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SINCLAIR KNIGHT MERZ

SKM

Geothermal Potential in Great Britain and Northern Ireland

In cooperation with Ove Arup and Partners

September 2011

Overview

- Introducing – SKM
- Scope/purpose of study
- UK resource review
- Reporting codes / Stored Heat Assessment
- Current projects in the UK
- Conceptual Projects / financial evaluation
- Geothermal policy support
- Possible development scenarios

Sinclair Knight Merz Group

- A global engineering, sciences and project delivery firm
- Independent, employee-owned and values-driven
- Established in 1964 in Sydney, with UK offices since 1996
- 58 offices across Asia, Australia, Europe, Middle East, Africa, New Zealand and South America
- 6,500 people globally (700 in Europe)
- Revenue in excess of £650 million (A$1 billion)
- Over 40 years global geothermal energy experience, SKM has been directly involved in developing 3,000 MW of geothermal generation
- Experience covers over 100 resources in 20 countries representing more than 50% of installed generating capacity

Purpose of Study

Background:

- 2020 UK renewable target of 15% energy from renewable sources – 12% of heat and 30% of electricity
- 2010 UK energy production from renewables was 3.3% - 1.8% of heat and 7.4% of electricity
- Renewable Heat Incentive introduced 2011
- Renewable Obligation banding review brought forward to 2011

Purpose

- To review the geothermal potential in Great Britain and Northern Ireland for heat and power
- Evaluate the support mechanisms that may be required for geothermal to contribute to renewable targets

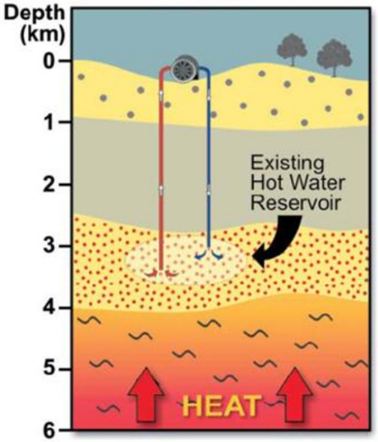
Scope of Study

Focus on deep geothermal resources 500m to 5,000m
Two geological settings for commercial development in the UK

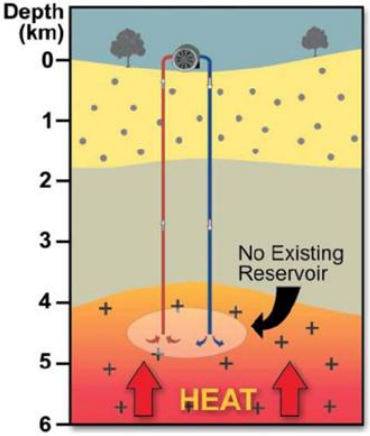
Pros:
- Naturally permeable
- Existing reservoir
- Commercially proven

Contras:
- Lower temp
  - > 100°C power
  - > 60°C direct heat
  - > 40°C heat pump
- Higher power plant costs
- Lower power density

Hydrothermal – Hot Sedimentary Aquifers



Petrothermal – Engineered Geothermal Systems



Pros:
- Higher temperatures
- Lower power plant costs
- Higher power density

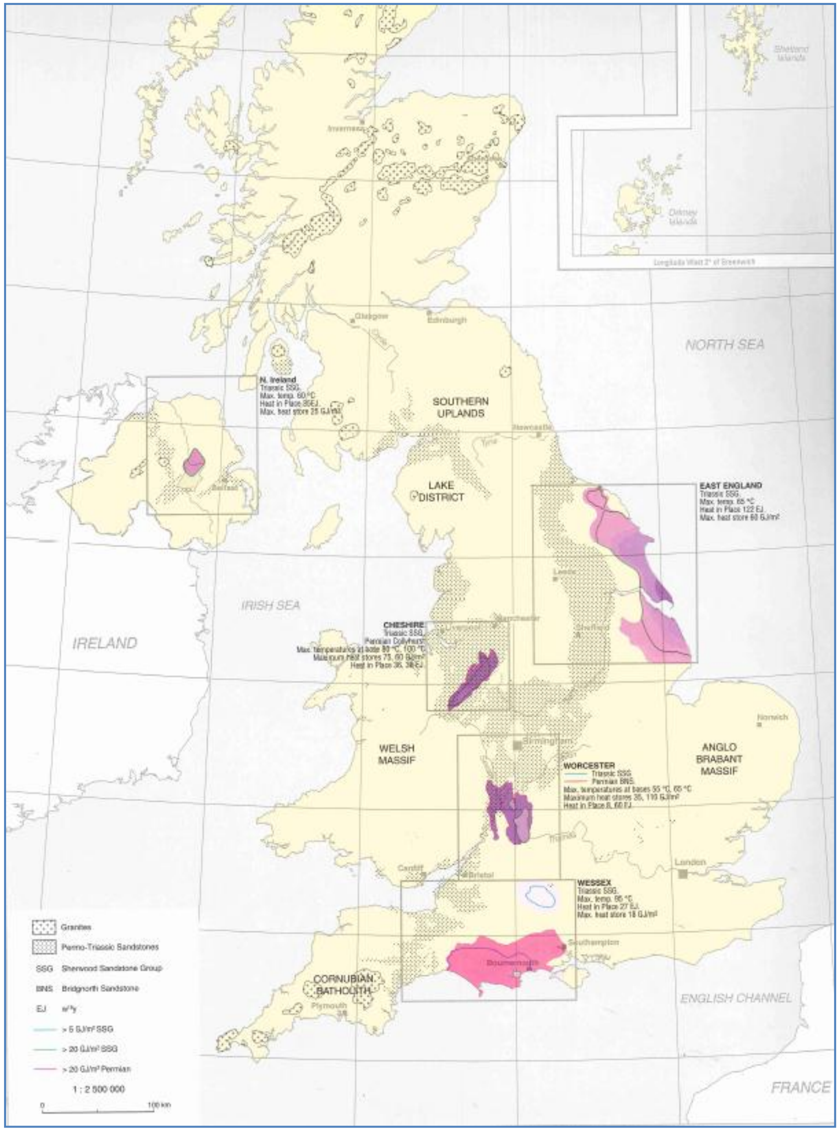
Contras:
- Reservoir has to be engineered
- Higher drilling costs (deeper)
- Distant to load centres

Image source courtesy of PANAX Geothermal Ltd.

Hydrothermal

- Potential and existing geothermal resources in the UK based on current publicly available information

Location	Area (km^2)	Reservoir Temp. (°C)	Depth of Base (m)	Thickness (m)
Wessex	3.5	108	3,000	200-500
Cheshire	33	115	4,500	200-1,200
East England	850	50	1,500	500
Worcester	200	45	1,900	900
Northern Ireland (Larne)	22.5	83	1,600	300-600



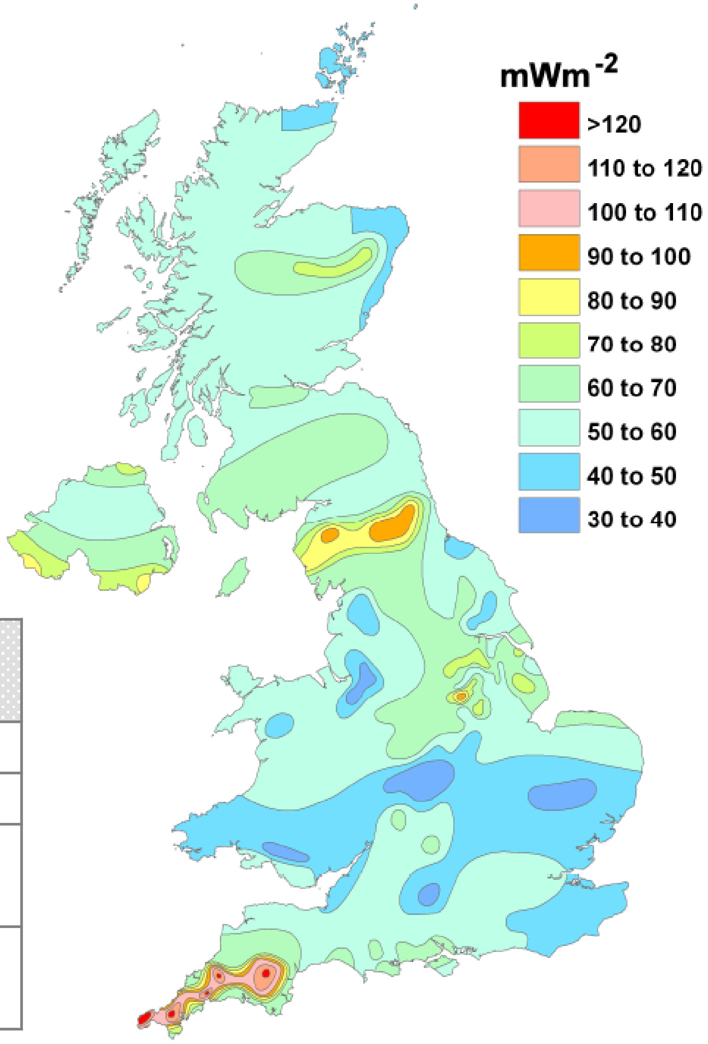
Deep sedimentary basins and major radiogenic granites in the UK (Hurter & Haenel 2002)

Petrothermal

- Background 52 mW/m², 21°C/km
- Cornubian batholith in SW Cornwall
- Caledonian granites in the Lake District and Weardale
- East Grampian batholiths of Scotland

	Heat flow (mW/m²)	Temp gradient (°C/km)	Inferred area (km²)
Cornwall	110	35	1,500
Weardale	115	38	1,500
Lake District	73-119	34**	153
Eastern Scotland	59-76	17**	1,635

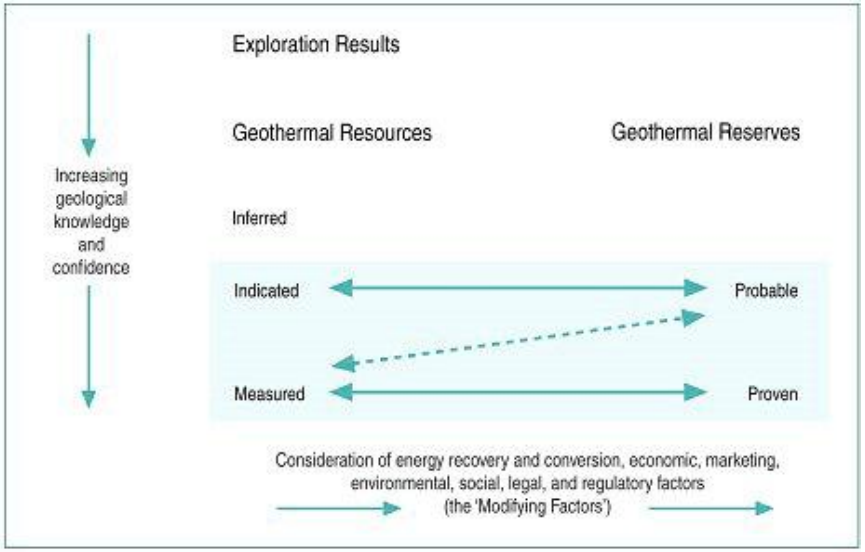
** Temperature gradients are based on estimates only with no firm data available at depths greater than 300m



Heat flow map of the UK (Busby 2010)

Reporting Codes

- Stored heat calculations are used to infer a geothermal resource
- Codes promote transparency, consistency and confidence in categorising geothermal resources and reserves
- UK Geothermal prospects fit mostly within the inferred category with limited information available to assess the viability
- Key 'Modifying Factors' detailed in the Australian code are needed to assess the prospects further



Relationship between Exploration Results, Geothermal Resources and Geothermal Reserves (Source Australian Reporting Code 2008).

UK Resource Review – Stored Heat

- Assumes 17.5% recovery for hydrothermal and 2% for petrothermal
- Assumes 25 year life and binary plant for generation

Type	Location	Area (km^2)	Reservoir Temp. (°C)	Base Temp. (°C)	Stored heat (PJ)	Generation Potential (MW_e)	Heat Potential (MW_{th})
Hydrothermal Medium	Cheshire	33	115	70	1,500	38	370
Hydrothermal Medium	Wessex	3.5	108	70	137	3	30
Hydrothermal Low	East England	850	50	25	16,300	N/A	4,000
Hydrothermal Low	Worcester	200	45	25	11,100	N/A	2,700
Hydrothermal Low	Northern Ireland (Larne)	22.5	83	45	2,060	N/A	510
Petrothermal	Cornwall SW	90	190	70	14,700	54	410
Petrothermal	Lake District	1,500	160	70	182,000	620	5,100

Current UK Projects and Technology

Hydrothermal Projects – Hot Sedimentary Aquifers (HSA)

Developer, Location	Construction Date	Depth (m)	Temp. (ºC)
Cofely, Southampton	1987	1,800	76
Keel University, Staffordshire	2012?	1,200	
Science Central, Newcastle	2011	2,000	
GT Energy, Manchester			
GT Energy, Ballymena			

Petrothermal – Enhanced Geothermal System (EGS)

Developer, Location	Construction Date	Depth (m)	Temp. (ºC)
Camborne School of Mines, Rosemanowes Quarry, near Redruth,	1976 - 1994	2,500 to 2,800	100
EGS Energy, Eden project, near St. Austell	2012?	4,000	
Geothermal Engineering, United Downs, near Redruth	2012	4,500	
Cluff Geothermal, Eastgate, Weardale	2004	995	45

Conceptual Projects

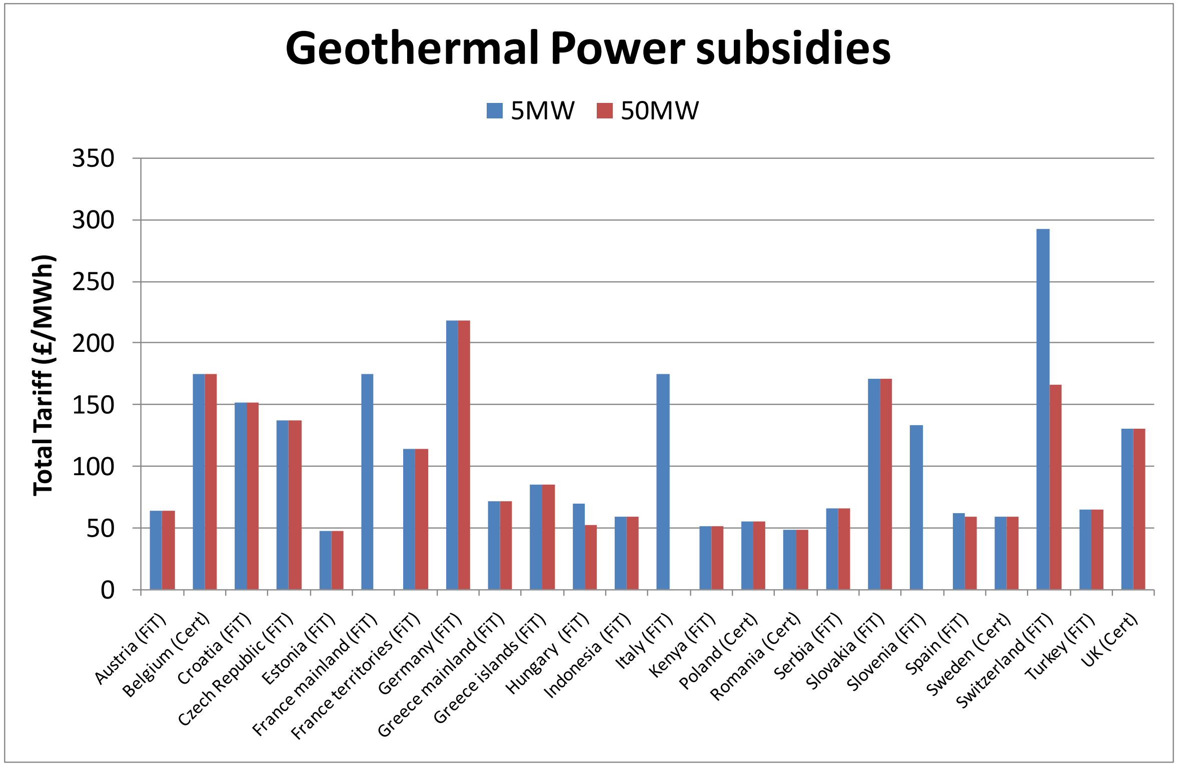
- 18 possible UK 'concept' project cases were assumed involving 6 of the most likely resources
- CHP modelled as well as pure generation

Resource	Application Type	Gross capacity Elec. / Heat (MW)	Well Depth (m)	CAPEX (£ million)
Wessex	Hydrothermal CHP	0.75/5.5	2,500	14
Wessex	Hydrothermal CHP	1.5/11	2,500	27
Cheshire	Hydrothermal CHP	0.75/5.5	4,250	22
Cheshire	Hydrothermal CHP	1.5/11	4,250	43
Cornwall	Petrothermal CHP	10/21	5,000	115
Cornwall	Petrothermal CHP	5/11	5,000	59
Lake District	Petrothermal CHP	5/10	5,000	59
Cheshire	Hydrothermal Direct Heat	-/11.5	3,400	18
Wessex	Hydrothermal Direct Heat	-/10	3,000	16
Lough Neagh	Hydrothermal Direct Heat	-/5	2,000	10
Newcastle	Hydrothermal Heat Pump	-/4	1,500	8

Financial Analysis - Results

- With the current available information and assumptions detailed in this study, the financial analysis suggests the following FiT and RHI tariffs as suitable:
- FiT levels for electrical and CHP projects
  - Approximately 300 £/MWh – equal to 5 ROC/MWh
- RHI levels for CHP and heat only projects
  - Retain existing RHI 30 £/MWh for CHP projects
  - Approximately 40 £/MWh for hydrothermal direct heat projects
  - Approximately 60 £/MWh for hydrothermal applications using a heat pump

Geothermal Policy Support



Very few policies address the critical area of geothermal development – high cost/risk of up front exploration drilling

Level of support	UK	Europe Best
Electricity	130 £/MWh	220 £/MWh (Germany, Switzerland)
Heat	30 £/MWh	26 £/MWh (Germany)
Grant	£2 million	£4.3 million (Germany)

Possible Development Scenarios

- Low – existing level of support
  - Electricity - 2 ROC per MWh (130 £/MWh)
  - Heat - 30 £/MWh
  - Grants of £1-2 million for drilling
- Medium - matching best available in Europe
  - Electricity - 4 ROC at ~ 220 £/MWh
  - Heat - 30 £/MWh
  - Grants of £6-8 million for drilling
- High
  - Electricity FiT of 400 €/MWh projects < 5 MW
  - 300 €/MWh projects < 5 MW
  - Heat – 40 £/MWh (33% uplift on the RHI for district heating)
  - Exploration risk mitigation
  - Drilling grants for pure heat projects
  - R&D funds
  - Specific geothermal licensing scheme

Possible Development 2030 Results

- Low
  - Only existing projects are developed as demonstrations
  - 0.5-2% of potential
- Medium
  - Slow development of most attractive projects
  - 5-10% of potential
- High
  - Steady development of projects at all resources
  - 15-30% of potential

	Low Support Level (MW)	Medium Support Level (MW)	High Support Level (MW)
Electricity	15	60	240
Heat	70	540	2,200

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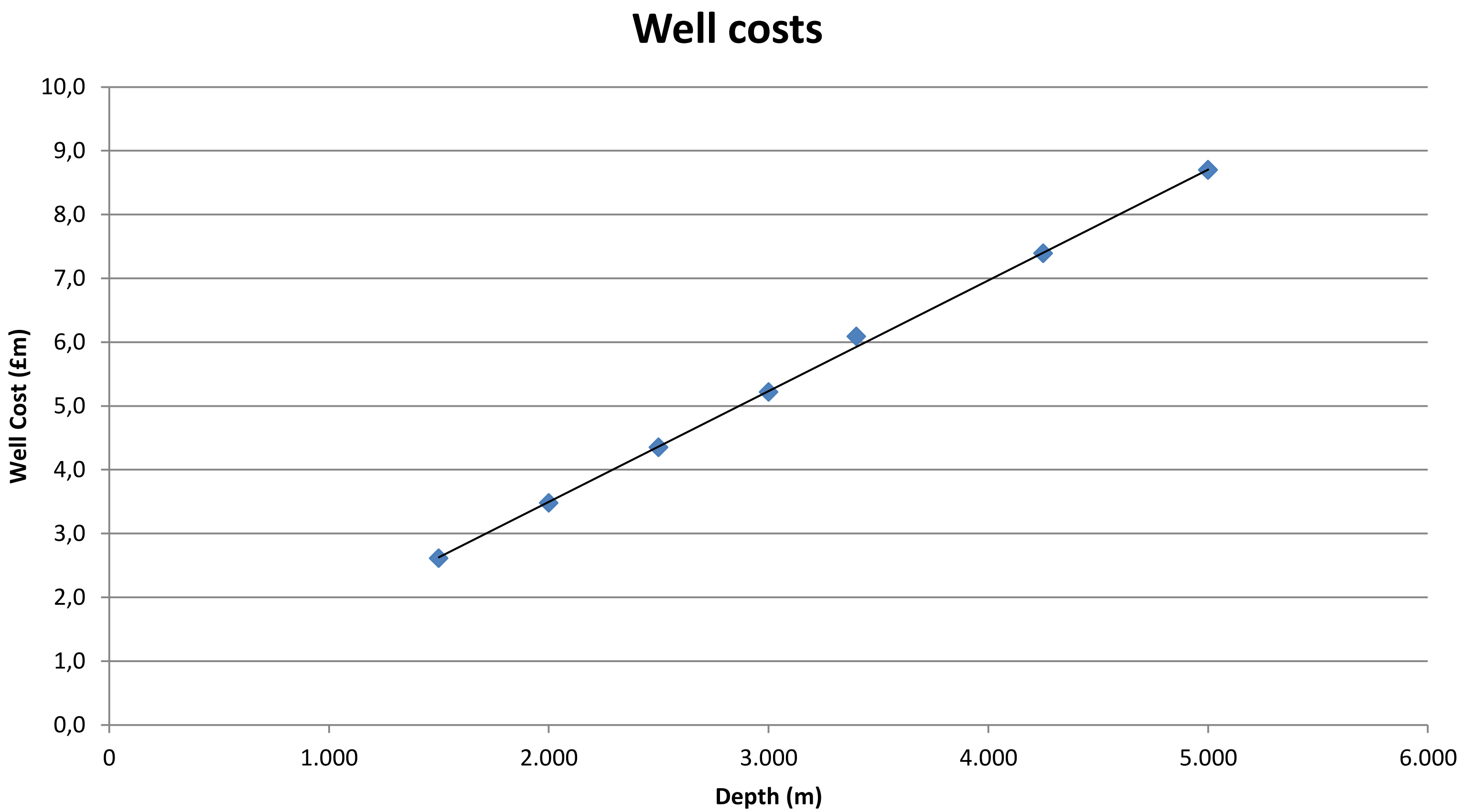
BACKUP


SINCLAIR KNIGHT MERZ
SKM
Engineering a sustainable future
Geothermal Developments Realised

Drilling Costs



Financial Analysis

- Feed in Tariffs (FiT) and Renewable Heat Incentive (RHI) evaluated
- Key assumptions:
  - Debt to equity ratio of 60:40 (80:20 scenario)
  - Cost of debt: 5% with loan term of 12 years
  - Cost of Equity at 20%
  - Capital grant - zero (£5 million scenario)
  - Project life of 25 years
  - Corporation Tax 25% with no capital allowances
  - Heating aspects used for 6 months of the year
  - FiT and RHI increased annually at inflation rate