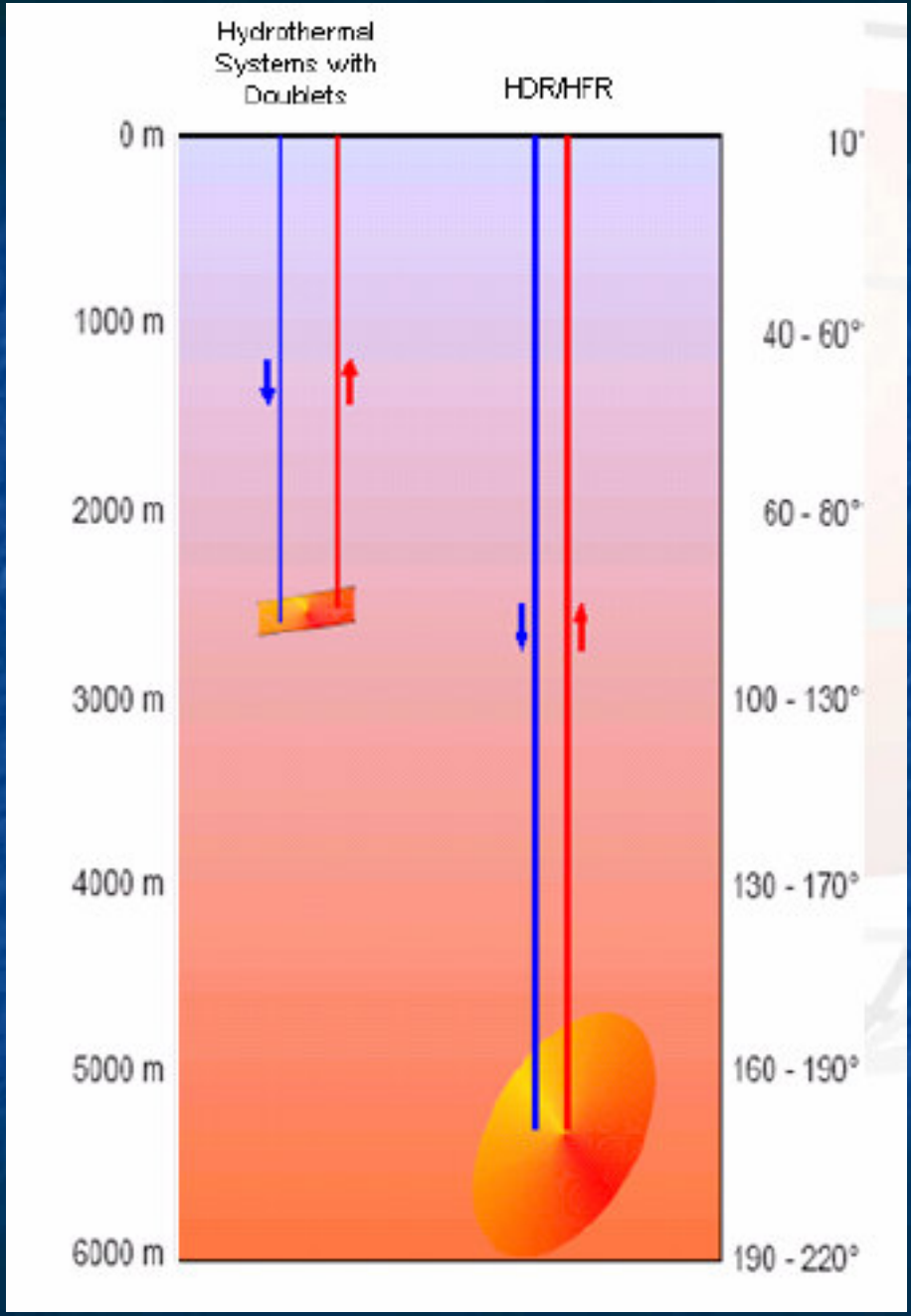
- Wind Farm
- Tidal Barrage
- Tidal Stream
- Wavepower
- Solar Photo-Voltaic

Dynamic Renewables - Use them or lose them

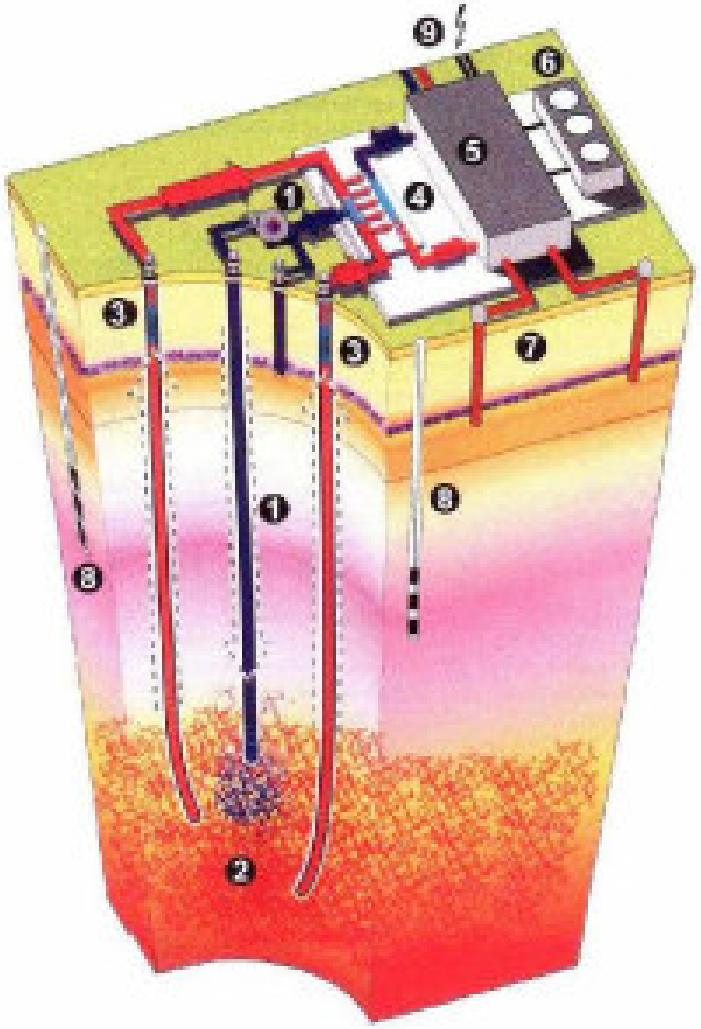
- Deep Geothermal
- Ground Source Heat Pump
- Biomass power station.
- Biomass Road Transport Fuel
- Hydro-electricity

Continuous Renewables Use when needed.

Deep Geothermal



Deep Geothermal Power Station



1. Injection Drill Hole and Injection Pumps
2. Stimulated Joint System
3. Production Drill Holes
4. Heat Exchanger
5. Turbines and Generators
6. Cooling Cycle
7. High Temperature Underground Storage
8. Seismic Monitoring Drill Holes
9. Consumers of Electricity and Heat

Biomass power sources

- Timber
  - Coppice or Forest
  - Harvested or waste
- Grasses and other crops
  - Miscanthus & switch-grass?
- Farm & urban waste
  - Chicken litter etc
  - Household waste
- Zero net carbon emissions if sustainably produced.
- But crops require land!

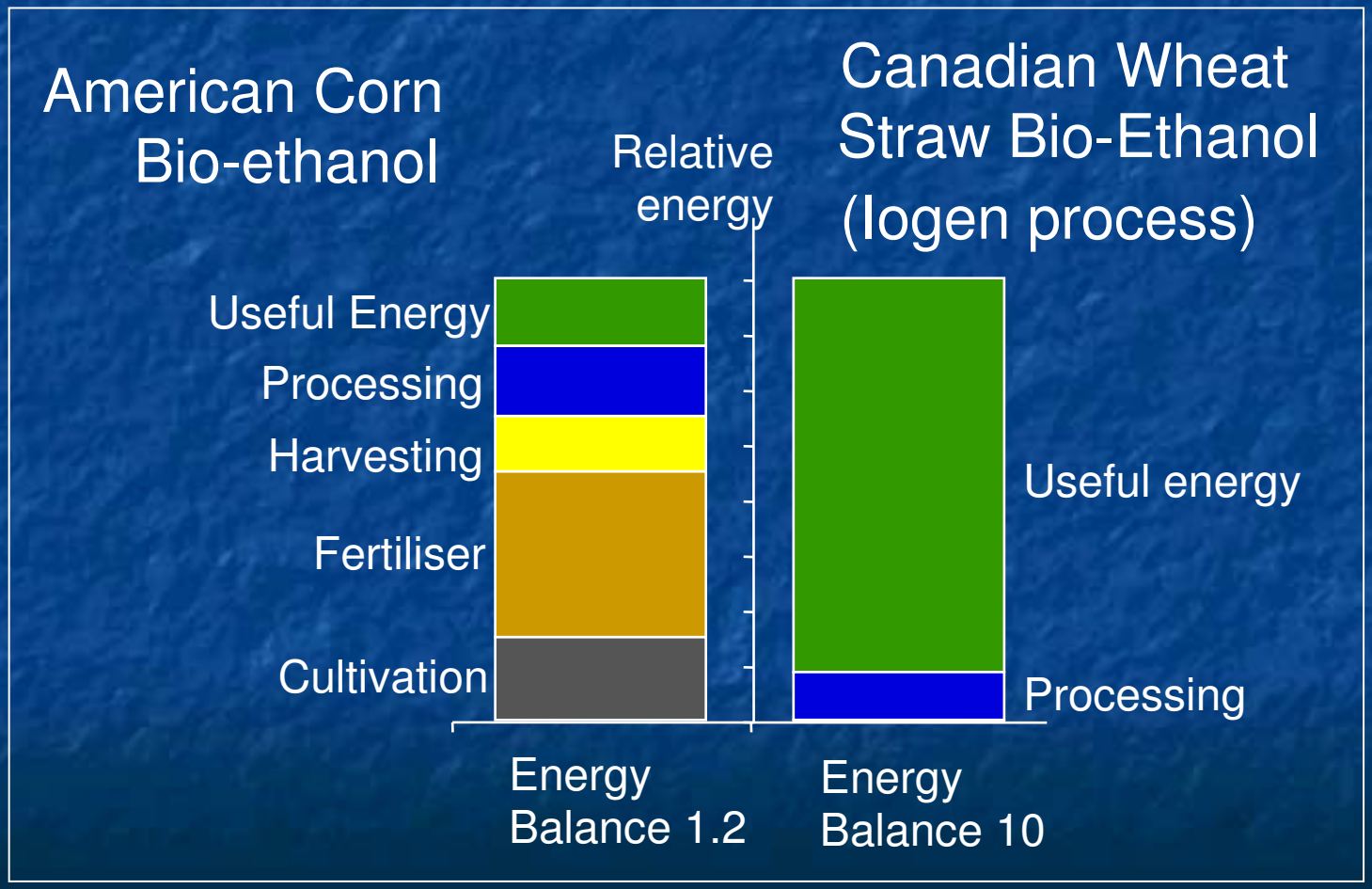
Biomass Road Transport Fuels

Many potential options

- Corn, sugar cane, grains, sugar beet etc
  - Sugars fermented to ethanol
- Oilseed rape, soy, other vegetable oils
  - Process to form bio-diesel
- Wood, grasses etc for gasification and chemical processing to ethanol

Biomass Road Transport Fuel

Some options make little sense!

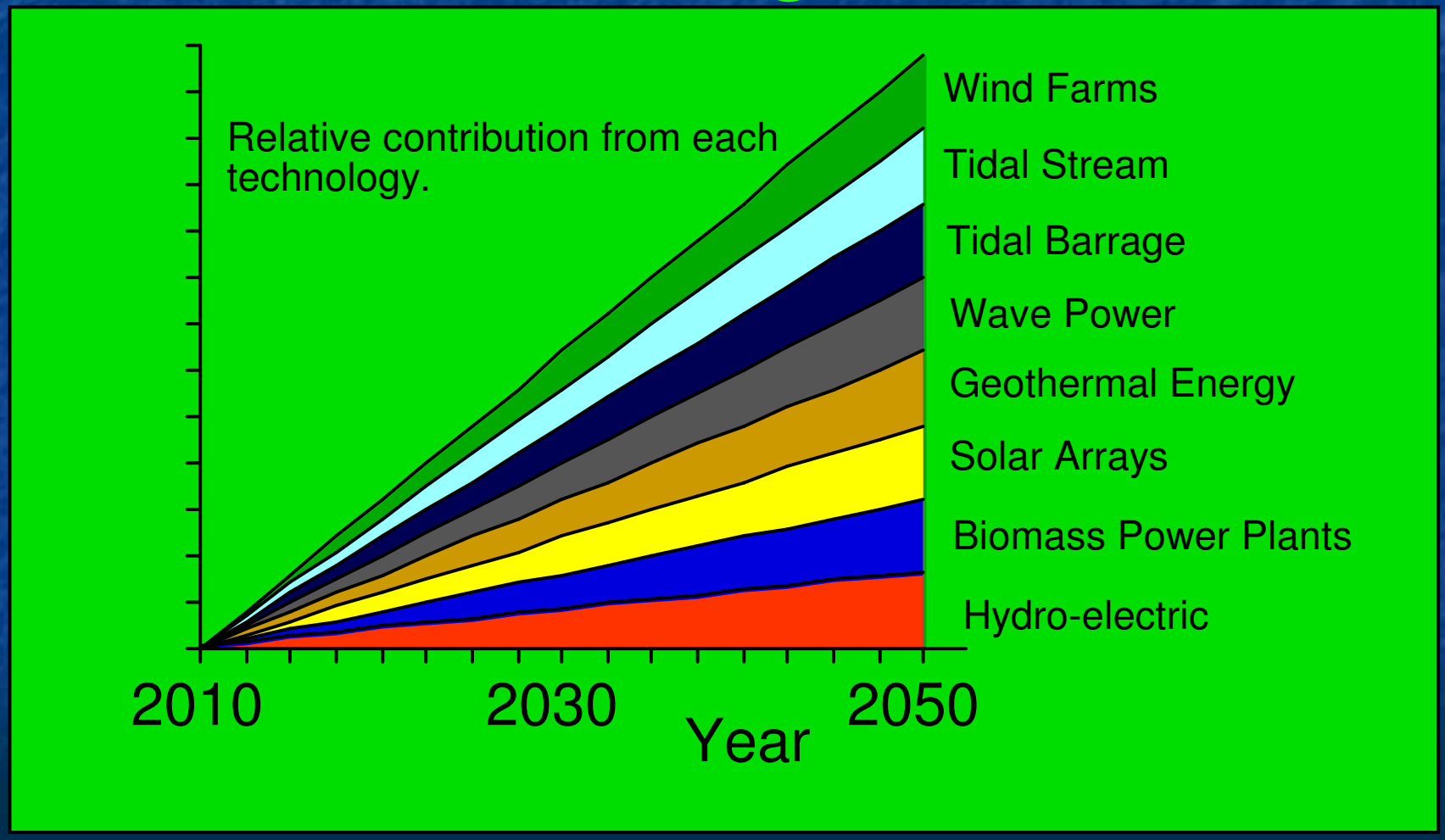


Biomass Road Transport Fuels

- Some Key Issues

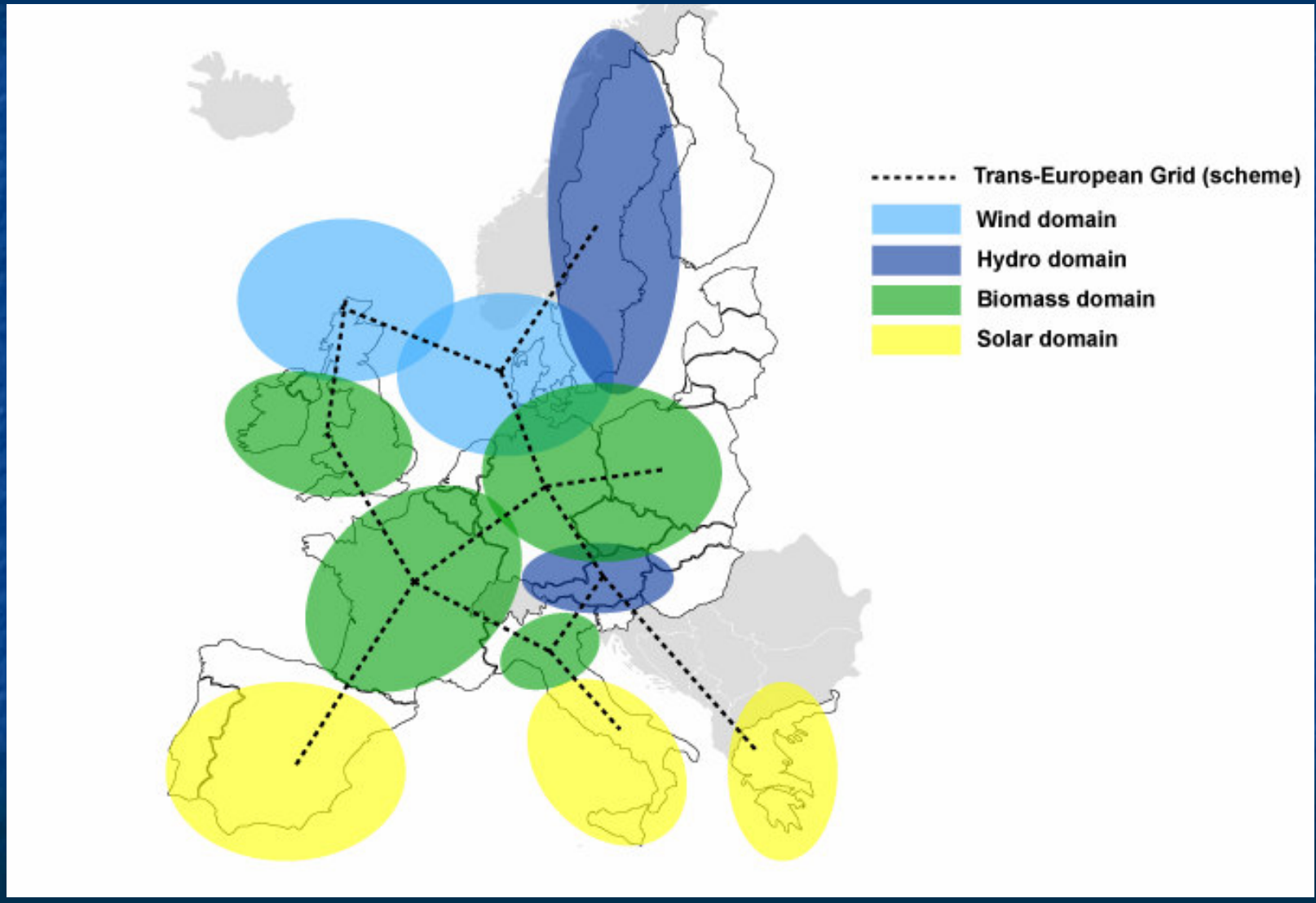
- Energy Balance
  - Ratio of useful energy produced to the energy used to produce it
  - Often barely greater than unity!
  - Published estimates vary widely for the same process
- Land area required to produce a useful amount
  - (10% RTF for US requires 10% of cultivated land area!!
- No substitute for fuel economy.

The Large Scale Renewables wedge



We need realistic targets for every sub-wedge with check points en-route and costed implementation plans, not spin!

Potential Interconnected Renewable Energy Domains (2030)



Source - J Schellnhuber, Potsdam Institute

Large Scale Energy Storage

A largely missing element!

- Needed to convert “use it or lose” to continuous.
- Technologies becoming available:-
  - Pump Storage (Dinorwic)
  - Compressed Air underground reservoir
  - Hydrogen reservoir
  - Flow Batteries
- But better cost-effectiveness sought.

A sustainable carbon-free society?

CCS electricity

Renewable Electricity

Micro-generation

All electric home with high energy efficiency

Rechargeable Electric

Hydrogen Fuel Cell

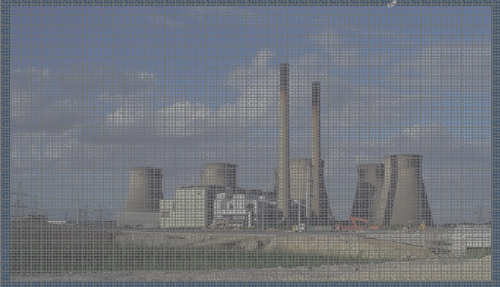
Hydrogen Generation

Hydrogen Storage

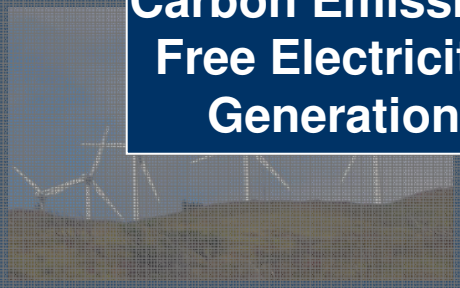
Hydrogen powered Generator

A sustainable carbon-free society?

CCS electricity

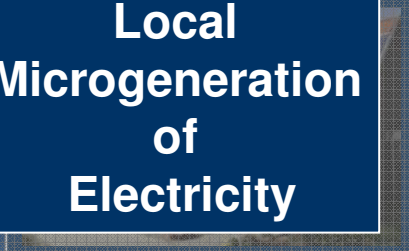


Renewable Electricity



Carbon Emission Free Electricity Generation

Micro-generation



Local Microgeneration of Electricity

All electric home with high energy

Energy efficient homes & businesses

Hydrogen Generation

Energy storage

Hydrogen Storage

Hydrogen powered Generator

Rechargeable Electric

Carbon emission free transport

Hydrogen Fuel Cell

The last words

The technology largely exists & we don't need to give up everything but we do need to act.

There remains the political & social challenge - will we (the human race) do it for our grandchildren or not?

Can we make it happen?

Finis