Finding a model for success with low temperature geothermal

Lessons from Denmark

David Simons – Geology Manager

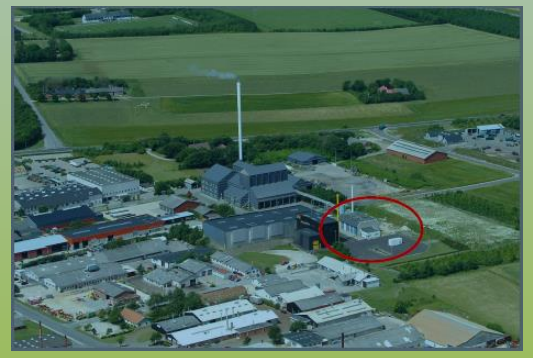
GEOOP

Summary

- Denmark - Summary of activity
- Future vision for Geothermal in Copenhagen
- Cost and risk mitigation
- Technology

What is happening in Denmark today?

- 3 working facilities
  - Thisted (1984) 7MW_{heat} Gassum Formation 43°C @ 1250m
  - Amager (2003) 14MW_{heat} Bunter Formation 74°C @ 2600m
  - Sønderborg (2012) 12MW_{heat} Gassum Formation 48°C @ 1200m
- Essential to success of low temperature geothermal is heating network
- Wide spead network (63% connectivity) mostly in urban areas
- EUDP funding to:
  - Cost and scope drilling a chalk storage well
  - New Geothermal well
- To make geothermal part of Denmark's energy future a much bigger vision is needed.



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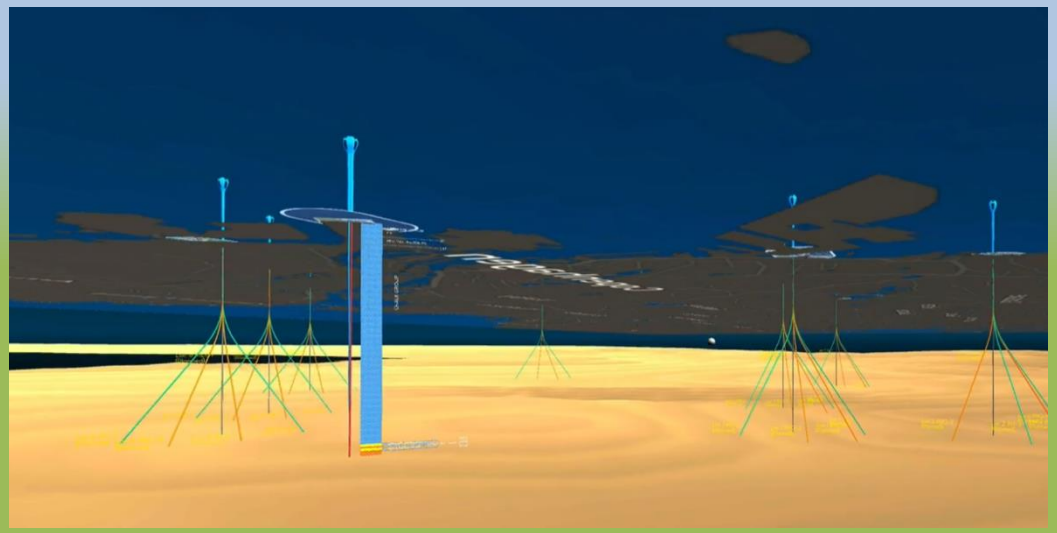
Forward Plan



- 8 new geothermal plants in the city
- Each plant will output 10-15 MW of heat and will consist of a vertical pilot well, 2 directional injector wells and 2 directional producers
- All wells target the Gassum Formation sandstones

Stills are taken from a video clip created using *Geologiq* ™

Is this justified?

ASSET VALUE

- Asset value. Total heat in place in Denmark recently estimated at 73 Billion Gj. This is 1.76 Billion BOE (*1)

DEMAND

- Aim is to deliver 30% Geothermal heat to the network. Over 30 years that equates to £12 billion in revenue(*2)

Despite this, investment remains shy as decisions are based on expensive prototype projects.

Methods for reducing costs and mitigating risks is a lesson that can be drawn from the oil industry.

*1 Frederikshavn, Halder, Gassum & Bunter Formations. Recovery factor is 0.33. 5 GJ per m2 assumption. New 3D heat model still under construction. Recovery is only 2% of total energy in place. 30 year model.

*2 Number equates to a total of capacity 1,091 MW run year round. Operated for 30 years with 2015 average heat price (355 DK or £42/MWh). Exchange rates from 19/10/16

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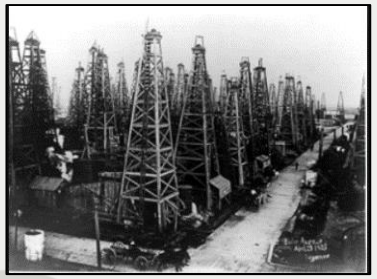
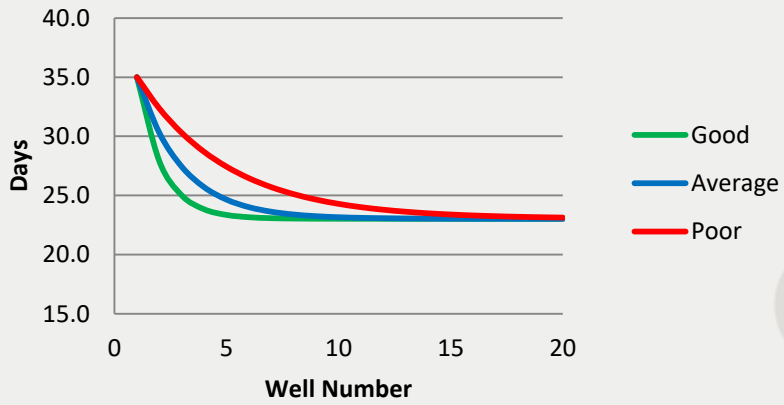
HOW TO REDUCE COSTS AND RISKS – LESSONS FROM THE OIL SECTOR

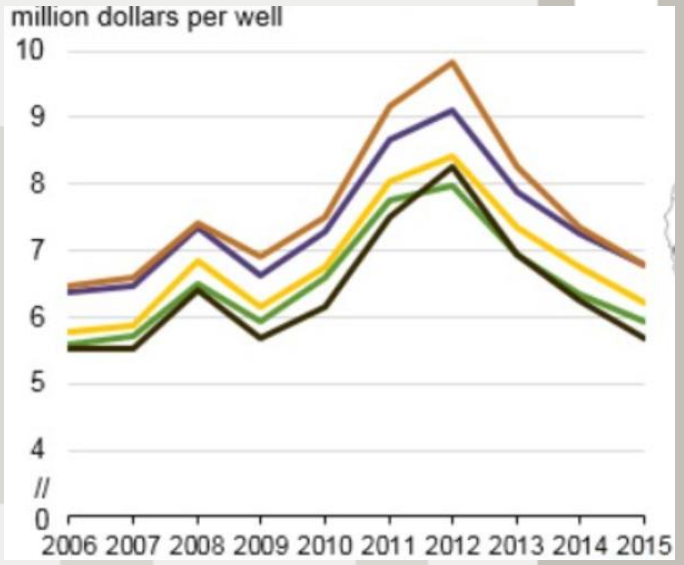
1900 → 1986 → TODAY



In the early days, the oil industry drilled expensive prototype wells with no knowledge sharing.



Brett and Millheim (1986) savings were up to 34% from first well costs.



Today in US Drill cost savings are up to 52% (US Energy Information Administration 2016)

- By upscaling geothermal operations and applying a 'whole cycle' manufacturing approach to project planning and execution, well costs reductions of up to 52% are achieved
- Optimised data acquisition to allow reservoir engineering to derisk the reservoir model

To harness these efficiencies, heating companies need a geothermal operating company, a professional partner with a vested interest delivering necessary savings to a project.

Network Temperature

- Heating network temperature has a significant impact on the economics of geothermal
- Danish network is generally run at or close to 80/55 (due to requirements of older housing stock)
- Geothermal heat production from Gassum typically +/- 70°C so heat pumps necessary in plant so increasing costs
- **A new build system today supplying buildings of modern construction could use a 'low temperature' network**
- This would make the economics of geothermal, and other renewable technologies very competitive.

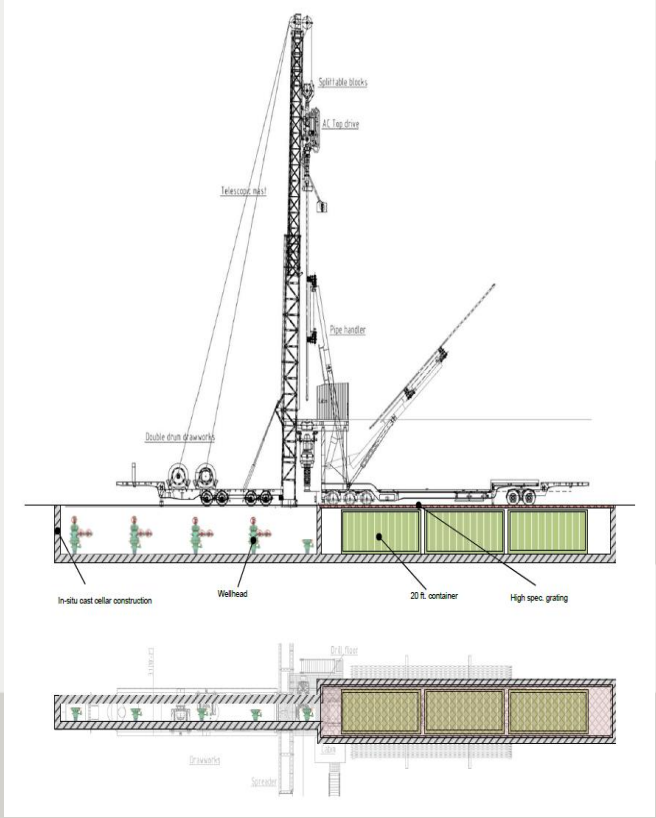
Biomass plant (woodchip) Copenhagen

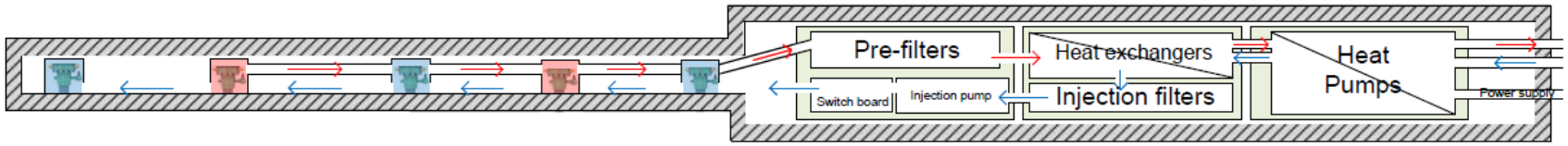
Geothermal Technology Centre

Tonder Geothermal test centre

Partnerships include:

- HUISMAN for rig technologies (urban drilling), composite casing and liner, casing while drilling.
- FORCE for corrosion management
- German oil tools for well head system. Make it simpler, lighter and cheaper. (Currently combines wellhead, casing hanger and xmas tree)
- GEOOP for reverse circulating cement to protect aquifers.
- Danfoss for modular container units.





Summary

Extremely valuable low temperature geothermal assets in Denmark

Upscaled and industrialized geothermal operations will provide:

- Suitably large heat outputs for the demand that exists in Denmark today
- Drilling cost reductions of up to 52%.
- Mitigation of uncertainty in the drilling process
- Mitigation of uncertainty in establishing connectivity between wells
- Better informed investment decisions - an end to expensive prototype projects and an understanding of the real cost of geothermal heat

David Simons
GEOOP Geology Manager
Mob: +44 (0)7966 960594
david.simons@live.co.uk
Bentzonsvej 6-8, Parterre, 2000 Frederiksberg, Denmark