Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Deep Geothermal in Ireland – Past, Present and Future
September, 2018

A review of recent developments and potential growth for the deep geothermal sector in Ireland

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Deep Geothermal in Ireland – Past Present and Future

Thursday September 6th, GSI Beggars Bush*, 10-4pm*

Research, demonstration & observations
Welcome
IRETHERM Project review (Sarah Blake GDG/UCD)
G.O. Therm & Irish crustal heat map (Ben Mather & Javier Fullea, DIAS)
GeoUrban project (James McAteer, GDG)
COSEISMIQ Project (Chris Bean, DIAS)

Research, demonstration & observations
Geothermal potential in the Irish Carboniferous Palaeokarst (Nick O'Neill, SLR Consulting)
International experience & opportunities for Ireland (Michael Chendorain, Arup)
Deep geothermal investigations in the Dublin Basin (Ric Pasquali, TerraGeoserv/for GT Energy)
Discussion

Policy & implementation
Social acceptance of geothermal energy (Teresa Hooks, UCD)
GeoEnergy Europe Cluster (Stephen Walsh, Geoscience Ireland)
District Heating for Dublin City (Stephen Cull, Dublin City Council)
4th generation district heating & geothermal potential (Donna Gartland, Codema)
Discussion

Next steps
GeoERA & Geological Survey's role (Taly Hunter Williams, GSI)
Swiss national research policy & strategy (Gunter Siddiqi, Swiss Dept. of Energy)
Research Opportunities in Geothermal (Aoife Braiden, GSI)
Discussion

Summary & close of meeting

The IRETHERM Project: An Overview

Jones, A.G., Rath, V.R., and The IRETHERM Team

IRETHERM was a significant academic-government-industry collaborative research project funded by Science Foundation Ireland, which ran from 2011 to 2016. The aim of IRETHERM was to develop a strategic and holistic understanding of Ireland's geothermal energy potential through integrated modelling of new and existing geophysical, geological and geochemical data.
Given the low-enthalpy geothermal energy setting in Ireland, deep sedimentary aquifers and “hot dry rock” (radiogenic granite) targets were chosen as the focus of an extensive geophysical exploration campaign. Deep-ranging electromagnetic geophysical methods (primarily magnetotellurics) were used to image electrically-conductive fluid-bearing horizons, and electrically-resistive granite bodies in various locations across Ireland. The geophysical results identified areas in the Lough Neagh and Rathlin Basins in Northern Ireland with high potential for geothermal district heating, and identified specific geological structures that are likely to control hydrothermal fluid flow in the subsurface. New geochemical data from Irish rocks were also collected, which identified buried granites and shales as the most likely targets for enhanced geothermal systems.

IRETHERM has generated valuable new data on Ireland’s deep geology and geothermal potential and highlighted areas of promising subsurface temperatures and permeability for district heating projects. Further information on the research output of IRETHERM is available on the project website

Project website: https://www.dias.ie/cp/geo/geo-iretherm/
Contact: Dr Sarah Blake , GDG Ltd sblake@gdgeo.com

IRETHERM

The IRETHERM Project
2011 – 2016

Science Foundation Ireland sfi For what's next

SFI Grant No. 10/IN.1/I3022

Presented by Sarah Blake (sblake@gdgeo.com)

Deep Geothermal in Ireland, September 6th 2018, GSI, Dublin

UCD Dublin | UCC Coláiste na hOllscoile Corcaigh, Éire University College Cork, Ireland | SLR | Geological Survey Suirbhéireacht Gheolaíochta Ireland | Éireann | Energy for the future | Geoserv | Department of Enterprise, Trade and Investment Geological Survey of Northern Ireland | NUI Galway OÉ Gaillimh | DIAS Institiúid Ard-Léinn Bhaile Átha Cliath Dublin Institute for Advanced Studies

What is geothermal energy?

- High temperatures > 160°C, typically 200 – 350 °C (“high enthalpy”)
- Depth: 1,000 – 3,000 m
- Related to volcanism and tectonism at plate boundaries
- Suitable for electricity production using conventional “flash” turbines

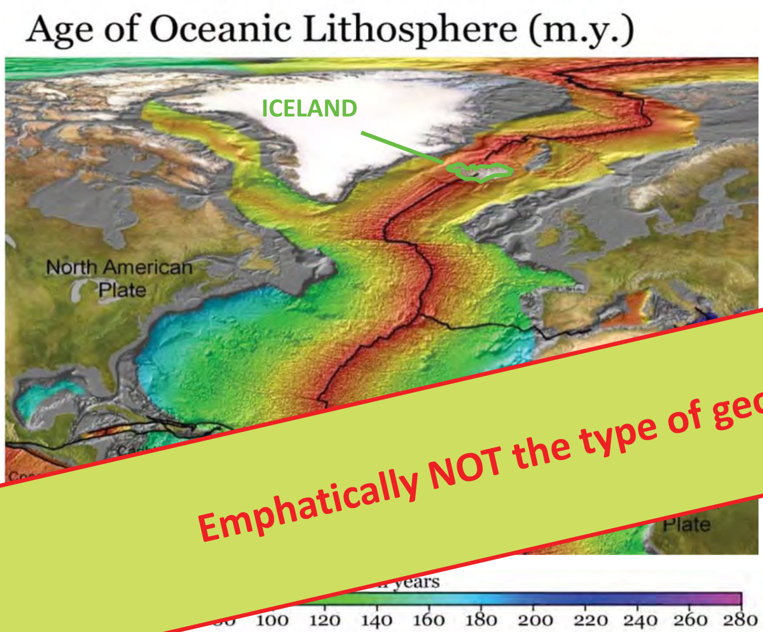


Image from: Muller, R.D., et al, 2008.

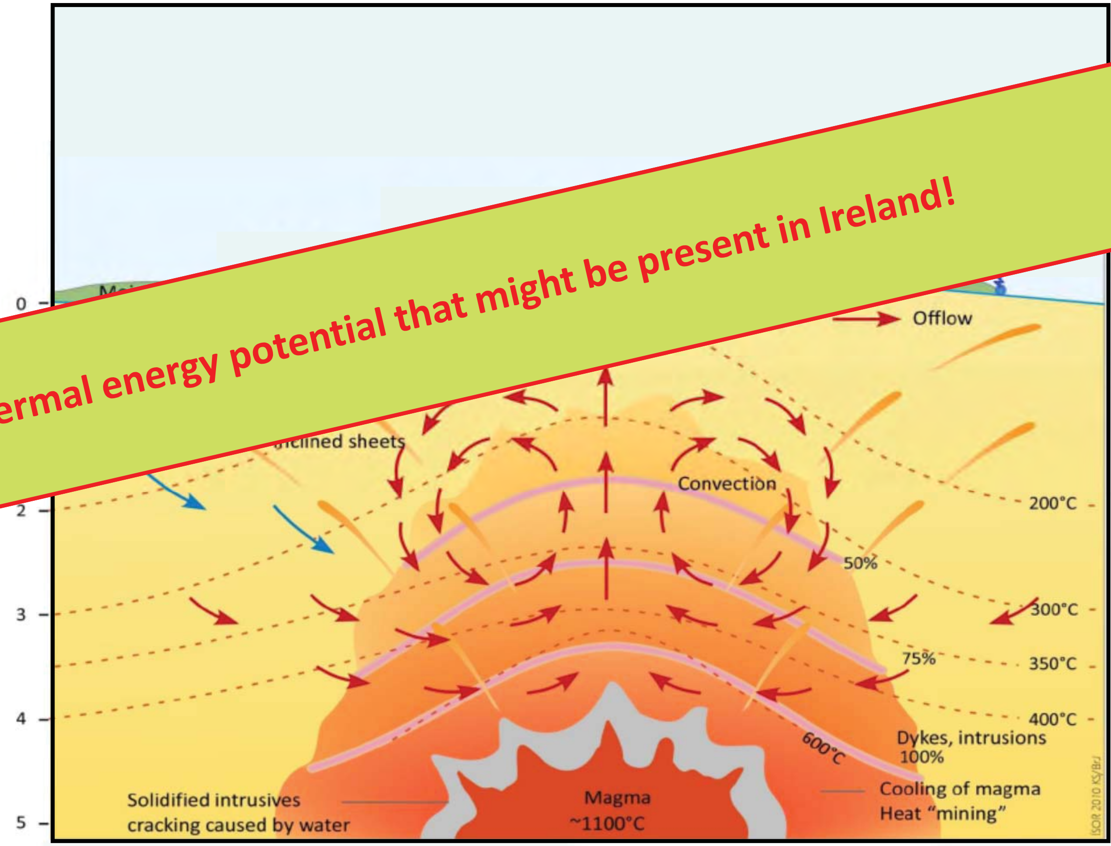


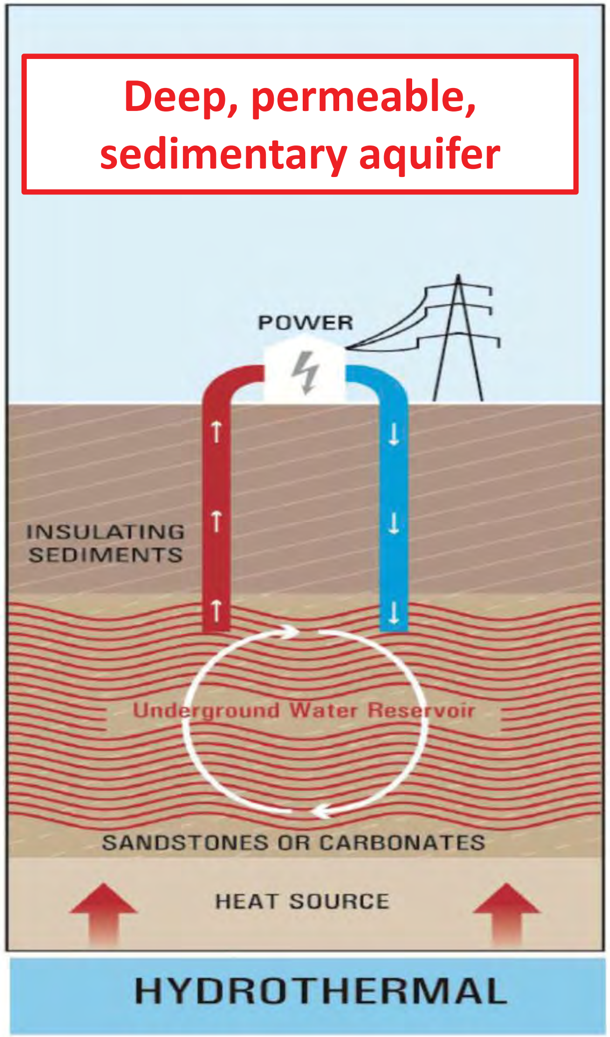
Figure: Kristján Sæmundsson, ÍSOR ©

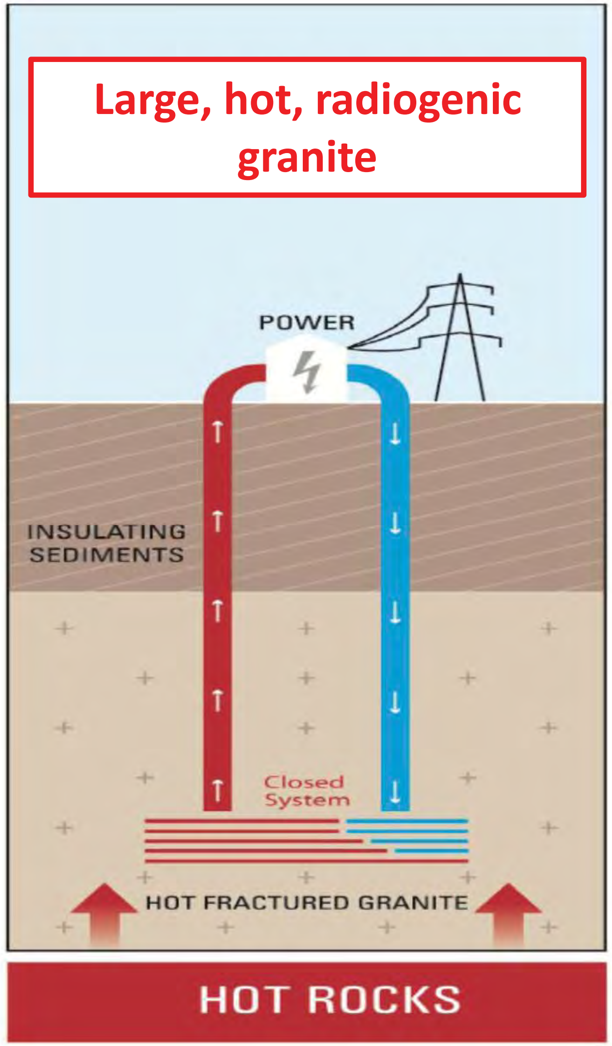
Emphatically NOT the type of geothermal energy potential that might be present in Ireland!

Low-enthalpy, "deep" geothermal energy resources

• **Soultz-sous-Forets, France** pilot EGS power-plant (1.5 MW_e)

- **Electricity generation** (binary-cycle power plants)
- **Using temperatures in the range 70 – 160 °C**





Given Ireland's geothermal gradient of 25 °C/km this means a depth range > 2.5 km

Low-enthalpy, "deep" geothermal energy resources

- **District-scale space heating** (heat exchangers)
- **Using much lower temperature waters**

- Mallow swimming pool, Co. Cork - direct utilisation of warm spring water (19 – 21 °C) with a heat exchanger
- Warm aquifer may be intercepted at depth for district scale central heating (e.g. Paris Basin, Southampton, Heerlen)

Mallow warm spring and swimming pool. From Goodman et al. (2004).

The IRETHERM project

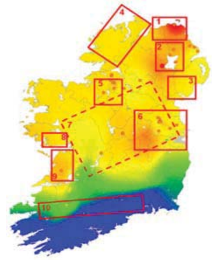
THERMAL MODELLING

- Determine the 3-D distribution of radiogenic heat production within the crust
- Model and understand the variation in temperature and heat-flow across Ireland
- Expand temperature database

DEVELOP NEW NUMERICAL GEOPHYSICAL MODELLING TOOLS

Joint inversion tools to enhance capacity for imaging and assessing the properties of geothermal resources: aquifers and granitic bodies

IRETHERM



ELECTROMAGNETIC FIELD SURVEYS (MT AND CSEM)

Test a strategic set of geothermal target "types"

IRETHERM aims to develop a strategic and holistic understanding of Ireland's geothermal energy potential through integrated modelling of new and existing geophysical, geological and hydrochemistry data.

Why use electromagnetic geophysical methods?

Main product of EM survey is a map of 3D variation of electrical conductivity

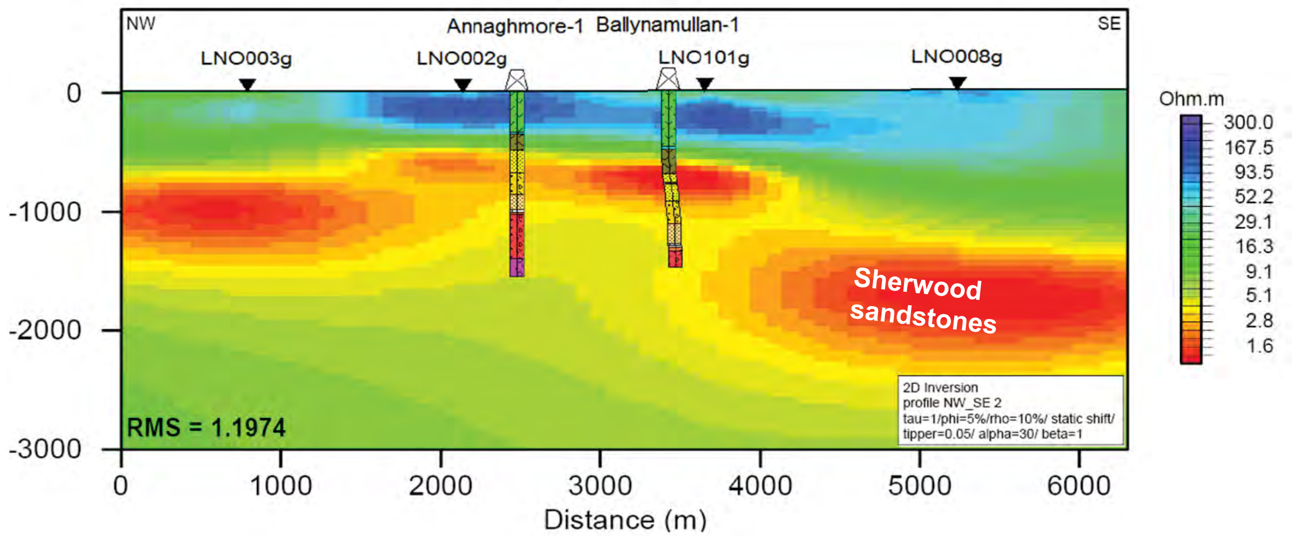
Two main research targets for IRETHERM:

1. **Deep, warm aquifers – a question of permeability**

- Fluid-bearing formations/structures more **conductive** than surrounding bedrock

2. **Hot, radiogenic granites – a question of volume and heat production**

- Granites are **resistive** bodies usually surrounded by more **conductive** lithologies

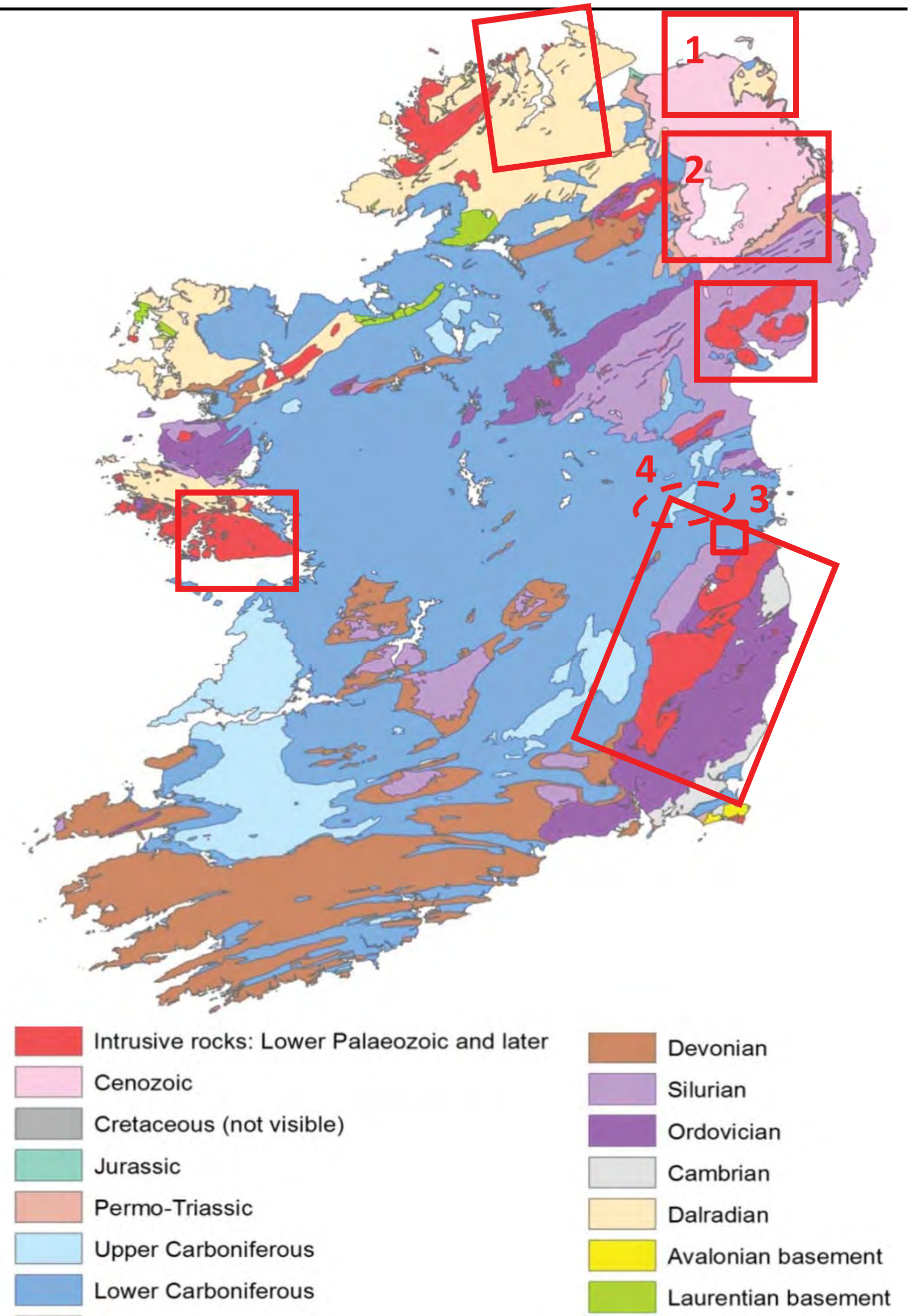


MT model of Lough Neagh basin, from Loewer (2011), MSc Thesis, DIAS/ETH Zurich

Results

1. **Deep warm aquifers – a question of permeability**
   - Identify formations and localities where higher primary porosities are preserved.
     e.g. buried Sherwood Sandstones, Rathlin Basin
   - Investigate zones of high secondary porosity
     e.g. along major crustal fault and shear zones

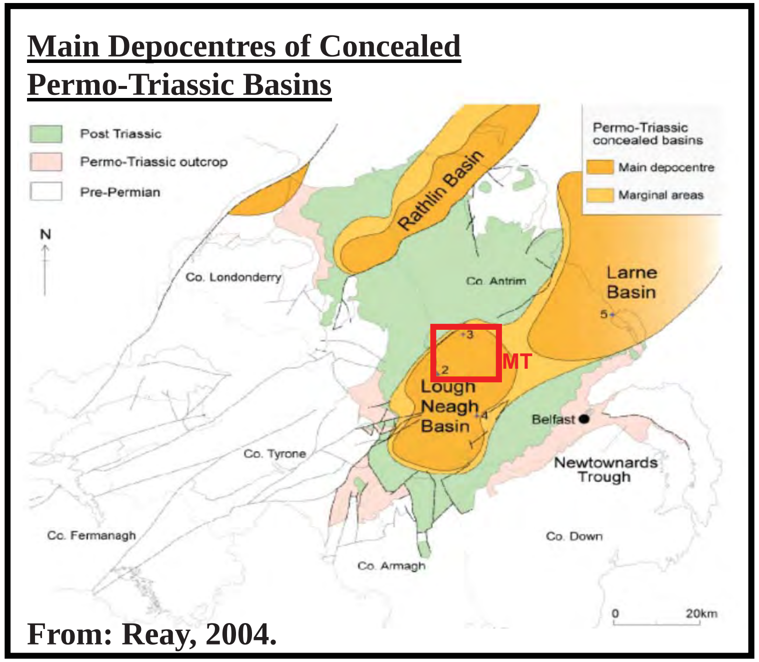
2. **Hot, radiogenic granites – a question of volume and heat production**
   - Identify extent of radiogenic granites
     e.g. Costelloe-Murvey granite, Galway
   - Assess radiogenic heat production rates of granites
     -> 3D model of Ireland's crustal heat production

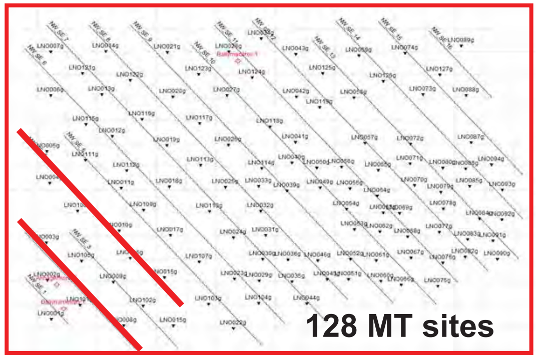


Results

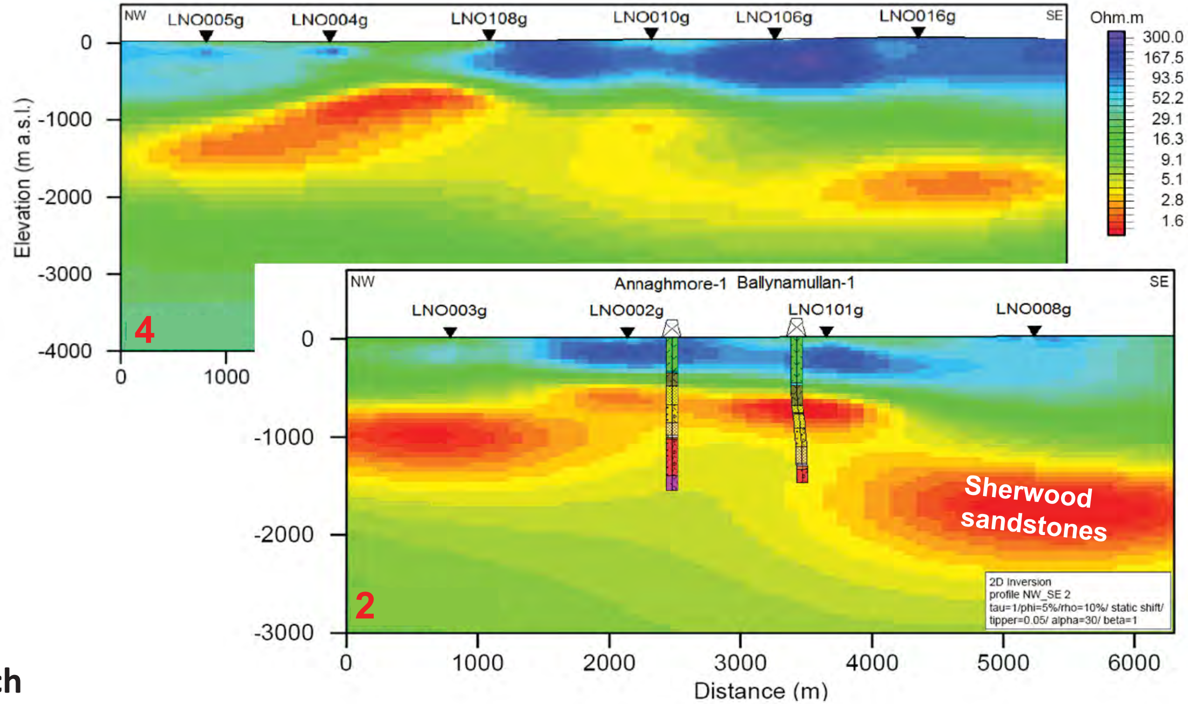
1. Deep warm aquifers – a question of permeability

Lough Neagh Basin
Triassic Sherwood
Sandstone aquifer





Sandstone porosity and permeability in boreholes is known to vary between 8 – 24% and 2 – 1000 mD.



- **Maximum depth of the conductive sandstones is 2,300 m**
- **<u>Maximum predicted temperature of about 78°C</u> (based on borehole temperatures and gradients)**

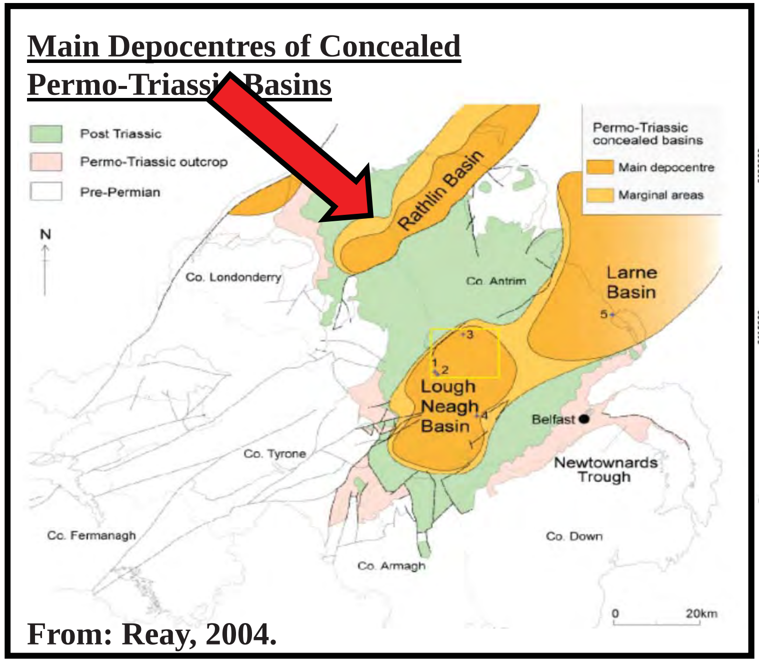
→ High potential for district heating

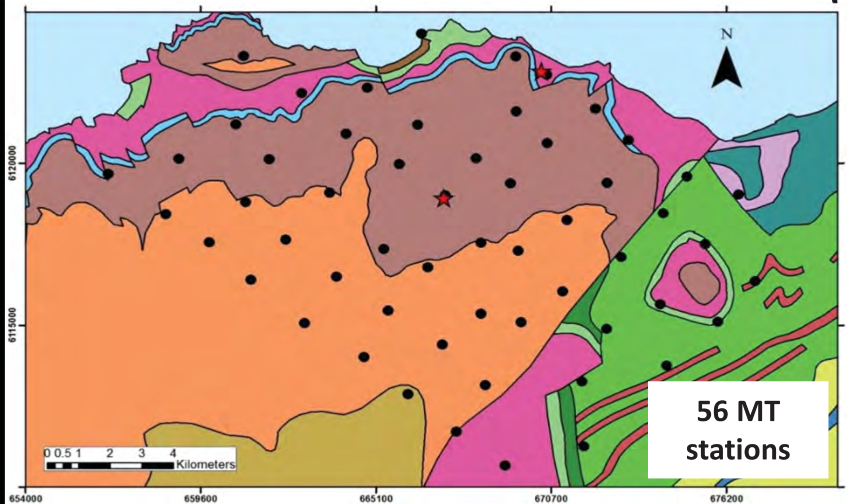
From: Loewer, 2011, MSc Thesis, DIAS/ETH Zurich

Results

1. Deep warm aquifers – a question of permeability

Rathlin Basin Triassic Sherwood Sandstone aquifer



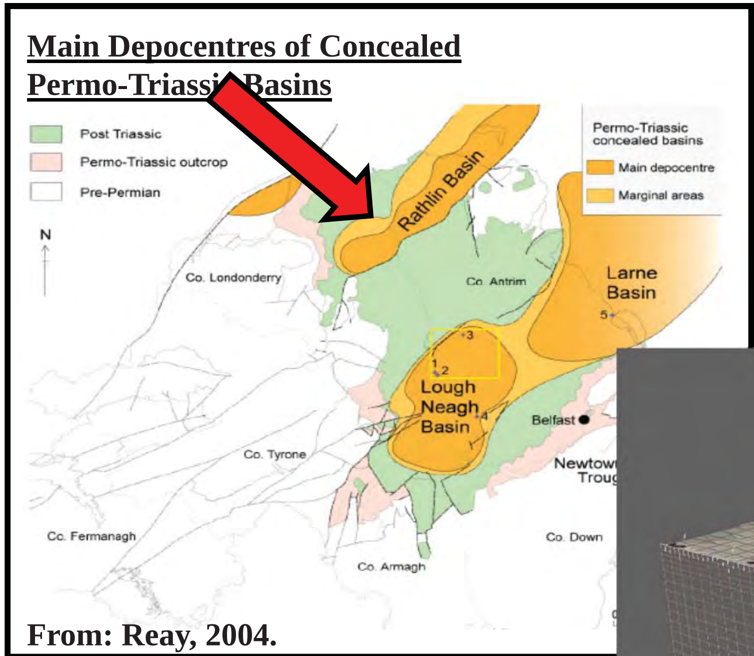


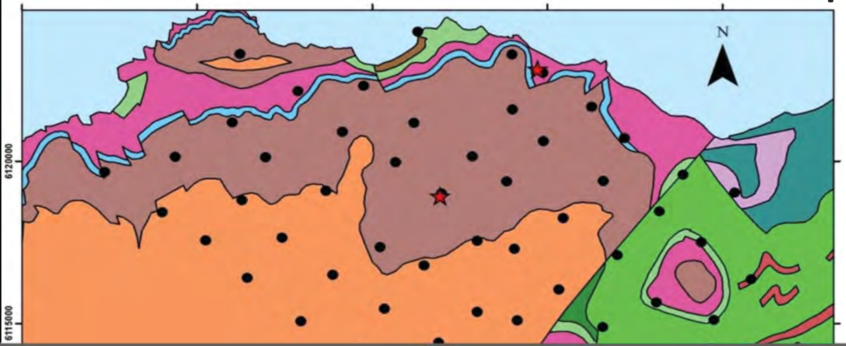
From: R. Delhaye, DIAS/NUIG

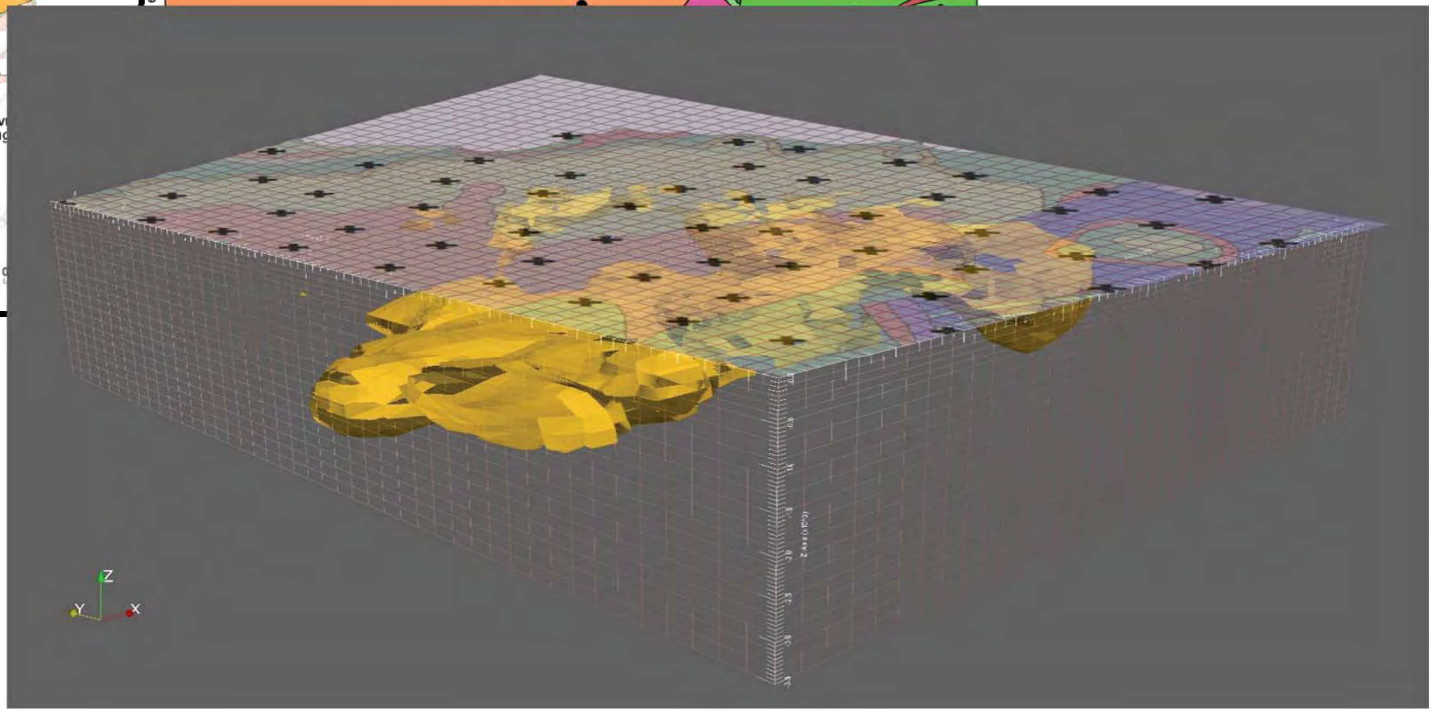
Results

1. Deep warm aquifers – a question of permeability

Rathlin Basin Triassic Sherwood Sandstone aquifer







• **Maximum depth of the conductive sandstones is 1,800 m**

→ High potential for district heating

From: R. Delhaye, DIAS/NUIG

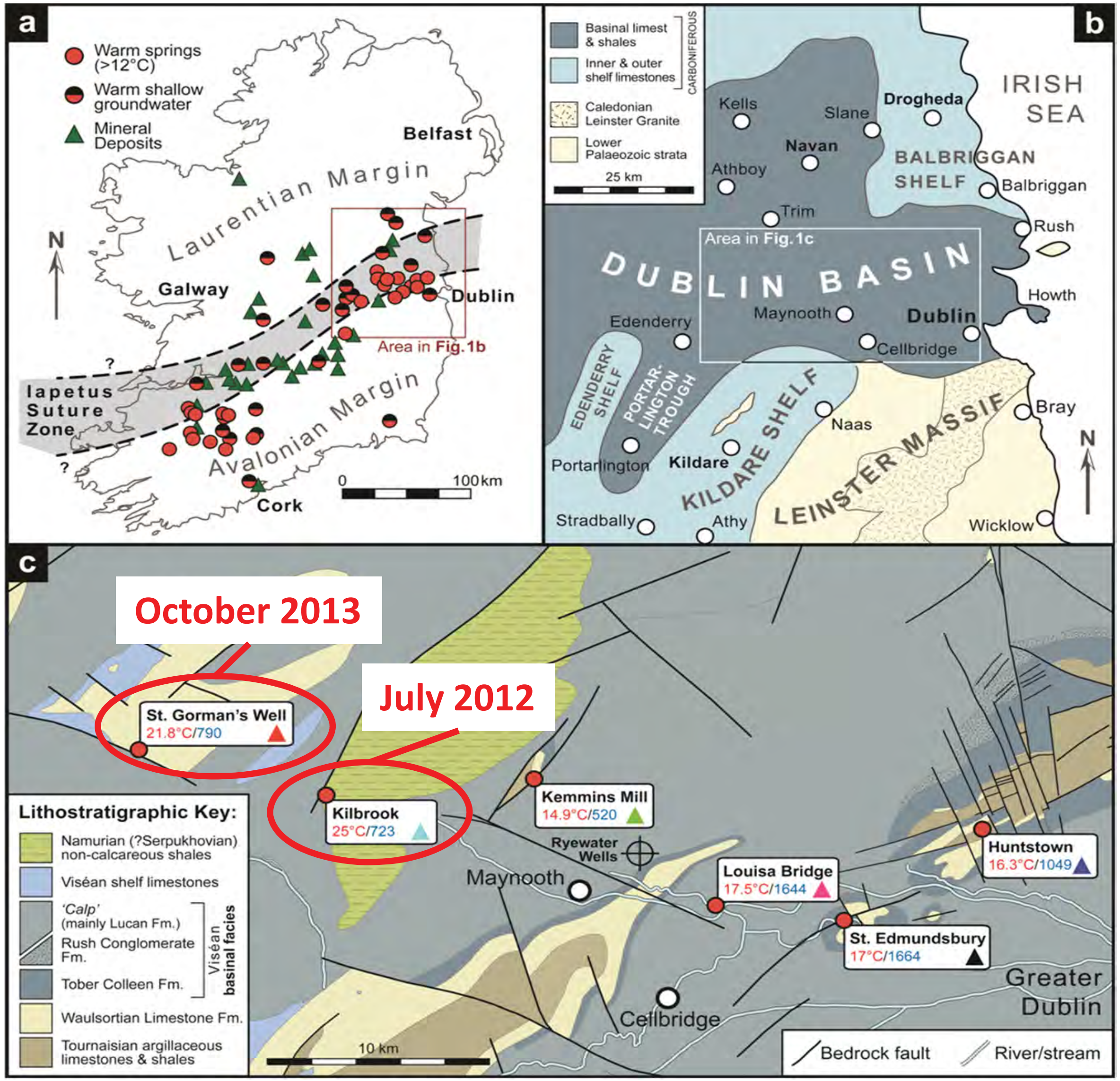
10 Ωm isosurface of M_c, extending to ~1800 m depth.

Results

1. Deep warm aquifers – a question of permeability

Irish thermal springs
Fracture porosity

- Carboniferous limestones → low 1° porosity → fracture and conduit flow
- Used AMT to identify (electrically conductive) fluid pathways in the bedrock
- Identification of Cenozoic strike-slip faults and Carboniferous normal faults at both survey locations
- Where these structures intersect likely to host hydrothermal circulation pattern

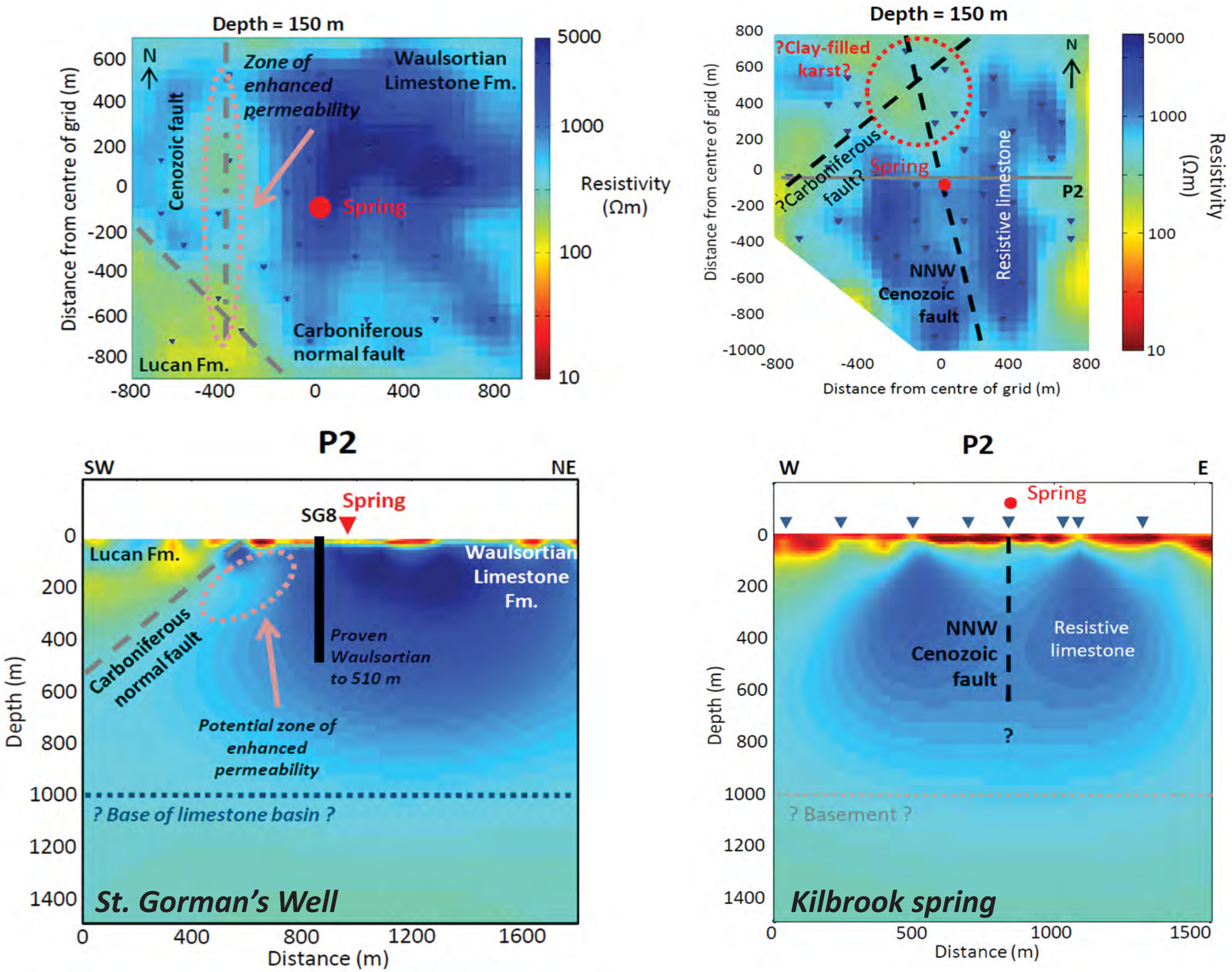


From: Blake, 2016, PhD Thesis, DIAS/NUIG

Results

1. Deep warm aquifers – a question of permeability

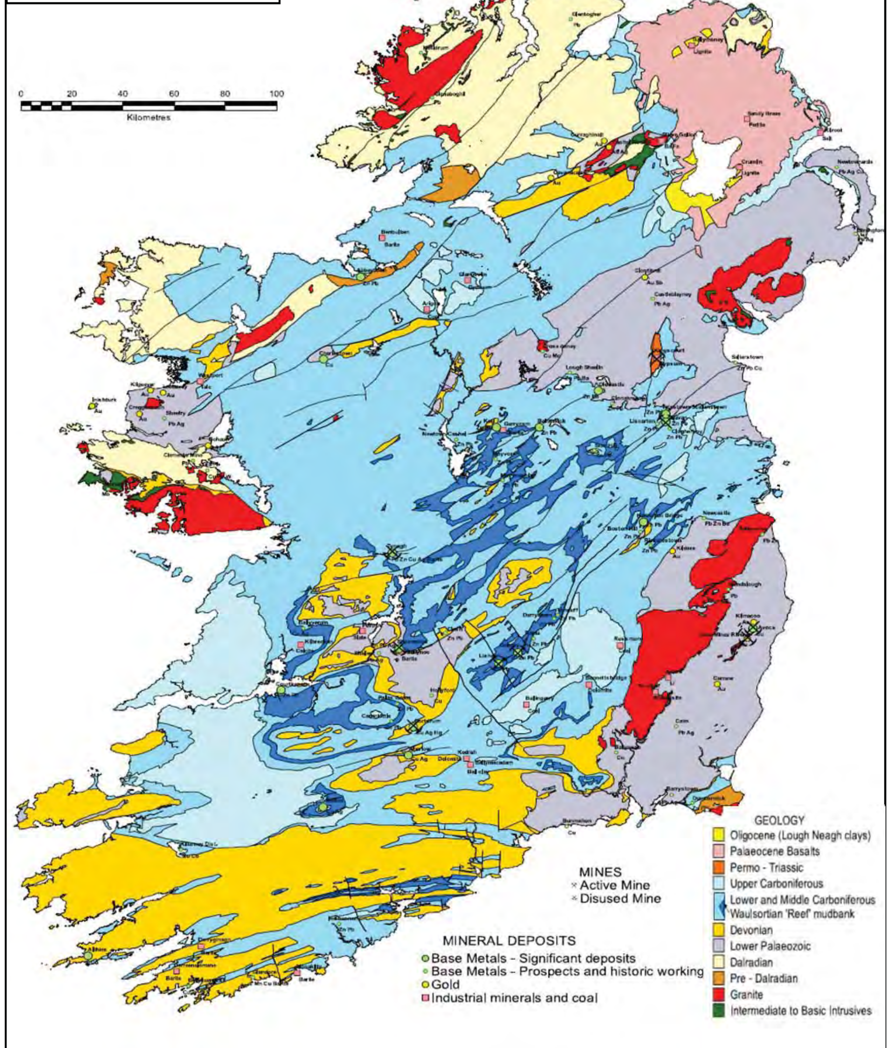
Irish thermal springs
Fracture porosity



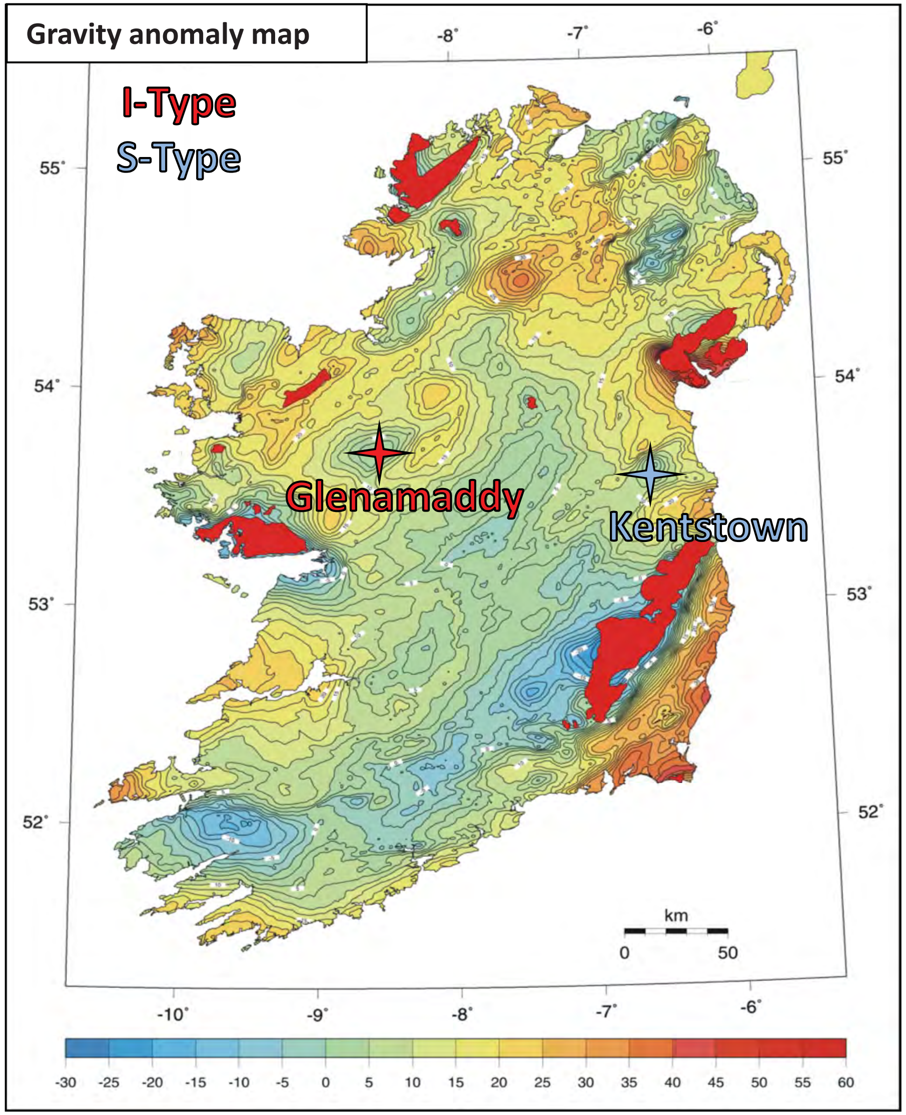
2. Hot, radiogenic granites – a question of volume and heat production

Volumetric modelling of Irish granites

Geological map



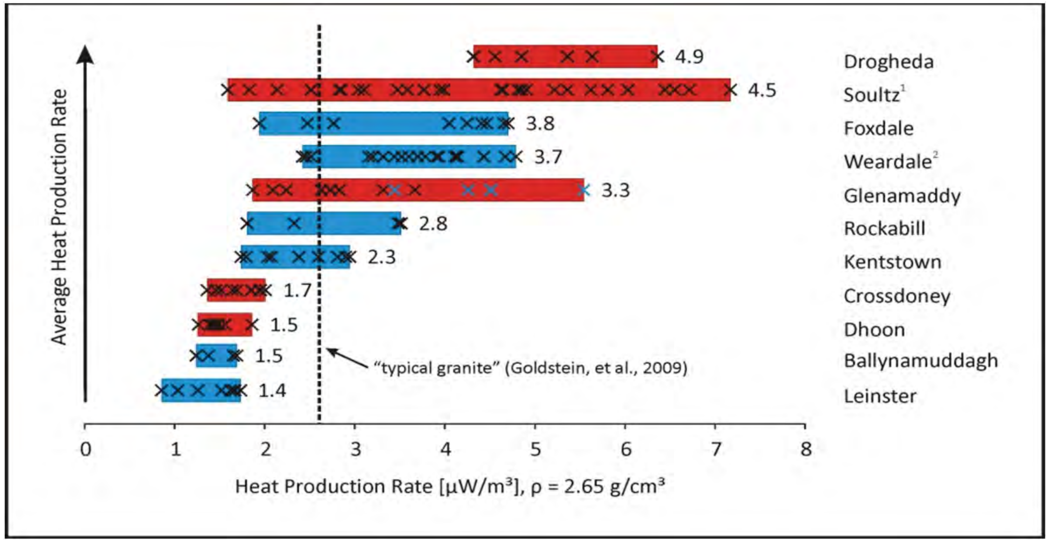
Gravity anomaly map

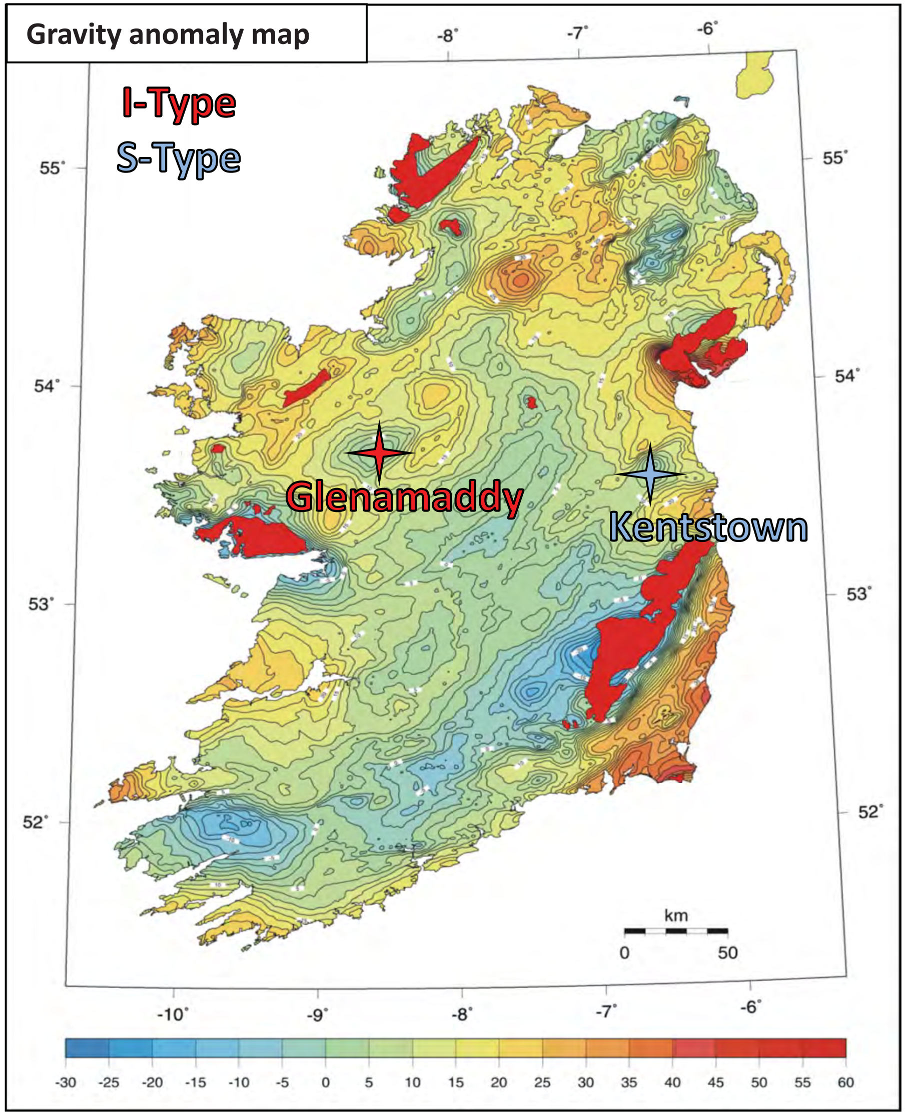


Results

2. Hot, radiogenic granites – a question of volume and heat production

Heat production rates of Irish granites



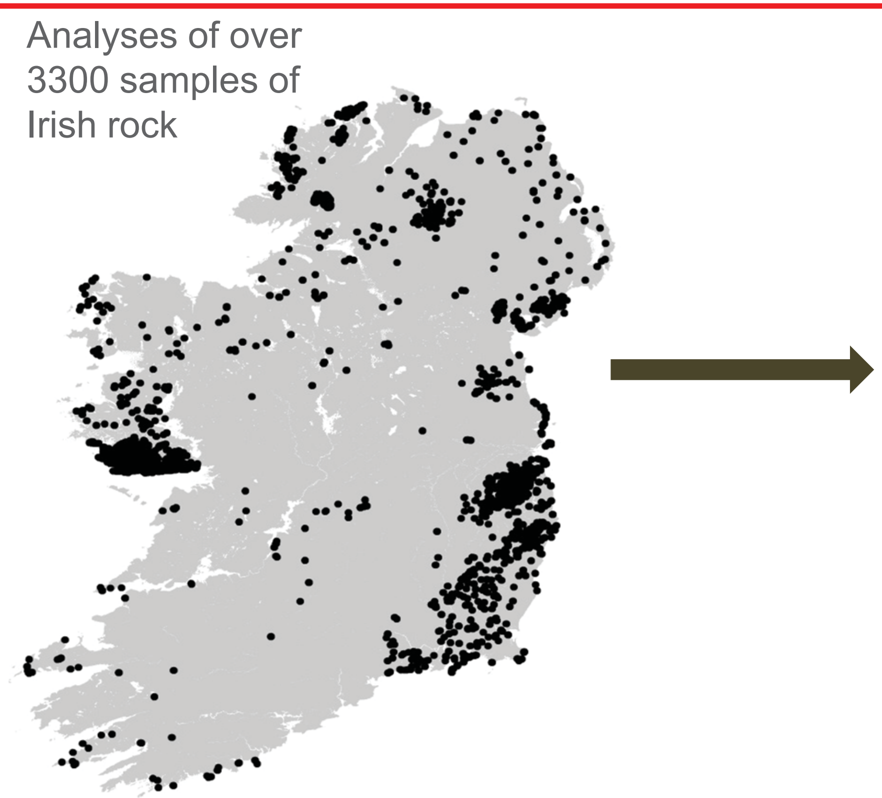


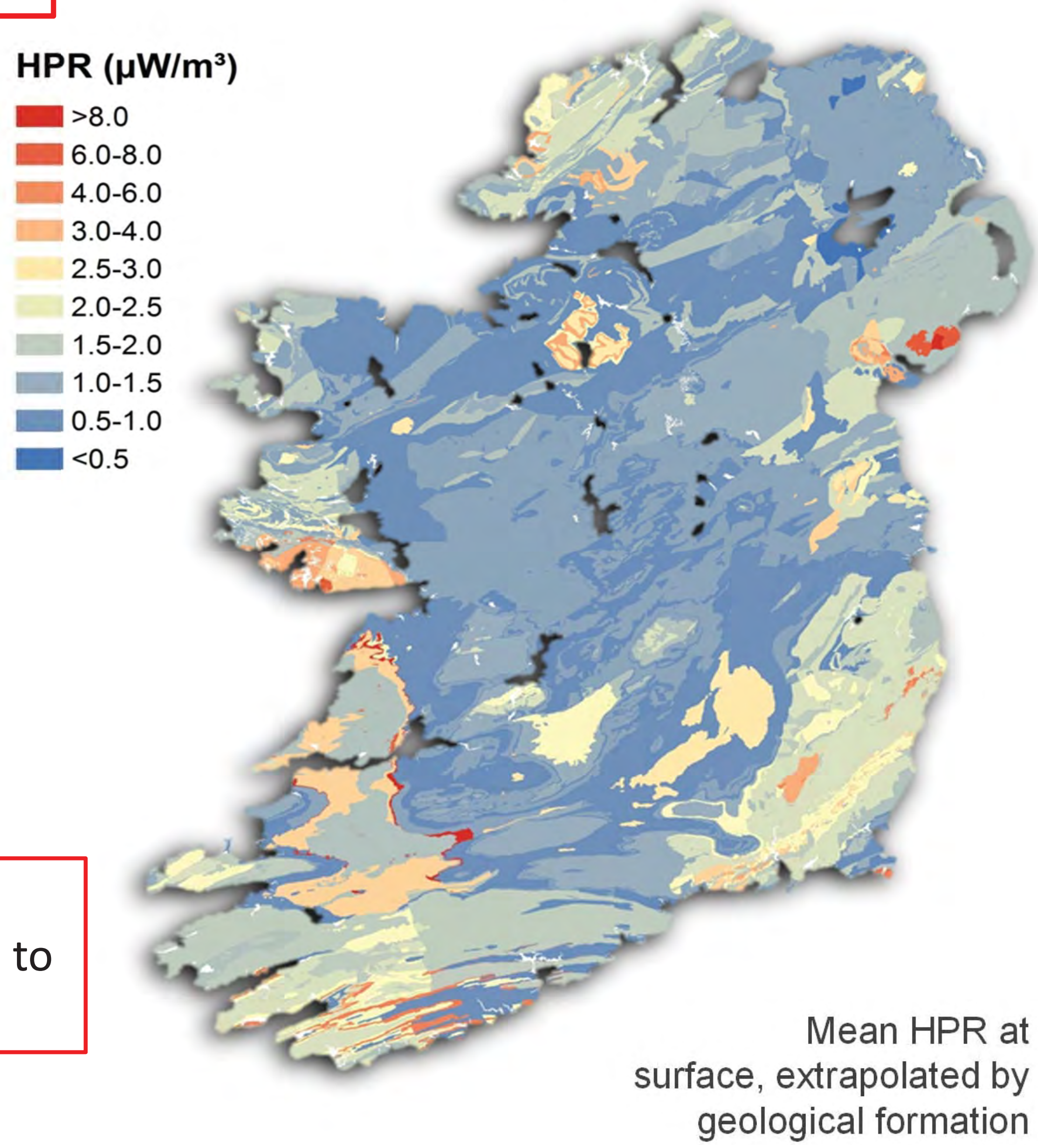
- Several Irish granites show higher heat production rates than the crustal average and are higher than commissioned or prospective European geothermal sites

From: Fritschle et al., 2015, presentation EGU

Results

2. Hot, radiogenic granites – a question of volume and heat production





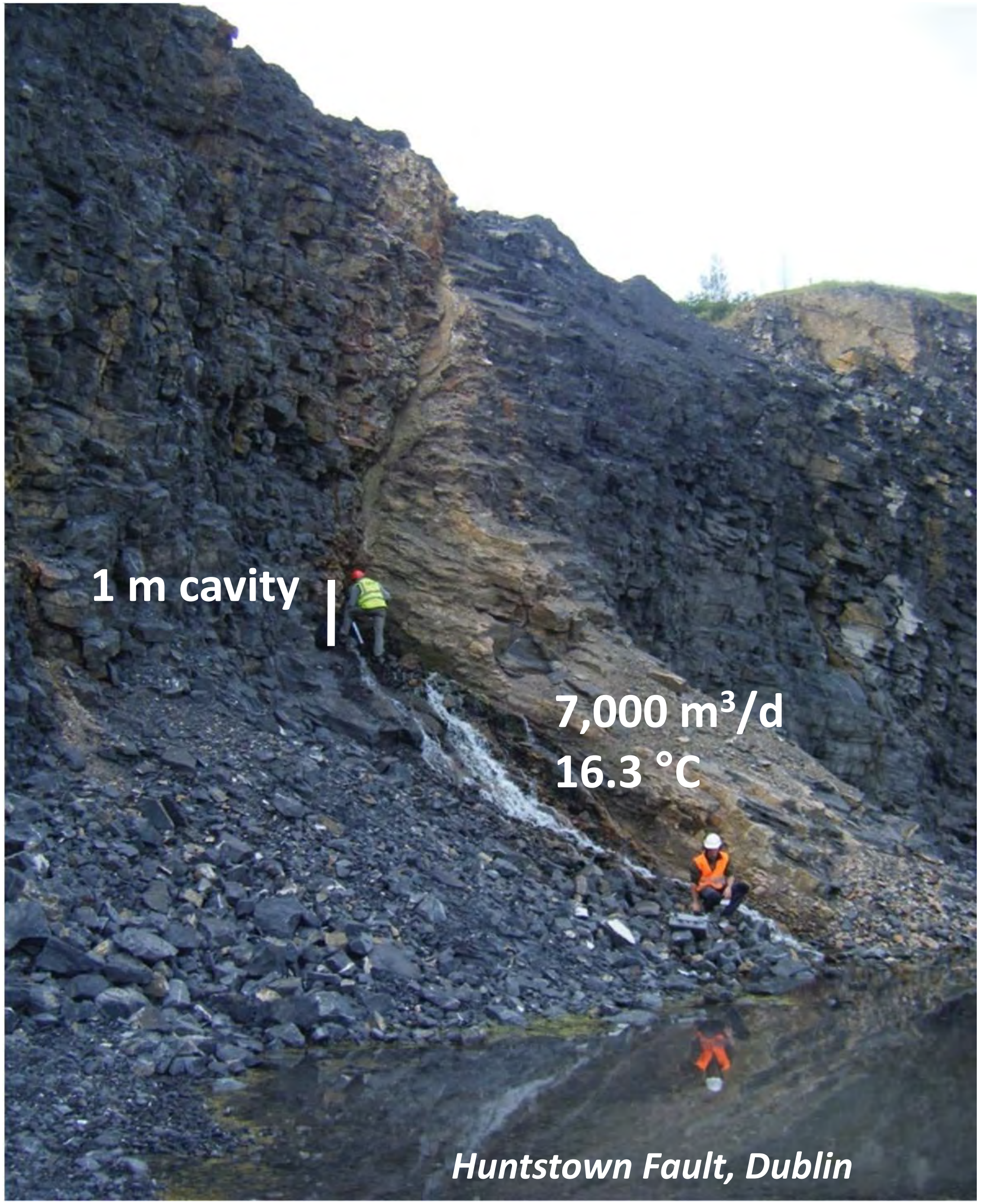
Large volumes of **high heat-producing shales** may offer an alternative source of buried heat to radiogenic granites.

From: Willmot Noller et al., 2015, presentation EGU

The future for deep geothermal in Ireland

Practical considerations for Ireland

- Fracture porosity dominant in most aquifers in Ireland
- Highly transmissive structures are extremely localised – hard to target
- Need to understand the geological structures and how they interact for the greatest yields
- Geophysical results de-risk the drilling enterprise



“Drill, drill, drill!”

and then

“Complete, complete, complete!”

Prof. Paul Younger
IRETHERM Final Workshop 2016

- Results of IRETHERM show areas of promising temperatures and permeability for district heating projects

- We desperately need real borehole data to help ground-truth our models

- Next phase of research should incorporate experts from the fields of engineering and social sciences

- Raising awareness of the benefits of geothermal energy – we need to actively engage endusers of the energy

- We need public funding – a couple of science observation boreholes in the right area will generate confidence for private investors

Thank you for your attention

G.O. Therm: Providing a 3D Atlas of Temperature in Ireland's Subsurface

Ben Mather & Javier Fullea

With the backdrop of climate change and Ireland's reliance on fossil fuels, the need to exploit Ireland's potential for secure, reliable and diverse indigenous renewable energy supply is immediate. The contribution of geothermal energy to the required energy transformation of Ireland has fallen behind targets and is far from realising its full potential. As a guide to geothermal conditions beneath our feet, Ireland's current maps of temperature within the subsurface are based on unrealistic assumptions and only a few shallow borehole temperature measurements. G.O.THERM.3D proposes a novel approach to quantify and map temperature in Ireland's crust in an integrated approach that simultaneously accounts for multiple geophysical and petrological datasets. Based on this integrative approach a new 3D temperature atlas for Ireland's crust will be built from the bottom up. The 3D temperature model will provide an insight into the thermal regime within Ireland's subsurface, offering a robust constraint on future quantitative modelling of both shallow and deep geothermal prospects across the country. The temperature model and its associated data will be made publicly available for the community on an interactive online platform and the main results will be presented in national and international conferences as well as outreach events to increase public awareness of geothermal energy. The outcomes of this project should assist in the development of public policy on geothermal energy exploration, mapping, planning and exploitation.

Contact: Dr Ben Mather, Dublin Institute for Advanced Studies bmather@cp.dias.ie Dr Javier Fullea , Dublin Institute for Advanced Studies jfullea@cp.dias.ie

G.O.THERM PROJECT

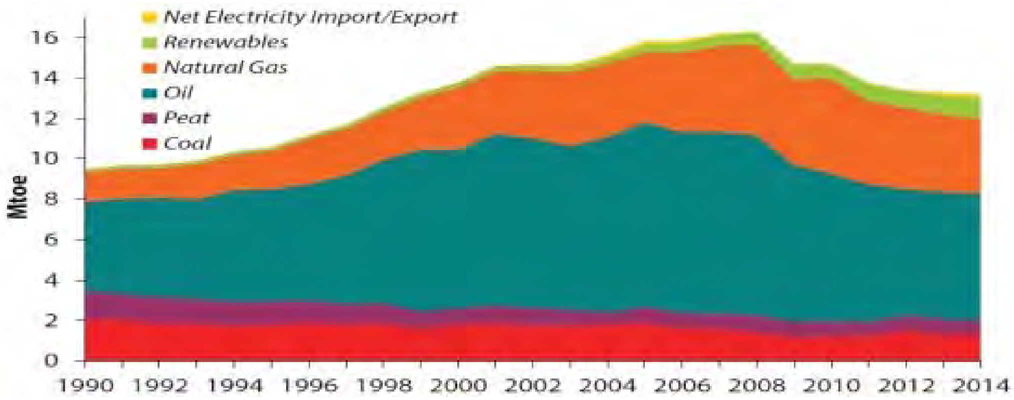
An integrated approach to probe the deep thermal structure of Ireland

Ben Mather, Thomas Farrell, Javier Fullea

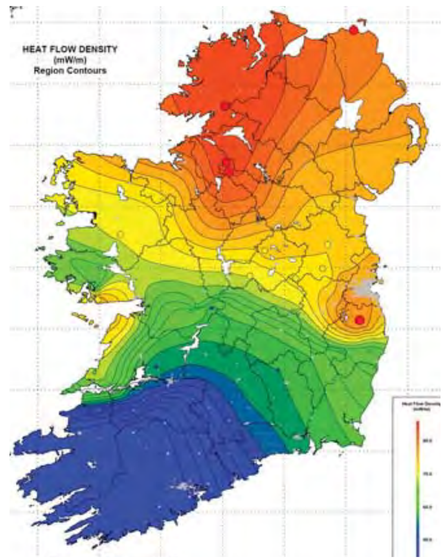
IRC Research for Policy & Society 2016 call
Co-sponsored by the GSI and SEAI

Motivation

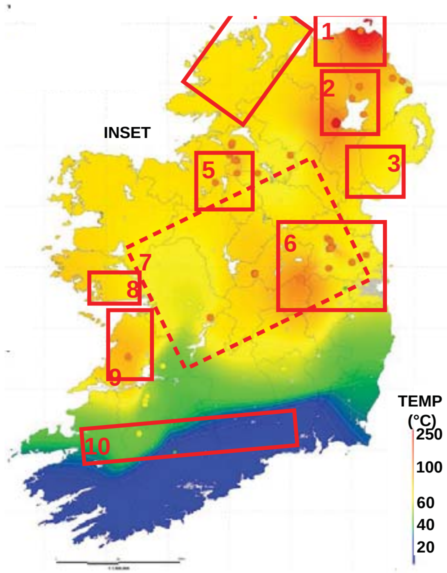
- Greenhouse gas emissions 80-95% lower than 1990 levels by 2050.
- Direct applications of geothermal energy resources can help achieve this ambitious commitment.
- **G.O.THERM** is funded through social sciences to produce research that can be disseminated publicly and to policy makers.
- Assess the *probability* of viable geothermal locations across Ireland.
  - Requires multiple datasets that are sensitive to temperature
  - Build on outputs from TELLUS and IRETHERM projects
- Collect/reassess data to help constrain regions where coverage is sparse.
  - New thermal conductivity measurements
  - Update heat flow predictions using new methodologies



Heat flow density

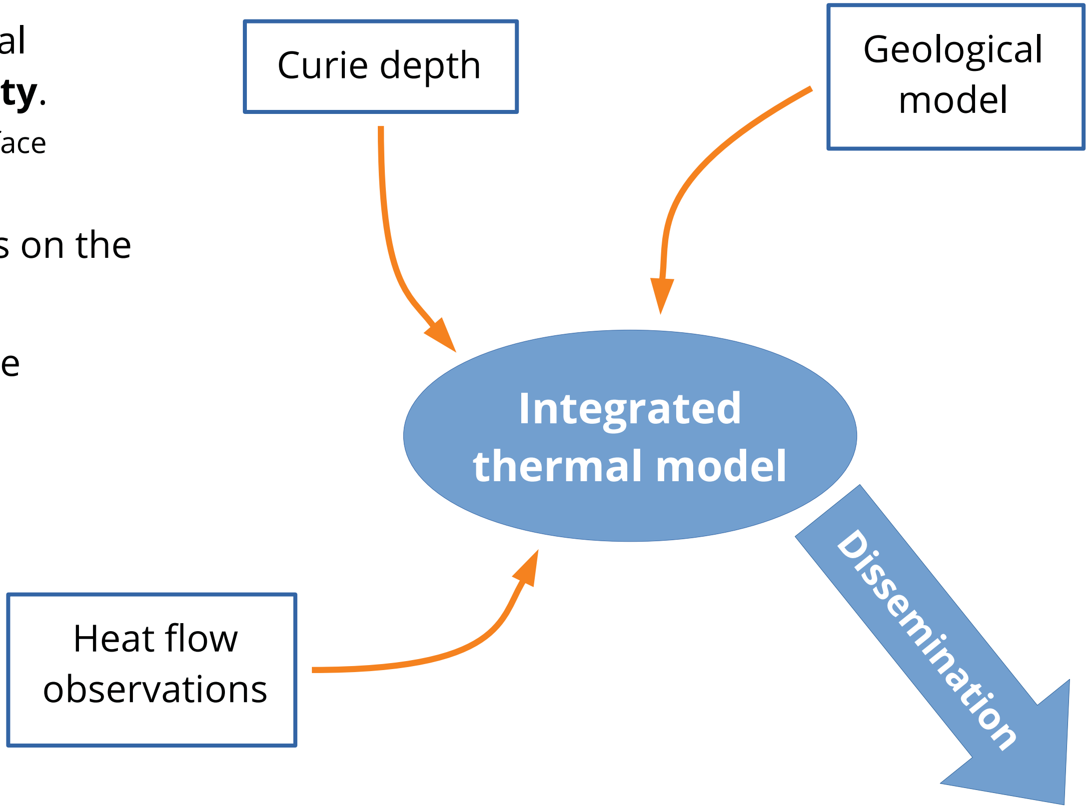


Predicted temperature at 2.5 km (GSI)



Project outline

- Produce not just a single model of thermal structure, but also quantify its **uncertainty**.
  - **Non-unique**: many configurations of subsurface rheology may fit our observations.
- Different datasets add unique constraints on the thermal regime of the lithosphere.
- Assimilating multiple datasets reduces the uncertainty of subsurface temperature.



Bayes' theorem:

$$P(\mathbf{m}|\mathbf{d}) \propto P(\mathbf{d}|\mathbf{m})\,P(\mathbf{m})$$

Posterior ~ likelihood x prior

Project outline

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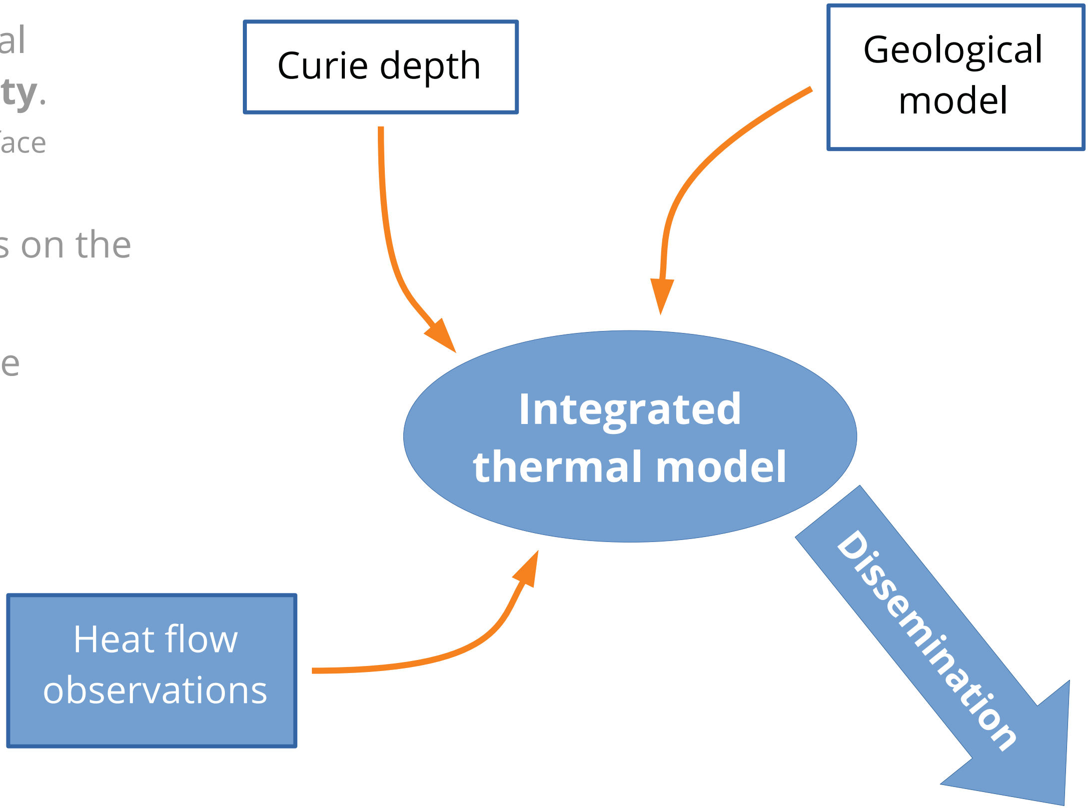
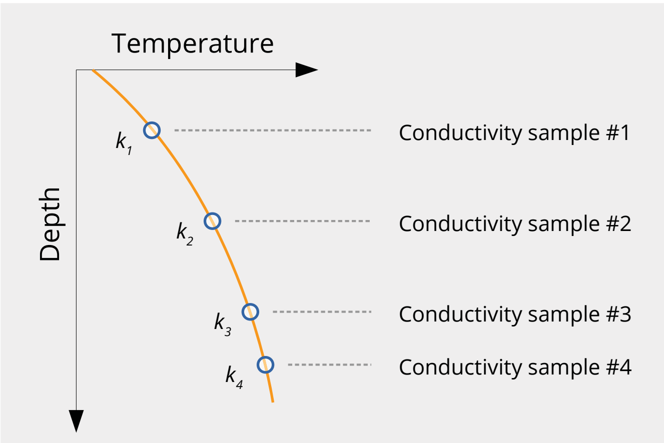
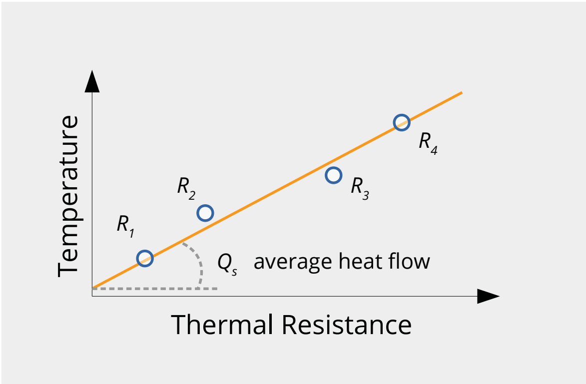


Existing heat flow data

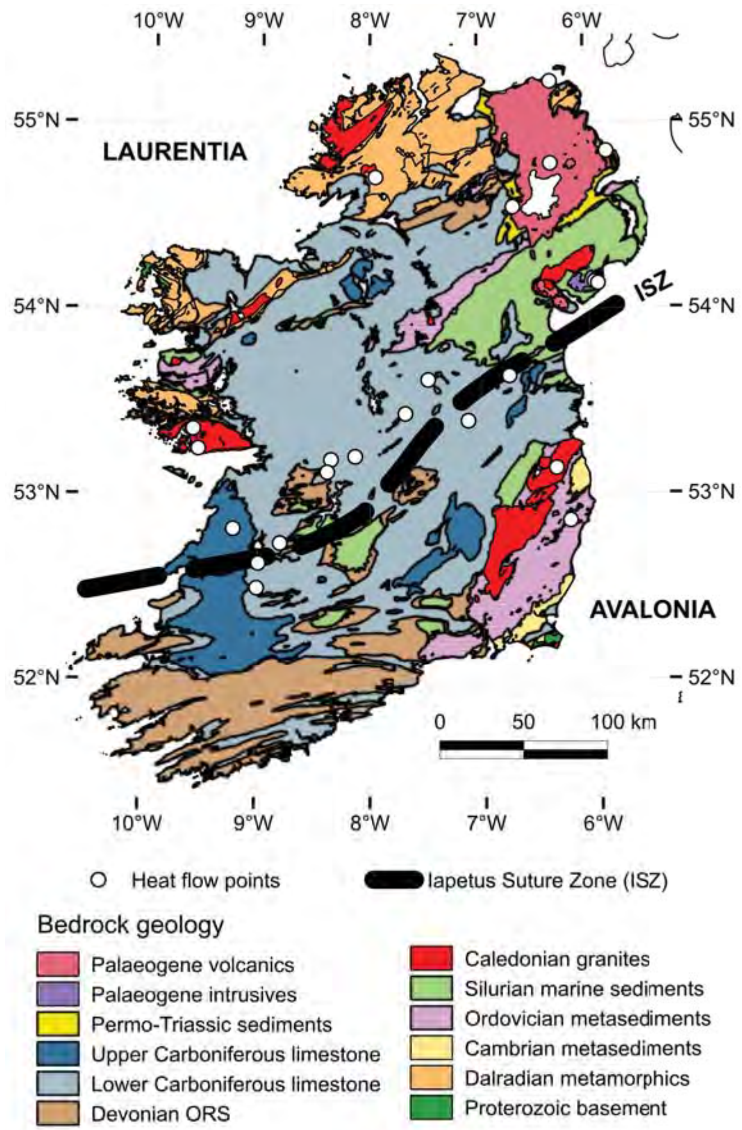
- Surface heat flow data is our **primary constraint** on subsurface temperature
- Originally collected in the 1970s and 1980s
  - Mixture of methods to calculate heat flow
  - Some of the original data is missing
- We reassess these data with a probabilistic methodology to **recalculate** surface heat flow



Temperature geotherm



Bullard plot

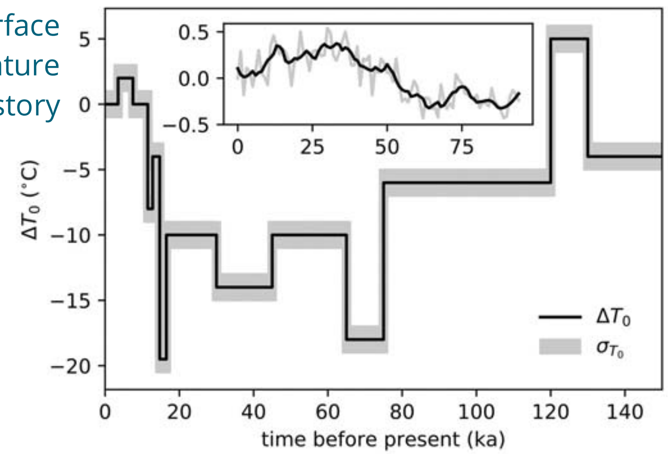


Mather *et al.* 2018 (JGR in review)

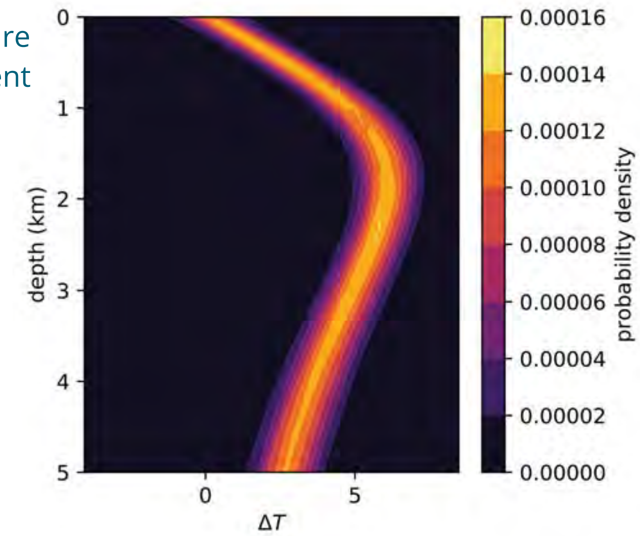
Palaeoclimate signal

- The temperature measured in a borehole is usually out of equilibrium with the rest of the crust.
- Palaeoclimate is the **biggest unaccounted factor** in current heat flow data
- Last glacial retreat ~17 ka where surface temperature was 18°C less than today
- Novel probabilistic method that applies a correction, while also quantifying uncertainty

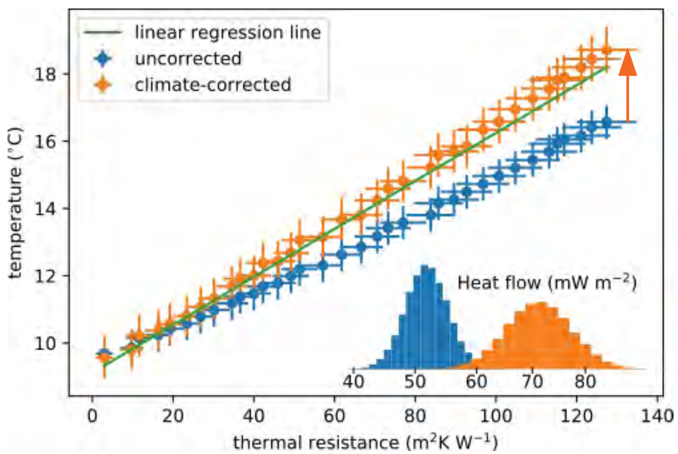
Surface temperature history



Temperature adjustment



Corrected Bullard Plot

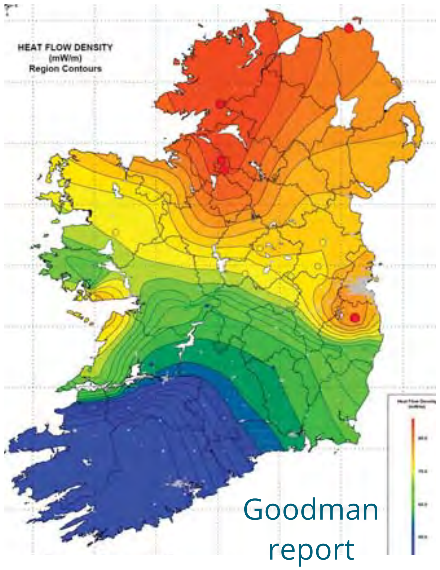


Mather *et al.* 2018 (JGR in review)

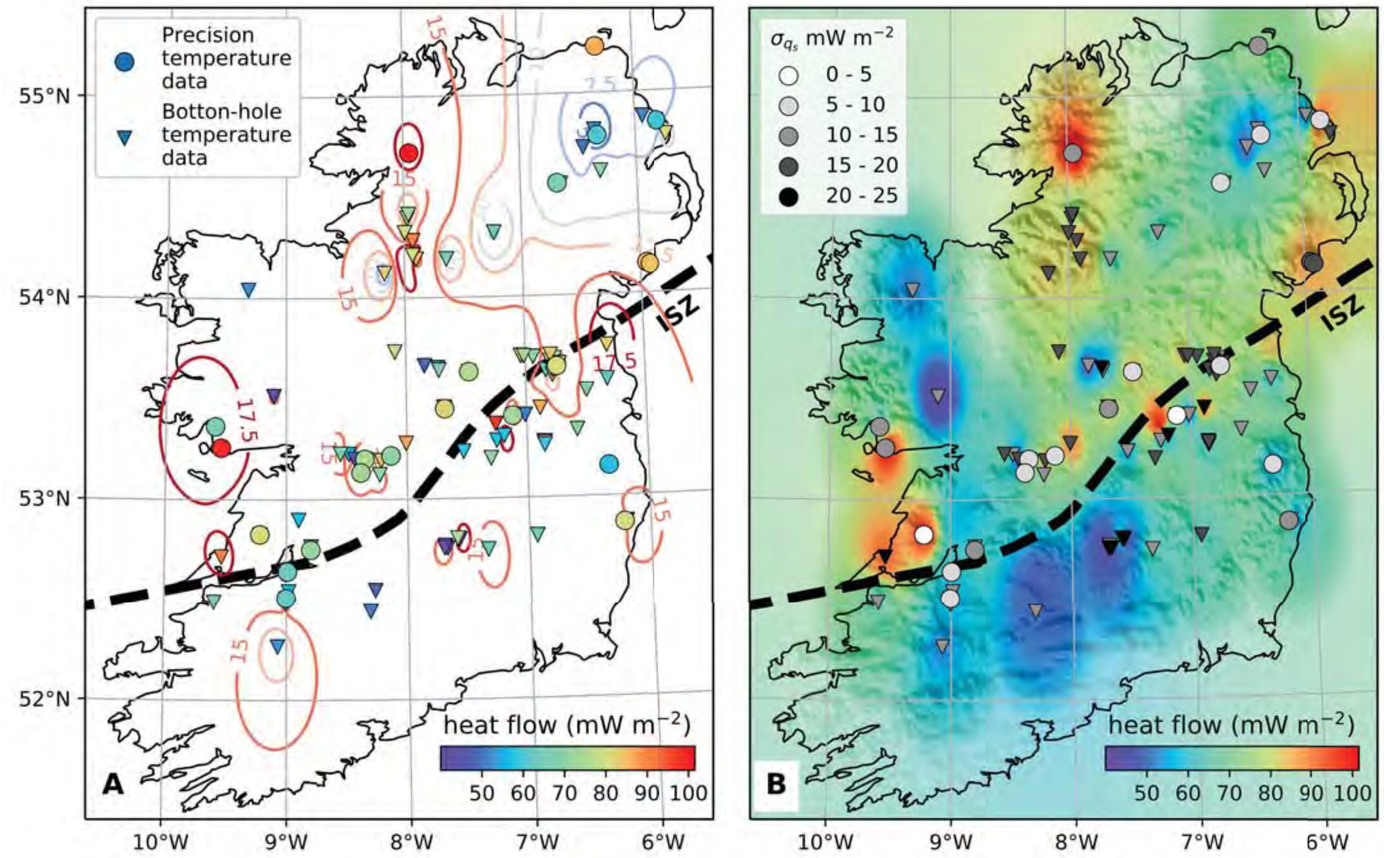
Updated heat flow map

~15 mW m-2 increase in surface heat flow (+6°C/km)

Parts of Ireland start to look more geothermally viable…



Goodman report



Contour lines indicate increase in heat flow with a palaeoclimate correction

Interpolated using inverse-distance weighting

Mather *et al.* 2018 (JGR in review)

Updated heat flow map

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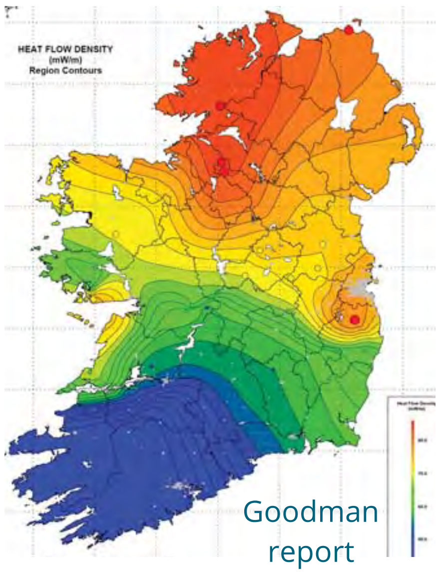
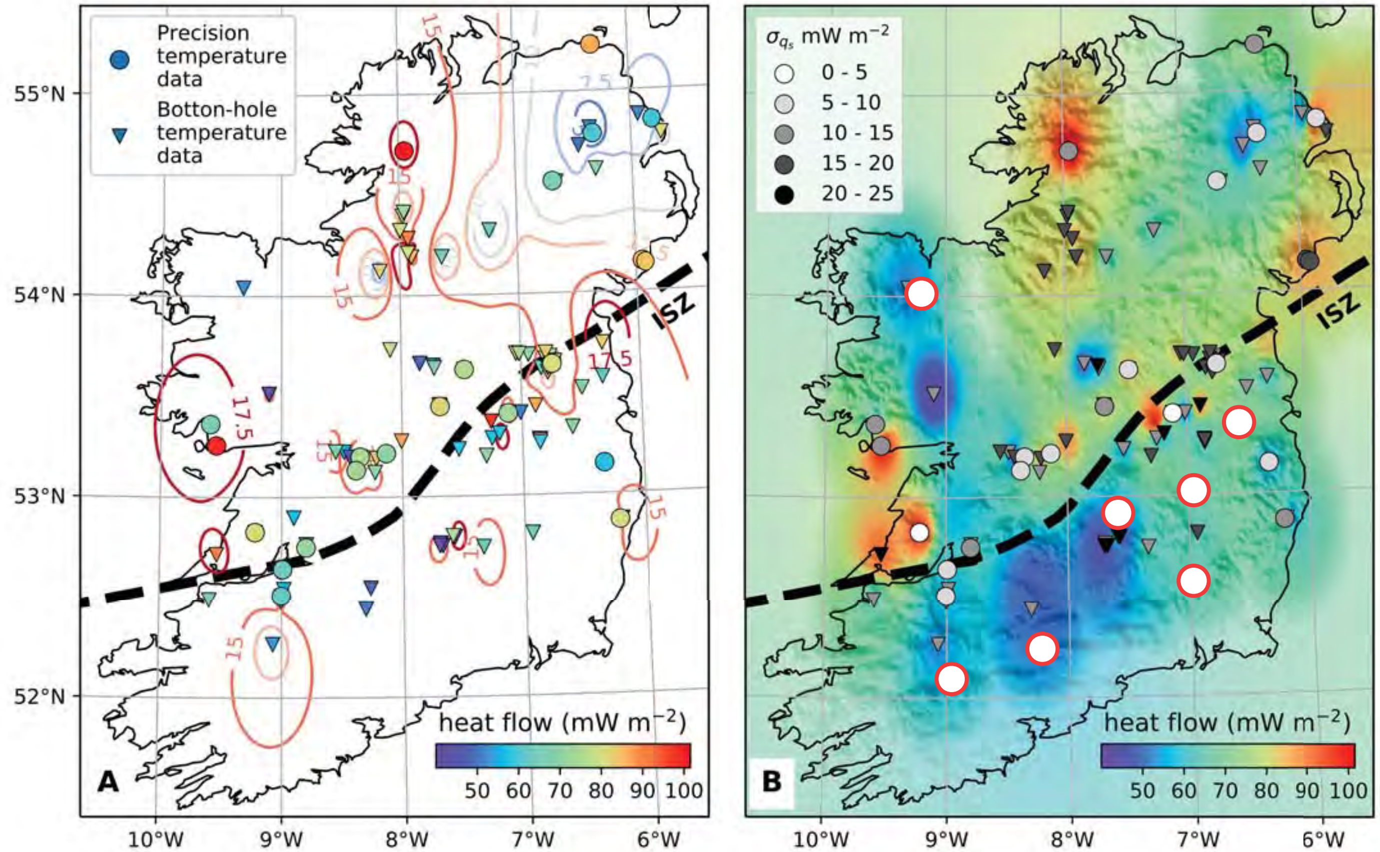
Parts of Ireland start to look more geothermally viable…

○ = Geoserv measurements



Goodman report

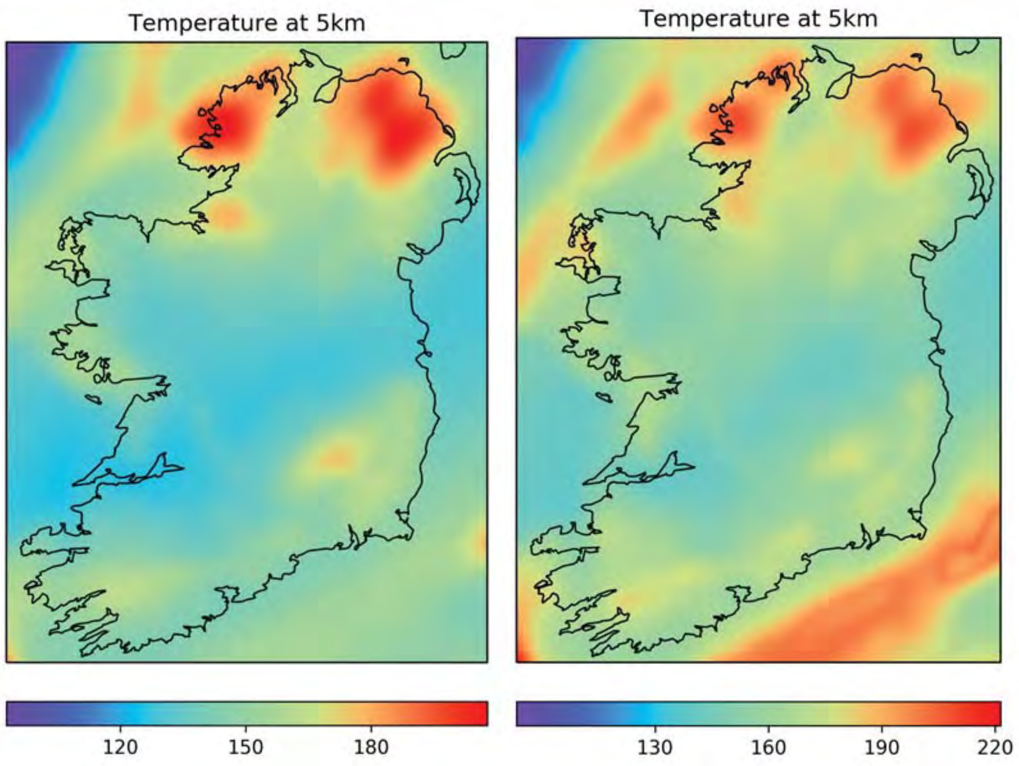


Contour lines indicate increase in heat flow with a palaeoclimate correction

Interpolated using inverse-distance weighting

The thermal conductivity conundrum

- Part of this project was to obtain new thermal conductivity measurements to
  - Increase the coverage across Ireland (e.g. Dalradian Metamorphics)
  - Provide new heat flow estimates
- GEOSERV found these were *much* lower than anticipated from historic measurements in mostly limestone (~2.1 W/mK vs. 2.8 W/mK).
- Significant implications for geothermal potential if top layer has much lower conductivity than previously anticipated.
  - Temperatures extrapolated to 5 km are 10°C higher if thermal conductivity is 25% of current estimates.
  - A change of 0.5–1km depth to geothermal resources.
- Scope for a new project to **reassess** thermal conductivity across Ireland.



Temperature at 5km with present conductivity values

Temperature at 5km with conductivity reduced by 25%

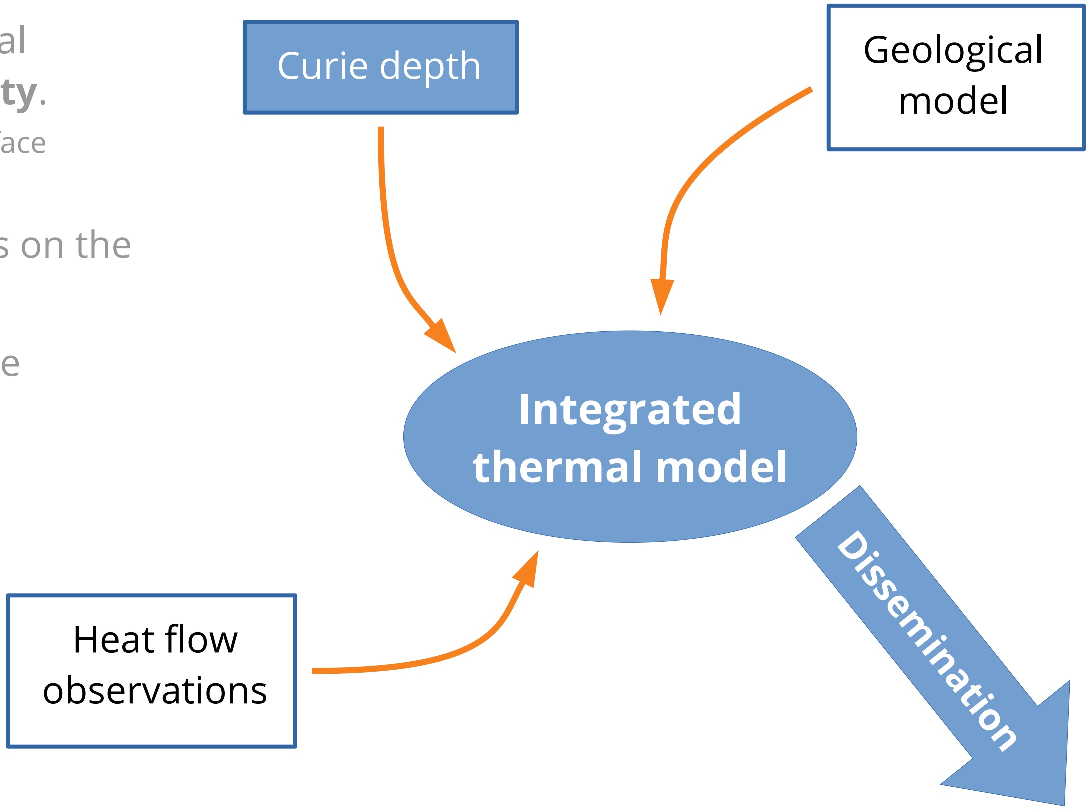
Project outline

- Produce not just a single model of thermal structure, but also quantify its **uncertainty**.
  - **Non-unique**: many configurations of subsurface rheology may fit our observations.
- Different datasets add unique constraints on the thermal regime of the crust.
- Assimilating multiple datasets reduces the uncertainty of subsurface temperature.

Bayes' theorem:

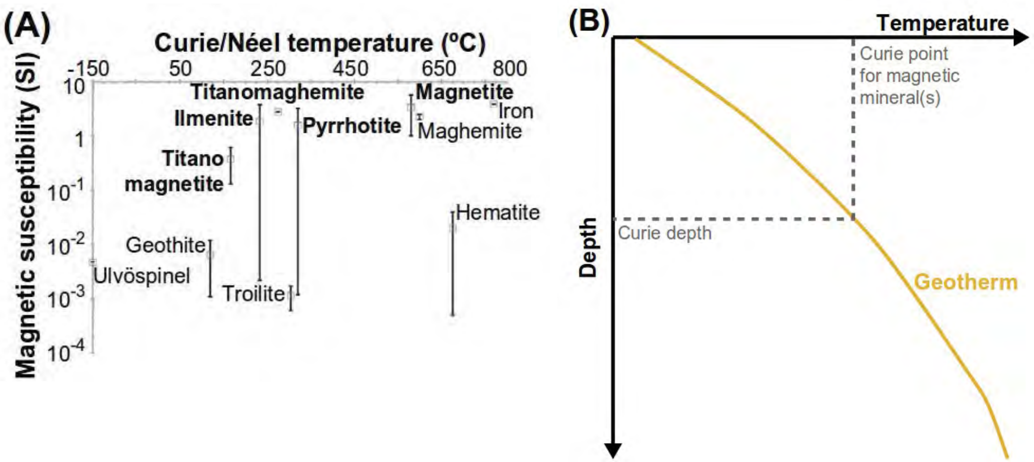
$$P(\mathbf{m}|\mathbf{d}) \propto P(\mathbf{d}|\mathbf{m})\, P(\mathbf{m})$$

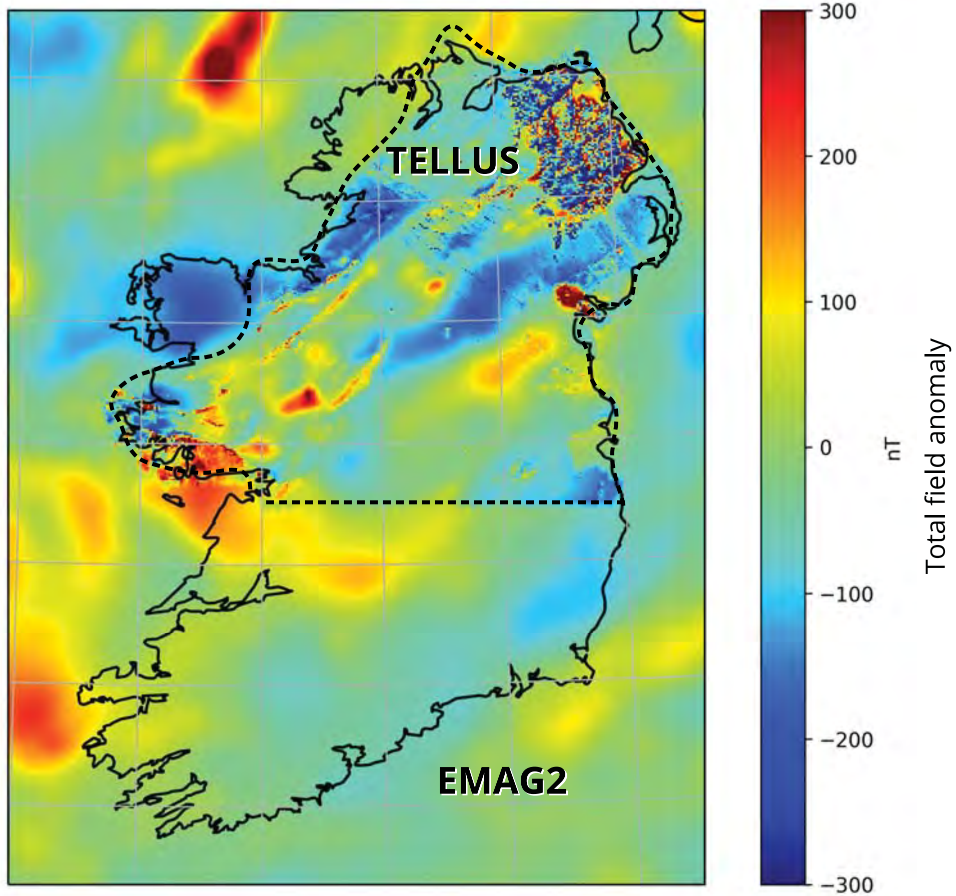
Posterior ~ likelihood x prior



TELLUS about Curie depth

- The temperature at which magnetic minerals lose their permanent magnetic properties is the "Curie temperature"
- Dominant magnetic mineral is **magnetite**, which has a Curie point of 580°C.
- We can analyse the magnetic anomaly to estimate the **depth to the 580°C isotherm** – i.e. "Curie depth".

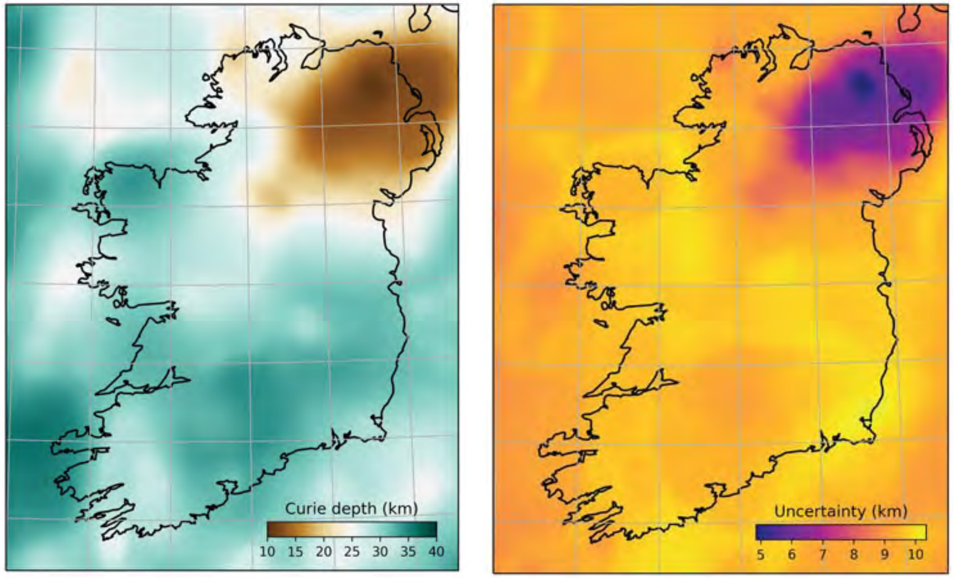


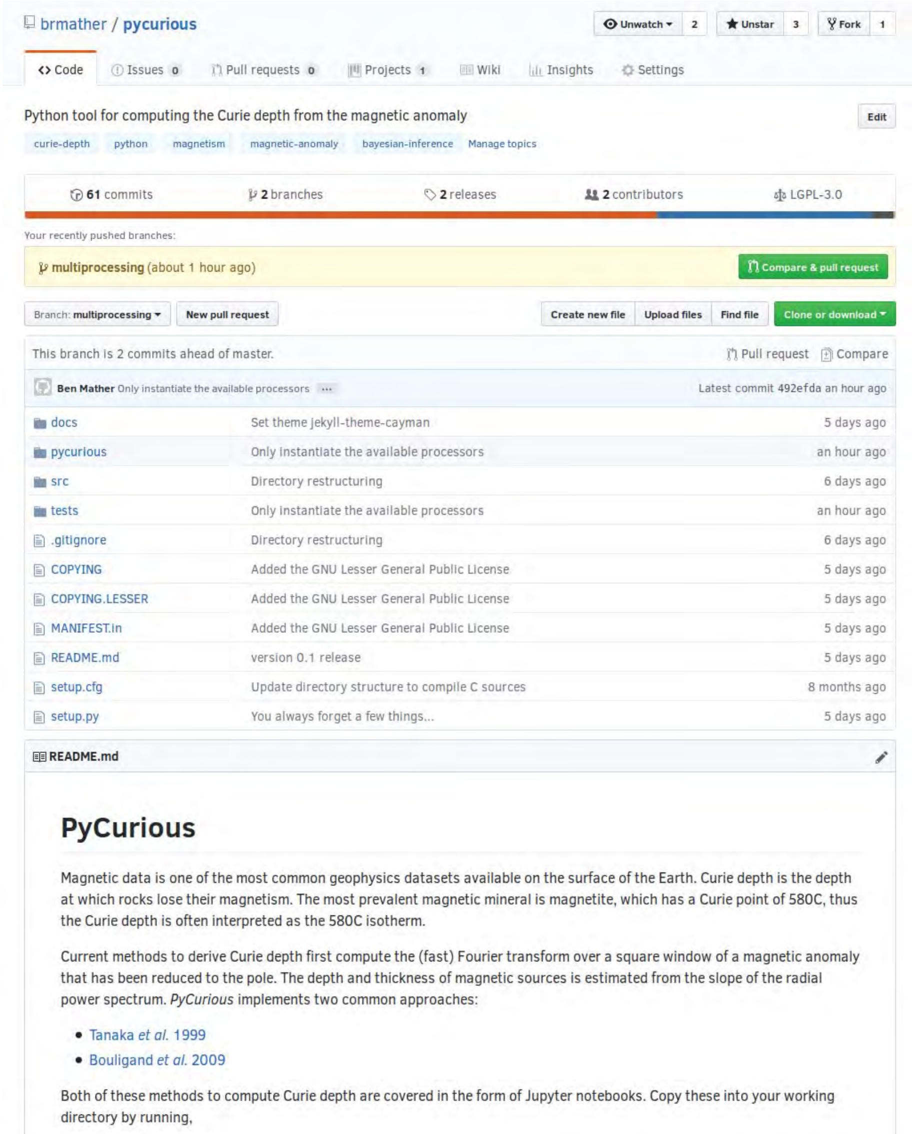


Magnetic anomaly

PyCurious

- Python tool for computing the Curie depth from the magnetic anomaly
  - Efficient parallel code
  - Few dependencies
  - Open source software that can be applied to many regions worldwide
- In Ireland, the depth to 580°C is shallow ~ 15 km





https://github.com/brmather/pycurious

Project outline

- Produce not just a single model of thermal structure, but also quantify its **uncertainty**.
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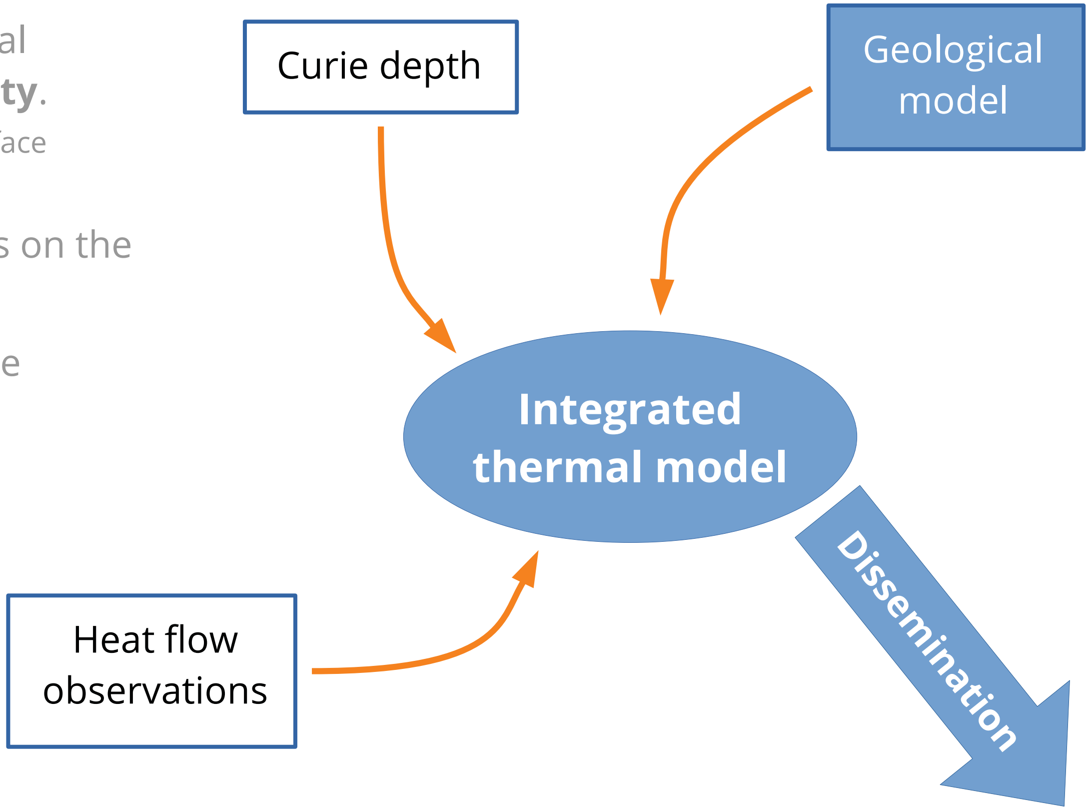
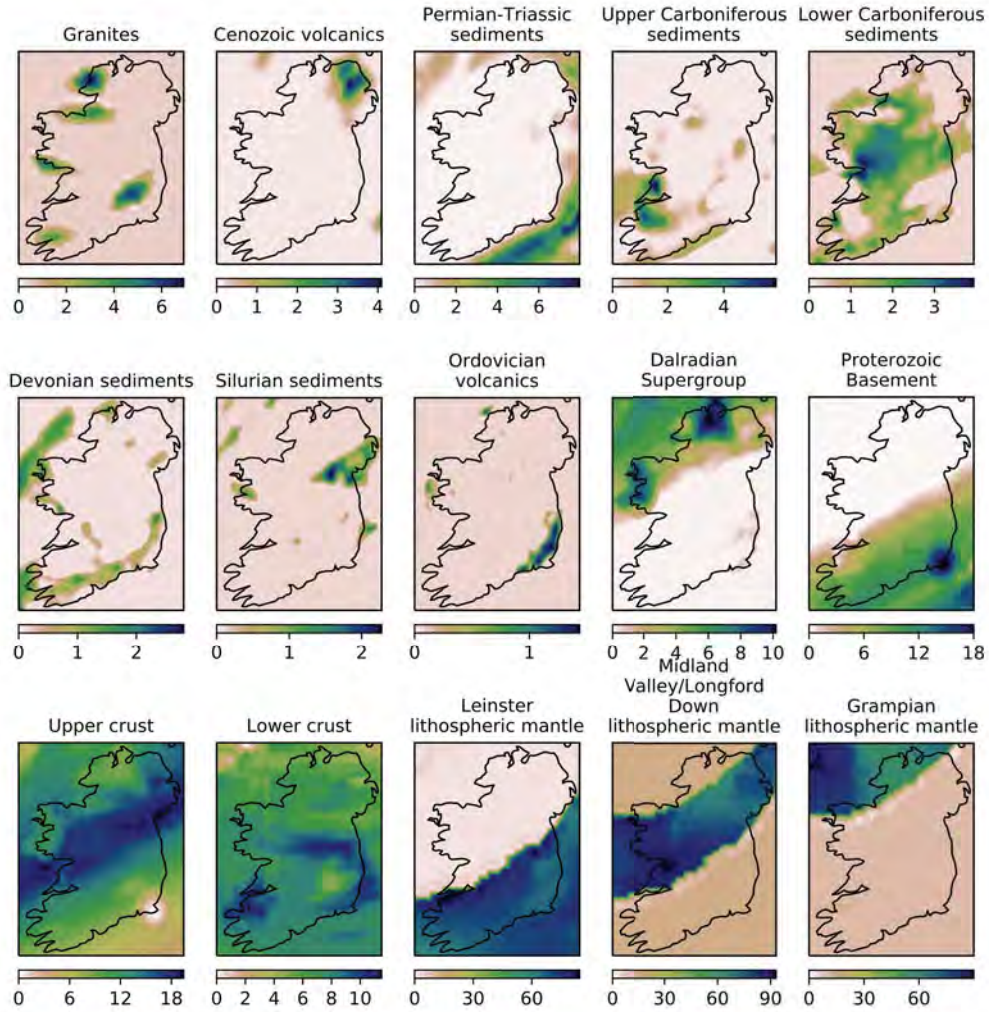


Geological model of the lithosphere

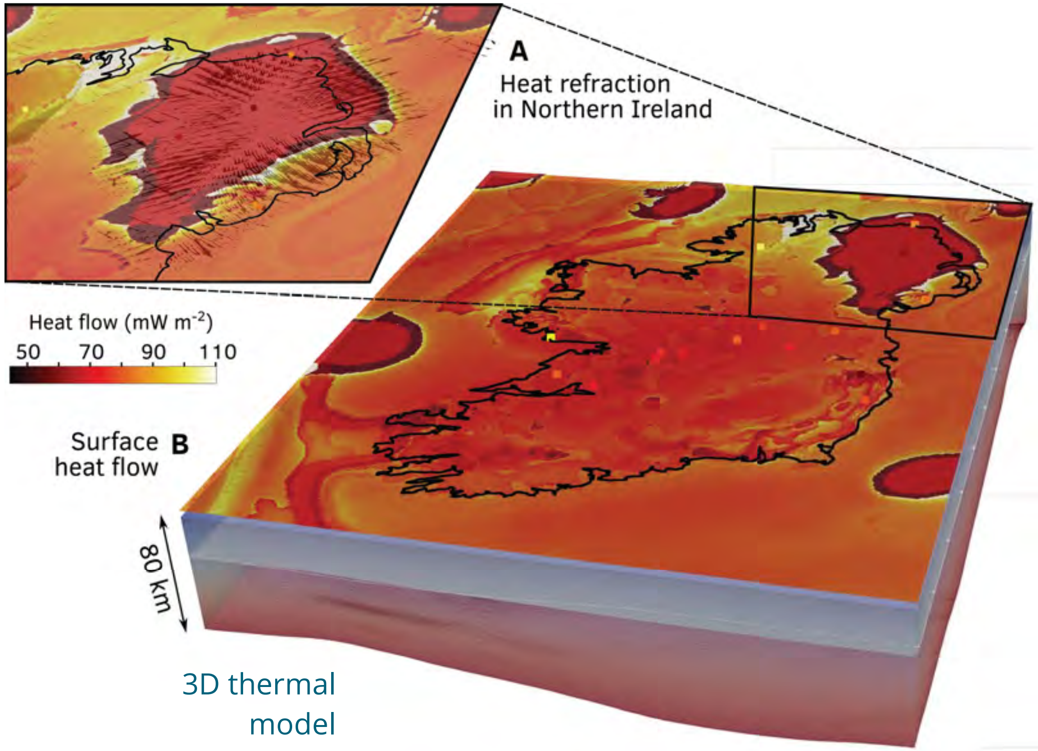
- Map thermal conductivity and heat production to various regions of the lithosphere.
- New model of the lithosphere integrates:
  - Surface geology (GSI map)
  - Vp/Vs ratios
  - Seismic refraction profiles
  - Regional P-wave tomography
- Model is not perfect, but it can be iteratively improved by *the geologists of tomorrow.*
  - Distributed in the hope it will be useful
  - IRELAND 1.0
- A wide range of potential applications, not limited to geothermal studies:
  - **Industy**: hydrocarbon potential, mineralisation
  - **Research:** structural interpretation, electrical conductivity, seismic tomography.



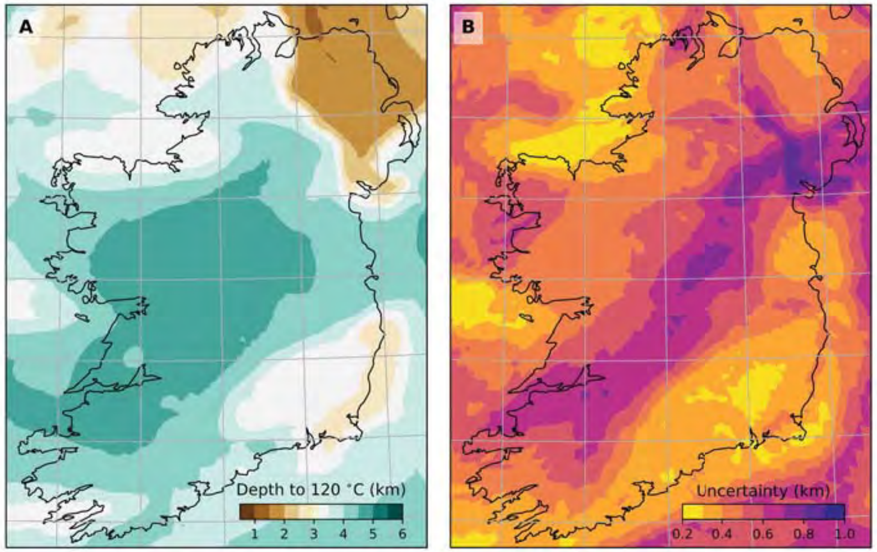
IRELAND 1.0
Layer thicknesses

Integrated thermal model (in progress)

- Assimilates corrected heat flow, Curie depth, and geological prior information.
  - Significant heat refraction in Northern Ireland.
  - High temperatures proximal to the Leinster Granite.
- Further constrain thermal structure with seismic velocity and gravity anomaly.



3D thermal model



Depth to 120C & uncertainty

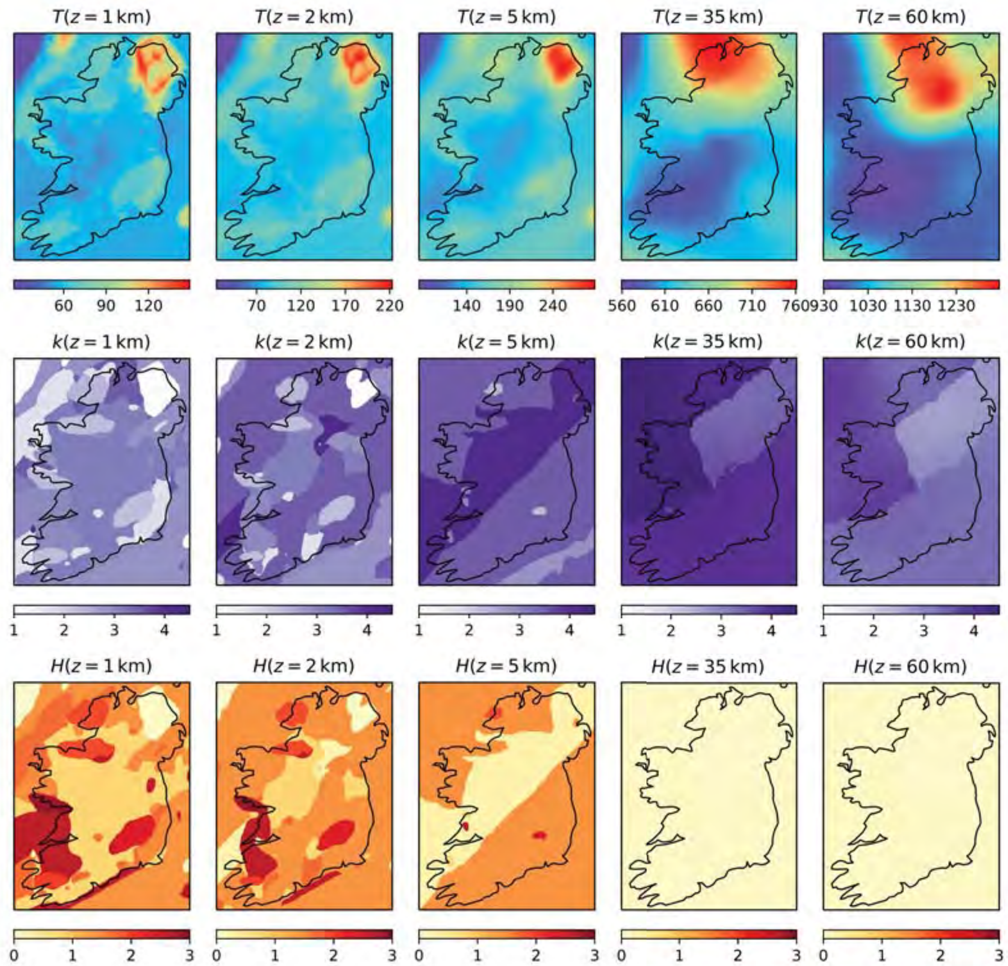
Mather & Fullea 2018 (in prep)

Conclusions

- Bayesian inversion produces a model with the optimal trade-off between each dataset.
  - Heat flow observations tell us about the integrated heat flux with depth.
  - Curie depth offers a 580°C isotherm constraint.
  - Seismic velocity helps to constrain subsurface rheology *(in progress)*
  - Gravity anomaly constrains density *(in progress)*
- Our thermal model of Ireland (and uncertainty) will be disseminated
  - Temperature maps at various depths online
  - 3D interactive model visualised in Paraview

Achievements

- Reassessment of historic heat flow data
- IRELAND 1.0 geological model
- PyCurious – open software to find Curie depth
- Preliminary 3D thermal model of Ireland



Thank you

Geourban: Identification and Assessment of Deep GEOthermal Heat Resources in Challenging URBAN Environments

James McAteer & Sarah Blake

The Geo-Urban project aims to evaluate novel geophysical exploration and modelling techniques for urban areas, which will be applied at two test locations, Vallès, Catalonia, Spain and Dublin, Ireland. Geophysical data collected during GEO-URBAN will feed into a commercialisation strategy for the exploitation of deep geothermal resources in challenging urban environments, which will draw upon existing knowledge and experience from partners in Denmark, where the deep geothermal heat industry is more established. Significant stakeholder involvement of local planning authorities and companies ensure that GEO-URBAN exploration activities align with local sustainable energy plans and district heating strategies. Furthermore, policy recommendations to assist the sustainable exploitation of deep geothermal energy resources in each region will be outlined. The overall objective of the GEOURBAN project is to identify the geothermal resources available in two challenging urban locations and to demonstrate a commercialisation strategy for such an environment that has the potential to be adapted in other similar locations.

Contact: Dr Sarah Blake , GDG Ltd sblake@gdgeo.com James McAteer GDG Ltd

GEO-URBAN

GEO-URBAN

Identification and Assessment of Deep GEOthermal Heat Resources in Challenging URBAN Environments

Project Overview

James McAteer
GDG
GAVIN & DOHERTY GEOSOLUTIONS

Deep Geothermal in Ireland – Past Present and Future. 6th September 2018

GEOTHERMICA This project has been subsidised through the ERANET Cofund GEOTHERMICA (Project no. 731117), from the European Commission and the Department of Communications, Climate Action and Environment / Geological Survey Ireland.
Project no. 731117

GEO-URBAN

Introduction to Geo- Urban

- The GEO-URBAN project aims to explore the potential for low enthalpy geothermal energy in urban environments.
- 7 Co-applicants & 3 Cooperation Partners
- Two target locations – Dublin, Ireland and Vallès, Catalonia, Spain
- Provide feasibility analysis for the commercial development of deep geothermal resources in these regions.

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Introducing our consortium

	IRELAND	SPAIN	DENMARK
Co-applicants	GDG (GDG Gavin & Doherty Geosolutions)	UB (Universitat de Barcelona)	GEOOP (GEOOP)
	iCRAG (iCRAG)	BSC (BSC)	
	DIAS (DIAS)		
	DCC (Comhairle Cathrach Bhaile Átha Cliath Dublin City Council)		
Cooperation partners	GAI (The Geothermal Association of Ireland)	ICGC (icgc.cat)	
		GEOPLAT (geoplat)	

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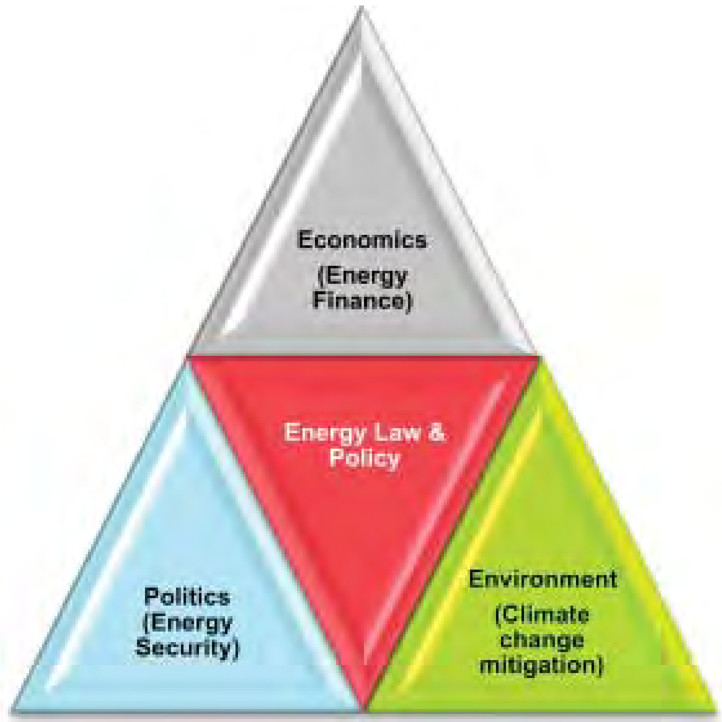
GEO-URBAN

Motivation

- Pressures faced by EU member states to increase energy efficientcy (32.5% efficiency by 2030)
- Heat sector (homes and businesses) accounts for around 40% of total annual energy expenditure in Ireland (SEAI, 2015)
- Geothermal heat energy could provide a solution to the “Energy Trilemma” (Heffron et al., 2015)
- Barriers to geothermal energy are high capital expenditure and lack of policy



Representation of the ‘Energy Trilemma’, or the aim of trying to achieve a balance between the competing demands of economics, politics and the environment. From Heffron et al., 2015.

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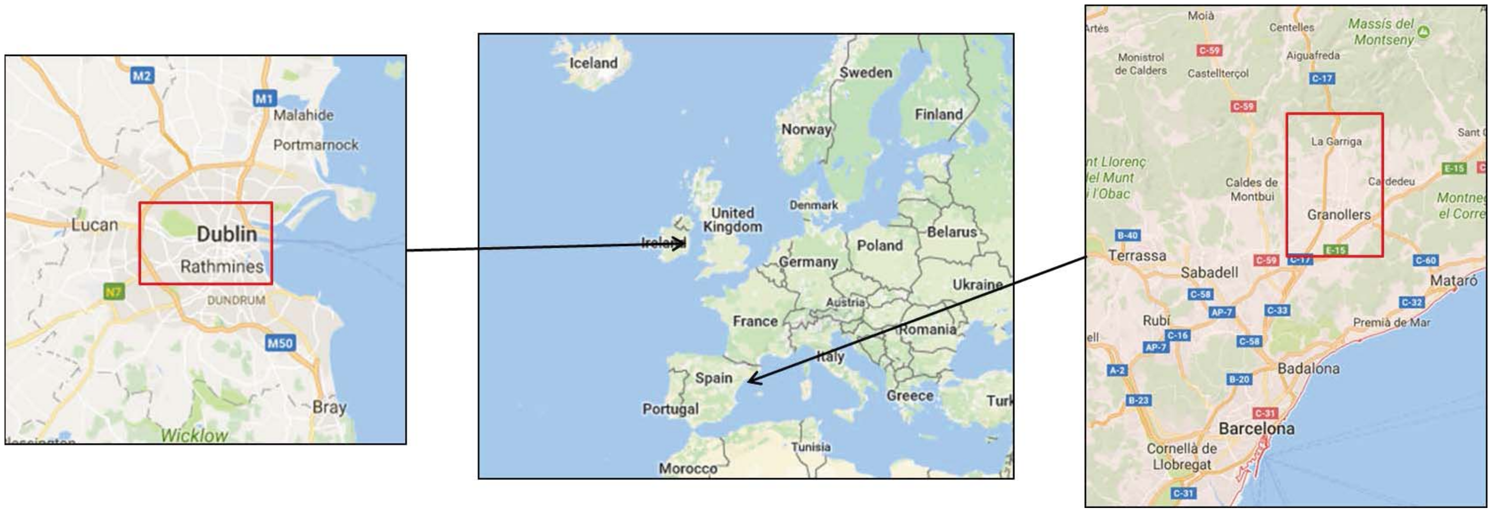
Aims and Objectives

“The **overall objective of GEO-URBAN** is to identify the geothermal resources available in two challenging urban locations and to demonstrate a commercialisation strategy that has the potential to be adapted in other similar locations, thus advancing geothermal energy from a TRL 5 to a TRL 7 in the target areas.” *GEO-URBAN Stage 2 Proposal Document, November 2017*

Dublin City
Ireland



Vallès, Catalonia
Spain

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Aims and Objectives

Specific objectives for each test location:

1. Feasibility analysis for commercial geothermal district heating
2. Improved conceptual understanding of the subsurface geology
3. Promotion of geothermal energy as an option for district heating

Dublin City
Ireland

Vallès, Catalonia
Spain

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Geothermal for DH

A successful geothermal resource will

1. Provide enough heat
   - Sliding scale between volume and temperature
   - Sliding scale between **permeability** and **depth**

2. Be accessible close to endusers
   - few kms at most
   - need to match favourable geology with areas of high heat demand

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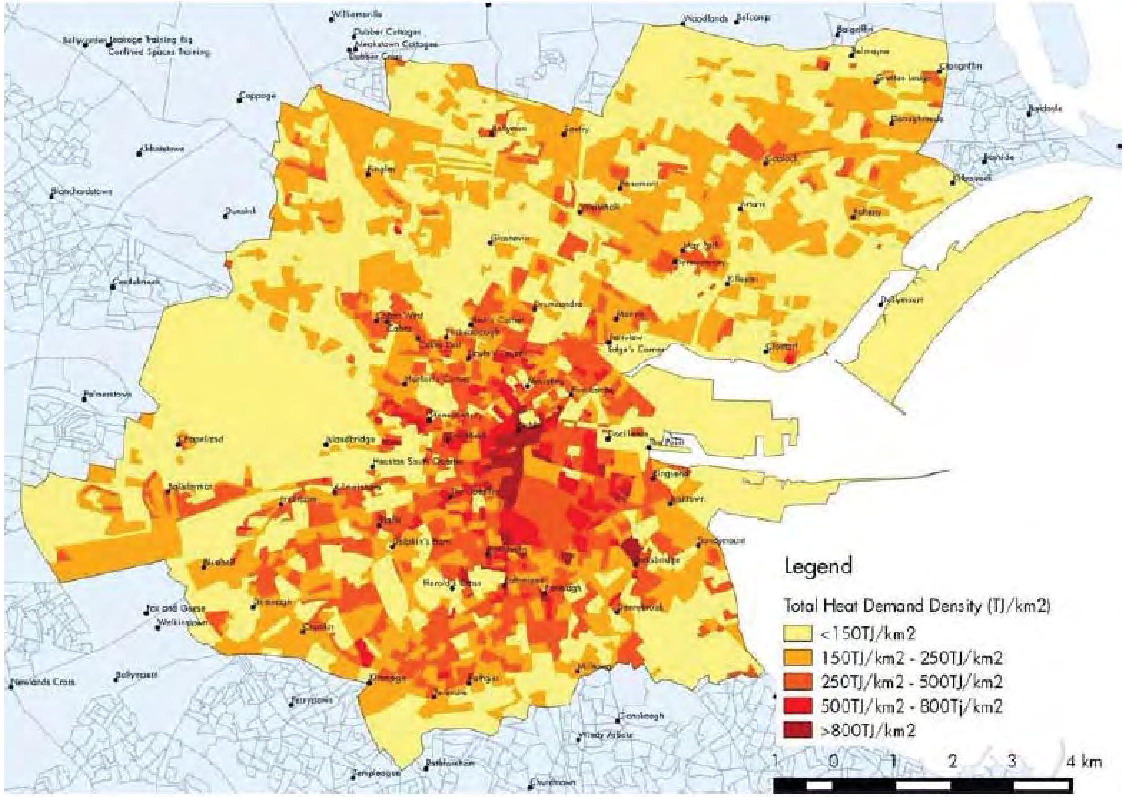
GEO-URBAN

For example in Dublin.....



CODEMA, 2015

Huntstown Fault, Dublin Basin

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Key considerations

- How can we promote geothermal DH and accelerate social acceptance?
- Drilling is expensive and CAPEX is high so **accurate geological characterization is paramount**
- **Outreach** to local, regional and national stakeholders **very important**

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GEO-URBAN

Research challenges

- Geological challenges – low enthalpy, hard rocks, fracture porosity
  - Dublin: limestone basin and metamorphic crystalline basement
  - Valles: granitic basement

- Is commercial development of these resources feasible?

- How can we accurately characterise the geological structures (fractures and faults) in the bedrock?

- Exploration challenges – noisy urban environments
  - Dublin: city centre, densely built up
  - Valles: urban centre of Granollers

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GEO-URBAN: Methodology and Work Packages

Work Package		Leader
1	Collate all existing relevant geothermal data	GDG
2	Evaluate novel (inexpensive!) geophysical techniques for urban areas - seismic - electromagnetic - joint interpretation	UB
3	Create new and improved geological conceptual models	iCRAG

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GEO-URBAN

GEO-URBAN: Methodology and Work Packages

Work Package		Leader
4	Use better understanding of resource in commercialisation study - is geothermal DH feasible? - recommendations for further exploration and pilot wells	GEOOP
5	Stakeholder involvement - outreach activities - policy recommendations to assist uptake and operations	GEOOP
6	Project management	GDG

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GEO-URBAN

GEO-URBAN in a nutshell

- An investigation of deep geothermal energy for district-scale heating in cities and towns
- Focussing on low-enthalpy geothermal settings in urban environments
- Two test areas, Dublin and Vallès
- Commercial partner in Denmark providing knowledge transfer from region where geothermal DH is established

GEOTHERMICA

This project has been subsidised through the ERANET Cofund GEOTHERMICA (Project no. 73111 ... ion and the Department of Communications, Climate Action and Environment / Geological Survey Ireland.

COSEISMIQ: COntrol SEISmicity and Manage Induced earthQuakes

Chris Bean

Over the last decade induced seismicity has become an important topic of discussion, especially owing to the concern that industrial activities could cause damaging earthquakes. Large magnitude induced seismic events are a risk for the population and structures, as well as an obstacle for the development of new techniques for the exploitation of underground georesources. The problem of induced seismicity is particularly important for the future development of geothermal energy in Europe, in fact deep geothermal energy exploitation projects such as Basel (2006) and St Gallen (2013) have been aborted due to the felt induced earthquakes they created and an increasing risk aversion of the general population. Induced seismicity is thus an unwanted product of such industrial operations but, at the same time, induced earthquakes are also a required mechanism to increase the permeability of rocks, enhancing reservoir performances. Analysis of induced microseismicity allows to obtain the spatial distribution of fractures within the reservoir, which can help, not only to identify active faults that may trigger large induced seismic events, but also to optimize hydraulic stimulation operations and to locate the regions with higher permeability, enhancing energy production. The project COSEISMIQ integrates seismic monitoring and imaging techniques, geomechanical models and risk analysis methods with the ultimate goal of implementing innovative tools recently developed but yet untested. These adaptive, data driven approaches for reservoir optimization and for the control and management of induced seismicity represent a major contribution to safe and sustainable geothermal energy exploitation. Within the project COSEISMIQ, we will demonstrate the usefulness of what we call the Real-Time Induced Seismicity Controller (RISC) in a commercial scale application in Iceland.
Understanding how to prevent or reduce large induced earthquakes plays a pivotal role in the development of future, innovative, and clean forms of natural deep underground energy resources.

Contact: Prof. Chris Bean, Dublin Institute for Advanced Studies chris.bean@dias.ie

Control SEISmicity and Manage Induced earthQuakes (COSEISMIQ)

ETH Zürich (co-ordinator)

ISOR (Iceland)

Dublin Institute for Advanced Studies (DIAS)

Reykjavik Energy

GeoEnergie Suisse AG

GFZ Potsdam (associate partner)

Start May 2018, for 36 months

Rationale

- Deep geothermal fields usually require permeability enhancement, to improve reservoir performance
- Interventions to enhance reservoir permeability can cause induced microseismicity
- Due to public concern, large induced events have led to project cancellations (e.g. Basel 2006; St Gallen 2013)
- COSEISMIC overarching aim:
  - Control and Management of induced seismicity
- Test site: Hengill Geothermal field, Iceland.

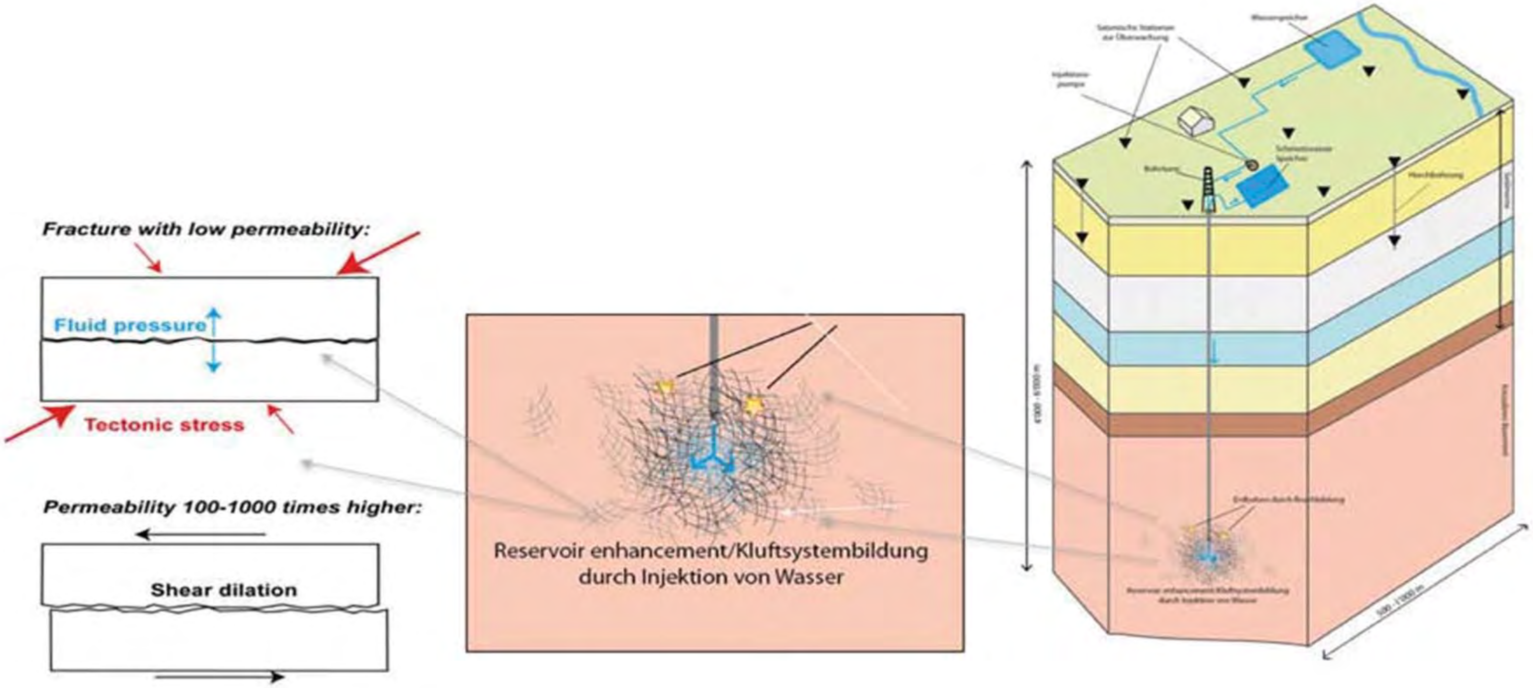
Some background…

- Detailed locations of induced seismicity give information on spatial distribution of reservoir ‘permeable’ fractures.

- Subsurface imaging (using microearthquakes and noise) can help identify larger faults with potential for the larger ‘problematic’ induced events

- Information on triggered microearthquake source types hold information on the evolving subsurface stress field, not just scale of the event

- These three points above can be used to both (i) locate the regions of higher permeability and (ii) control and manage of induced events.

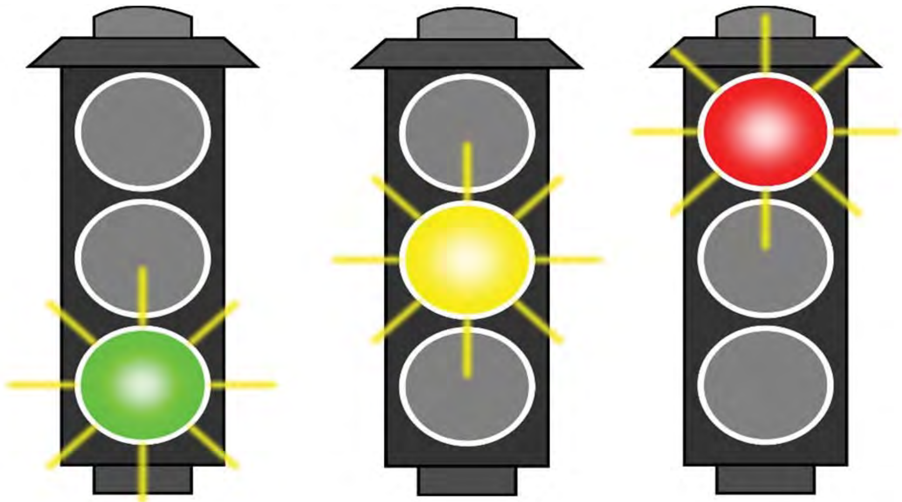


- Permeability enhancement – Illustration of the EGS concept (Basel style). Water injected under high pressure in the crystalline basement at depth of 4.5 km will lead to numerous micro-earthquakes and potentially some felt or even damaging earthquakes.
- Each of these earthquakes is a shear dilatation on a fracture, and typically the permeability of the fracture increases permanently by a factor of 100-1000. This process of hydro-shearing eventually builds up a lasting heat exchanger in the deep basement that ideally can be operated for up to 30 years.

Existing monitoring methods

Usually static "Traffic Light Systems" (TLS) are used

- For example, to stop operations once a fixed earthquakes magnitude is reached – yet still below some "unacceptable" value
- these thresholds are both static and subjective (based on expert opinion)
- systems work in real-time



What is new here?

COSEISMQ will have dynamic model-based objective decision making system

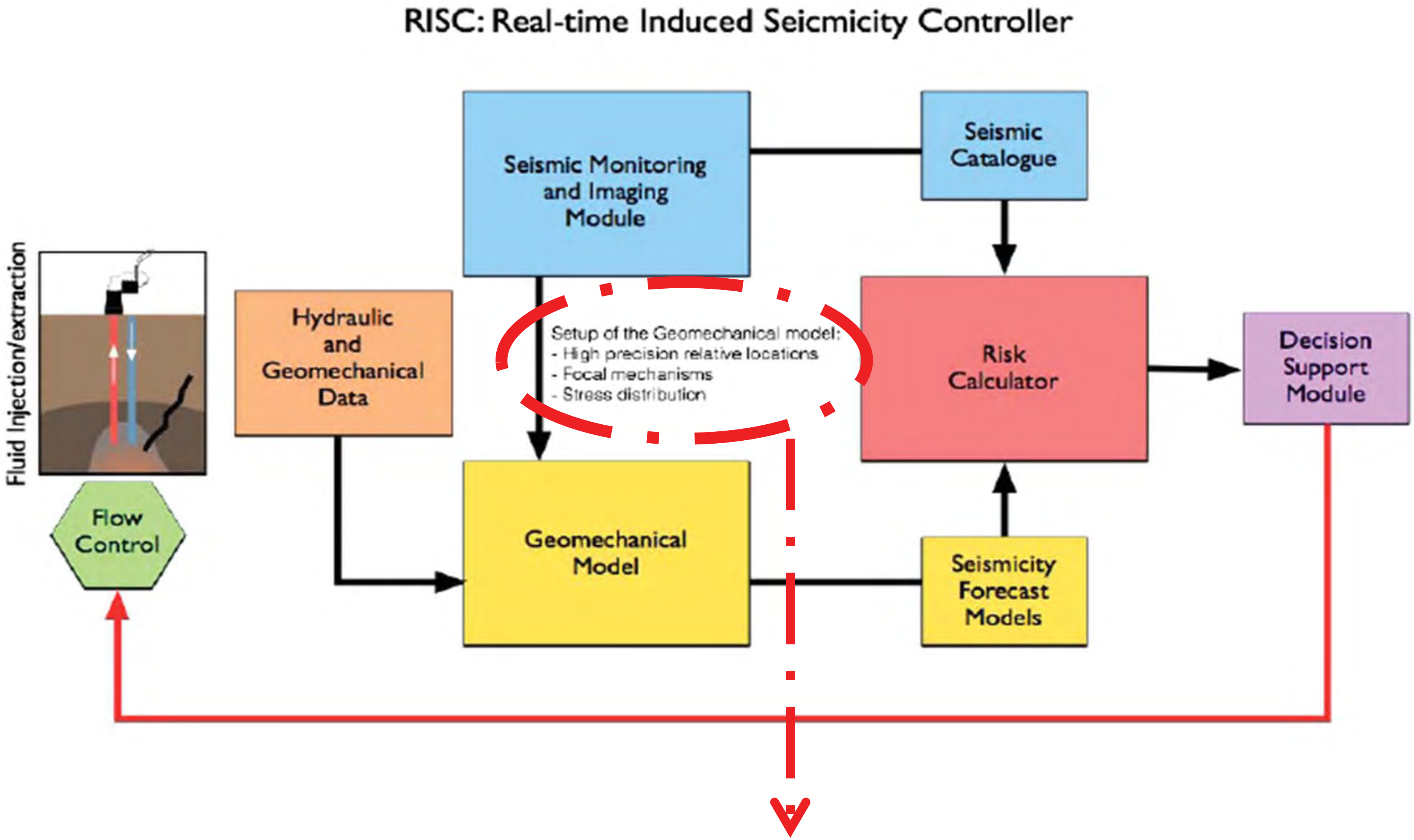
- Real-time seismicity observations from the field (event size, location, focal mechanisms)
- These are fed into a coupled hydro-mechanical model (which has been tuned by previous observations & previous model runs), updating the models stress state & mechanical properties
- The model forecasts (Bayesian, with uncertainties) future state of the system
- Ground shaking associated with model event forecasts are simulated and compared to predefine risk metrics (by regulator)

To summarise

- ***COSEISMIQ*** will help in decision making for operations (e.g. injection pressures) which are made based on **real-time modelling of evolving physical situation** at the site and how they will **impact pre-define risk** metrics

This is completely different to saying ‘if we get magnitude ‘x’, we are shutting down operations’

  – An acceptable risk mag=x does not imply that you will get a unacceptable risk mag=y.
  – In COSEISMQ the ‘likelihood’ that **overall risk** will exceed the pre-defined metric is assessed, **in realtime**


RISC: Real-time Induced Seicmicity Controller
Seismic Monitoring and Imaging Module
Seismic Catalogue
Fluid Injection/extraction
Hydraulic and Geomechanical Data
Setup of the Geomechanical model:
- High precision relative locations
- Focal mechanisms
- Stress distribution
Risk Calculator
Decision Support Module
Flow Control
Geomechanical Model
Seismicity Forecast Models

DIAS work.....

The Dublin Contribution

Set up of the Geomechanical model:
- High precision relative locations
- Focal mechanisms
- Stress distribution

- Seismic monitoring stations
- Seismicity characterisation – especially unusual/small events which are difficult to locate and precisely classify
- Characterising the seismicity - software tools will plug-in to the *RISC* management tool that is being developed.

Test site: Hengill volcano, Iceland

- Intersection of the Western Volcanic Zone, the Reykjanes Volcanic Zone and the South Iceland Seismic Zone
- Volcano-tectonic faulting is prominent

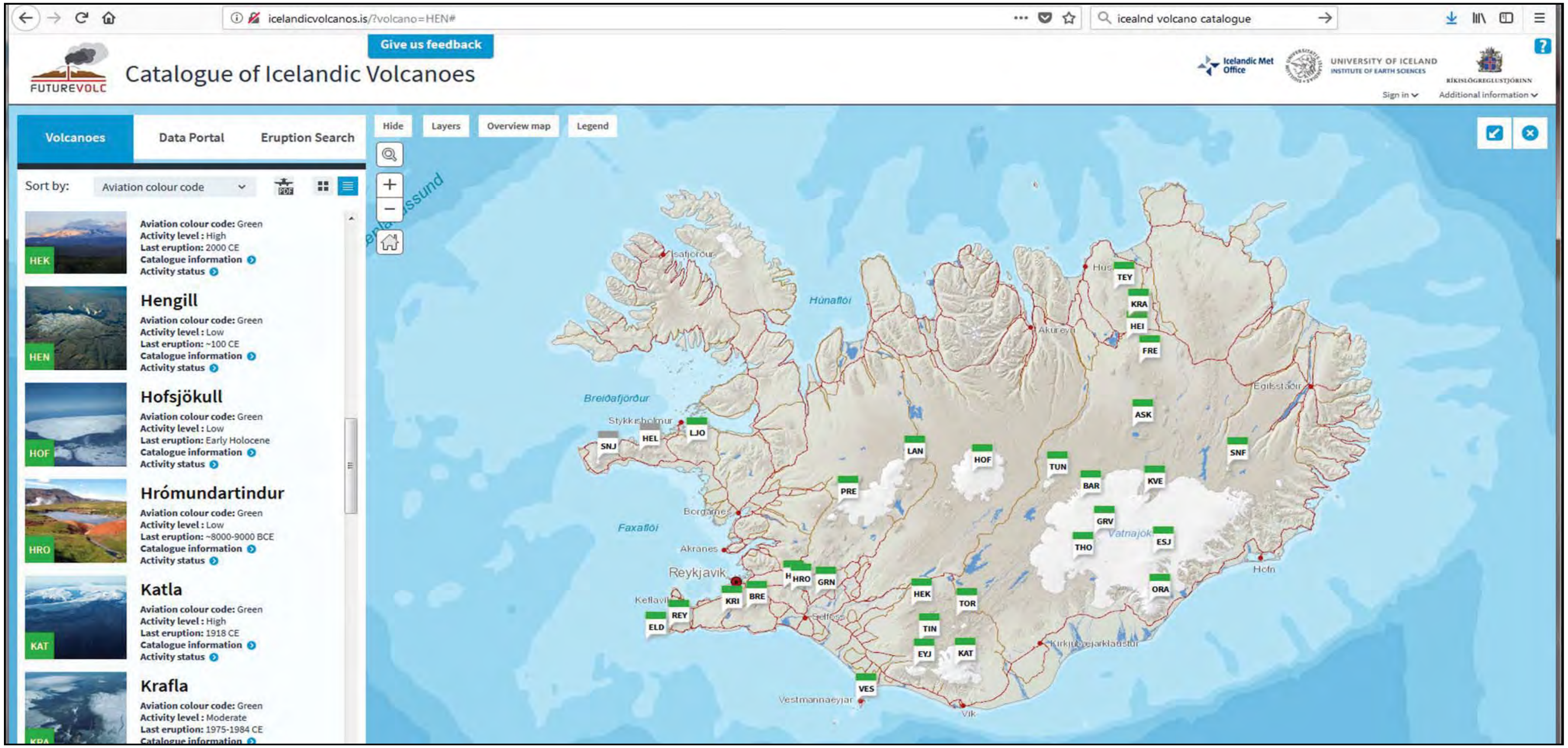


Image: Oddur Sigurðsson, 1985

Test site: Hengill volcano, Iceland

- It hosts Iceland's second largest geothermal system

- The Hengill volcanic system has been quiet since a rifting episode in 1789 CE. Seismic activity during the last 10 years appears caused by geothermal exploitation (present power production: 420 MW_e +433 MW_t) from the geothermal reservoir. Reinjection of effluent water has induced small but numerous earthquakes.

Image: Dave McGarvie, 2005

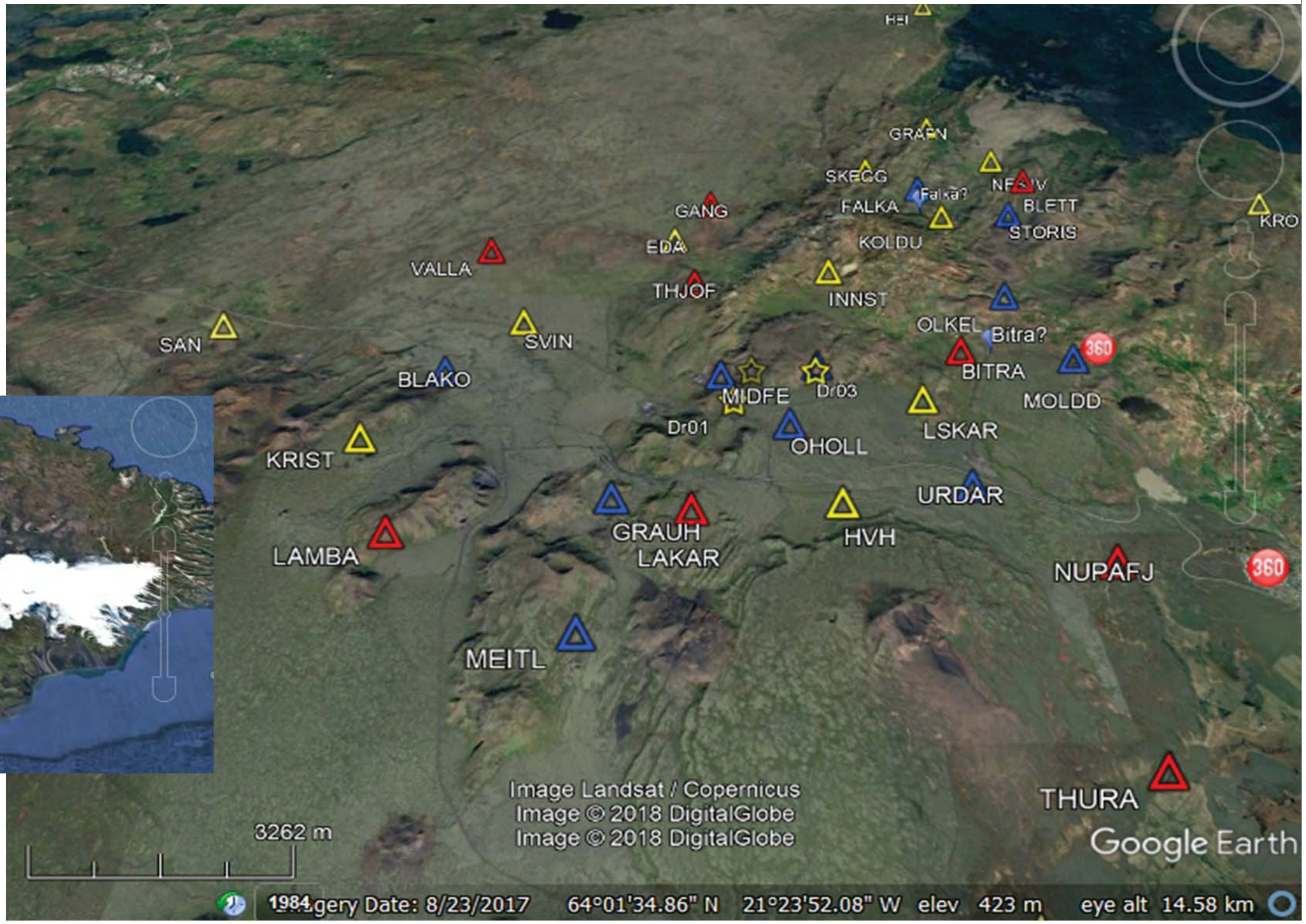
Test site: Hengill volcano, Iceland

- This exploitation-related activity could obscure precursory symptoms of a pending volcanic and/or volcano-tectonic activity.

New data will be collected to get a better insight…..

- Proposed seismic station locations for deployment in October
  (ISOR, ETH & DIAS)

- Drill holes marked as stars



Chris Bean

Dublin Institute for Advanced Studies

Chris.bean@dias.ie

Investigation of Geothermal Potential in the Irish Carboniferous Palaeokarst

Nick O'Neill, Deirdre Lewis, Sarah Blake, Lloyd Vaz,

In accordance with Ireland's National Mitigation Plan (July 2017) and the GSI Research Roadmap, the GSI commissioned a short-call research project focused on investigating geothermal potential of the Irish Carboniferous karstified limestones at depth. Anecdotal evidence of dropped rods, cavities and non-recovery of core from mineral exploration drilling in Ireland casts doubt on the assumption that Palaeozoic rocks at depth have negligible porosity and permeability. Evidence from the oil and gas industry shows that coalesced collapsed paleocave carbonate reservoirs exist in the Ordovician Ellenburger Ramp Carbonate play of West Texas. So why not in the Irish Carboniferous?

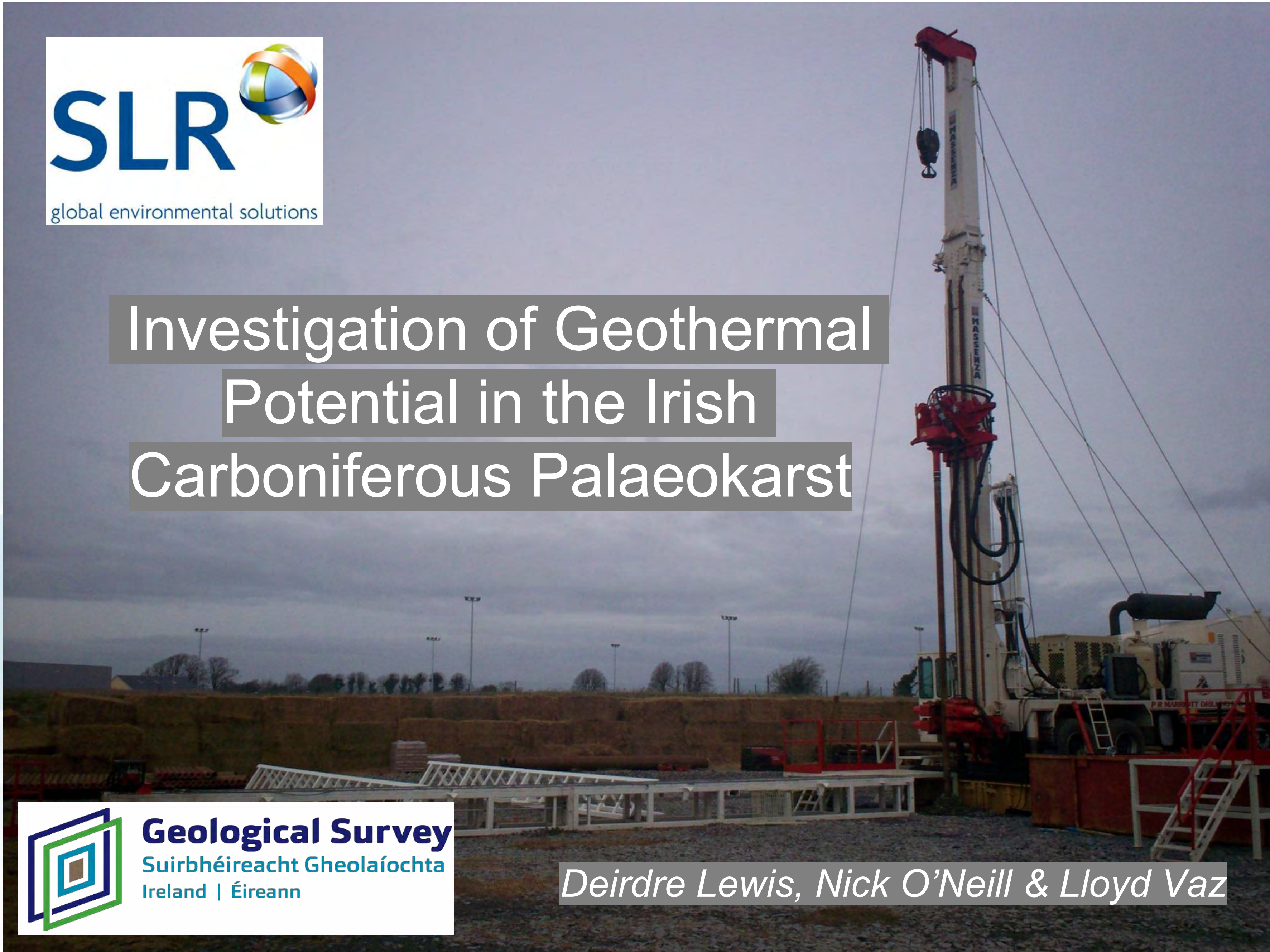
The 'Coalesced Collapsed Paleocave' play, characterised by moderate porosities and permeabilities in the Ellenburger is considered to be a good analogue for geothermal resource potential of the Waulsortian Mudbanks. A review of numerous published articles, well-reports, etc. and personal meetings with Irish Carboniferous Geology experts provided substantial evidence to support the hypothesis of the presence of preserved karst within the Waulsortian at depth. Between the two main Carboniferous Basins viz. Dublin Basin and Shannon Trough, the latter was considered as the better prospect to intercept the Waulsortian coalesced mudmounds at depths of >1000m. A focused seismic interpretation was carried out on four recently acquired 2D seismic lines in the north of the Shannon Trough (Kilbricken Mine area) by Hannan Metals Ltd. The analysis showed a number of 'karst indicators' (sag features, polygonal faults etc) towards the base of the Waulsortian Formation which were inferred to be related to preserved collapsed structures, like those observed in the Ellenburger Group. The 'Kilmurry Prospect' is a proposed drilling target, intersecting a collapsed paleocave at ~900m depth with a potential for temperatures of up to 30°C. Drilling the prospect will allow the acquisition of a comprehensive suite of wireline logs to prove the exploration model. A recommendation is made to investigate the potential of similar Waulsortian karst systems, in the deeper parts of the Shannon Basin i.e, south of the Kilbricken area, in the Adare region, once the Kilmurry Prospect is proven.

Contact: Dr Deirdre Lewis, SLR Consulting, dlewis@slrconsulting.com

SLR

global environmental solutions

Investigation of Geothermal Potential in the Irish Carboniferous Palaeokarst



Deirdre Lewis, Nick O'Neill & Lloyd Vaz

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Acknowledgements

- Hannan Metals for kindly providing access to Seismic and Borehole data
- Murray Hitzman, John Walsh and Jennifer Craig
- iCRAG Researchers John Conneally and Koen Torremans
- Sarah Blake
- Deidre Lewis, Paul Gordan, John Kelly, Gareth Ll Jones from SLR Consulting Ireland

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Why?

"We will establish a regulatory framework to facilitate the exploration for, and development of, geothermal energy resources."

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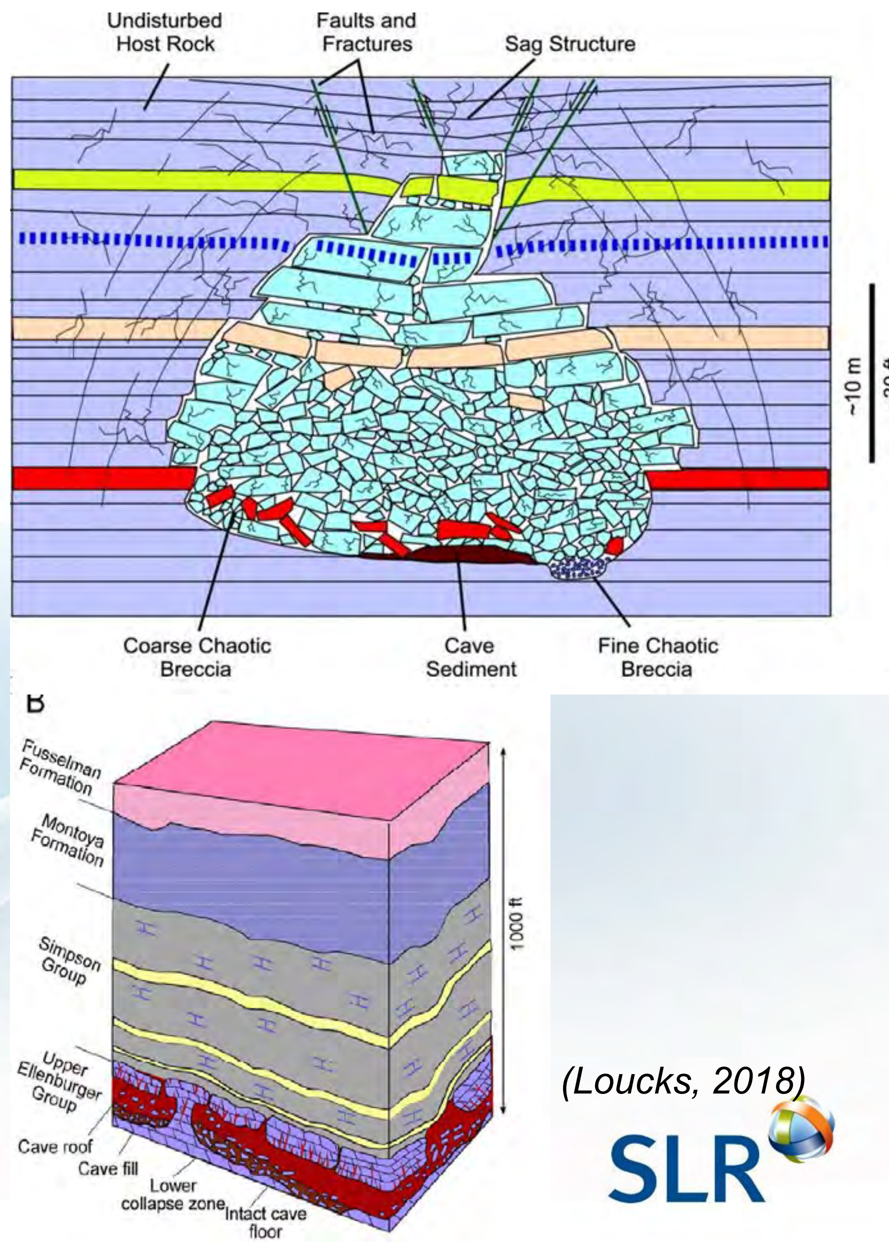
Oil & Gas Analogue

- Coalesced collapsed palaeocave exploration model
- The Ellenburger Group of the Permian Basin is part of a Lower Ordovician carbonate platform sequence
- **Ramp carbonates play**
  - mid-to-outer ramp
  - dolomitised and karst-modified(secondary)
  - characterised by 2-14% porosity and permeability 0.8 – 44 md
  - produced ~164 MMbbl of oil as of 2005
- Apply oil & gas exploration techniques, PFA, AFTA, seismic, petrophysical wireline logging etc



(Loucks, 2018)

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Project Objectives

- Compile, map, quantify and assess evidence of presumed ancient karst features in Ireland
- Add additional GIS layers to the existing SEAI Geothermal Play Fairway Analysis Project
- Identify a target location for a borehole to assess deep geothermal and CO_2 storage potential onshore Ireland

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Key Factors for Effective CO_2 Geological Storage

Accessibility	**Location economically accessible to the CO_2 source**
	Operator has legal rights to storage at that site
Capacity	**Formation/structure has adequate porosity and permeability to store CO_2**
	Storage volumes are adequate
Injectivity	**Formation/structure can store CO_2 at the rate required to serve the intended source(s)**
Security	**Well defined trapping mechanism(s)**
	Sufficient depth to retain supercritical CO_2
	Cap rock is impermeable, continuous and thick enough to prevent upward migration
	Geological environment is sufficiently stable to ensure integrity of storage site
	No pathway faults or uncapped wells penetrate the cap rock and storage formation
	Source IEA (January 2008)

Reason for omitting CO_2 Geological Storage in Karst onshore Ireland

Security: Karstic weathering is largely unconstrained and it is difficult to see how we could contain the CO2 to prevent migration (upfault/ up-caverns).

Poor constraints of 3D geometry of potential carbonate reservoir!

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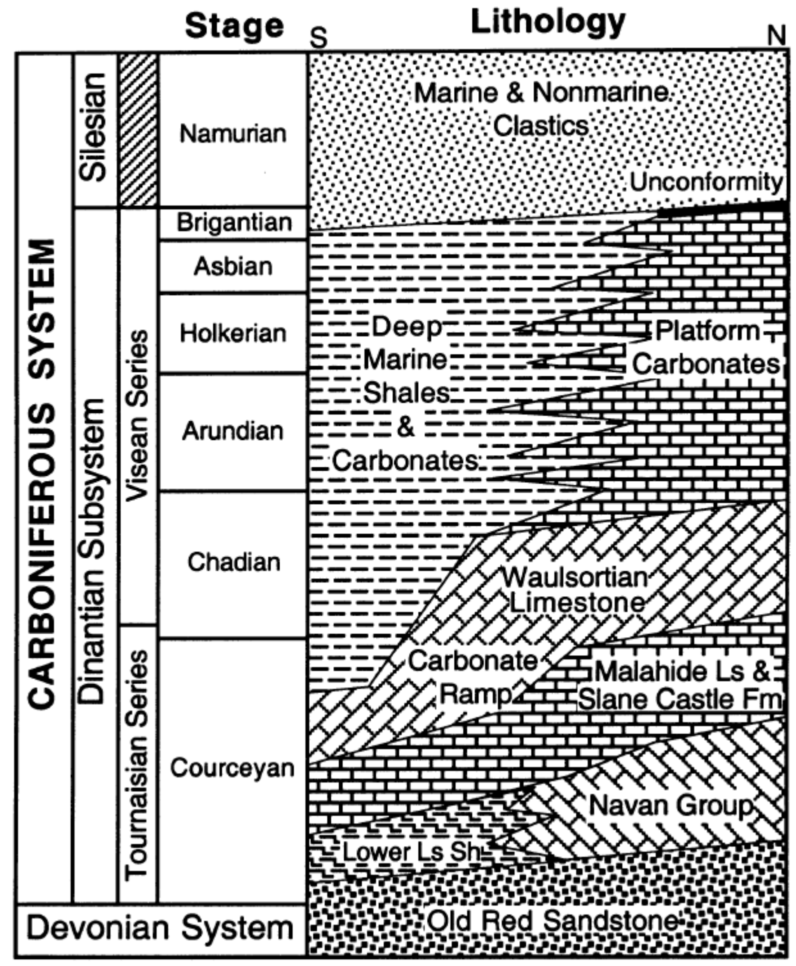
Irish Ramp Carbonate Play

- Dinantian age Dublin Basin and Shannon Trough both hosted early **deep-ramp limestones (and shales)** and late platform and basin limestones (Strogen, et al., 1996)

- The early Courceyan unit, referred to as the Ballysteen formation, is made up of a sequence of calcareous shales, argillaceous limestones and limestones. **The late Courceyan (to early Chadian) unit comprises of the 'Waulsortian mudbanks'** that is represented by a series of accreted carbonate buildups (Murray & Henry, 2018)

- Both Basins have undergone a low degree of tectonic inversion, with gentle folding and minor overthrusting.



(Gregg, et al., 2001)

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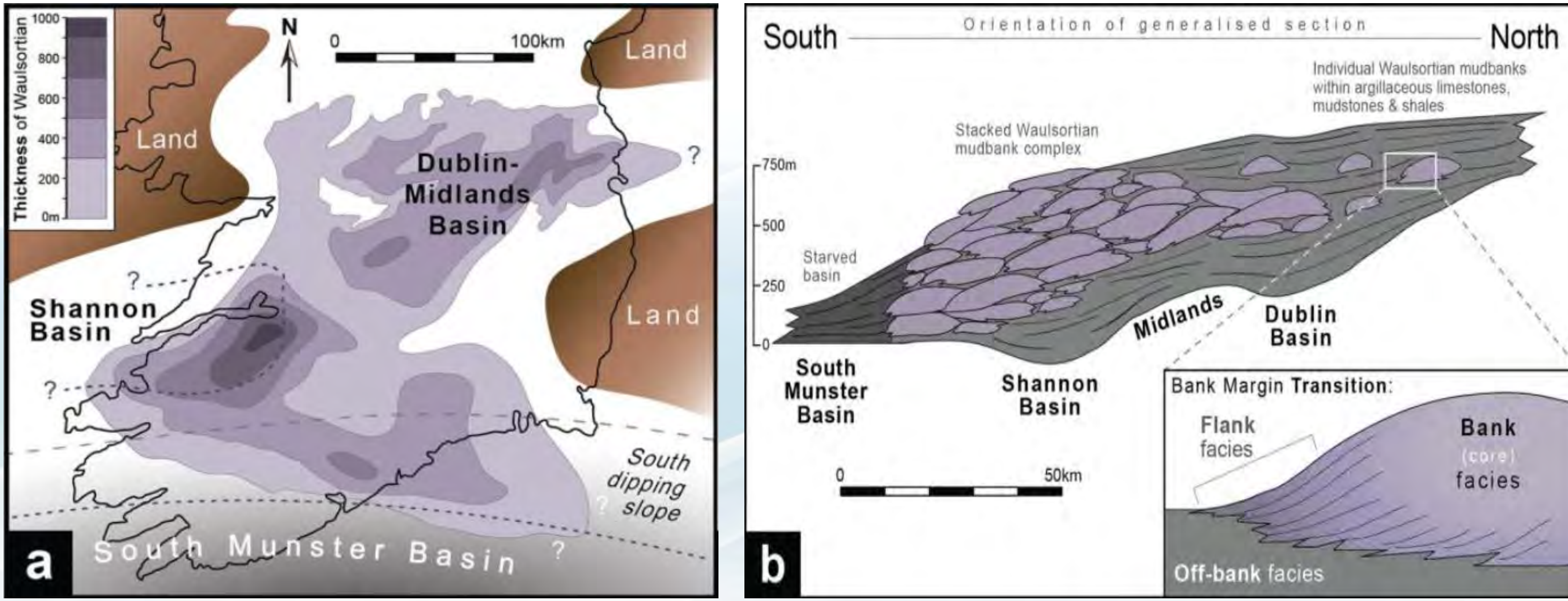
Irish Ramp Carbonate Play

- Coalesced Waulsortian Mudmounds are expected to be **thicker and deeper** in the Shannon Basin than in the Dublin Basin
- Possibility of finding more coalesced mounds in the Shannon Basin



(Murray & Henry, 2018)

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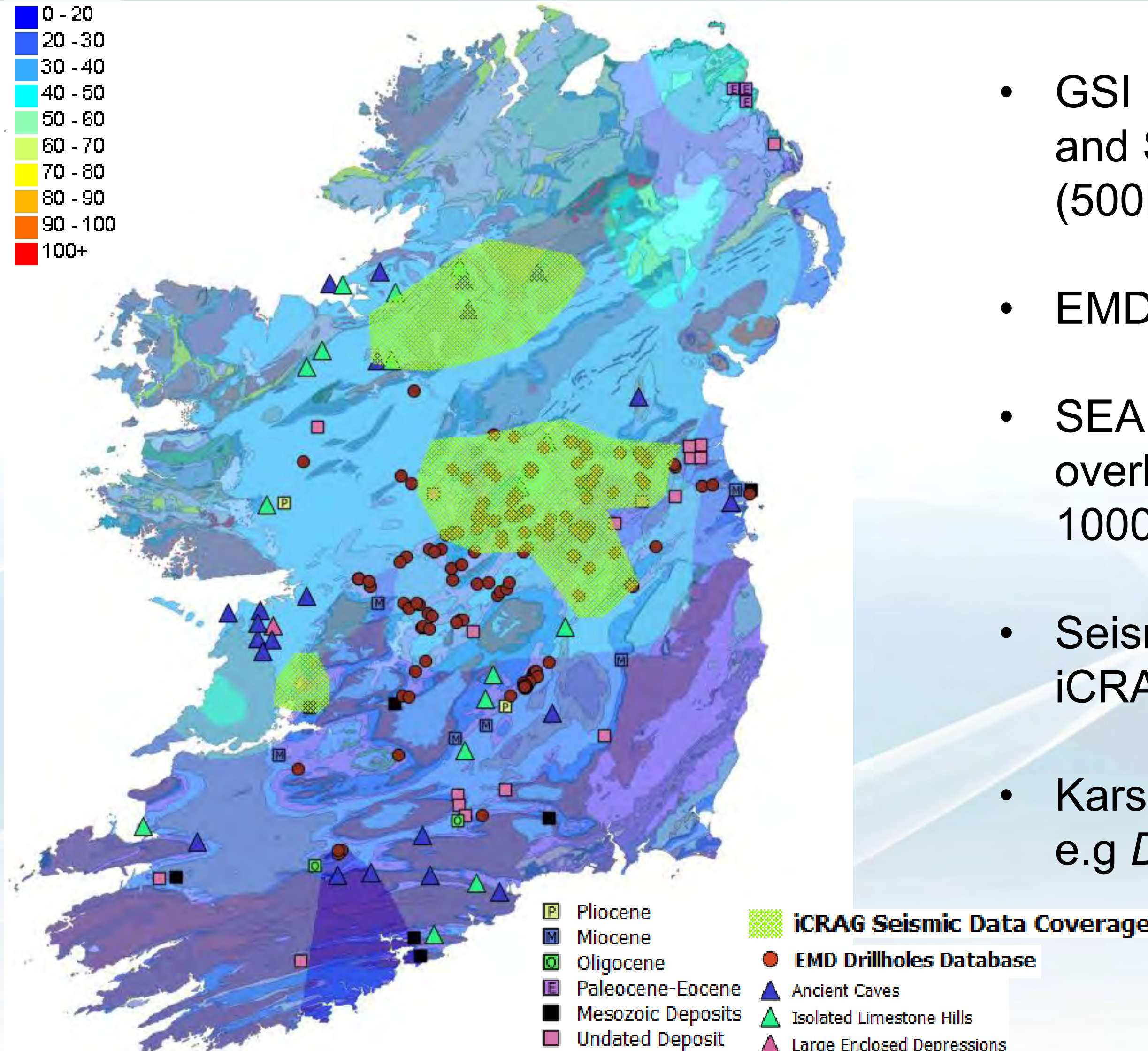
Database



- GSI Bedrock Geology, Faults and Structural Features (500K)
- EMD Drillholes Database
- SEAI Temperature at depth overlays (fig – Temp at 1000m)
- Seismic Data Coverage at iCRAG
- Karst Features from literature e.g *Drew & Jones, 2000*

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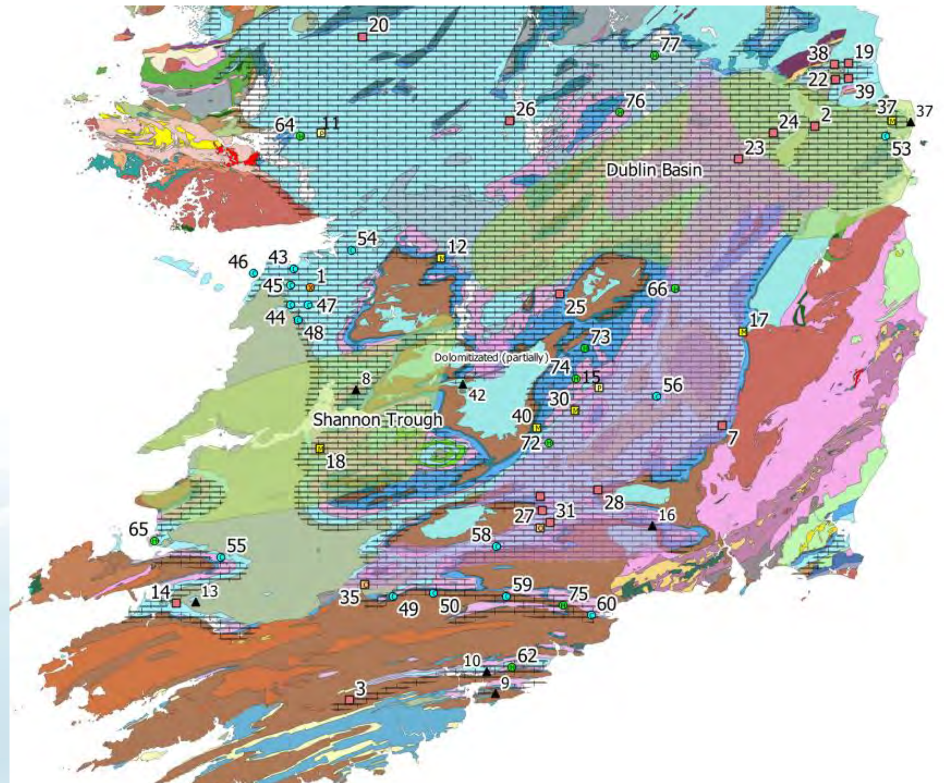
Evidence of Karstification

1. Karst Features in Outcrop/Borehole data

- Infilling features observed in field outcrops
- Cavities, brecciation, fractures, faults and broken ground, dropped drill-rods logged in Borehole descriptions; Abandoned drilling operations due to cavities recorded.



(Project GIS Database)

Sediment/etc. infilled depressions, some with caves or pipes *(from Drew & Jones, 2000)*

8	Ennis	Clare	?	?		silica sand fill ?	industry. pers. comm.
18	Aughinish, Island	Limerick	R28 52	<30	Middle Tertiary	deep karstic hollows, –125 m OD +	Mitchell (1985)
42	Silvermines	Tipperary	N82 72	c. 90		red clay in large fissure in mine	miners (pers. comm.)

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Evidence of Karstification

2. Uplift and erosion post deposition of Waulsortian

- Evidence from literature of post Carboniferous uplift and erosion of Waulsortian resulting in karstification

ERA	PERIOD	EPOCH	SOUTH-EAST (after Keeley 1996)	AGE OF DEPOSIT * = marine	MIDLANDS (after Naylor 1992)	ULSTER BASIN
CENOZOIC	Quat-ernary	Holocene	karstification	west Burren caves	karstification	karstification
		Pleistocene	cold climate	cave bones dated >45ka cave calcite dated >350ka	cold climate	cold climate
	Tertiary Neo-gene	Pliocene		Galmoy, Pollnahalia	erosion	
		Miocene		Cormackstown, Hollymount, Lisheen, Tynagh	/ karstification	
		Oligocene	erosion >0.5km uplift	Aughinish Loughshinny Ballygiblin Ballymacadam	/ mantling	L. Neagh clays & lignites
	Palæo-gene	Eocene		Garron Point		igneous activity & interbasaltic soils
		Palæocene	erosion >1km uplift		erosion / karstification	erosion / karstification
MESOZOIC	Creta-ceous	Upper	sedimentation >0.5km	Ballydeenlea *	sedimentation variable around islands/ in valleys?	sedimentation <3km
		Lower	sedimentation <0.5km	Piltown (*)	erosion	
	Jurassic				erosion	
			erosion/ karstification >1.5km uplift	Cloyne	sedimentation around islands?	sedimentation >0.25km
	Triassic		sedimentation >1km		Topography Established erosion	sedimentation <3km
PALAEOZOIC Upper pars	Permian	Upper				
		Lower	erosion >2km uplift			
	Carbon-iferous	Silesian	sedimentation ~2km		sedimentation	
		Dinantian	erosion will include the karstification of limestones			

(Drew & Jones, 2000)

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Evidence of Karstification

3. Marine incursion allowing interaction of fluids with Waulsortian at shallow depths

"The end of the Carboniferous Period, marked by earth movements and general elevation of the land, left all of Ireland above sea level in the early Permian and the succeeding eras saw a series of marine incursions from the east in the Upper Permian, Rhaetic, Liassic and Upper Cretaceous times. Cretaceous chalk at Ballydeanlea appears as matrix in a breccia of Namurian shale formed probably by collapse of a cavern in the underlying Carboniferous Limestone which mixed unconsolidated Cretaceous sediment with brecciated shale from the seafloor" *(Wilson, 1981)*

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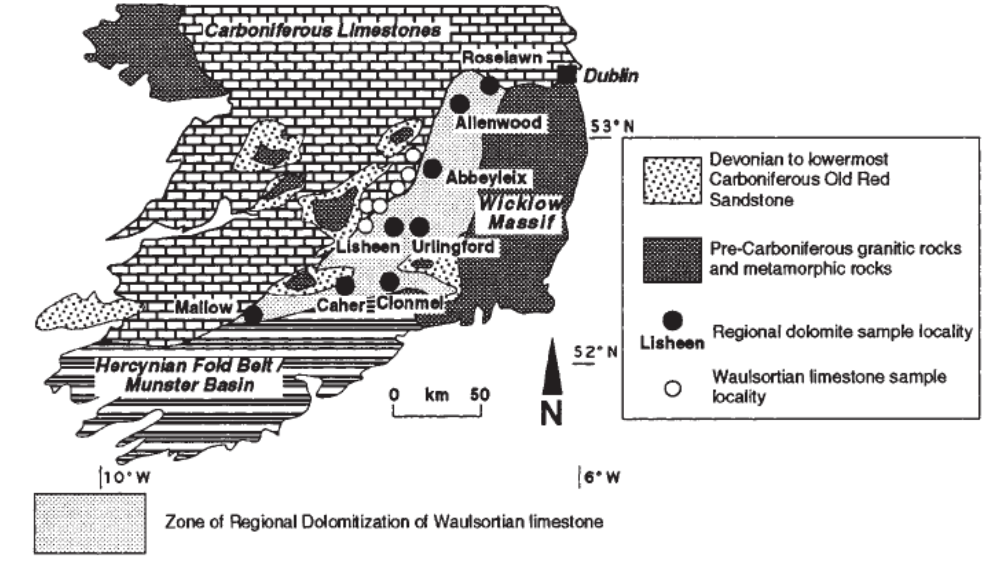
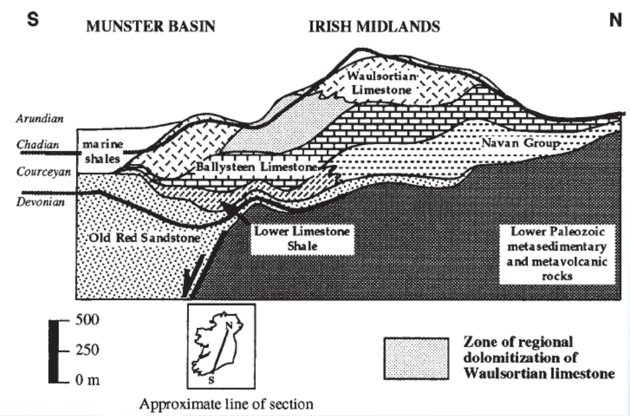
Evidence of Karstification

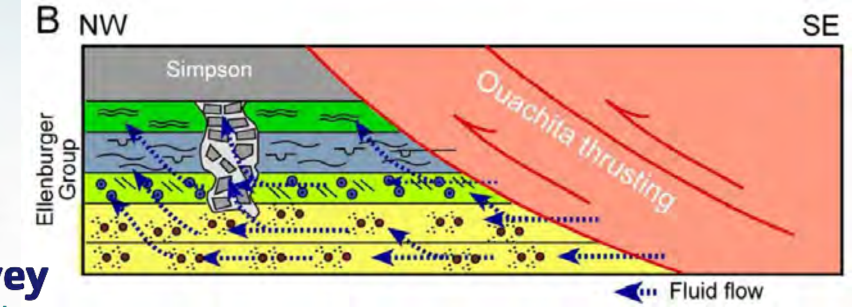
4. Faults as conduits of fluid flow

- Fluid flow northwards as a result of the Hercynian Orogeny, causing regional dolomitization





(Hitzman et al., 1998)



(Loucks, 2018)

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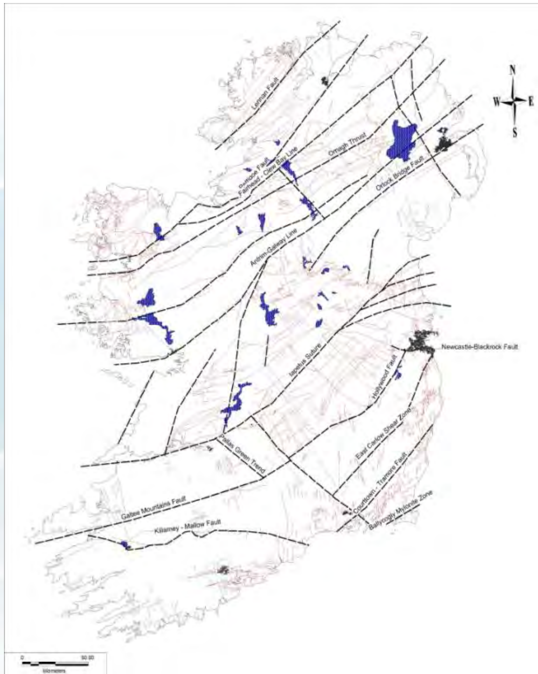
Seismic Interpretation

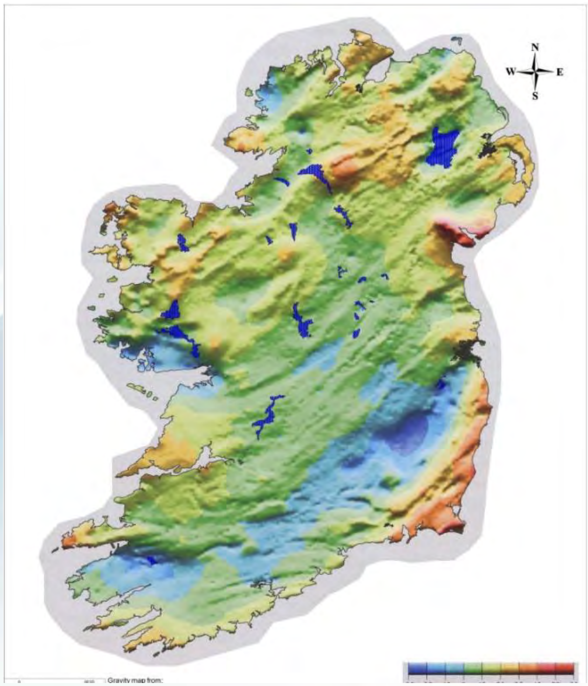
Step 1

- ➢ What are my objectives?

  to identify **Karst Indicators** within the Waulsortian at depth

- ➢ What are the regional tectonic, structural, and depositional trends?





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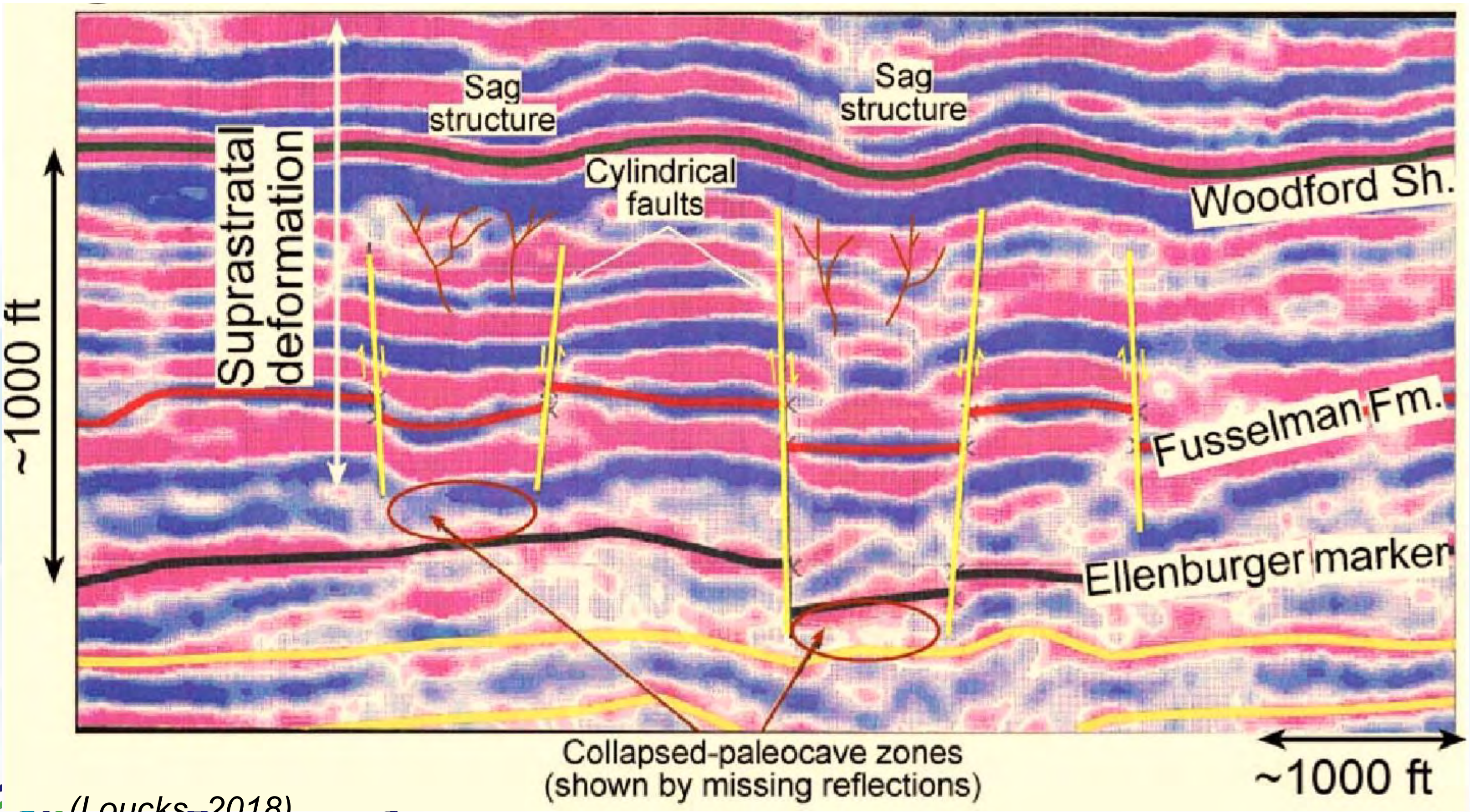
Seismic Interpretation

Step 1

➢ What seismic patterns should I be looking for?



(Loucks, 2018)

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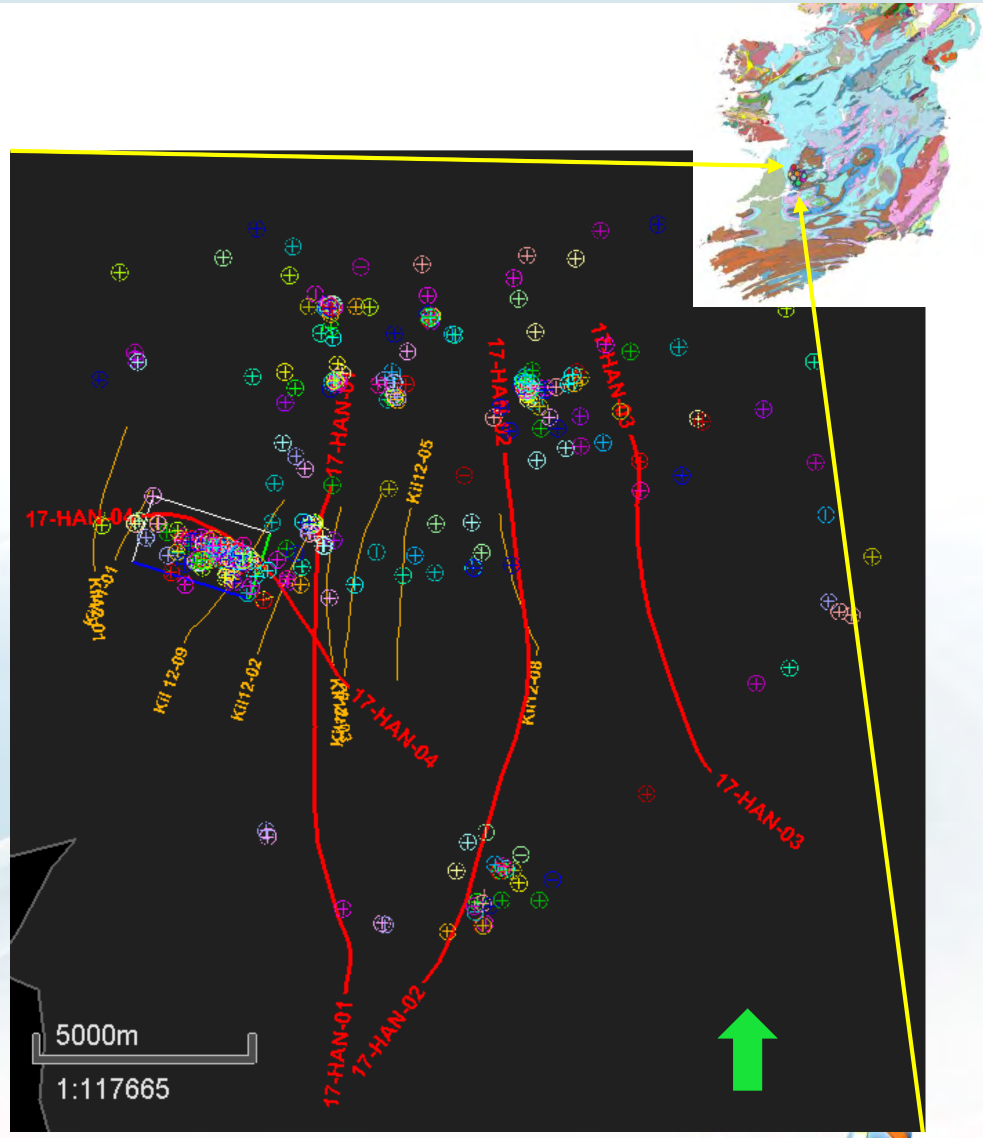
Seismic Interpretation Database

Step 2

- ➢ Building and merging datasets
- Hannan's Kilbricken Petrel Dataset
  - Four 2017 2D Seismic Lines
  - Seven 2012 2D Seismic Lines
  - One 2012 3D Seismic Dataset
- Hannan's Kilbricken Borehole Database
  - Locations and Trajectory of 458 Boreholes
  - Logs of Alteration, Assays, Breccia, Drill Collar, Lithology & Mineralization for most
  - VSP Log for **1 Well** (125m from 17-Han-04) – TDR used to convert all data from Time to Depth



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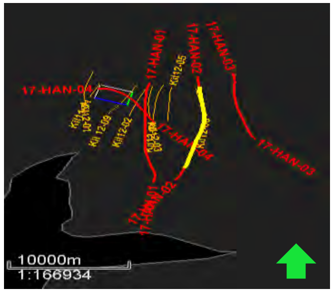
Seismic Interpretation

Step 2

- Uninterpreted Seismic Line



Confidential

- Very poor reflector continuity ~ lack of bedding
- Patchy high amplitude reflectors ~ unit edges/mineralisation?
- No obvious fault trends

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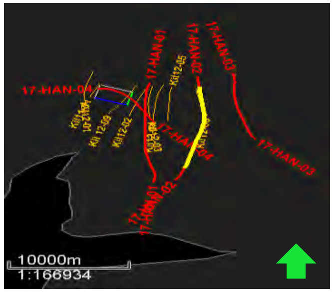
Seismic Interpretation

Step 3

- Wells (up to 350m away) projected on the line to constrain interpretation

Chadian	Transition (CHT)
Courceyan - Chadian	Waulsortian Lst (WAL)
Courceyan	NMU - Nodular Micrite Unit



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- Synthetic seismogram shows significant seismic events are expected at near Top Transition Unit and Intra-Waulsortian Limestone levels *(Hannan Metals, June 2018, IAEG)*

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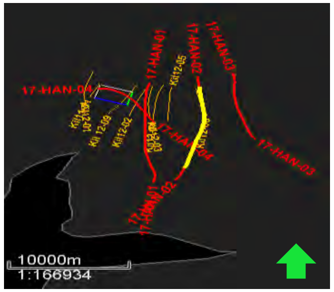
Seismic Interpretation

- Interpretation of Base Waulsortian with aid of Lithology Logs projected on Seismic line
- Waulsortian deepest (~900m) towards the Main Fault in the South (blue) (Northward dipping)



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Base Waulsortian

Chadian	Transition (CHT)
Courceyan - Chadian	Waulsortian Lst (WAL)
Courceyan	NMU - Nodular Micrite Unit

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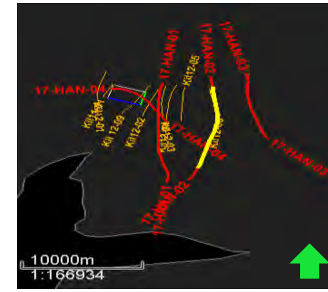
Seismic Interpretation

- **Interpretation of Base Waulsortian with project of Cavities and Brecciated zones as described in well logs**
- **Well 11-3643-10 located in the Southern area appears to contain extensive brecciation and cavities as deep as 740m (depth at which hole was abandoned)**



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	Chadian	Transition (CHT)
	Courceyan - Chadian	Waulsortian Lst (WAL)
Base Waulsortian	Courceyan	NMU - Nodular Micrite Unit

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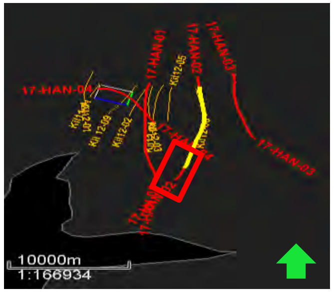
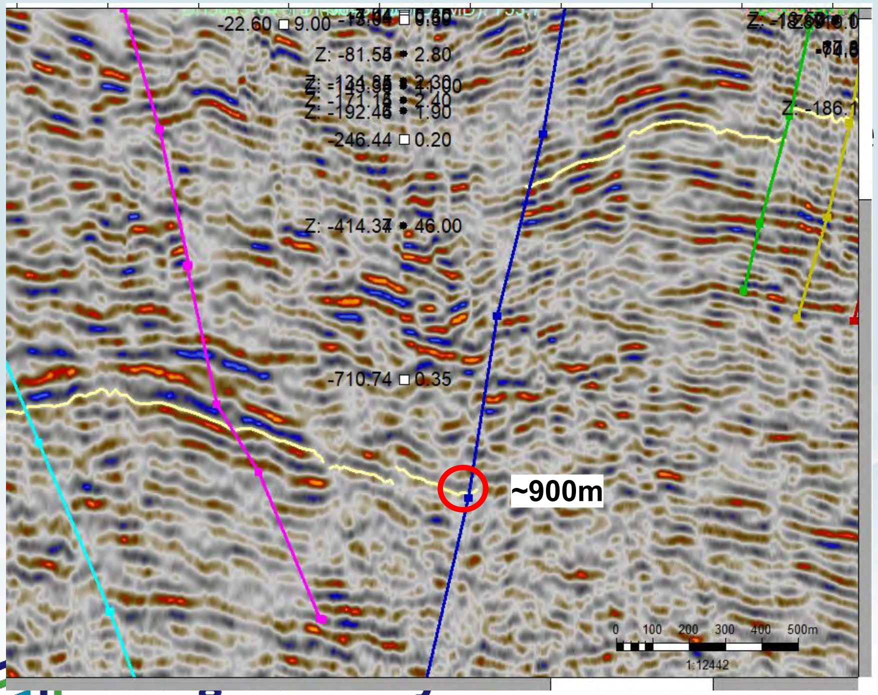
Seismic Interpretation



- Zoomed into the region of interest – anomalous high amplitudes, with small sag features and apparent small faults

- Breccia + Cavities overlaid on seismic – coincidence of features with anomaly

ntial



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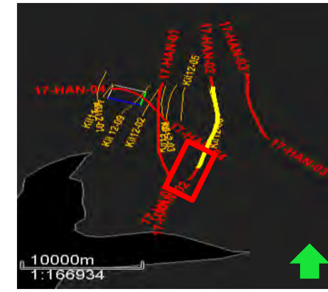
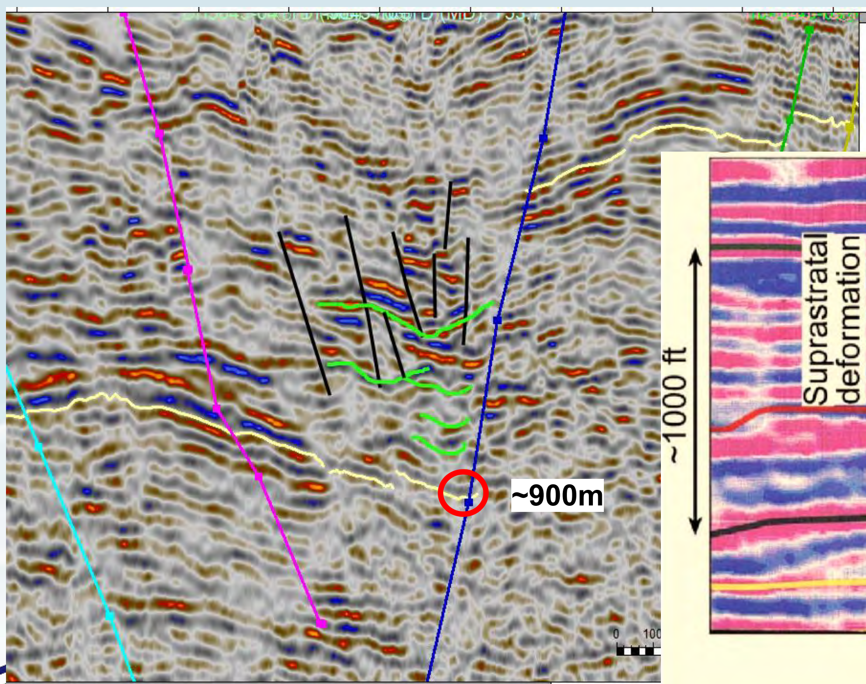
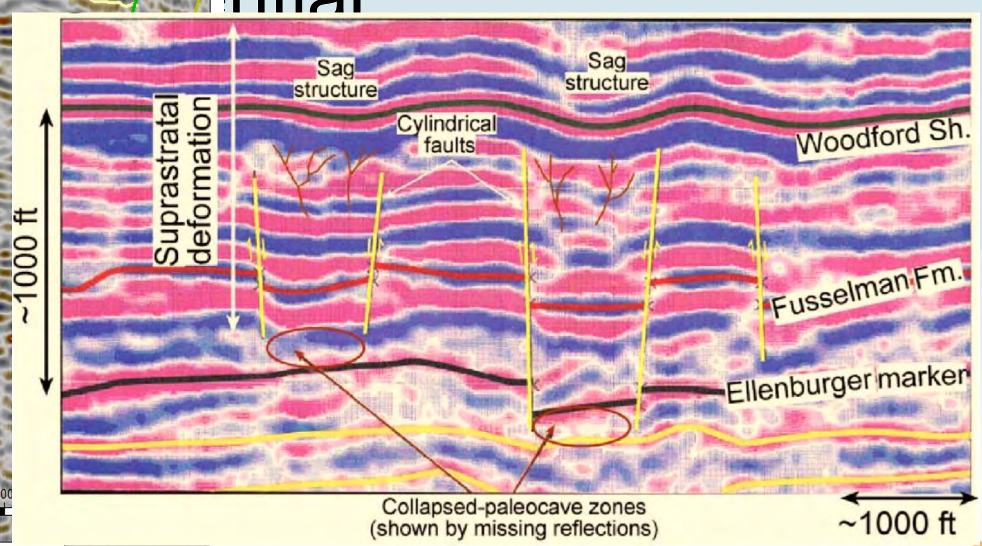
Seismic Interpretation

- Interpreted zone containing target
- Sag features, polygonal fault – related to supra-stratal deformation in the layer overlying a collapsed paleocave (as in the Ellenburger!)







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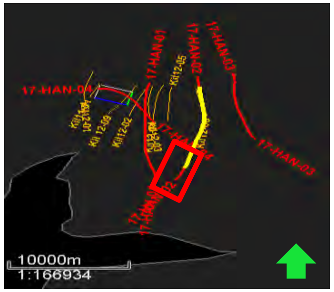
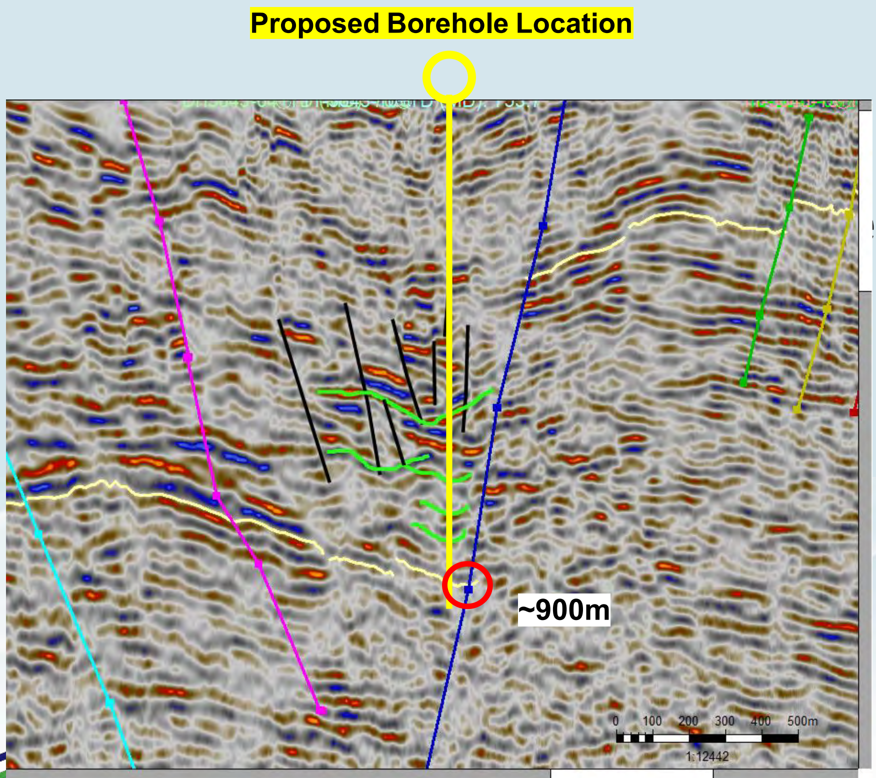
The Kilmurry Prospect!

- Collapsed Paleocave – at **~900m depth**
- Potential for temperatures of **up to 30°C** (SEAI Modelled Temperatures at Depth)
- As in Ellenburger 'Ramp Carbonates' play type, one would expect porosities from 2 to 14% with moderate permeabilities





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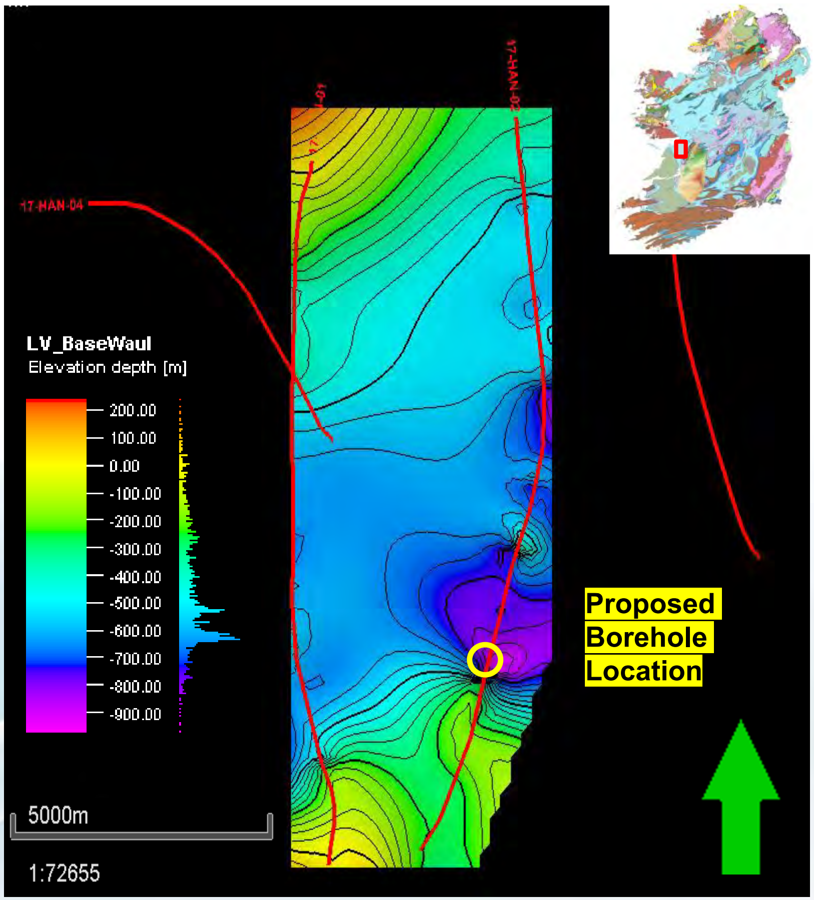
Next Step – Kilmurry Prospect

- **Drill the Kilmurry Prospect to verify seismic interpretation of Karst indicators**
- Acquire Petrophysical wireline logs to better characterise the stratigraphy and create a more constrained methodology for identifying karst indicators on seismic.



Base Waulsortian Surface (Project Interpretation)

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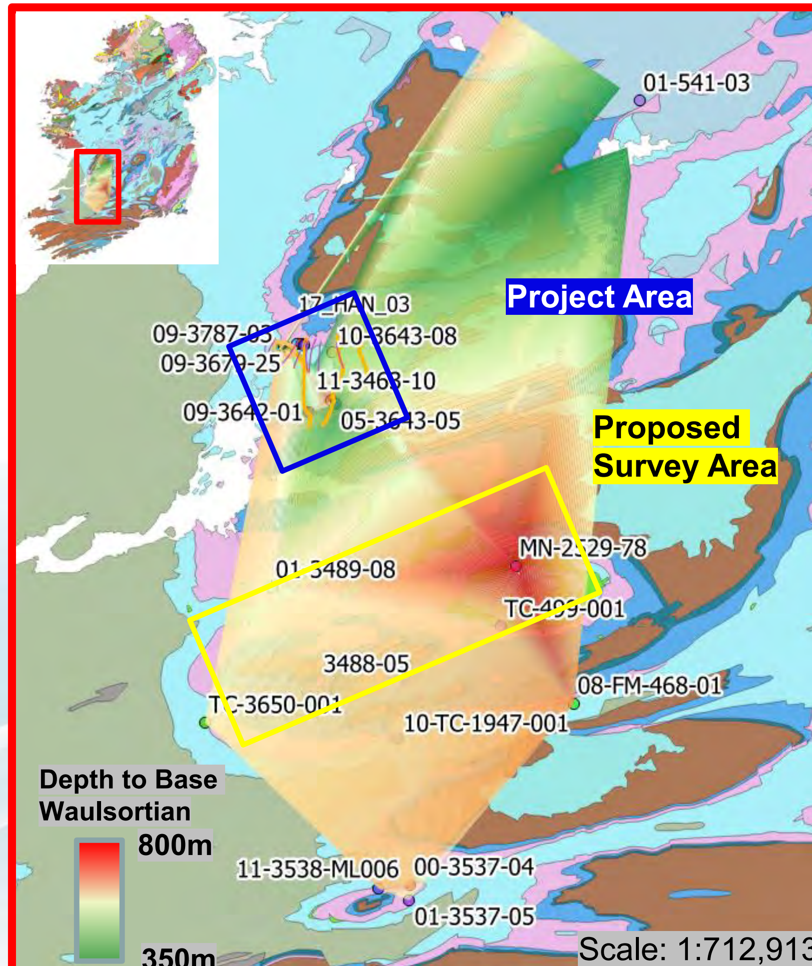
Next Step – Adare Play

Acquire seismic data, (preferably 3D Seismic) further south where the Waulsortian is predicted to be deeper – the Adare Play.



Depth to Base Waulsortian as described in released deep boreholes

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Our Opportunity

You see things and you say “Why?”. But I dream things that never were and I say “Why not”.

Address to the Dail, 9th June 1963 quoting George Bernard Shaw,

Nick O’Neill T: +353 1 296 4667 M: +353 87 2311069 E: noneill@slrconsulting.com

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ARUP - International experience & opportunities for Ireland

Michael Chendorain & Marie Fleming

Arup provided an overview of its international experience with a focus on the st1 Deep Heat project in Finland. st1 Deep Heat is developing a geothermal doublet to deliver deep geothermal heat to local district heat networks. As part of the project, two circa 6.5 km deep wells are intended to be drilled as a geothermal doublet in the City of Espoo, just west of Helsinki, Finland. The first well was stimulated in June-July 2018 to improve the rock permeability in contact with the well.

The stimulation took place in a densely populated area with multiple sensitive receptors. The City of Espoo's buildings department therefore required that a seismic Traffic Light System (TLS) be developed and approved before the start of well stimulation activities.

The TLS thresholds were based on a combination of the surface expression of induced seismicity and associated magnitudes in order to prevent false alarms related to surface expression not due to an induced seismic event. A peak ground velocity (PGV) of 1 mm/s associated with a ML ≥ 1 event triggered an Amber alert, while a PGV of 7.5 mm/s associated with a ML ≥ 2.1 event triggered a Red alert. Specific thresholds based on PGV and peak ground acceleration (PGA) were gathered for sensitive receptors and related to earthquake magnitudes in a probabilistic way.

To address data gaps in the surface network, TLS exceedances solely based on magnitude were also adopted. A ML ≥ 1.2 event alone triggered an Amber alert, while the ML 2.1 threshold alone was maintained for a Red alert.

The implementation of the TLS relied on two seismic monitoring networks. A surface monitoring network was composed of 17 1Hz 3-component geophones located at the surface and in the basement of sensitive receptors in order to quantify PGV and PGA. A satellite network was composed of 12 4.5Hz 3-component gimballed geophones installed in boreholes at depth ranging from 240 to 1,200m to estimate magnitude and location of induced events.

From a regulatory point of view, the absence of existing local data prevented the design of a TLS solely based on forward-looking models, and the TLS in Otaniemi therefore relied on conservative thresholds and associated hazard mitigation measures. Data from the project indicates that forward-looking models would have overestimated the probability of a TLS red alert, given the deficit of ML ≥ 1.5 events compared to the magnitude-frequency distribution of ML < 1.5 events.

Contact: Michael Chendorain, ARUP UK Michael.Chendorain@arup.com Marie Fleming, ARUP Ireland Marie.Fleming@arup.com

International Experience & Opportunities for Ireland

Michael Chendorain, MS, PE (California)

ARUP

Arup

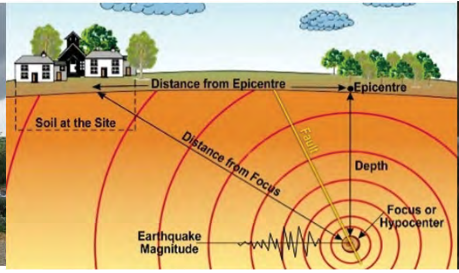
- Founded by Ove Arup in 1946 in London
- “Shaping a Better World” and “Total Design”
- 14,000+ engineers, consultants, and support staff
- 92 offices in nearly 40 countries, including Dublin, Cork, Limerick & Galway

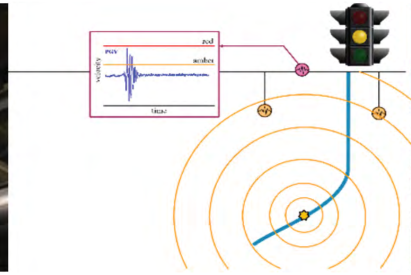

Marina Sands, Singapore


Sydney Opera House

ARUP

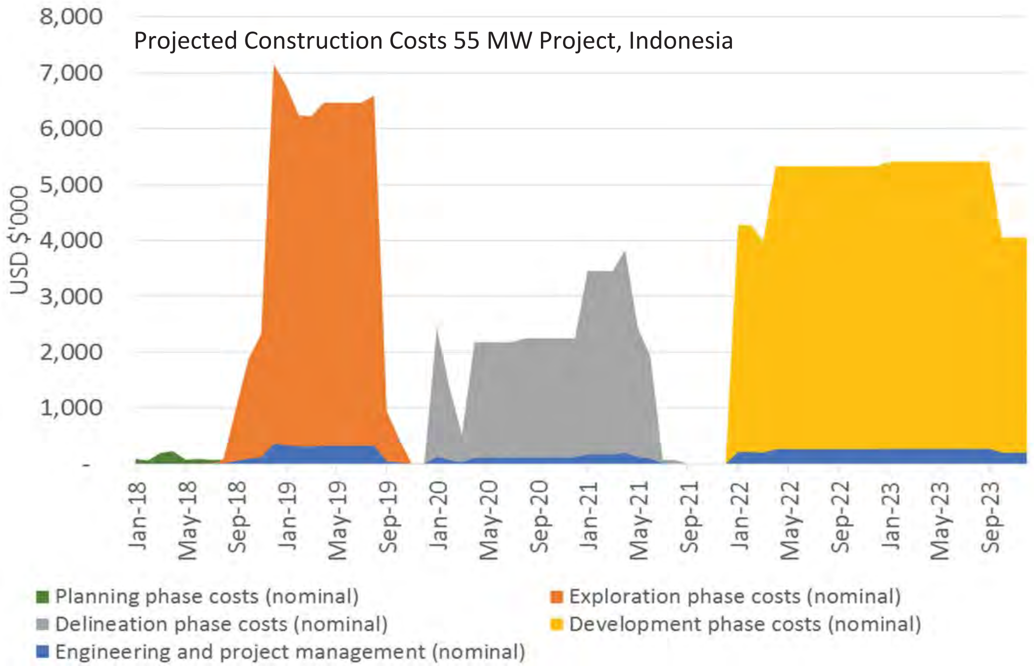
Arup Geothermal

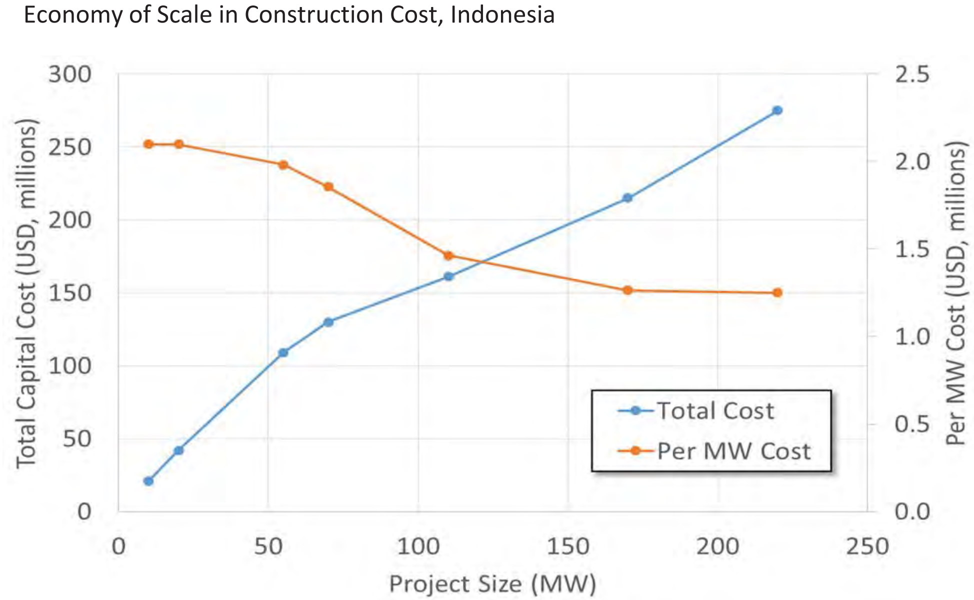


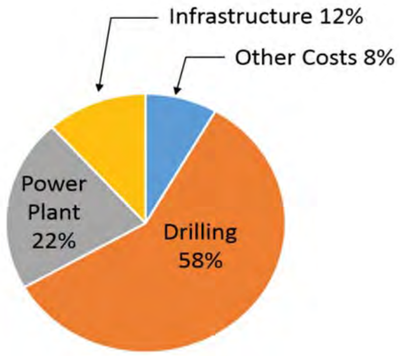


- Transaction support in Philippines, Turkey, Germany
  - Macquarie 2017 $1.2 billion investment into EDC Philippines
- Development of Tariff system for Indonesian Ministry of Energy and Mineral Resources
- Expert review for geothermal doublet in Belgium (Fortune 500 company client)
- Seismic Hazard Assessments in UK, Belgium, and Finland
  - Seismic Traffic Light System in Finland

Geothermal Investment



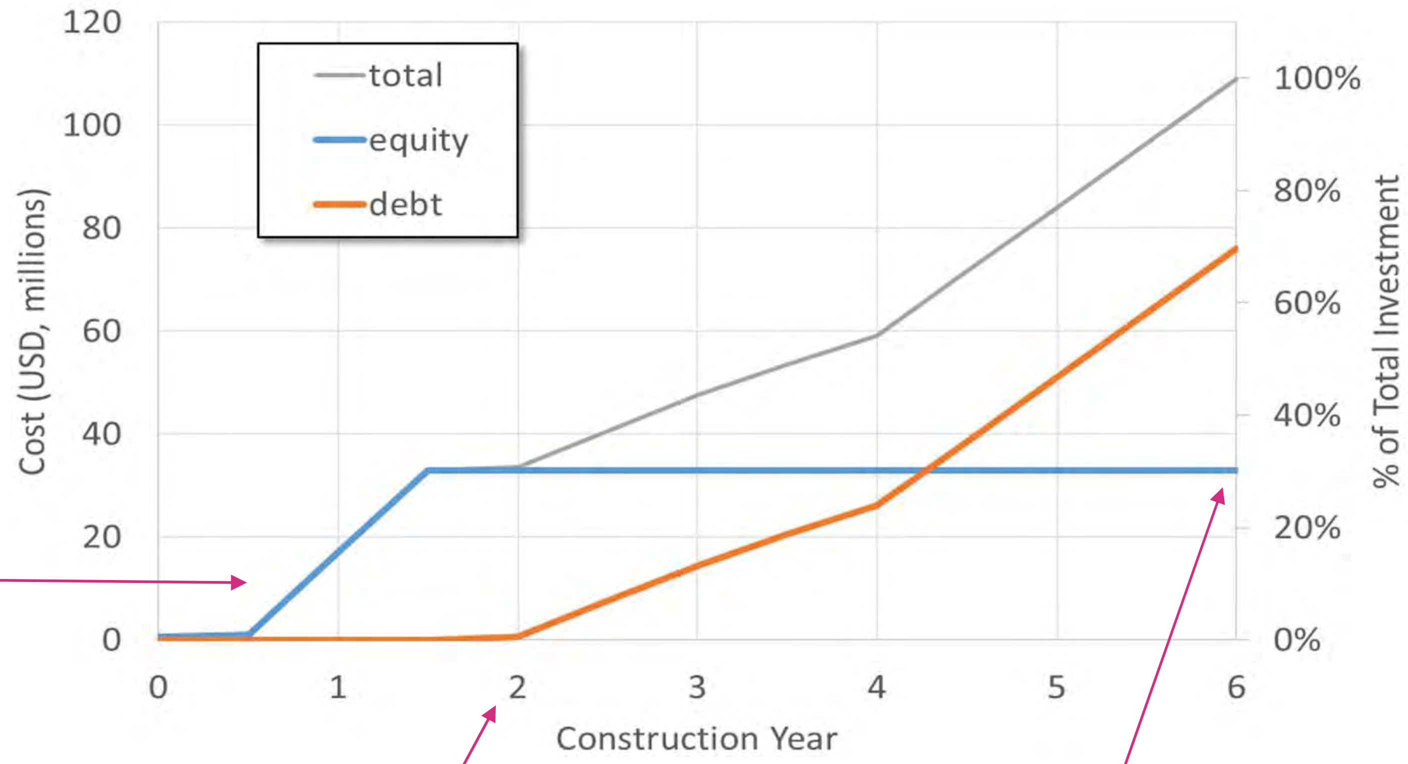




Cost Breakdown, 5 MW

- Capital intensive construction with high risk drilling
- Grant funding critical to establish geothermal in new markets
- Key developers/investors are typically cash flush companies interested in 'greener' energy

Equity vs Debt



Initial investment
- Equity
- Grants
- Bridge loans

Financial Close:
- Allows developer to access debt
- Banks require resource to be proven (i.e. enough production wells)

Banks typically require around 30% of costs to come from other sources

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Seismic Hazard Assessment

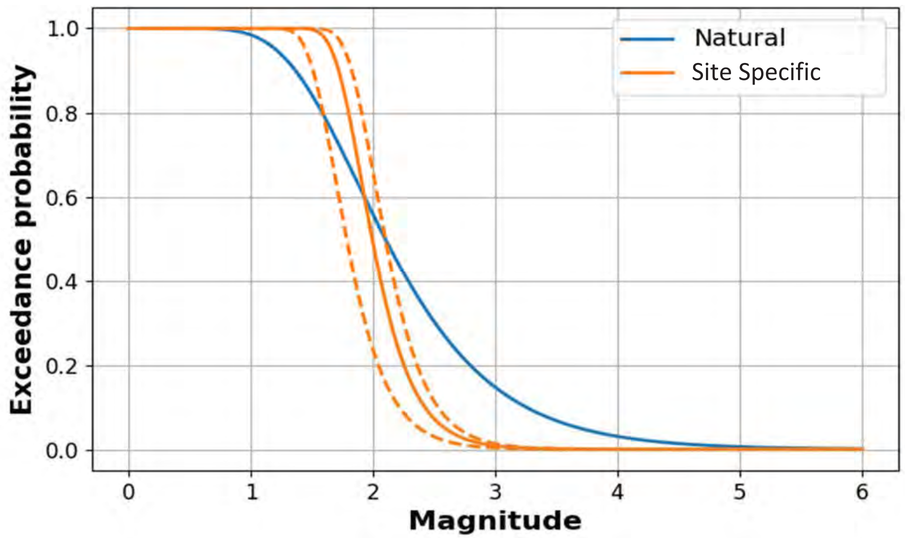
Natural Seismicity
- Assess natural seismic regime

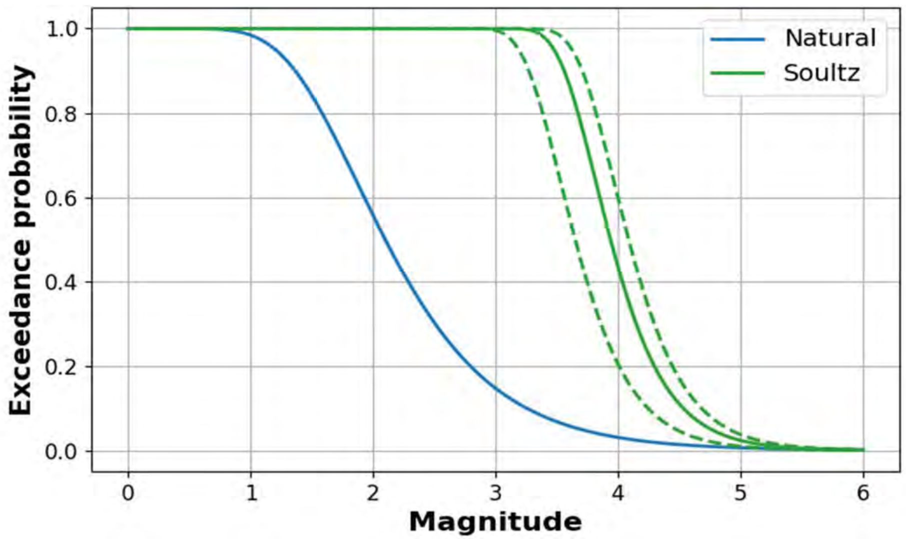
Induced Seismicity
- Define geothermal activity
- Estimate potential for induced seismicity
- Compare against natural seismicity

Surface Impacts
- Select Ground Motion Prediction Equation (GMPE)
- Relate seismicity to potential for surface impacts

Seismic Monitoring
- Develop seismic monitoring program
- Monitor baseline seismicity
- Traffic Light System (TLS), Mitigation, & **Communication**

Seismic Hazard – Estimating Seismicity





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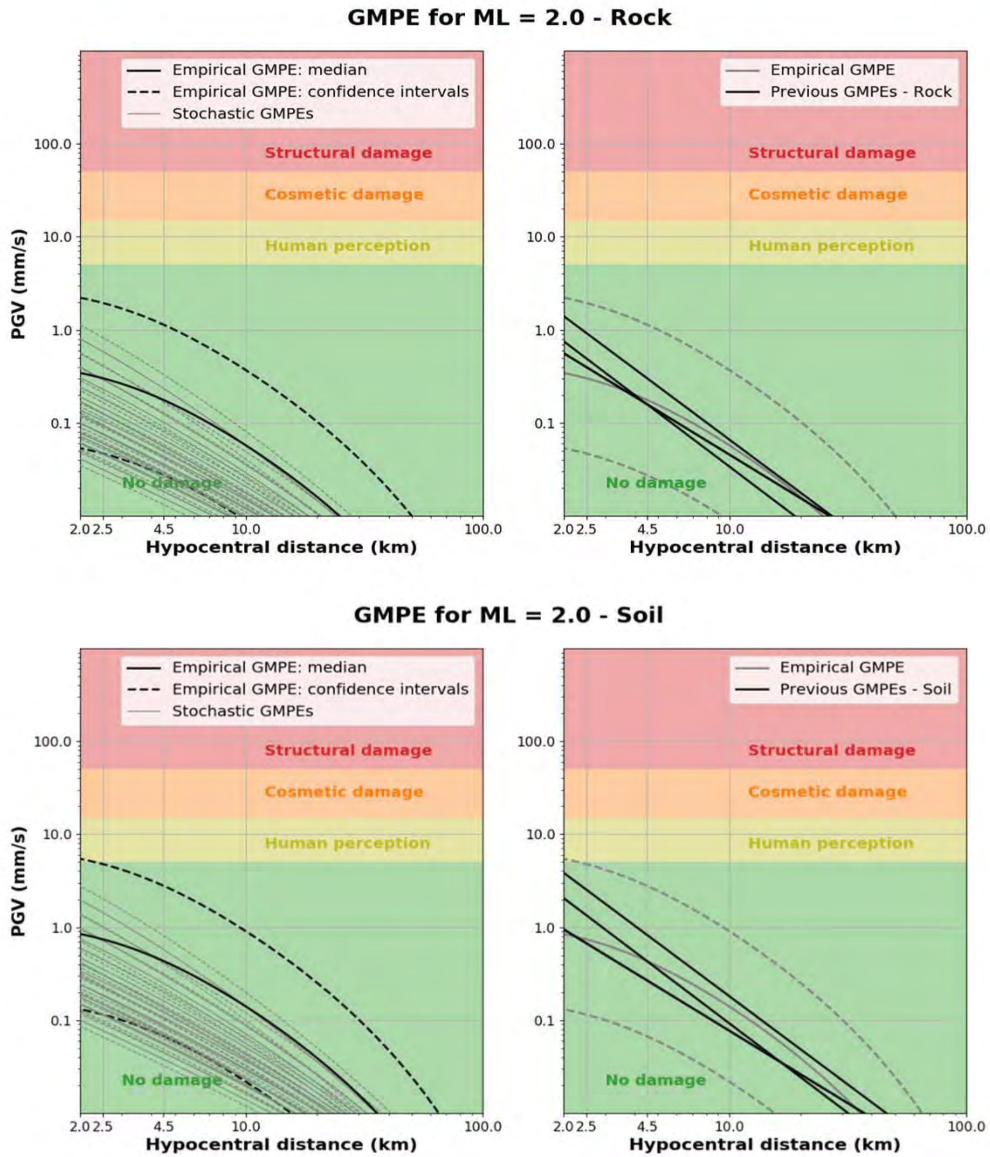
Seismic Hazards – Qualification of Seismicity

Classification	**M_L**	**Rationale**
Expected	1	All relationships indicate a reasonable probability of occurrence (example: between 35 and 100%)
Possible	2	Some relationships indicate high probability (example: between 68 and 100%) and others indicate low probability of occurrence (example: 0.3 to 3.6%).
Unlikely	3	While most relationships indicate low probability to occur (example: between 0.002 to 7%) there is one relationship with a relatively high probability (example: 35%).
Very Unlikely	4	All relationships indicate a probability less than 5%.
Negligible	5	All relationships indicate a probability less than 1%.

Seismic Hazard Assessment



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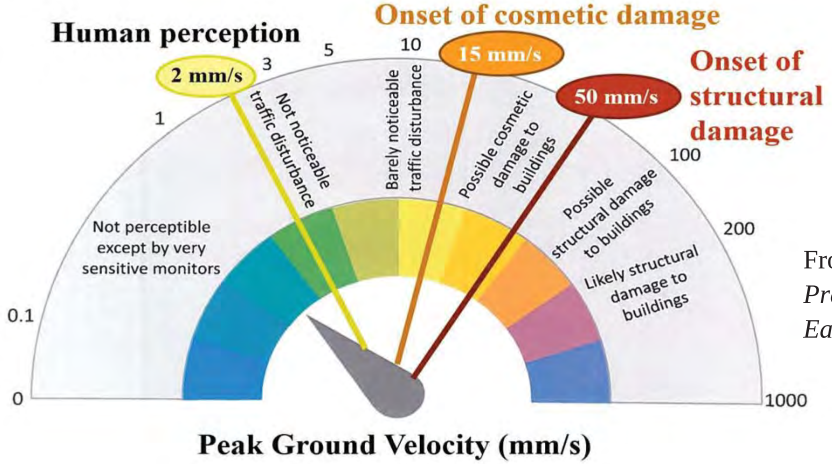
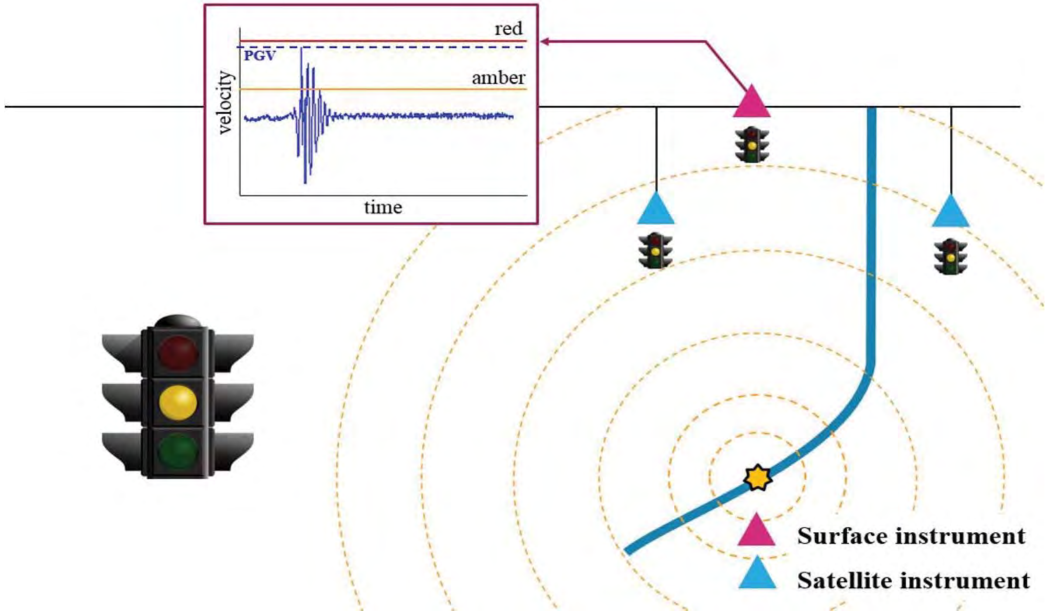
Seismic Hazards & Monitoring



From: *Bommer, J., Alarcon, J., (2006). The Prediction and Use of Peak Velocity. Journal of Earthquake Engineering, Vol. 10, No. 1, 1–31.*

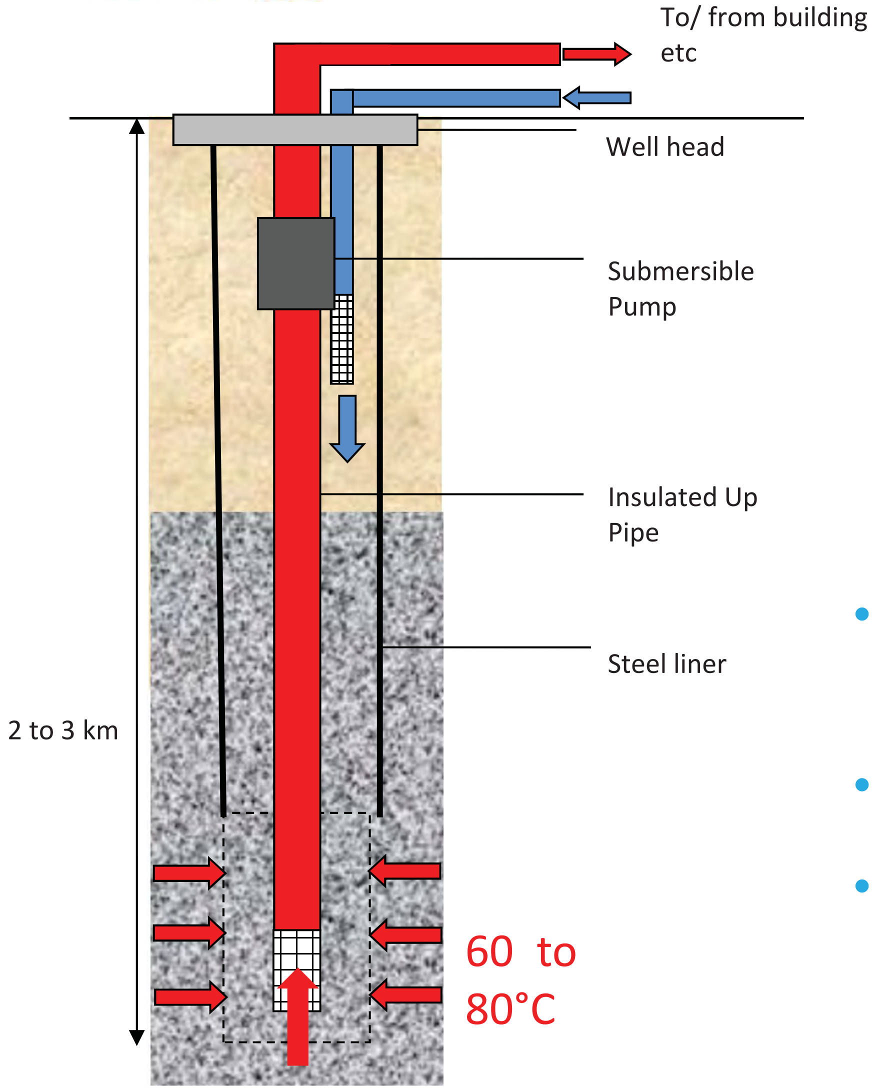


CONDITIONS & ACTIONS	GREEN	AMBER	RED
PGV & Magnitude based:	PGV < 1 mm/s & M < 1.0	1 ≤ PGV < 7.5 & 1.0 ≤ M < 2.1	PGV ≥ 7.5 mm/s & M ≥ 2.1
or	or	or	or
Magnitude Only Based:	< 1.2	≥ 1.2 & < 2.1	≥ 2.1
or	or	or	or
Site Specific:	*See TLS Plan*	*See TLS Plan*	*See TLS Plan*
Actions:	Continue	Notify & Continue	**STOP** & Notify Resume only if permissible

Date of last revision: 12 February 2018, thresholds may be revised with approval from ISUH

Non-Electricity Applications

- Applications
  - Direct Heating for Industrial Processes
  - District Heating
  - Ongoing Projects in Belgium, Cornwall UK, Scotland, Finland (6.4 km doublet)
- Technologies
  - Traditional Geothermal Doublet
  - Deep Coaxial Well (Geon well)



- Joint Venture between Arup and Geothermal Engineering Limited (GEL)
- Successful demonstration in 2016
- Projects
  - Penzance Pool, Cornwall (drilling, pictured)
  - Scotland Resort (planning phase)

Deep geothermal investigations in the Dublin Basin

Ricardo Pasquali & Pádraig Hanly

GT Energy – in conjunction with Newcastel Energy Ltd and part funded by SEAI (Sustainable Energy Association of Ireland) - undertook an exploration programme of the Newcastle to Blackrock fault line on the margin of the Dublin Basin in 2007. The programme aimed to assess the feasibility for developing deep geothermal resources and was focussed on identifying the geological conditions at Newcastle including target depths, formation temperatures and productive zones. Two deep geothermal boreholes were drilled and a temperature of 46.2 °C at 1,337m recorded. In April 2010 a seismic reflection survey in the southern margin of the Dublin Basin was completed to better define the depth of the geothermal targets. Based on the positive results of the initial phases of exploration that showed the presence of potential targets to a depth of greater than 3,000m, GT Energy obtained planning permission in 2011 for the first deep geothermal electricity plant comprising two deviated boreholes to a depth of 4,000m and a binary cycle plant with a maximum capacity of between 2 and 4 MWe.

Contact: Pádraig Hanly, GT Energy padraig.hanly@gtenergy.net Ricardo Pasquali rpasquali@geoservsolutions.com

GT Energy

Energy for the future

Deep Geothermal exploration in the Dublin Basin

GT Energy
Energy for the future

Contents

- About GT Energy
- Background to the Newcastle Project
- Phase 1 to 3 of exploration – 2006 to 2010
- IRETHERM project collaboration
- Planning & Project Development
- Future Outlook
- Discussion

About GT Energy

GT Energy
Energy for the future

DEVELOPMENT ACTIVITIES

- 1st company to carry out geothermal exploration programme and subsequently secure full planning permission for a geothermal project in Ireland
- 1st company to secure full planning permission for a geothermal heat project in the UK
- Targeting major cities for the development of geothermal district heating systems in the UK

CONSULTANCY

- Leading team of experts in geothermal district heating
- Strong track record of working with local authorities and private industry
- Advisory services covering all aspects of geothermal development

ukDEA.org.uk The UK District Energy Association

REA RENEWABLE ENERGY ASSOCIATION

GEOTHERMIEKOMPETENZ.DE

Project companies

GT Energy
Energy for the future

SLR

Geoserv

LIFFEY DEVELOPMENTS

PR MARRIOTT DRILLING LTD

apex geoservices

ERDWERK hydrogeologie geothermie

TESLA EXPLORATION

EGS

Weatherford

VSProwess

PATRICK BRIODY & SONS LTD

The geothermal potential of Ireland – Why Newcastle ?

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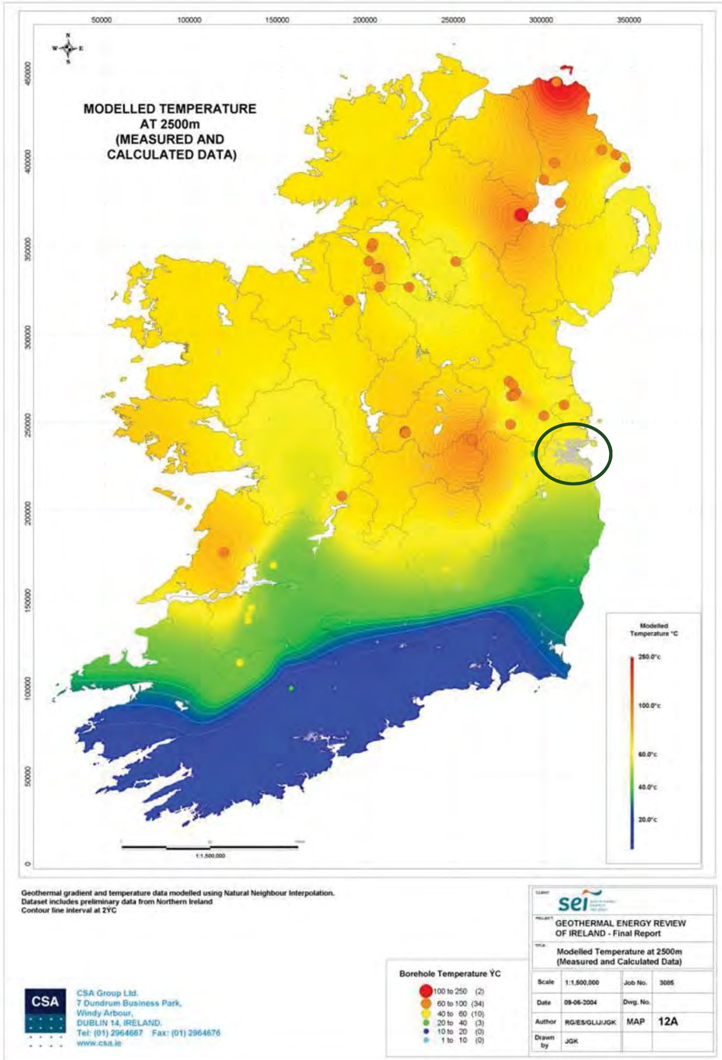
- In 2004 The Geothermal Potential for Ireland report was produced by SLR for SEAI;
- The report identified the Blackrock to Newcastle Fault (BNF) as a potential geothermal target.
- Insufficient geological information in urban areas such as Dublin;
- Some deep geological data in Newcastle (500m deep borehole);



Initial Geological Model

GT Energy
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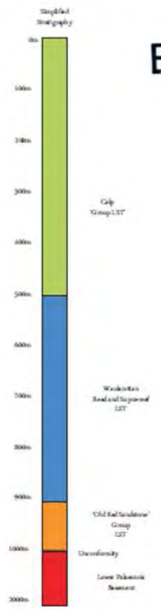
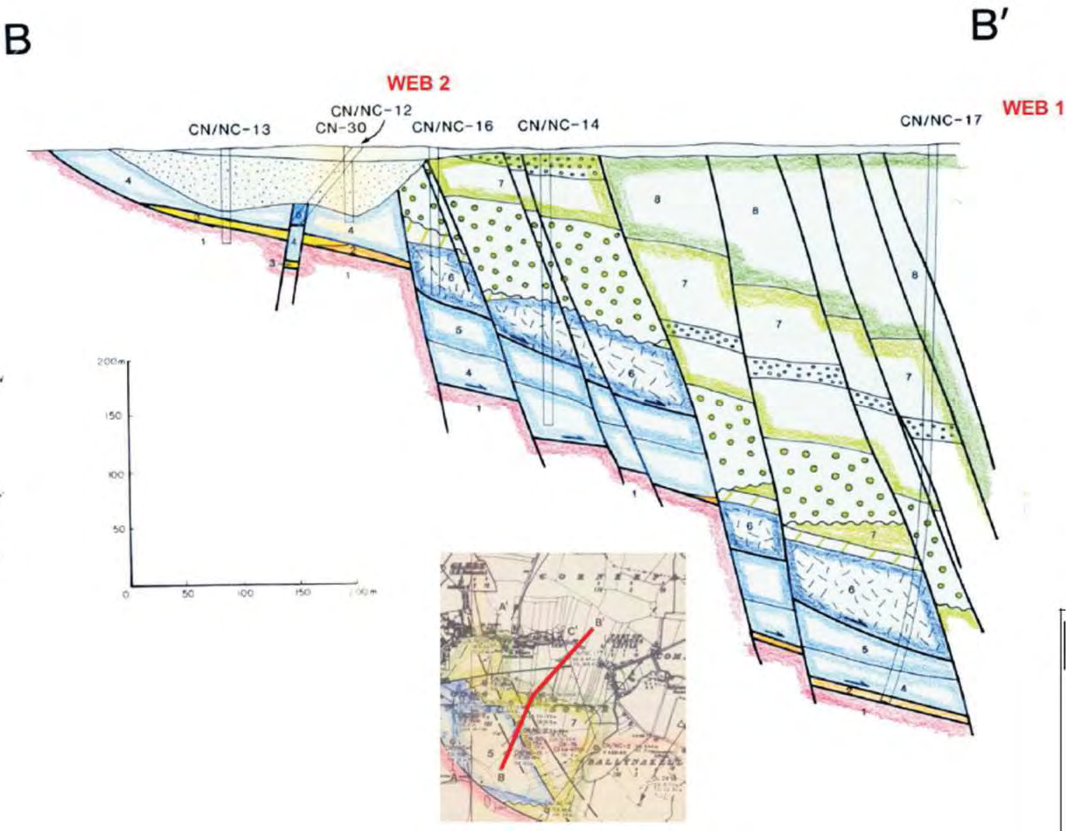
Legacy Mineral Exploration Data

- Noranda 1976 Exploration Geophsyical Data
- Aquitaine mineral Exploration data and borehole logs
- 'The Newcastle Channel'





The Newcastle Project

GT Energy
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Summary of works undertaken

- First geothermal exploration project at the Blackrock to Newcastle Fault (BNF) identified as a potential geothermal target;
- Part funded by SEAI;
- Commenced in 2007 and consisted of four phases;
  - **Phase 1** - drilling of two boreholes to depths of 300m (2007);
  - **Phase 2 -** drilling of two deep exploratory boreholes to a depth of 1,400m (2008);
  - **Phase 3 -** logging, testing and mapping of the boreholes to develop a deep geological model of the Newcastle area (2008);
  - **Phase 4** – Planning (2009/2010)

Phase 1 Exploration

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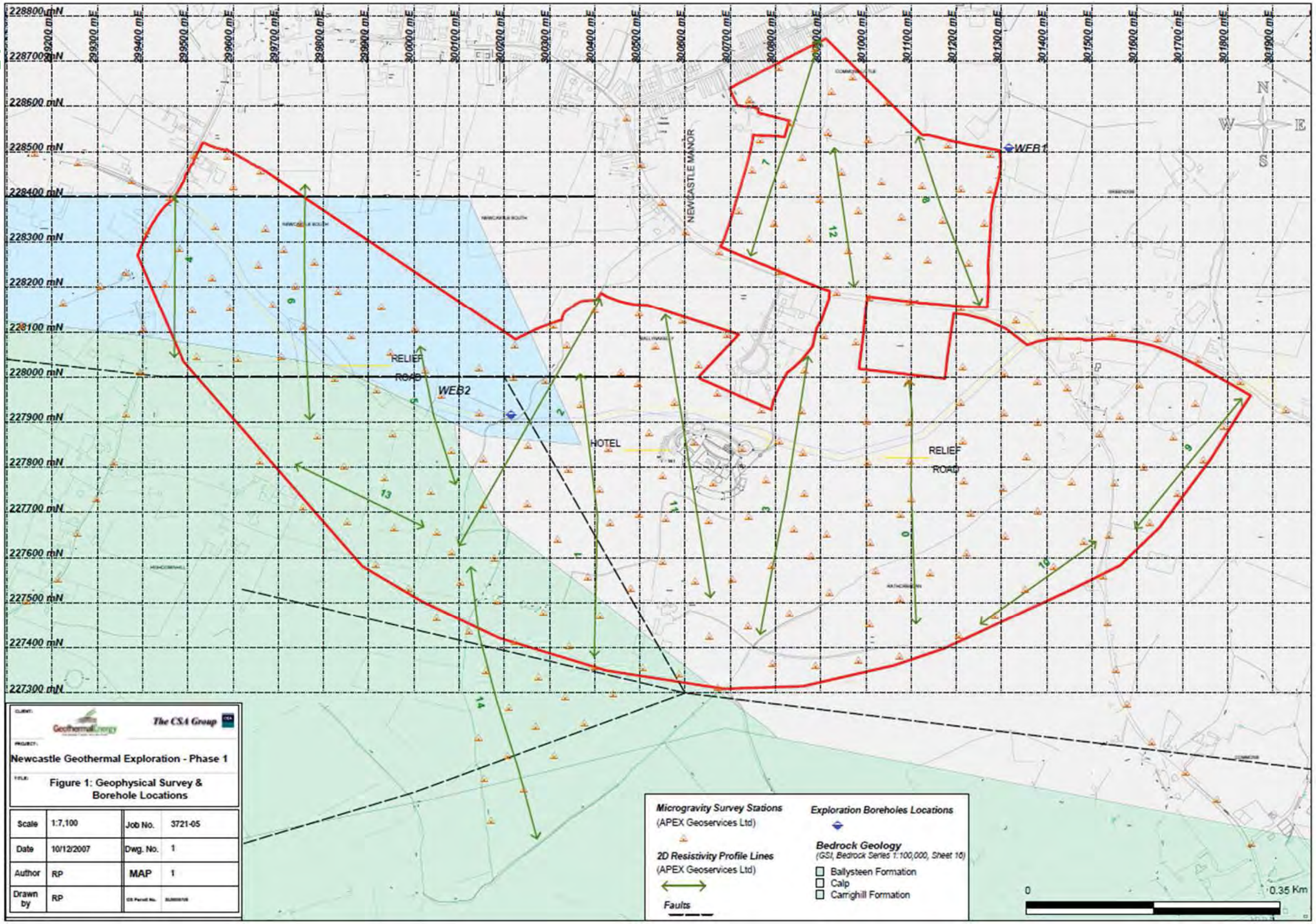
Summary of Work Undertaken

- Microgravity Survey
- VES Resistivity Profiles
- Shallow Exploratory Drilling:
  - 1 No. 300m borehole near the ‘Newcastle channel’
  - 1 No. 150m borehole in Greenogue
- Thin section & Petrography
- Temperature Logs
- Hydrogeological Characterisation

Phase 1 Exploration

S



Phase 1 Exploration

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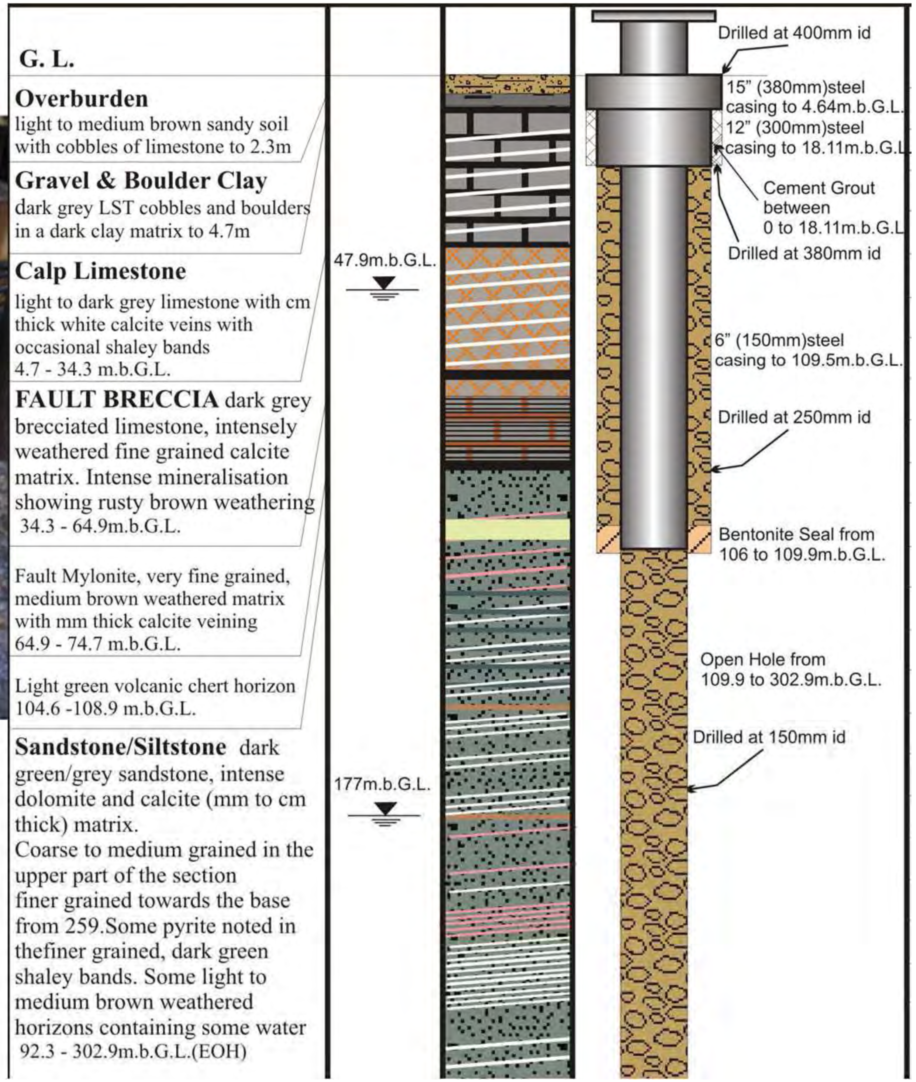
Shallow Drilling



Phase 1 Exploration

Main Findings & Next Steps

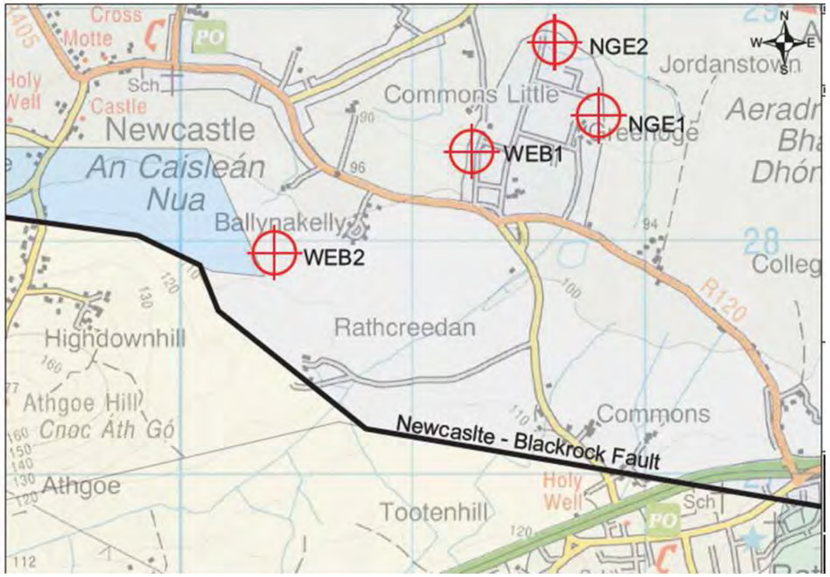
- Mapped continuation of BNF fault system at Newcastle
- Large water bearing fault structure

- Extension of the fault planes into the Basin?
- Water present at greater depth – 1,000 to 1,500m or greater?

Phase 2 Exploration

Summary of Works

- Drilling of 2 Deep boreholes
  - NGE 1 – 1340 m
  - NGE 2 – 1400 m
  - Petrography & Stratigraphy



- NGE 1 Geophysical Logging:
  - Optical Televiewer & Acoustic Imaging
  - Caliper, Natural Gamma,
  - Full Wave Sonic
  - Temperature, Conductivity
  - Focussed Resistivity

Phase 2 Exploration

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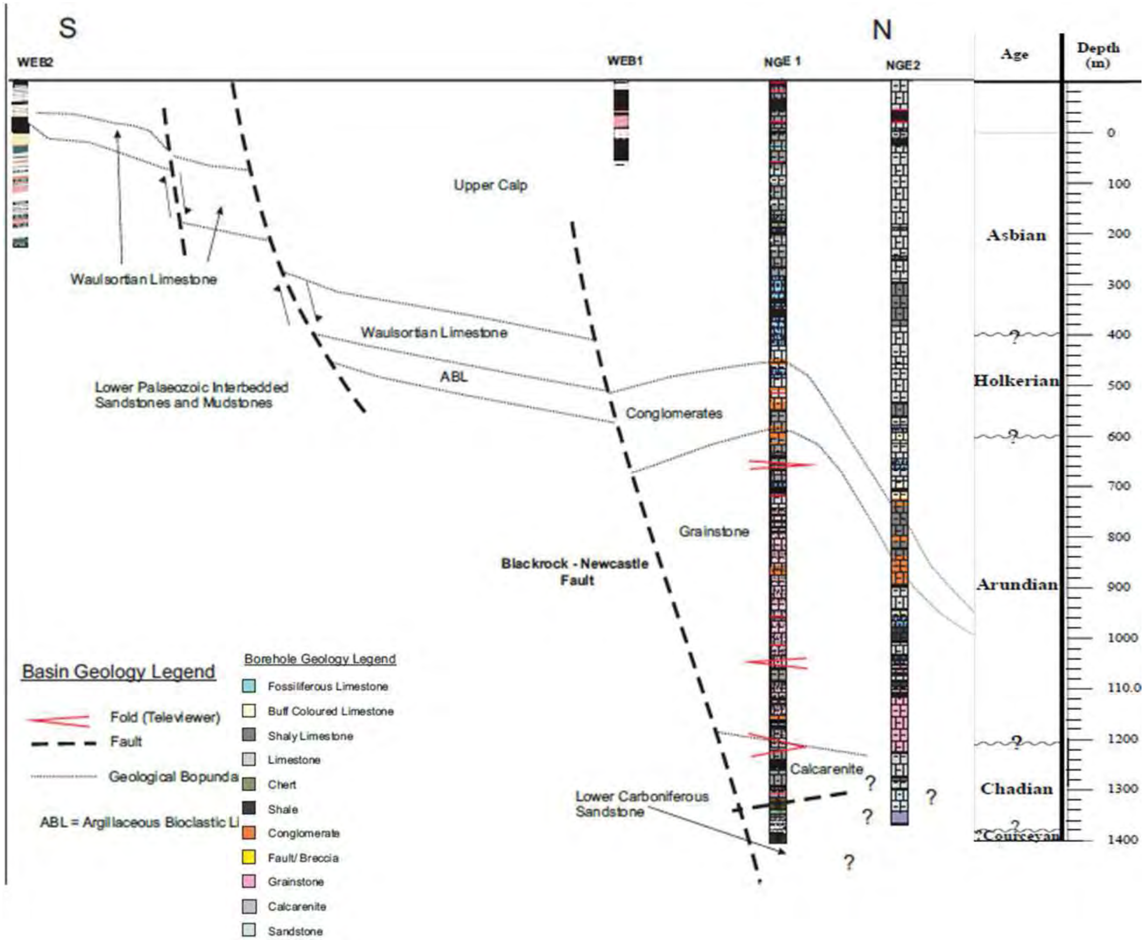
Deep Exploratory boreholes



- measured temperature at 1,337m of 46.2°C

Phase 3 Exploration

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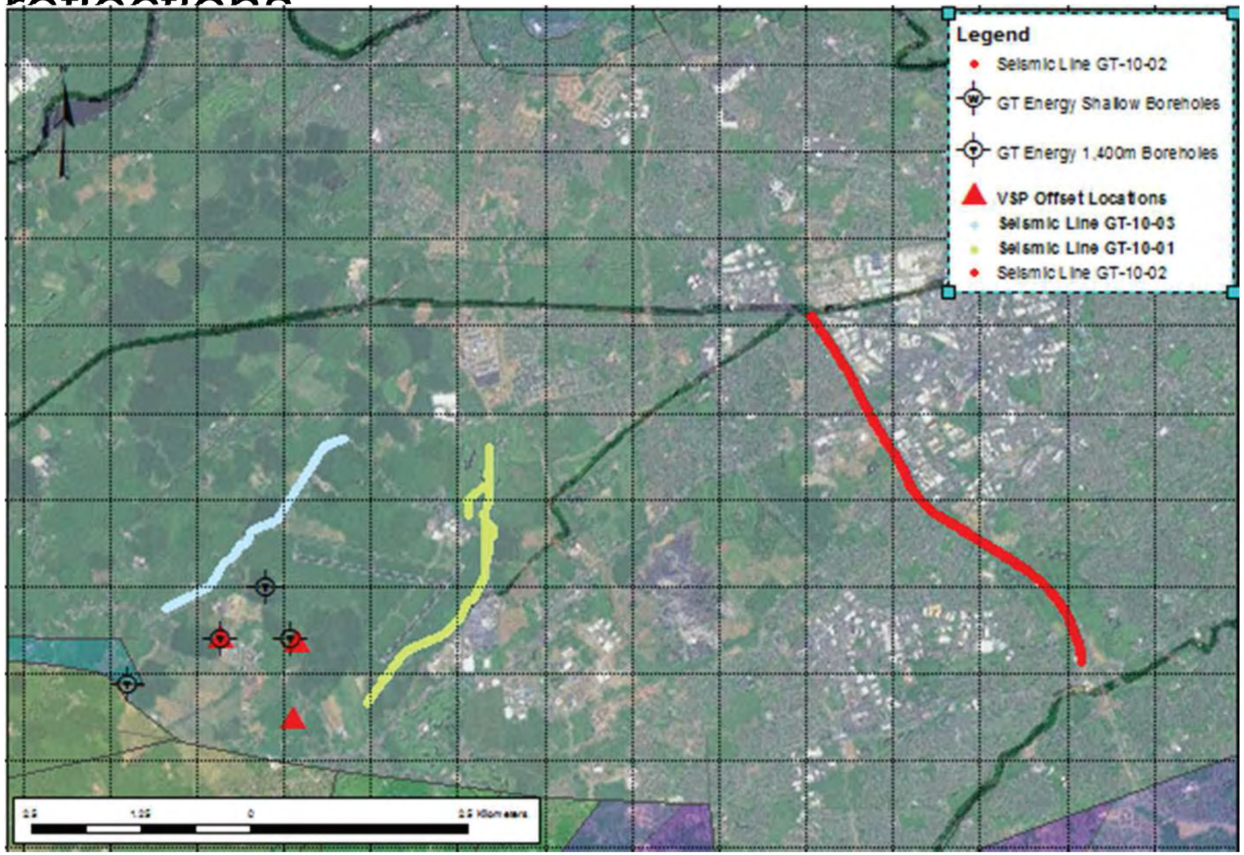
Summary of Works

- Vertical Seismic Profile (VSP) at NGE1
- 12km of seismic reflections

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND



Phase 3 Exploration

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Seismic Reflection

- Source Spacing 20m
- Receiver Spacing 10m

Phase 3 Exploration

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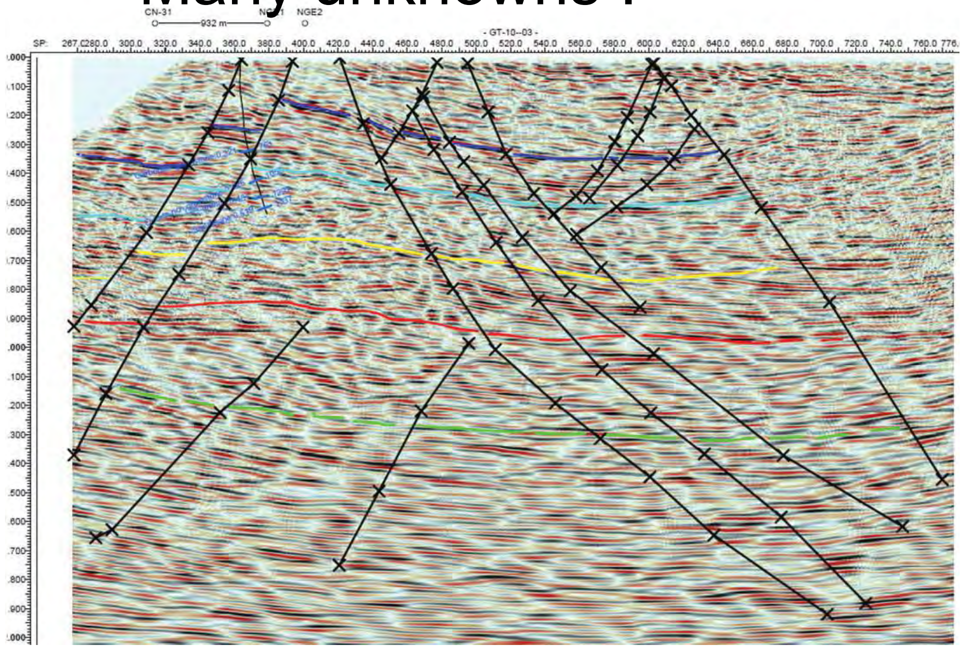
VSP Survey

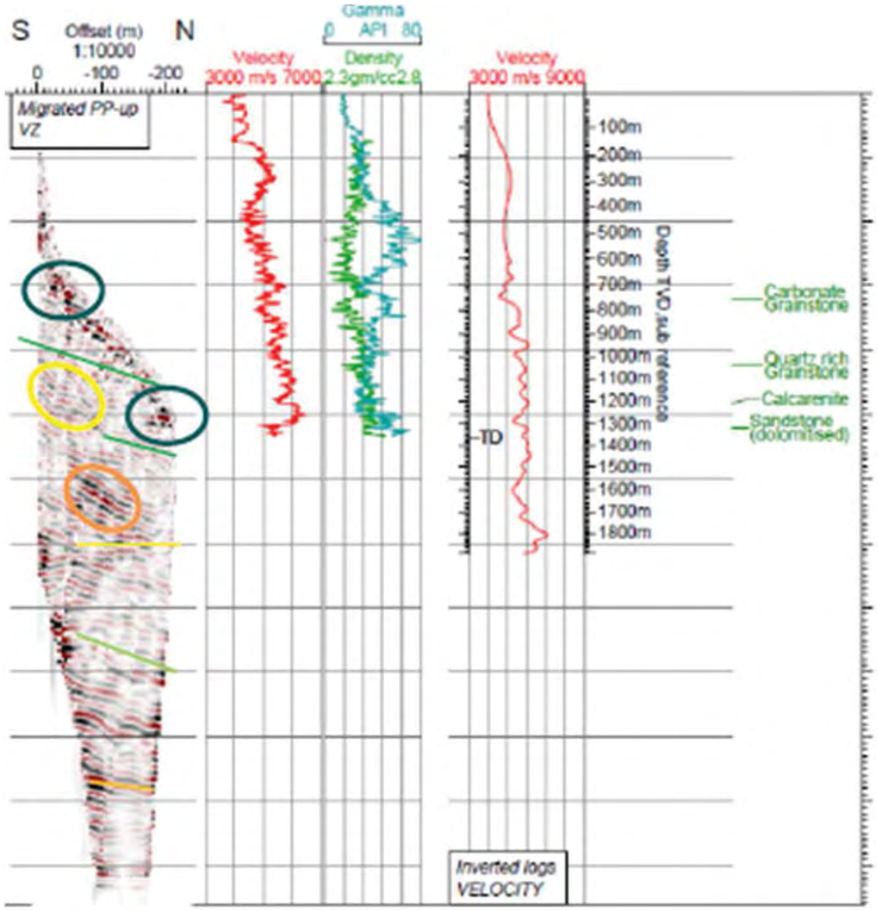
- Geophone Spacing: 10m
- Source: Vibroseis

Phase 3 Exploration

Results

- Complex Faulted Basin Margin
- Correlation with well data
- Many unknowns !



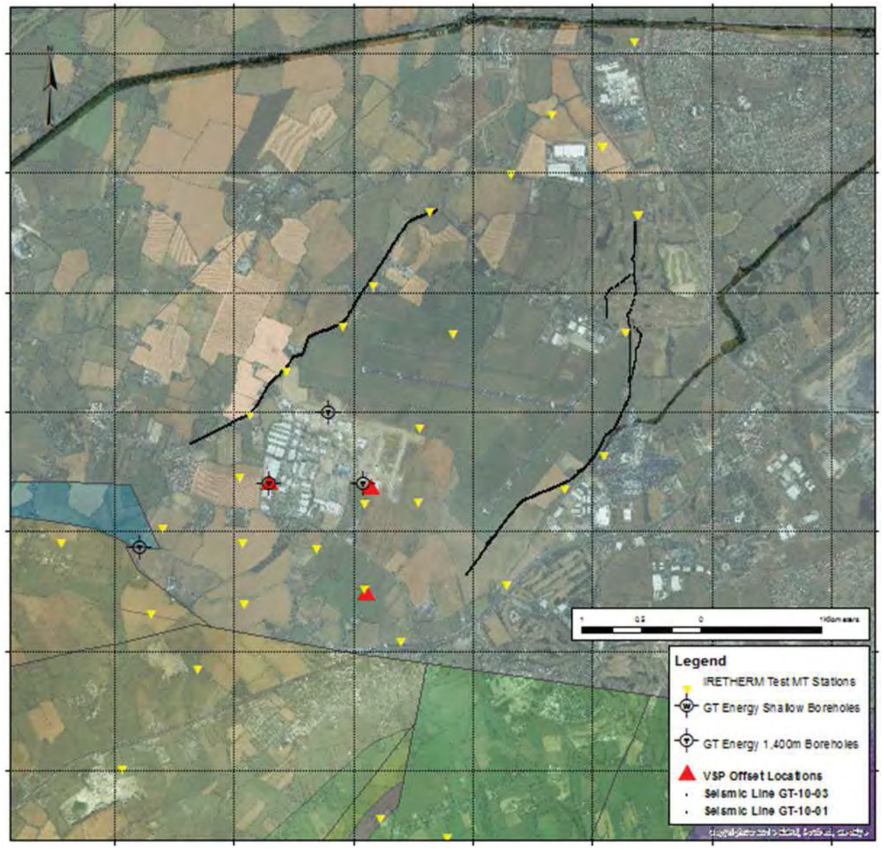


IRETHERM Project Collaboration

GT Energy
Energy for the future

MT Survey

- GT Energy Exploration Data supplied as part of research by Dr. Jan Vozar



IRETHERM Collaboration

GT Energy
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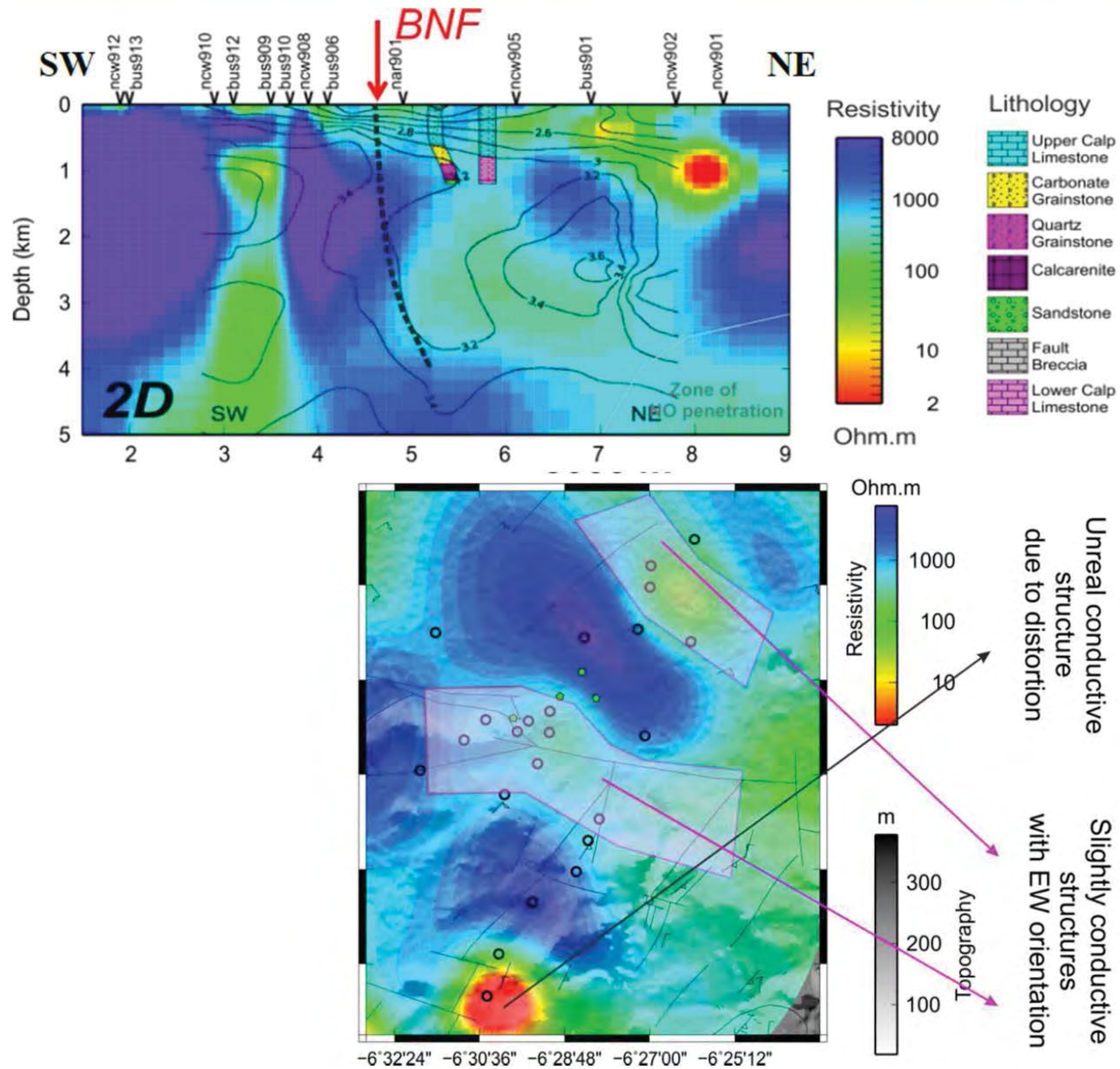
Results

- Potential conductive structure in proximity to the BNF at a depth of c. 3,000m
- Subsequent Passive seismic acquisition by Licciardi, A.



Vozar, J. *in press*

Project Development

GT Energy
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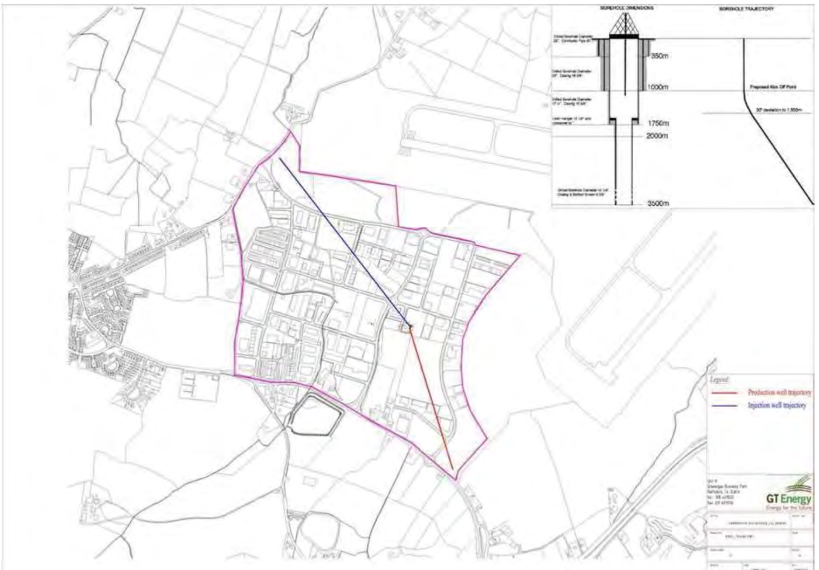
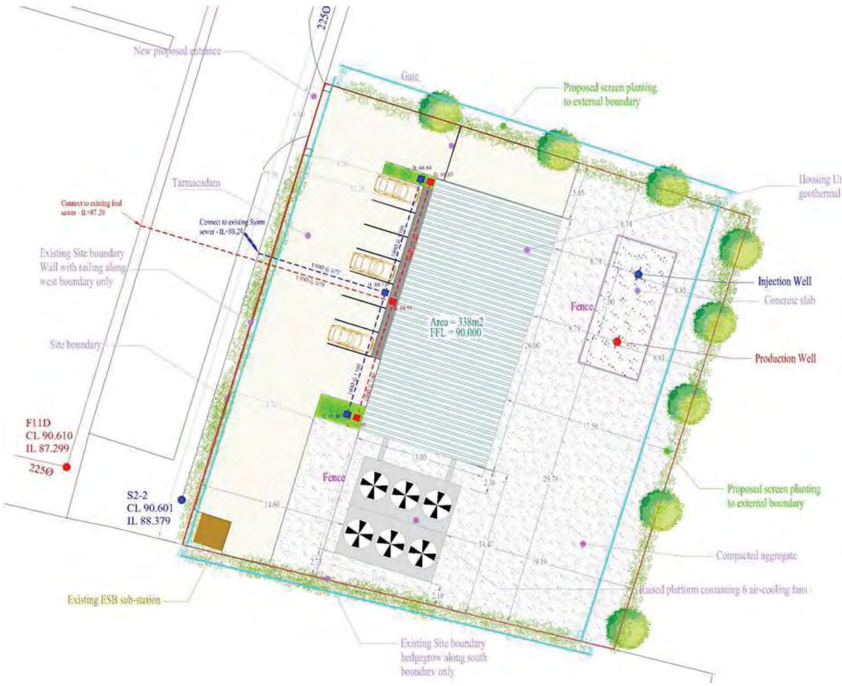
Power Generation

- Electricity Generation – Gate 3 Process & ~~REFIT~~
- Planning secured in 2010 for
  - 2 No. Geothermal boreholes to a depth of 4,000m
  - 4 MWe Binary Power plant
- Expected Investment € 35.8 M





Project Development

District Heating

- Independent Heat Demand Analysis South Dublin (2009)
  - Total of 60.9 GWh of heat demand
  - Anchor Loads including:
    - Tallaght Hospital 22.7 GWh
    - South Dublin Business Park 24.6 GWh

- Peak Load Profile for a DHN of 70 MW

Future Outlook

GT Energy
Energy for the future

- Where to next ??
- Geological targets associated with fault structures such as the BNF show promising results
- Potential for further assessment of Dublin Basin targets based on GT Energy data and recent research should be undertaken
- Geothermal Heat market and district heating in Ireland remains uncertain

Discussion

Public acceptance and risk perception of Geothermal Energy in Ireland

Teresa Hooks, Geertje Schuitema & Andrew B. Moynihan

Public acceptance is an important precondition for change and can often manifest in support but also strong resistance. Acceptance has been defined as a broad concept that refers to people general evaluation of, or the extent to which they tend to favour or disfavour, a certain development, in this case geothermal energy projects. Acceptance is heavily influenced by people's risk perceptions or the fear of negative impacts on elements such as the environment or the local economy, among others. Risk perceptions are essentially subjective responses to potential negative outcomes and are influenced by a wide range of factors e.g. the media, social and cultural beliefs, the institutions involved. This presentation focuses on risk perceptions towards geothermal energy in an Irish context based on some preliminary data analysis. Preliminary data analysis of expert views of public risk perceptions towards geothermal energy are lower in comparison to other energy sources e.g. hydrocarbons, but in the overall list of activities are ranked as having average risk. Furthermore, a nationwide survey of a random sample of the Irish population (N= 724) shows that public acceptance of geothermal energy was generally high with risk to the environment, society and the economy perceived as being low. Environmental and societal risks were deemed as the most important factors that influence overall public acceptance of geothermal energy in Ireland. In conclusion, geothermal energy in Ireland is generally acceptable to the Irish public, however this analysis only looked at the general population and public acceptance is context specific. Overall, we can say that currently public acceptance of geothermal energy is high however the challenge is to maintain this acceptance. Thus, it's important that communities are involved in the process of geothermal energy development from the beginning and are well communicated with in order to stabilize and generate acceptance.

Contact: Dr. Teresa Hooks:, UCD Teresa.hooks@ucd.ie

Public acceptance and risk perception of Geothermal Energy in Ireland

Dr. Teresa Hooks, Dr. Geertje Schuitema and Dr. Andrew B. Moynihan

UCD College of Business, Carysfort Ave, Carysfort, Blackrock, Co. Dublin

Irish Centre for Applied Geosciences (ICRAG), O Brien Centre for Science, Belfield, UCD

GSI Haddington Road, Dublin

6th September 2018

Public acceptance of Geothermal energy

- Public acceptance is an important precondition for change, e.g., ***strong resistance*** is found for various reasons:
  - Milos Island (Greece) - fear of negative impact on tourism “What tourist would come to have holidays near such a plant?” (Popovski, 2002)
  - Nisyros Island (Greece) - fear of negative impact on environment/ distributive fairness (Popovski, 2002)
  - Araucania region (Chile) – lack of trust, spiritual relationship with volcanoes, and uncertainty about environmental impact (Payera, 2018)

Public acceptance of Geothermal energy

- But there are also examples where geothermal energy is ***supported*** by communities

  - Power plant in Guadeluppe (France): innovativeness- ‘something new’ to the local economy: tourism, job opportunities, cheaper electricity (Desplan, 2002).

Public acceptance Geothermal energy?

- **Acceptance*:*** a broad concept that refers to people’s general evaluation of geothermal energy

- Acceptance is influenced by fear of negative outcomes, e.g. on
  - The environment
  - Disturbing nature
  - Local economy and tourism → **Perceived risks**

- Acceptance is influence by the interaction between communities and authorities/ developers
  - Trust
  - Communication strategies
  - Fairness → **Community involvement**

Risk perceptions

- Risk perceptions are "all about thoughts, beliefs and constructs" (Sjöberg, 2000) of negative outcomes associated with geothermal energy

    - The environment
    - Public health
    - The economy
    - Local culture/values

- Thus, perceived risks are subjective responses to potential negative outcomes (Dobbie and Brown, 2014)

What informs our risk perceptions?

- Media… Birkholz et al. (2014) report the most dramatic risks, thus decreasing public risk perceptions surrounding everyday risks i.e. drinking water contamination

- Range of factors in the social system:
  - Values, social and cultural beliefs, context, knowledge and individual capabilities, and organisations and institutions involved and trust among other factors (Stern, 2000; Suvedi *et al*., 2000; Po *et al*., 2003; Renn, 2008; Birkholz *et al*.,2014; Dobbie and Brown, 2014; Gisbon *et al*., 2016)

What informs our risk perceptions?

- People rely on their own ‘intuitive risk judgements’ or their own risk perceptions, even when presented with scientific knowledge (Slovic, 1987; Mileti *et al*., 2004)

- Especially true when the information is complex…often reject information that is not in line with those beliefs (Slovic, 1987; Kahan *et al*., 2009)

- Scientific information rarely results in attitudinal or behavioural change… already made up their mind based on gut instinct or by responding to social cues (Wood *et al*., 2012; Kirschoff *et al*., 2013; Stewart and Lewis, 2017)

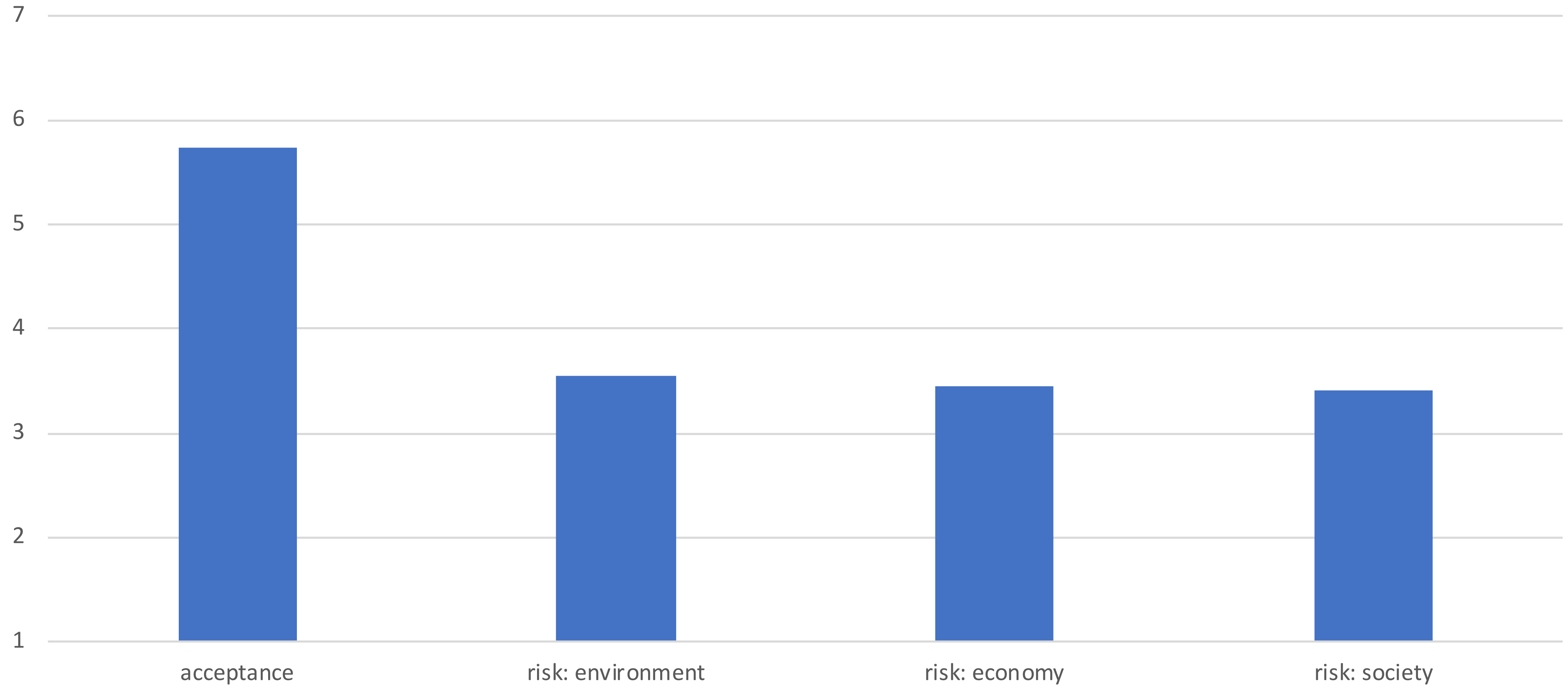
What do experts expect the Irish public sees as risky?

Expert analysis: mixed ideas

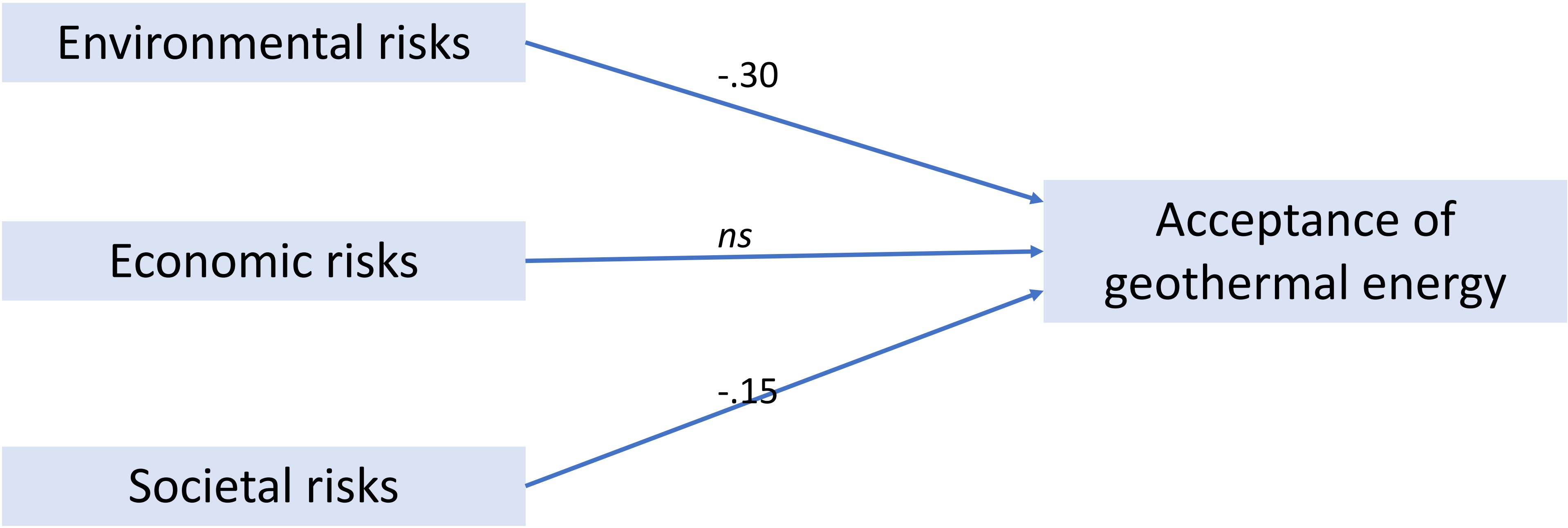
"When I painted the public, I put things like wind energy and geothermal energy as kind of, they generally have positive connotations, so that's generally why I ranked them lower"

"I have put quarrying, exploration and production, geotechnical engineering, geothermal energy all in the top third to half of the public perception because all of that is involving the subsurface and I think people don't quite understand what the subsurface is or isn't"

Public perception of geothermal energy in Ireland



Public perception of geothermal energy in Ireland



F (3. 720) = 55.7, p<.001; R^2 = 19%

Conclusion

- Geothermal energy generally acceptable to the Irish public, however
  - Acceptance is context specific – thus may locally not be acceptable

- Acceptance is unstable – and can change, often due to lack of trust or "irrational" responses

- Therefore, the public should be involved from the beginning: initial high acceptance levels are a promising starting point

GeoGeo -Energy Europe Energy Europe Energy EuropeEnergy EuropeEnergy Europe Energy Europe

Elizabeth Murphy & Stephen Walsh

Funded under the “Clusters Go International” call, which is part of the European Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME) program, the project (Geo-Energy Europe) will consist in creating a transnational cluster specifically aimed at increasing the performance & competitiveness of European SMEs in all industries concerned by the use of subsurface for energy, or "geo-energy", on transnational (EU) and world markets.

The GEO-ENERGY EUROPE project officially started on January 1, 2018 for a duration of 2 years, and involves 8 partners from 7 EU and COSME participating countries: POLE AVENIA (coordinator) and GEODEEP in France, EGEC in Belgium, GEOPLAT in Spain, GEOENERGY CELLE in Germany, CAPES in Hungary, JESDER in Turkey and GEOSCIENCE IRELAND. The consortium composition is made of 4 clusters in applied geoscience or geo-energy at large and 4 business network organizations specialized in geothermal energy, the funded 2 years program will primarily target its networking activities, cross-sectorial skill & technology transfers, market studies and strategic planning towards the promotion and industrial take-off of the emerging deep geothermal energy industry for district and industrial heating and power generation, in line with the European and most national energy transition goals.

Project Website: https://www.clustercollaboration.eu/escp-profiles/geo-energy-europe
Contact: Elizabeth Murphy: Elizabeth.murphy@gsi.ie Stephen Walsh: Stephen.walsh@gsi.ie

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

GEO-ENERGY EUROPE

Geoscience Ireland

Elizabeth Murphy & Stephen Walsh

6th September 2018| *Deep Geothermal in Ireland – Past, Present and Future*

GEOSCIENCE IRELAND
Exploring
Developing
Sustaining

Geoscience Ireland (GI) | Geoscience Ireland (GI) is a network of 36 companies, delivering integrated expertise in water, minerals, environmental and infrastructure development to clients in over 50 countries.

GEO-ENERGY EUROPE Project

GEO-ENERGY EUROPE

POLEAVENIA Geosciences Innovation Valley	France (coordinator)
EGEC GEOTHERMAL	Belgium
geoplat	Spain
GEODEEP	France
Cluster of Applied Earth Sciences CAPES	Hungary
JESDER	Turkey
GeoEnergy Celle e.V. Competence in Oil, Gas, Geothermal Energy	Germany
GEOSCIENCE IRELAND Exploring Developing Sustaining	Ireland

GEO-ENERGY EUROPE Project

Partners:

- 8 partners from 7 EU and COSME participating countries
- 380 SMEs

Funding:

- “Clusters Go International” call, which is part of the European Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME)

Duration:

- 2 years (Commencement February 2018)

GEO-ENERGY EUROPE Project

Purpose & Objectives:

- Creating a transnational cluster specifically aimed at increasing the performance & competitiveness of European SMEs in all industries concerned by the use of subsurface for energy, or "geo-energy", on transnational (EU) and world markets – Key market focus: **Geothermal**.

- To develop, & propose an implementation roadmap for, a **joint internationalisation strategy** to help this ESCP go international

- Build a **European Strategic Cluster Partnership** (ESCP) to help create a sort of European label for export opportunities and cooperation in know-how and technology transfer with third countries

GEO-ENERGY EUROPE Project

GI's Role:

- Map, assess and prioritize high potential deep geothermal energy markets in Europe and around the globe

GI's Expectations :

- Enhanced opportunities for Irish geo-energy companies exporting their expertise internationally
- Creation of pan European network of collaboration partners
- Increased job creation and economic growth arising from business opportunities in emerging markets

Thank You!

Contact Information

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Stephen D. Walsh| Market Advisor | stephen.walsh@gsi.ie | 00 353 1 678 2808

www.geoscience.ie GeoscienceIre science Ireland

Project Information

GEO-ENERGY EUROPE European Cluster Collaboration Profile (ECCP):

https://www.clustercollaboration.eu/escp-profiles/geo-energy-europe

geoenergyeurope

District Heating for Dublin City

Stephen Cull

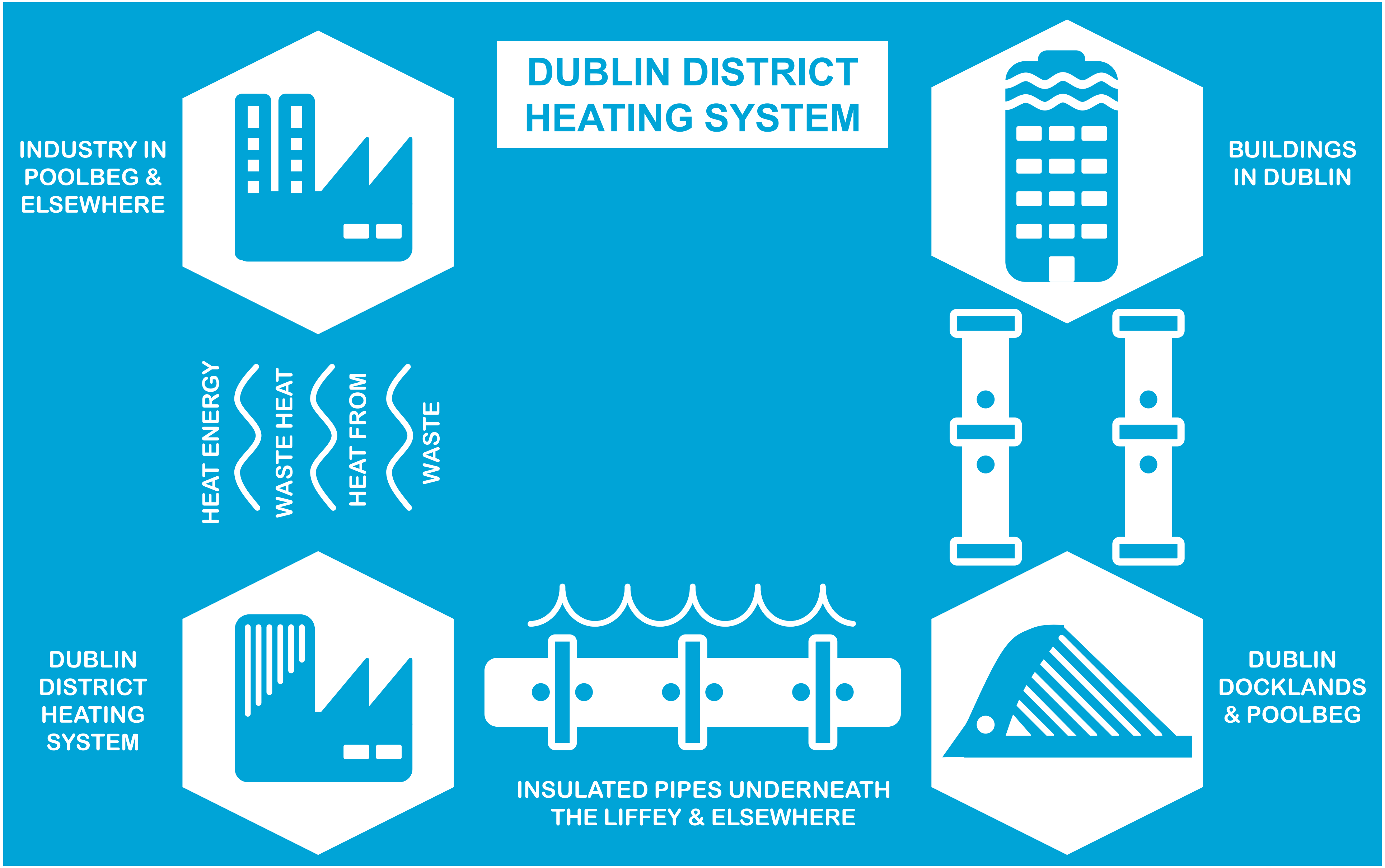
The Dublin District Heating System (DDHS) is currently being developed by Dublin City Council (DCC). Since 2011, DCC planning policy has been to encourage energy efficiency initiatives such as District Heating (DH), policies which are stated in the previous and current city development plans, and the 'Poolbeg West' Strategic Development Zone's (PWSDZ) & 'North Lotts and Grand Canal Docks Strategic Development Zones' (commonly called the Docklands SDZ). The PWSDZ and Docklands SDZ are being chosen as the initial location of the DDHS as they are the fastest growing areas in Dublin. The Docklands area is home to some 26,000 residents, and home to over 500 businesses which employ in excess of 44,000. The Docklands provides 9% of the Irish GDP. The PWSDZ will provide 3,800 new housing units, office and commercial spaces.

The DDHS involves the development of a proposed DH network to recover and distribute waste heat from industrial facilities on the Poolbeg peninsula of Dublin, primarily focussing on the Dublin Waste to Energy (DWtE) Plant, which recently begun operations in November 2017.

The proposed DDHS will use hot water for thermal energy transfer and distribution. The system design assumes a max 90MW energy based on 85-90°C / 45°C flow and return temperatures, however these figures may change depending on the full design of the DDHS network and the number of potential customers willing and able to connect to the DDHS network.

The DH System envisaged for Dublin will be based on best experience from Scandinavian countries. The System will be modern and highly efficient. It will also be designed to give individual customers full control of their heating and value for money. Elements of the DDHS infrastructure have already been installed within the north docklands area, and within the new Liffey Services Tunnel, which facilitates the roll out of DH network both north and south of the River Liffey.

Contact: Stephen Cull, Dublin City Council stephen.cull@dublincity.ie

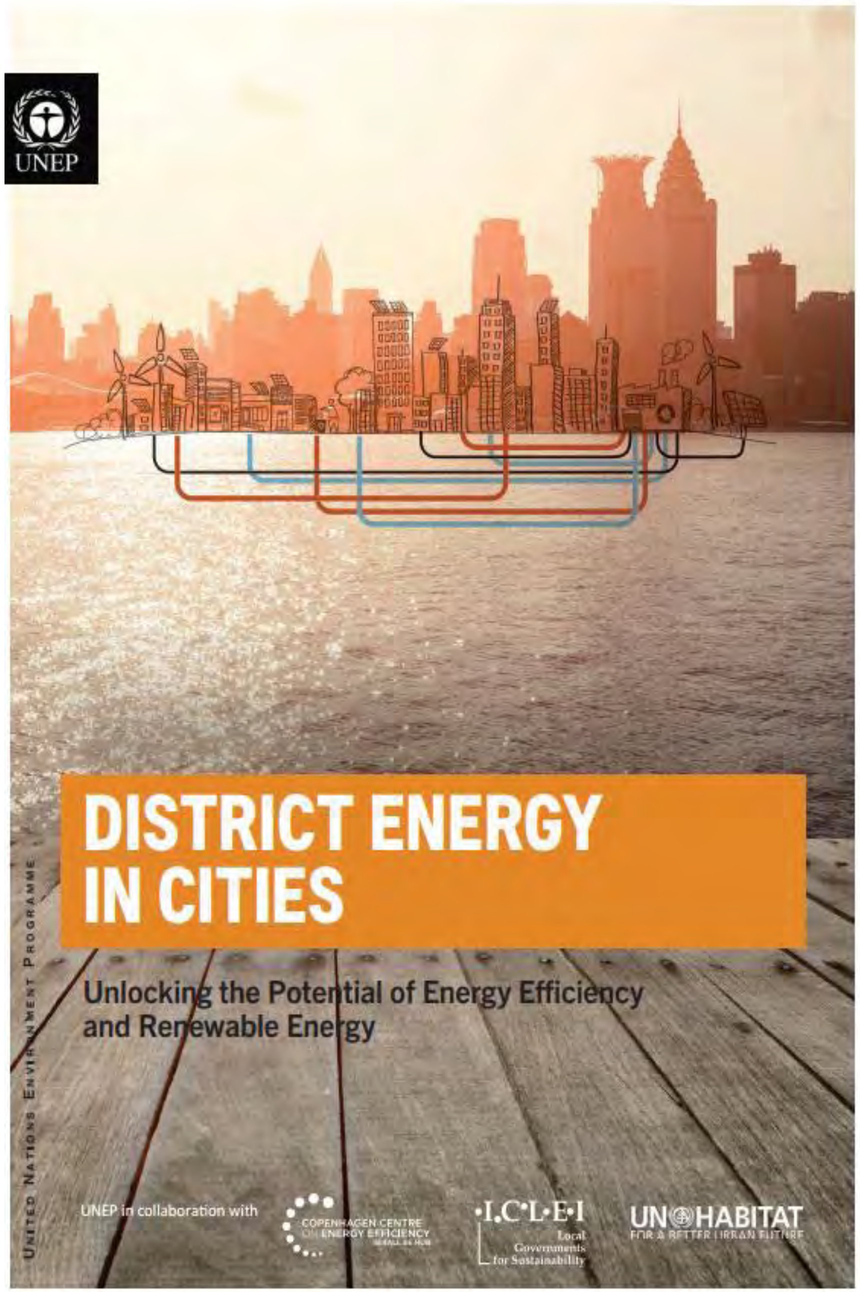


Deep Geothermal in Ireland – Past Present & Future

6th September 2018

Stephen Cull, Dublin City Council

Comhairle Cathrach Bhaile Átha Cliath
Dublin City Council



Why District Heating

Cities have a central role to play in the transition to sustainable energy: as managers of interdependent services and utilities, they are uniquely placed to enable the integrated solutions necessary to rapidly advance both energy efficiency and renewable energy. One such integrated solution is the development of modern district energy systems.

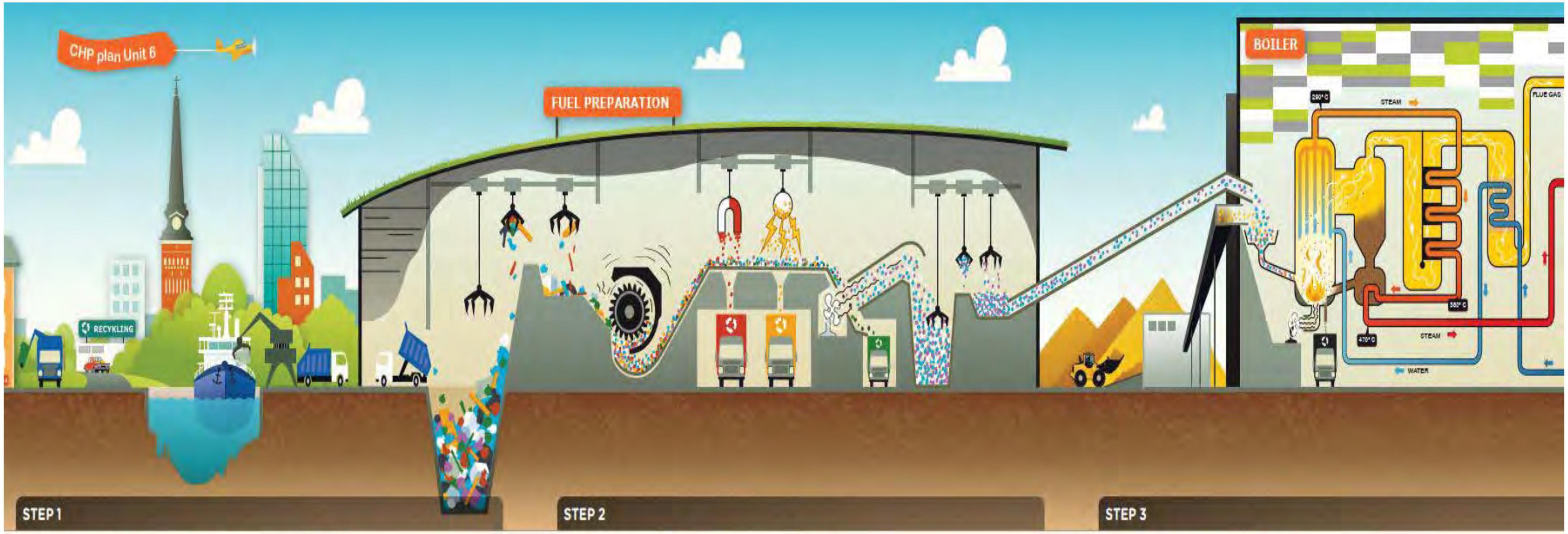
The UNEP report *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy* **identifies modern district energy as the most effective approach for many cities to transition to sustainable heating and cooling,** by improving energy efficiency and enabling higher shares of renewables.

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

What is District Heating

District Heating DH is a thermal energy network which distributes hot water or steam through insulated dual (supply and return) pipe lines to serve property energy demands.

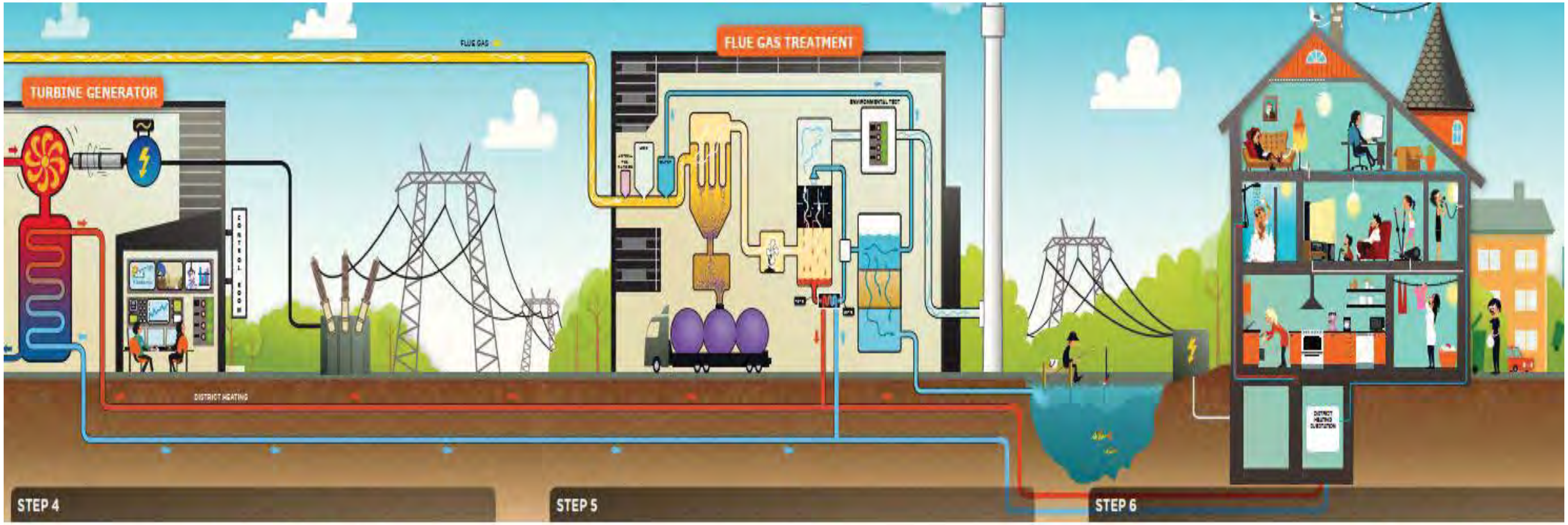
Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council



Your waste is transformed into heat.

Here, waste becomes fuel.

Nothing is wasted here.



The vapour generates heat and electricity.

The flue gases are purified.

The heat and electricity reach your home.

Benefits of District Heating

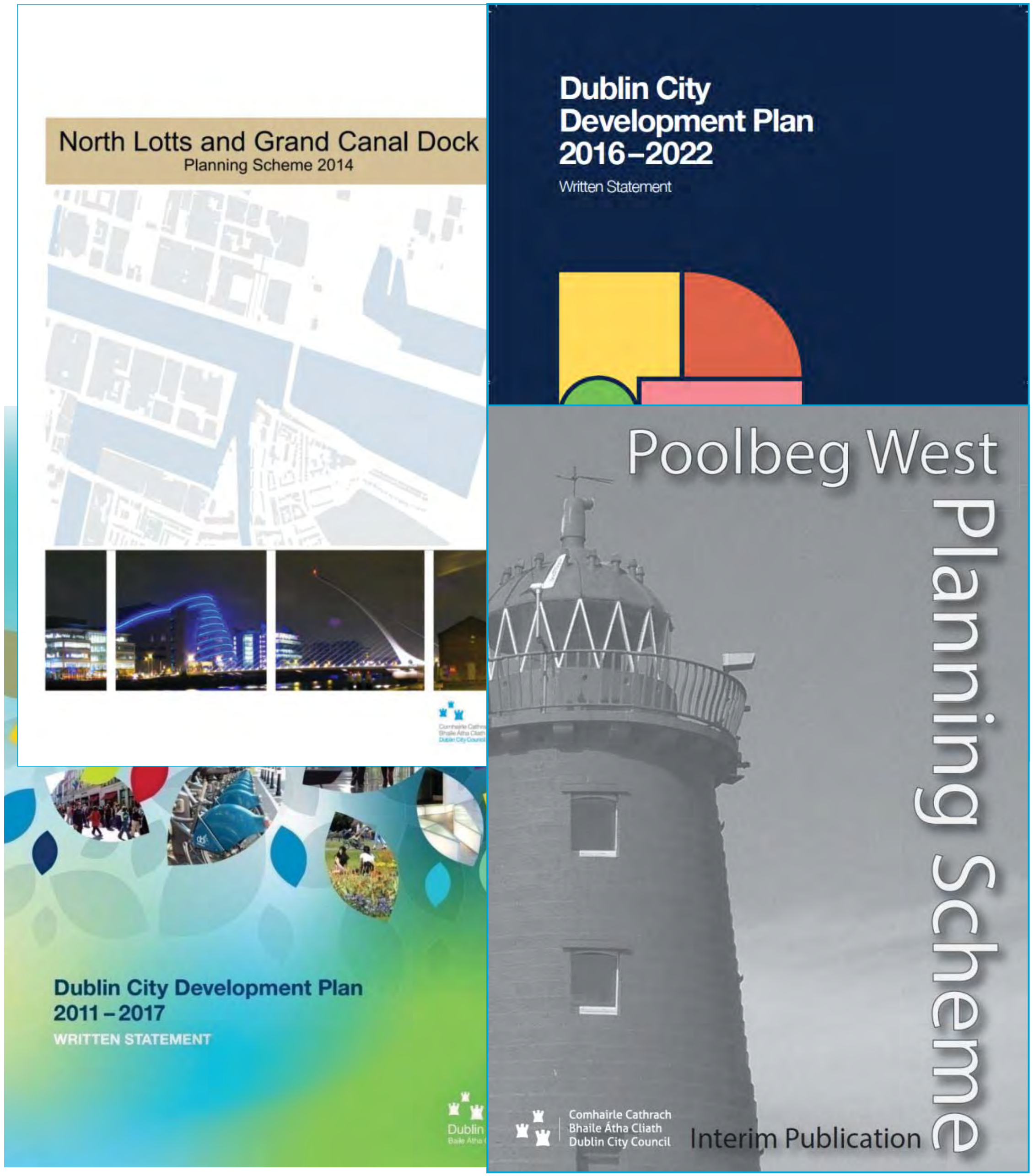
- Reduced CO^2 emissions and other pollutants
- Less dependence on imported fuels
- Use of local energy resources and sources
- Fuel Flexibility
- Greater de-carbonisation of the heat sector
- Installation is labour intensive, local labour, local products
- Improved safety having no fuel in home
- sustainability and competitiveness.

- 62% of homes in Denmark are supplied by DH, or 50% of the total heat demand
- 92% of citizens in Iceland were served by district heating in 2013

"European Commission Joint Research Centre 2012"

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

DCC Policy / Documents



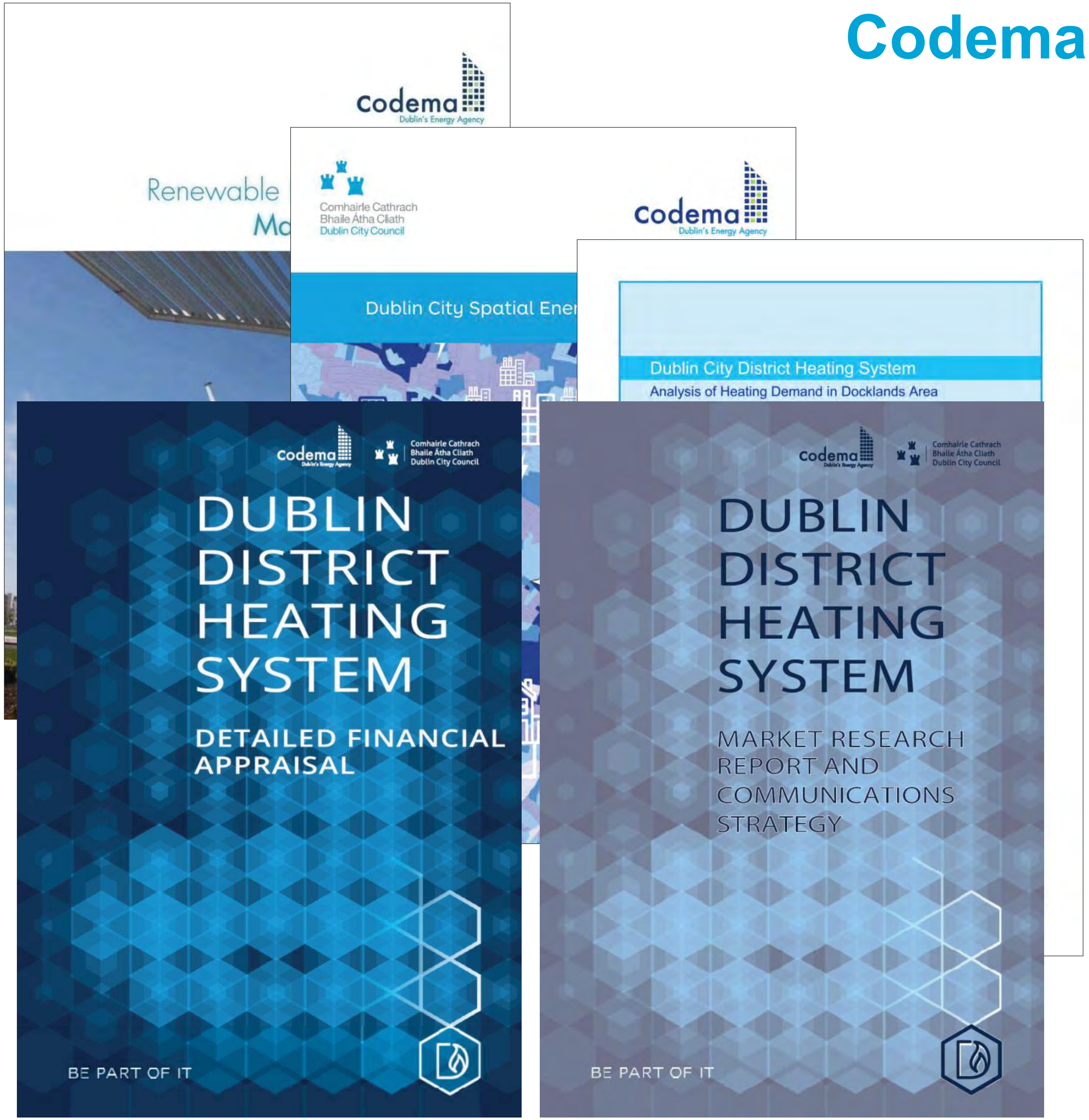
It is the policy of Dublin City Council
SI62 To support the development of energy efficient initiatives such as the district-heating network for Dublin and combined heat and power.
SI63 To promote the use of Combined Heat and Power in large developments

SI14 That all proposed developments be district heating enabled in order to provide an environmentally sustainable source of heating and cooling.

4.14.2 [B] Design of the Building
Building design will be required to comply with criteria in the following key areas:
Thermal energy and integration into a District Heating Scheme

It is an Objective of Dublin City Council:
CCO9: To encourage the production of energy from renewable sources, such as ….. combined heat and power (CHP), heat energy distribution such as district heating/cooling systems, and any other renewable energy sources……..
SIO33: To support the development of energy efficient initiatives such as use of District Heating and Combined Heat and Power, and to promote the use of CHP in large developments.

IU9 That all proposed developments of an appropriate scale be district heating-enabled in order to provide an environmentally sustainable option for heating and cooling
IU10 To investigate the feasibility of providing a district heating boiler station in the eastern/industrial portion of the SDZ area



Codema Reports

Dublin District Heating System Market Research Version 2
September 2013

Dublin City Spatial Energy Demand Analysis
June 2015

Analysis of Heating Demand in Docklands Area
October 2015

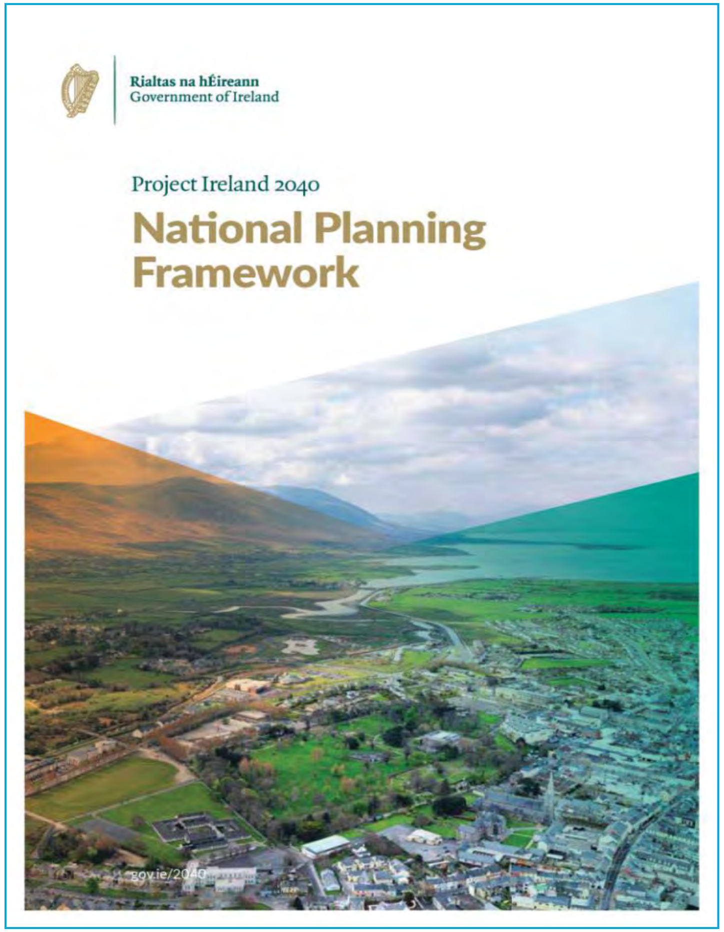
Detailed Financial Appraisal
July 2017

Market Research Report and Communications Strategy (Draft)
January 2018

codema
Dublin's Energy Agency

National Policy / Documents

(published 16th Feb. 2018)



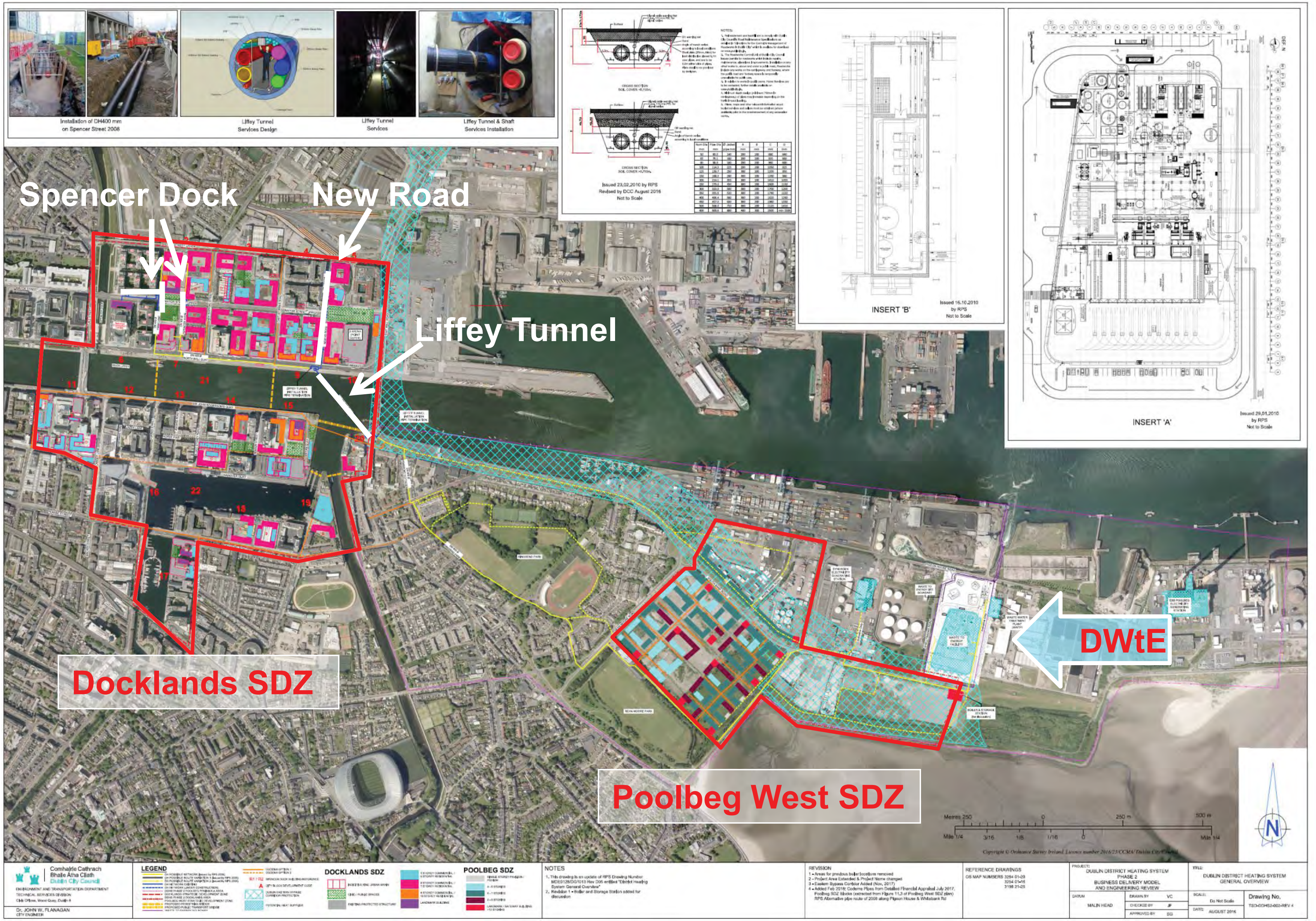
Key future growth enablers for Dublin include:

- Improving sustainability in terms of energy, waste and water, to include district heating and water conservation;
- Improving sustainability in terms of energy, waste management and resource efficiency and water, to include district heating and water conservation.

Investment Action.

- Support New initiatives in District Heating (such as the **Dublin Docklands ' District Heating Scheme**) in cities and large towns with a leading role for State bodies, for example, Gas Networks Ireland, and Local Authorities.

General layout for Dublin District Heating System



Installation of District Heating Spencer Docks

DH pipes & Liffey Services Tunnel

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

New DH pipes laid under new road beside the 3Arena

(The Point)

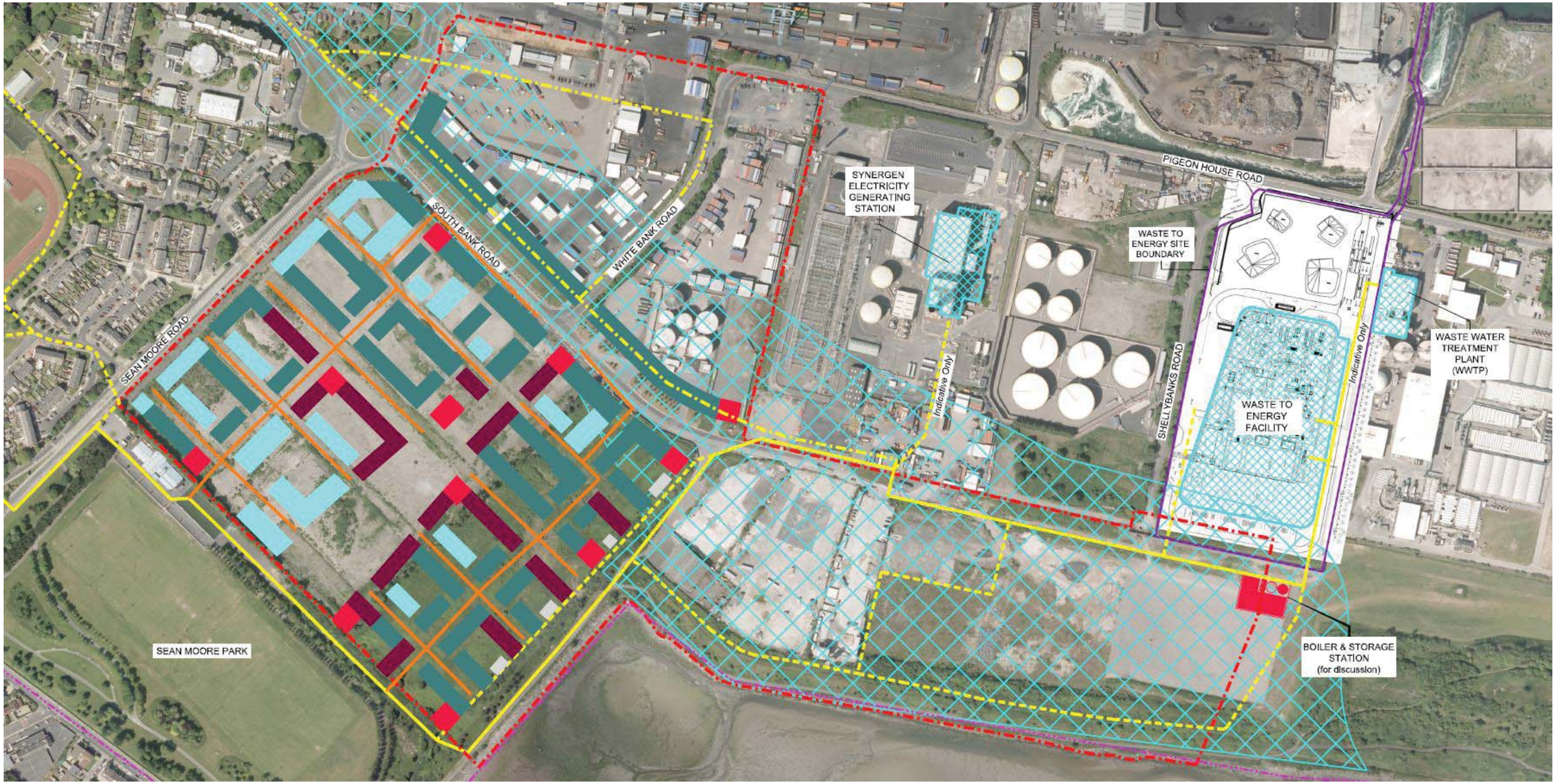
Dublin Waste to Energy Overview

- PPP between DCC (acting on behalf of the four Dublin Local Authorities) & Covanta.
- Commenced Construction in 2014
- Built at cost of €500million
- Fully operational Nov 2017

- **600,000 tonnes** of waste processed annually
- Electricity for **80,000 homes** – 60MW exported to National Grid
- Heating potential for **50,000 homes** (90MW of DH)
- 250,000 fewer tonnes of fossil fuels required for energy generation

Extracted from www.dublinwastetoenergy.ie

Timelines for Poolbeg West



- 17th May 2016, 34 Hectares designated Poolbeg West SDZ by Irish Government
- 2nd Oct. 2017, City Council 'Made' Poolbeg West SDZ - Appealed
- Spring 2018, Decision by An Bord Planeála
- Summer / Autumn 2018, Developers carry out designs
- 2021 – Developments occupied

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

Challenges for DH in Dublin

- Public Acceptance
- Capital Costs
- Competition from other energy providers (Gas & Electricity)
- Government Investment for distribution and connection
- No Regulatory Framework
- No guaranteed customer base

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

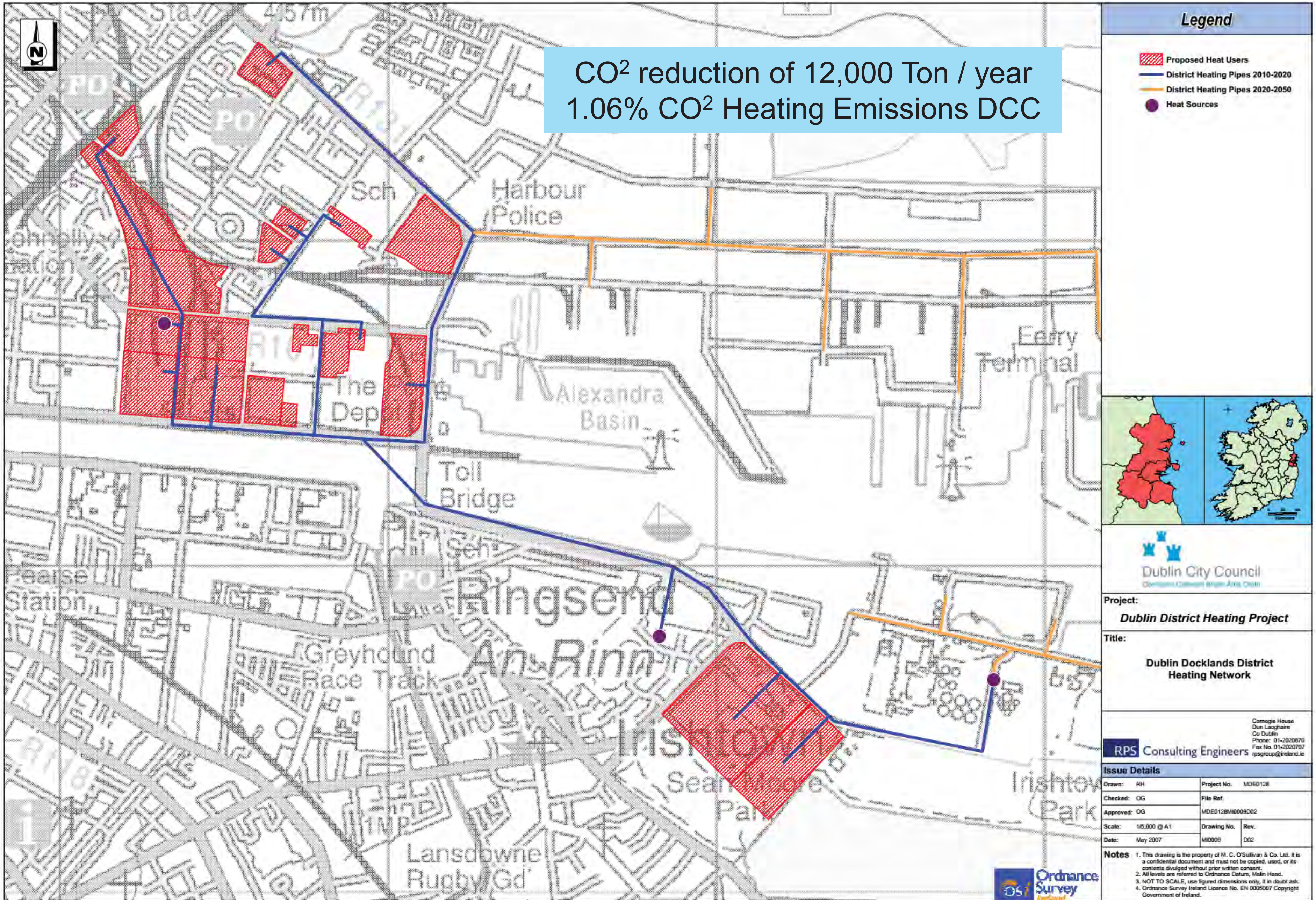
Next Steps

- Secure finance for Poolbeg West SDZ and the Docklands SDZ
- Complete Business Delivery Model and Engineering Review
  - Recommendation on DH Company Structure
  - Engineering / Infrastructure
    - Identify most suitable site for Energy Station
    - Establish Planning Authority requirements
    - Carry out Preliminary Design
    - Detailed Design and Construction
- National District Heating Working Group with DCCAE
- Submission to Climate Action Fund

Comhairle Cathrach Bhaile Átha Cliath
Dublin City Council

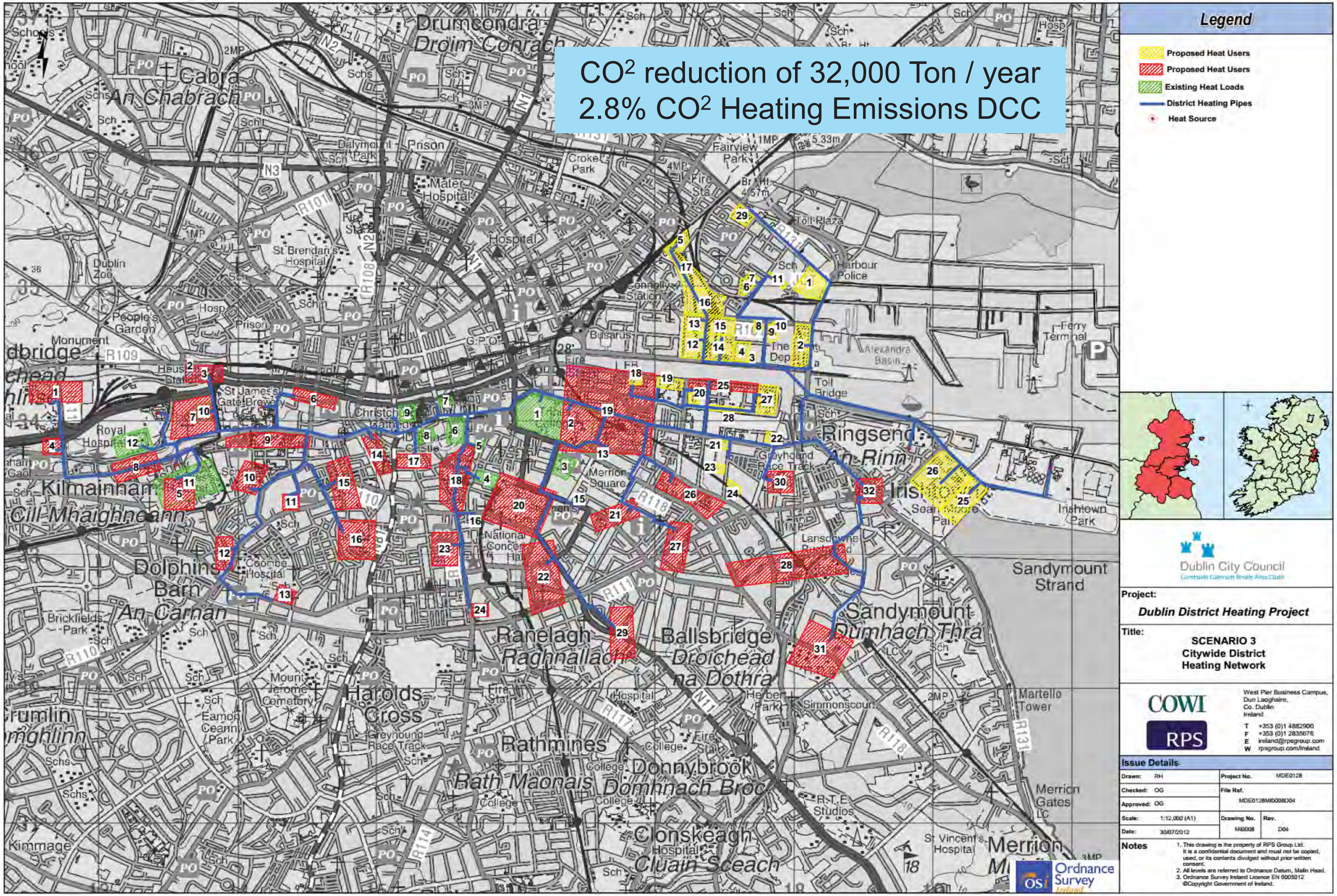
2008 Feasibility Report Scenario 1

CO^{2} reduction of 12,000 Ton / year
1.06% CO^{2} Heating Emissions DCC



2008 Feasibility Report Scenario 3

CO^2 reduction of 32,000 Ton / year
2.8% CO^2 Heating Emissions DCC



GEO-URBAN Project

'Identification and Assessment of Deep Geothermal Heat Reserves in Challenging Urban Environments'

GEOTHERMICA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731117

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Conduct a feasibility study for the identification and assessment of deep geothermal heat reserves in challenging urban environments in two urban locations (Dublin, Ireland and Vallés, Spain),

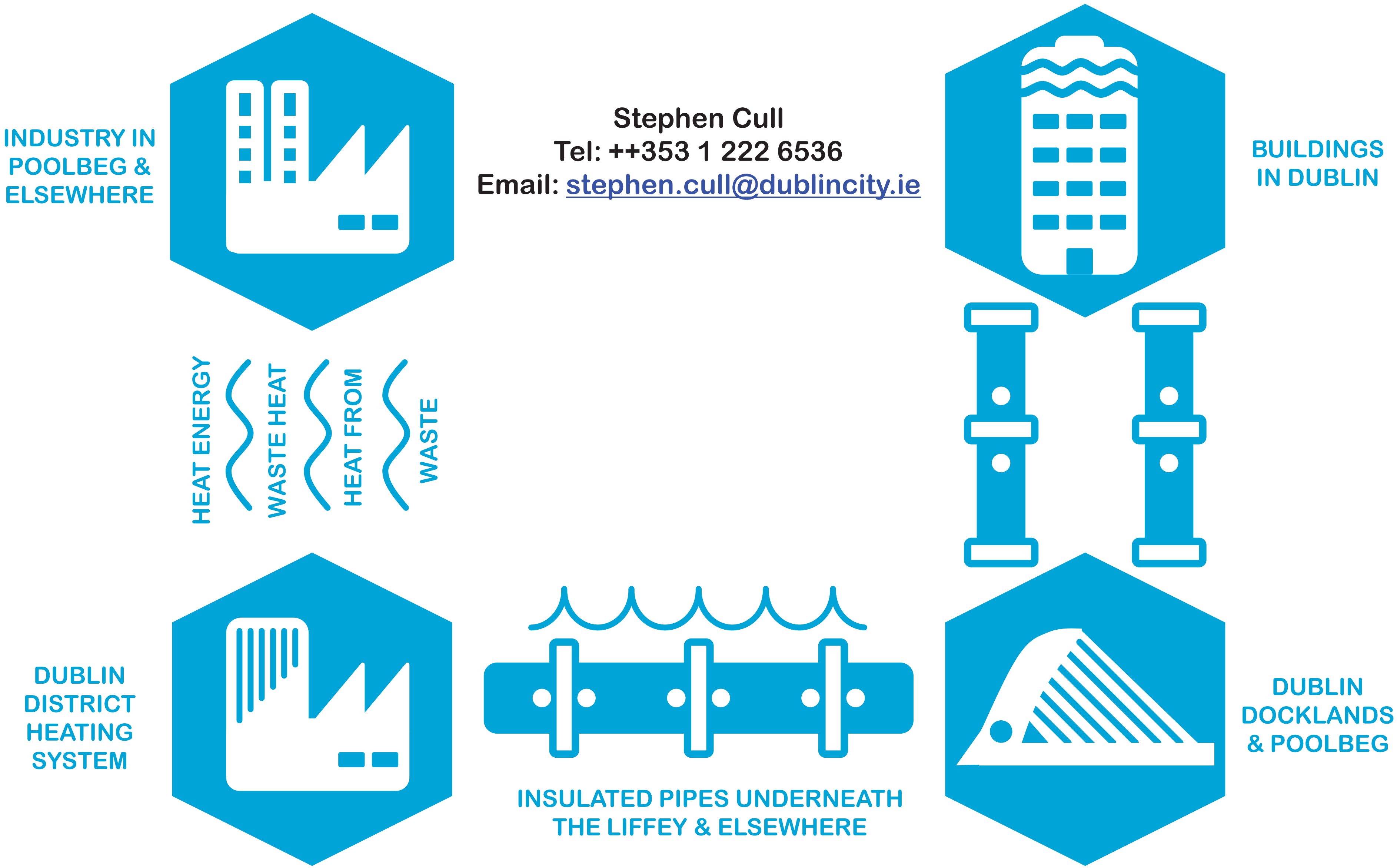
1. **Identification of possible geothermal targets in Dublin city as part of Work Package 1 (Pre-feasibility Study).**
2. **Assistance with access to Dublin sites for geophysical data collection in Work Package 2 (Geophysical Surveying).**

Organisation	*Country*	*Project Role*
Gavin & Doherty Geosolutions	Ireland (National Coordinator)	Leader WP1, WP6
University of Barcelona	Spain	Leader WP2
Irish Centre for Research in Applied Geosciences	Ireland	Leader WP3
Geotermisk Operatorselska	Denmark (National Coordinator)	Leader WP4, WP5
Dublin Institute for Advanced Studies	Ireland	WP2
Barcelona Super Computing	Spain (National Coordinator)	WP2
Dublin City Council	Ireland	WP1/2
Geothermical Association of Ireland	Ireland	WP5
Spanish Geothermical Technology Platform	Spain	WP5
Cartographic and Geological Institute of Catalonia	Spain	WP2

Celsius Awards 2017

Comhairle Cathrach
Bhaile Átha Cliath
Dublin City Council

Stephen Cull
Tel: ++353 1 222 6536
Email: stephen.cull@dublincity.ie



Thank You

Comhairle Cathrach Bhaile Átha Cliath
Dublin City Council

Email: ddhs@dublincity.ie

4^{th} generation district heating & geothermal potential

Donna Gartland

Codema are leading a €11.5m EU Interreg project called HeatNet, which focuses on the growth of 4th generation DH systems in North West Europe, where the take-up of DH in general is very low in comparison with the rest of Europe. Codema are investigating opportunities for 4th generation DH in Dublin, which includes opportunities to supply these schemes with sources such as geothermal energy.Ireland has one of the lowestsharesofDHinEurope, only comparable to shares in Mediterranean countries Cyprus, Malta, Greece and Spain. Thereisa positivecorrelation between countries with high levels of DH and high levels ofrenewable heat;itismuch easier tointegraterenewables into DH schemes than implementing individual building level solutions. 4th generation DH is distinguished from earlier generations as it seeks to supply lower temperature (40-50 degrees) heat to energy efficient buildings, meaning more sources of heat become feasible to utilise, and seekstocreatea smart DHsystemwhich canintegrate the electricity and heating sectors, utilising thermal storage. Codema are developing Ireland's first Regional Energy Masterplan for Dublin, and mapping the potential for DH and supply ofgeothermal energywill be keytothis work.

Contact:Donna Gartland, Codema-Dublin's Energy Agency donna.gartland@codema.ie

4th Generation District Heating & Possibilities in Ireland

Donna Gartland, Executive Energy Planner Ireland @Codema – Dublin's Energy Agency
Director @ **Irish District Energy Association**

Irish District Energy Association

Interreg North-West Europe HeatNet NWE
EUROPEAN UNION
European Regional Development Fund

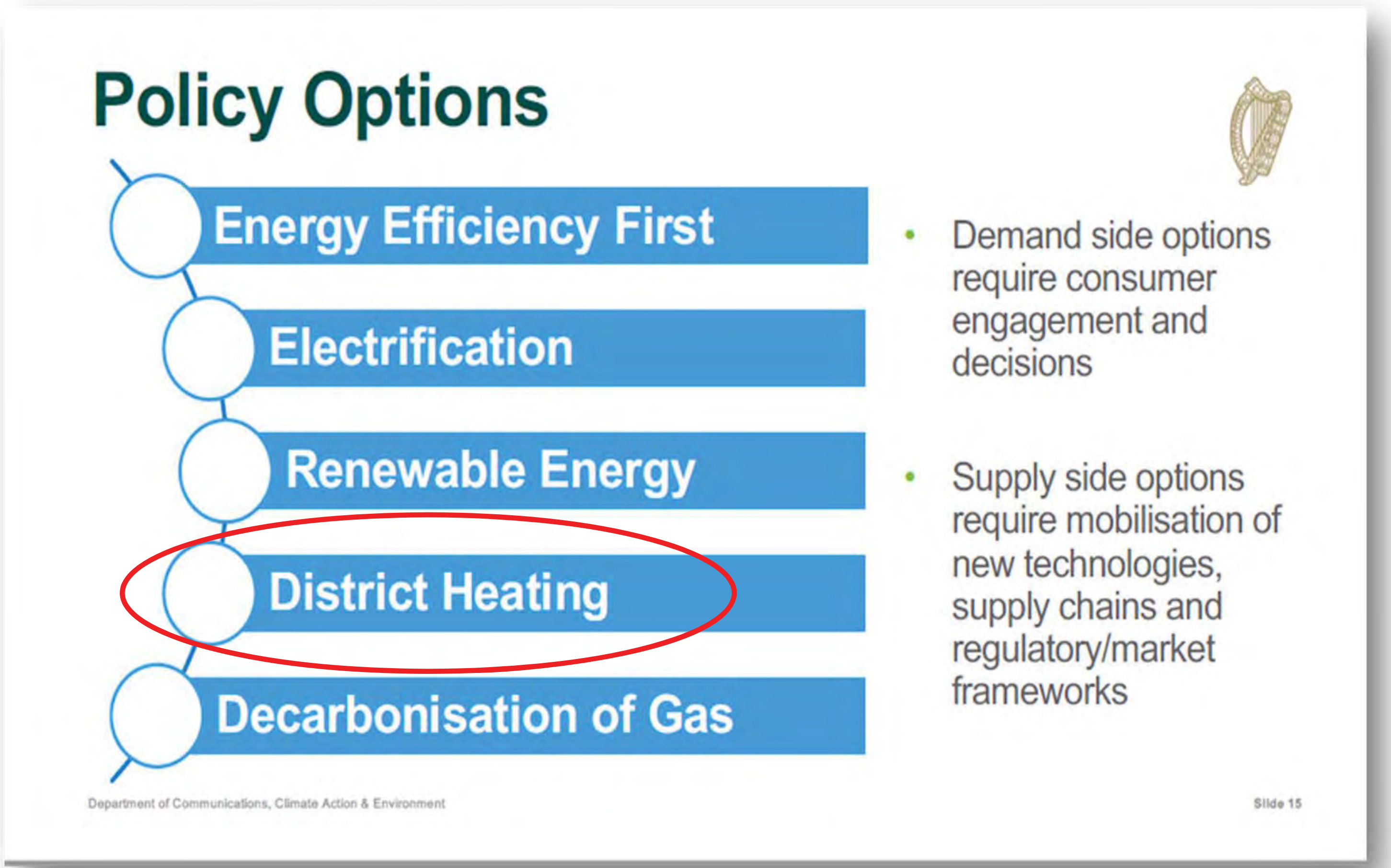
codema Dublin's Energy Agency

Current situation **in Ireland…**

- Very few small scale DH systems in operation, no district level systems
- Lack of national level regulatory, financial or legislative support for DH
- Many barriers including lack of knowledge, local authority experience in utilities, & funding mechanisms such as low-cost ‘green’ loans
- Ireland not on trajectory to meet 2020 RES-H targets

District Heating **Policy…**

DCCAE Starting to recognise DH in Policy

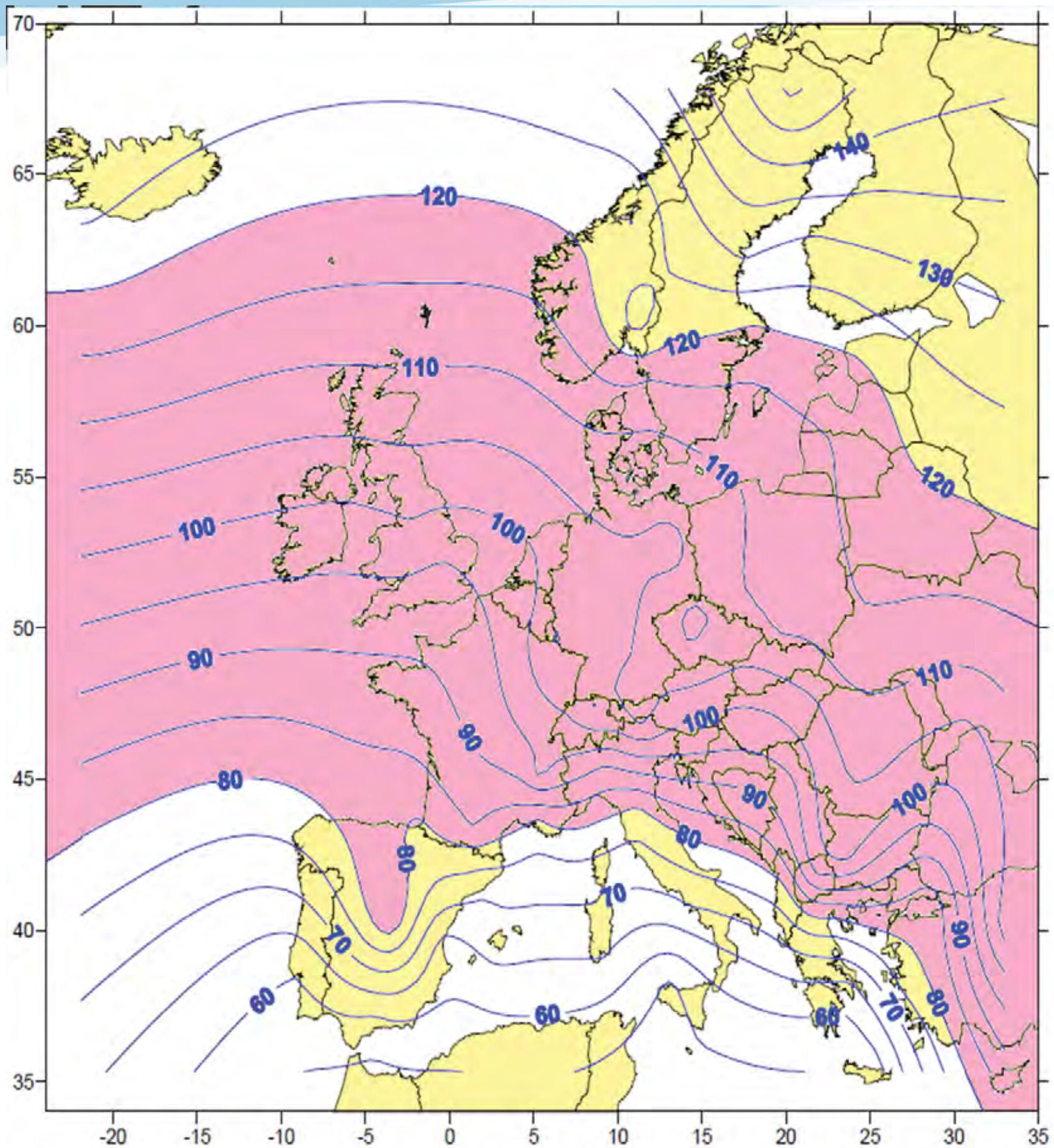


Why don't we have **DH in Ireland**?

Reasons usually given....

- Ireland not cold enough, only works in very cold countries
- Ireland population density not suitable

Is Ireland cold enough for DH?



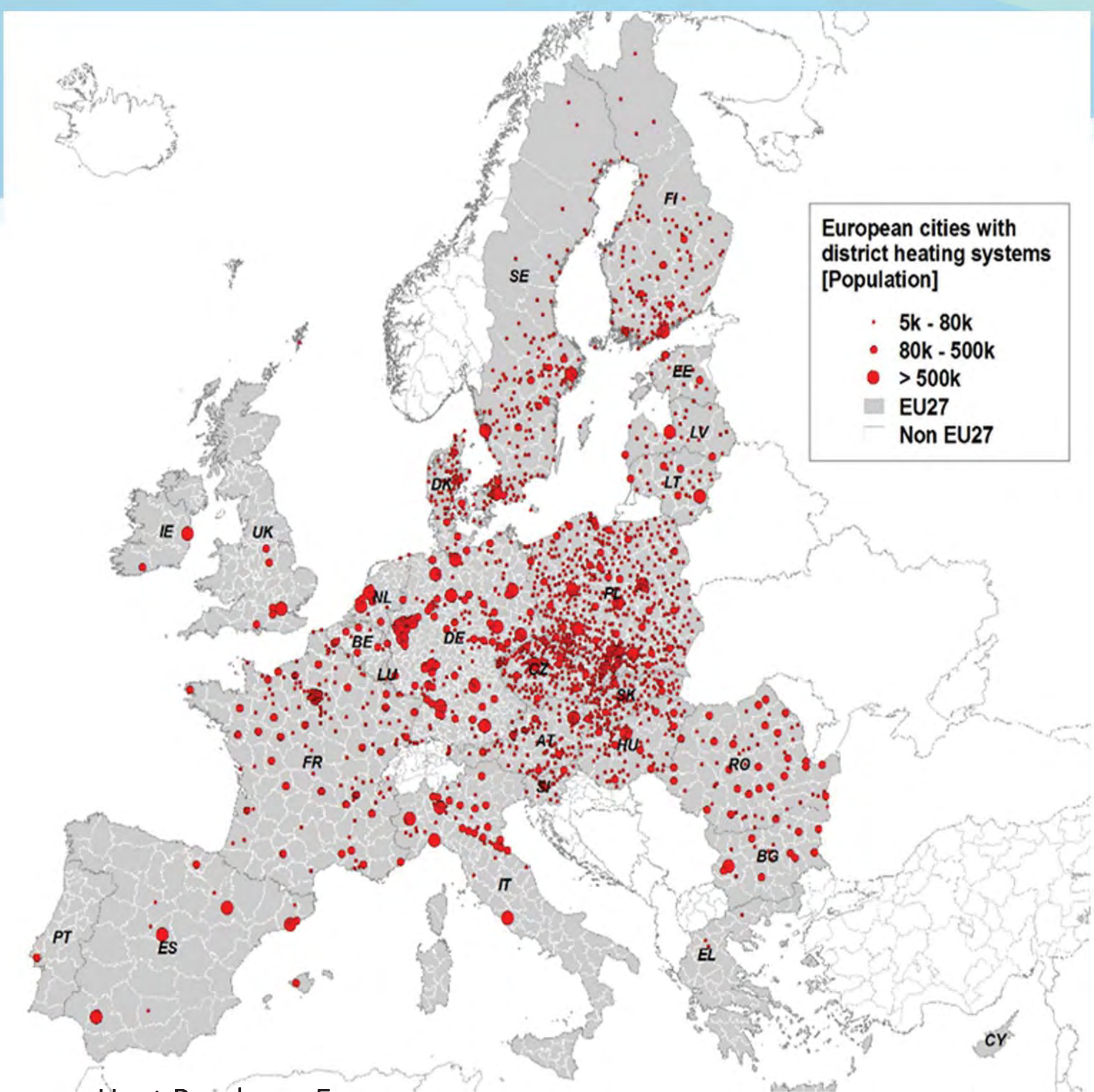
European Heating Index

Across Europe +/- 20% difference in heat demands

(Source: ecoheatcool)

codema
Dublin's Energy Agency

District Heating Systems in Europe



Source: Heat Roadmap Europe

Is Ireland cold enough for DH?



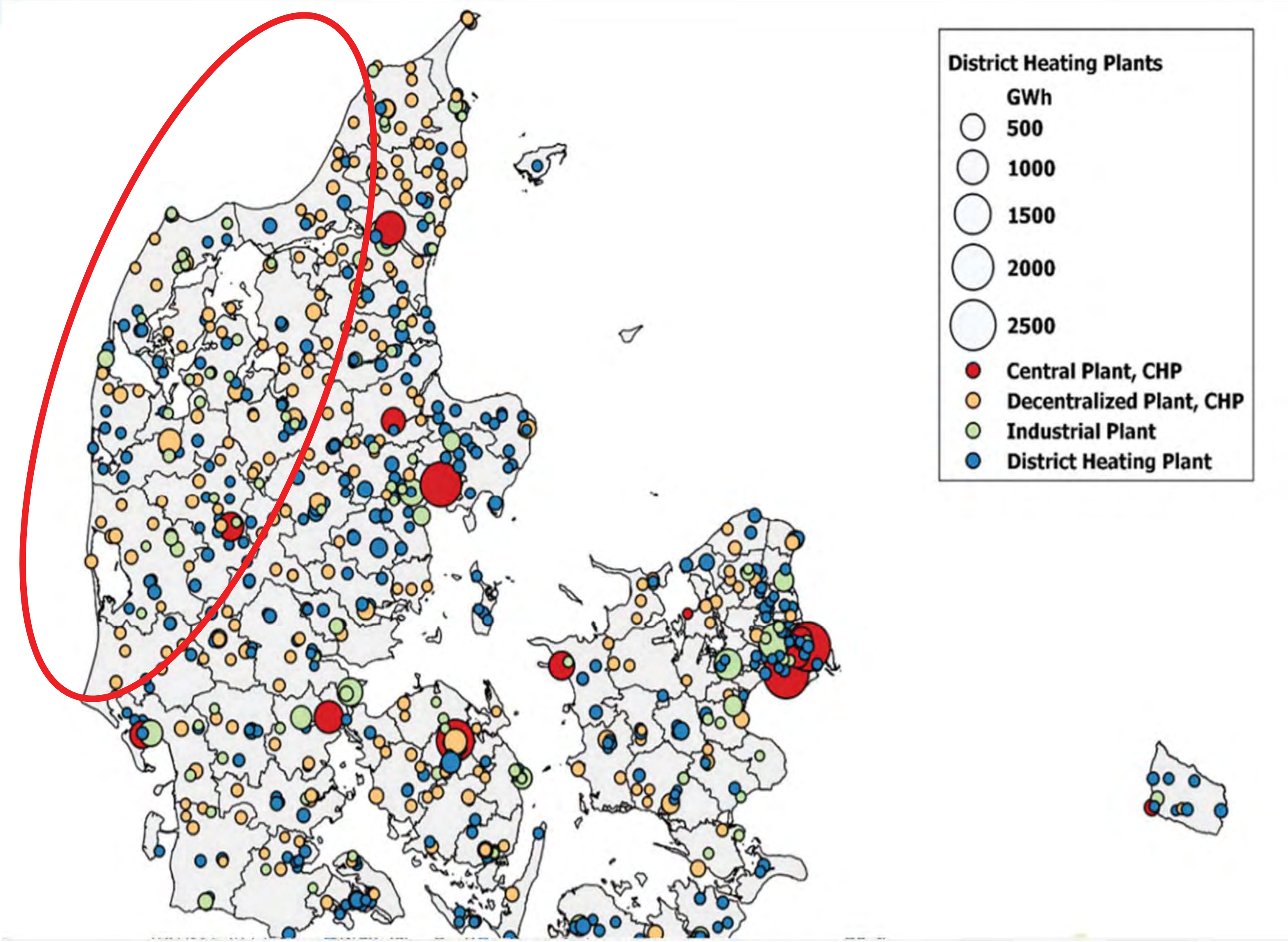

15 MWh/year **15 MWh/year**

Average Danish Vs Average Irish

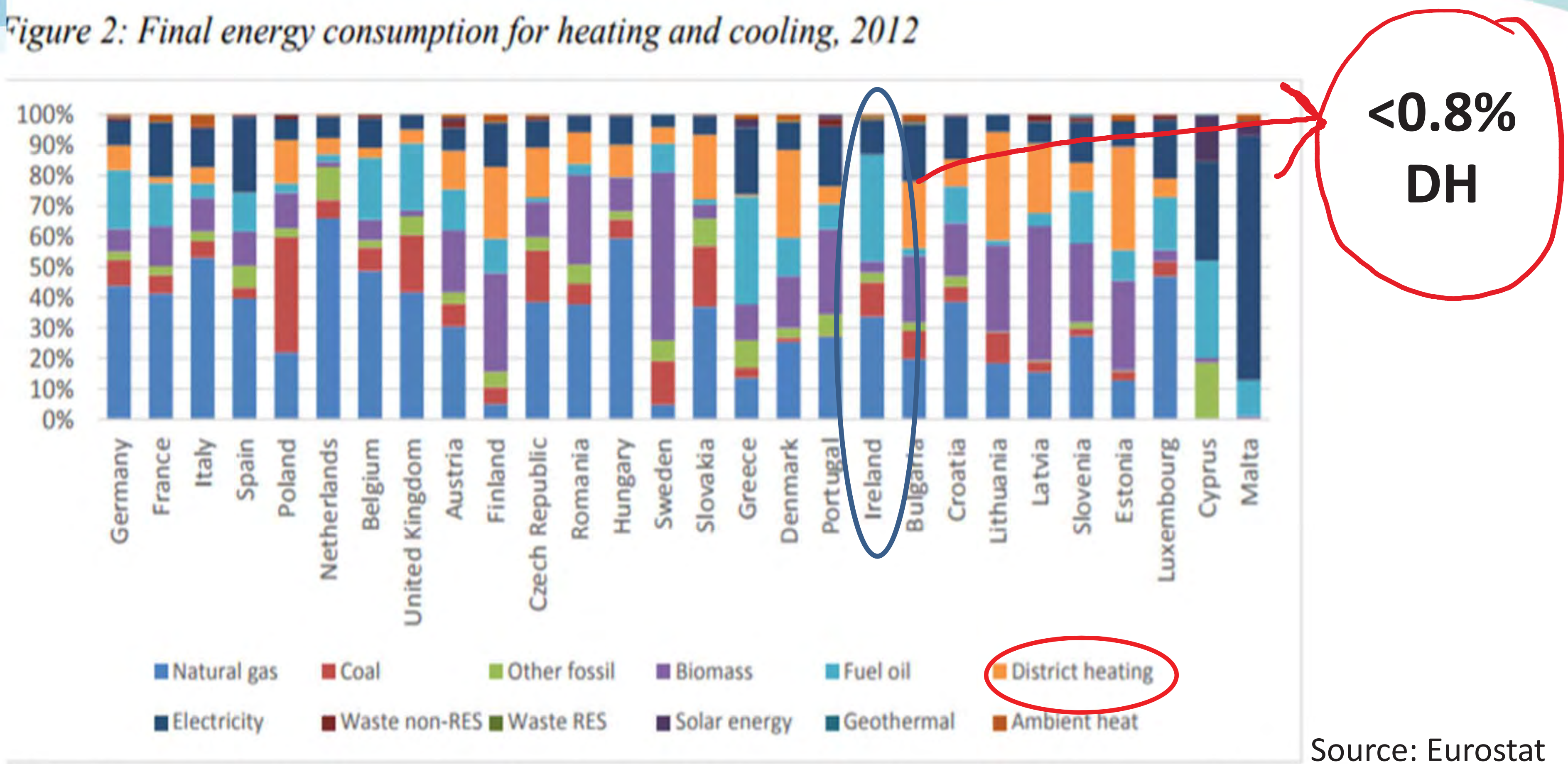
18.2 MWh/year **18.1 MWh/year**

Average Dublin Vs Average Copenhagen

Rural District Heating in **Denmark**



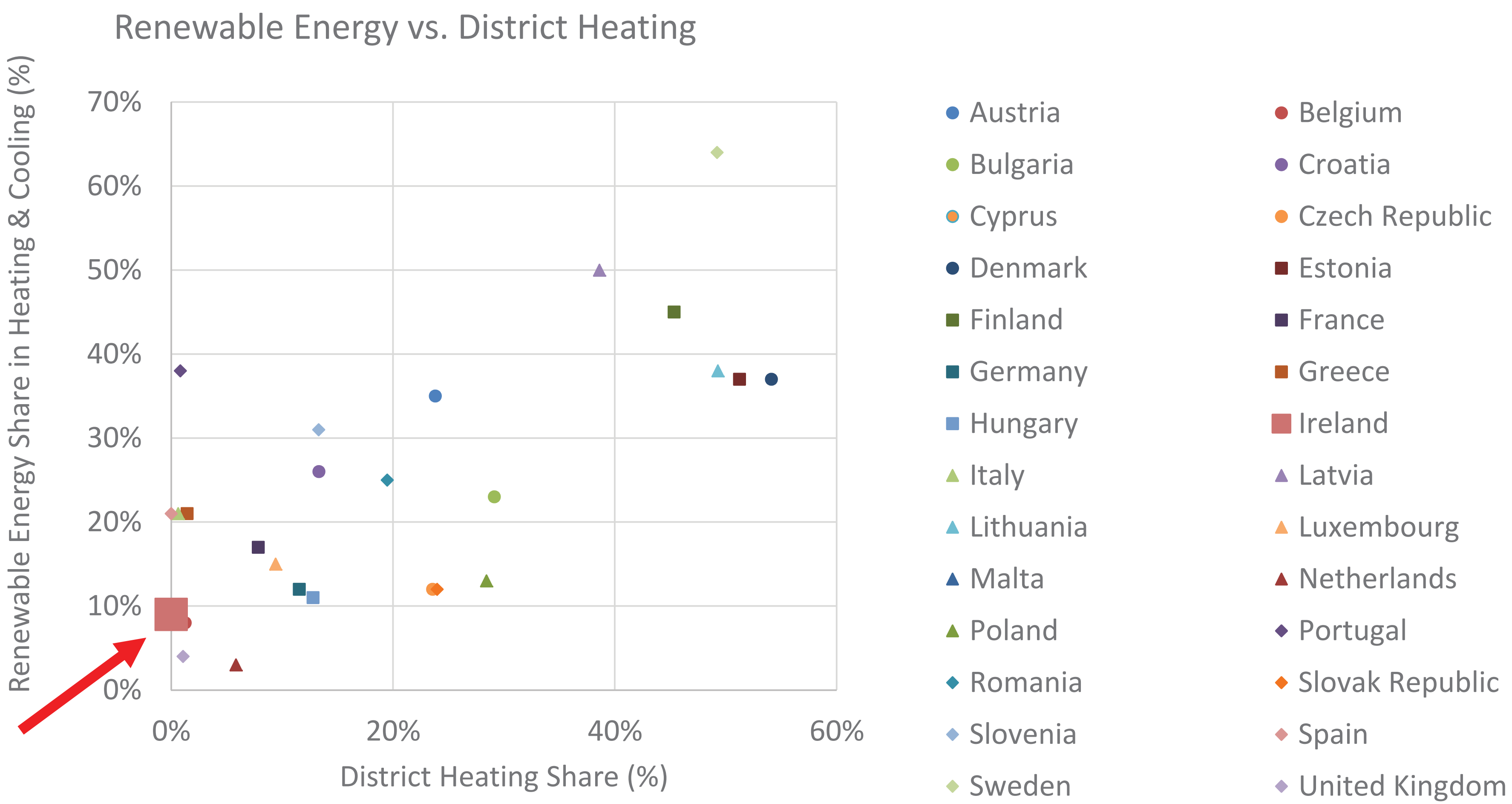
Shares of DH across EU



Source: Eurostat

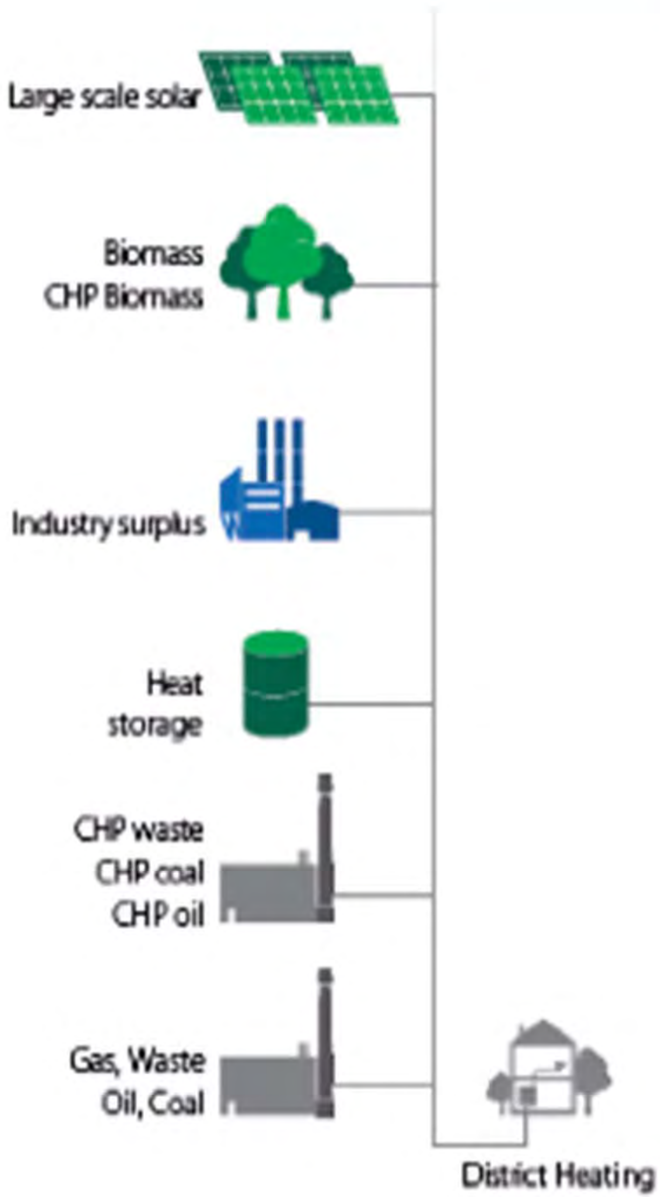
- **EU Countries with little or no DH:**
  - **Ireland, Cyprus, Malta, Greece, Spain**

Renewable Energy & DH



Source: Heat Roadmap Europe

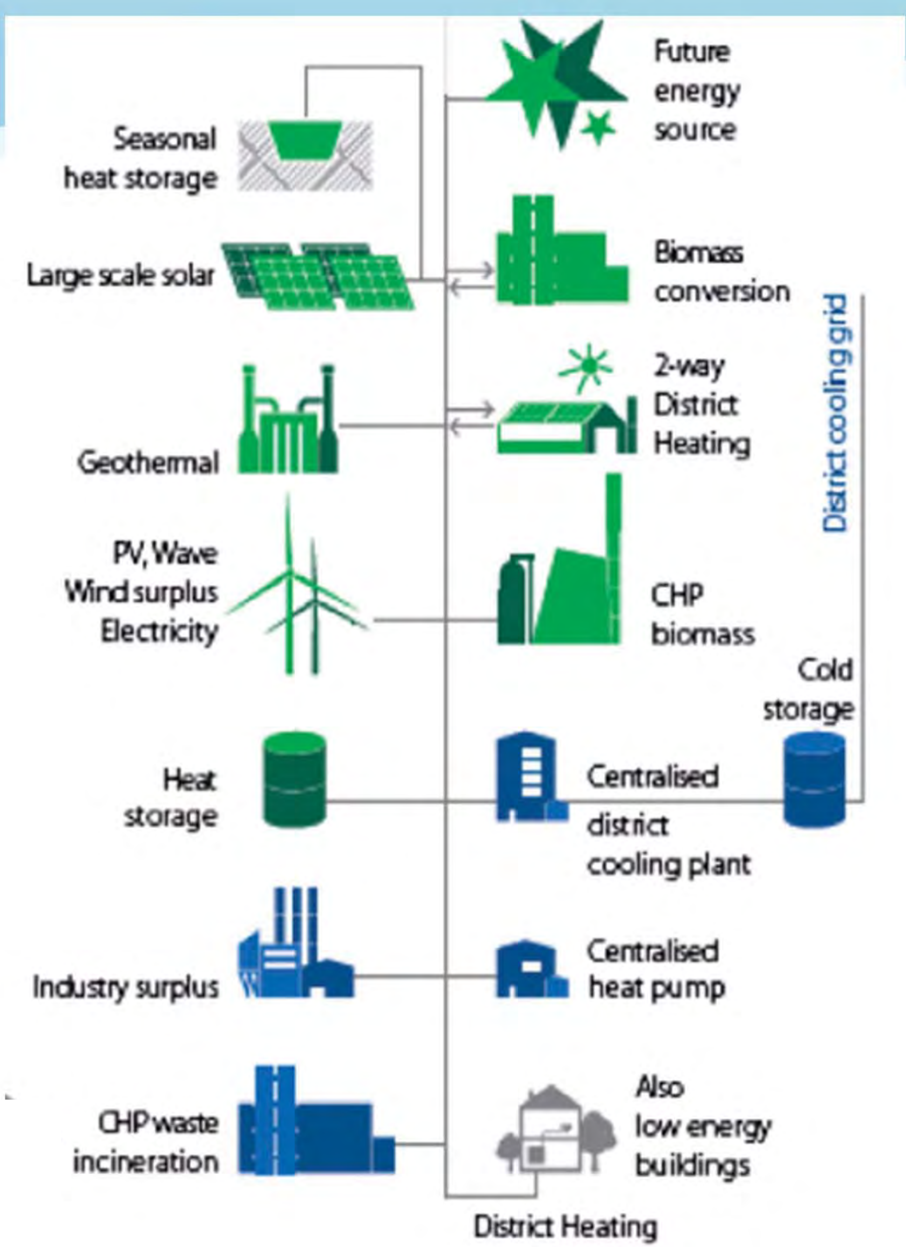
3rd Generation DH systems



- Traditional 70 to 80°C supply temps
- High focus on CHP
- Steel network pipes
- Most current new systems

Source: 4DH Centre, Denmark

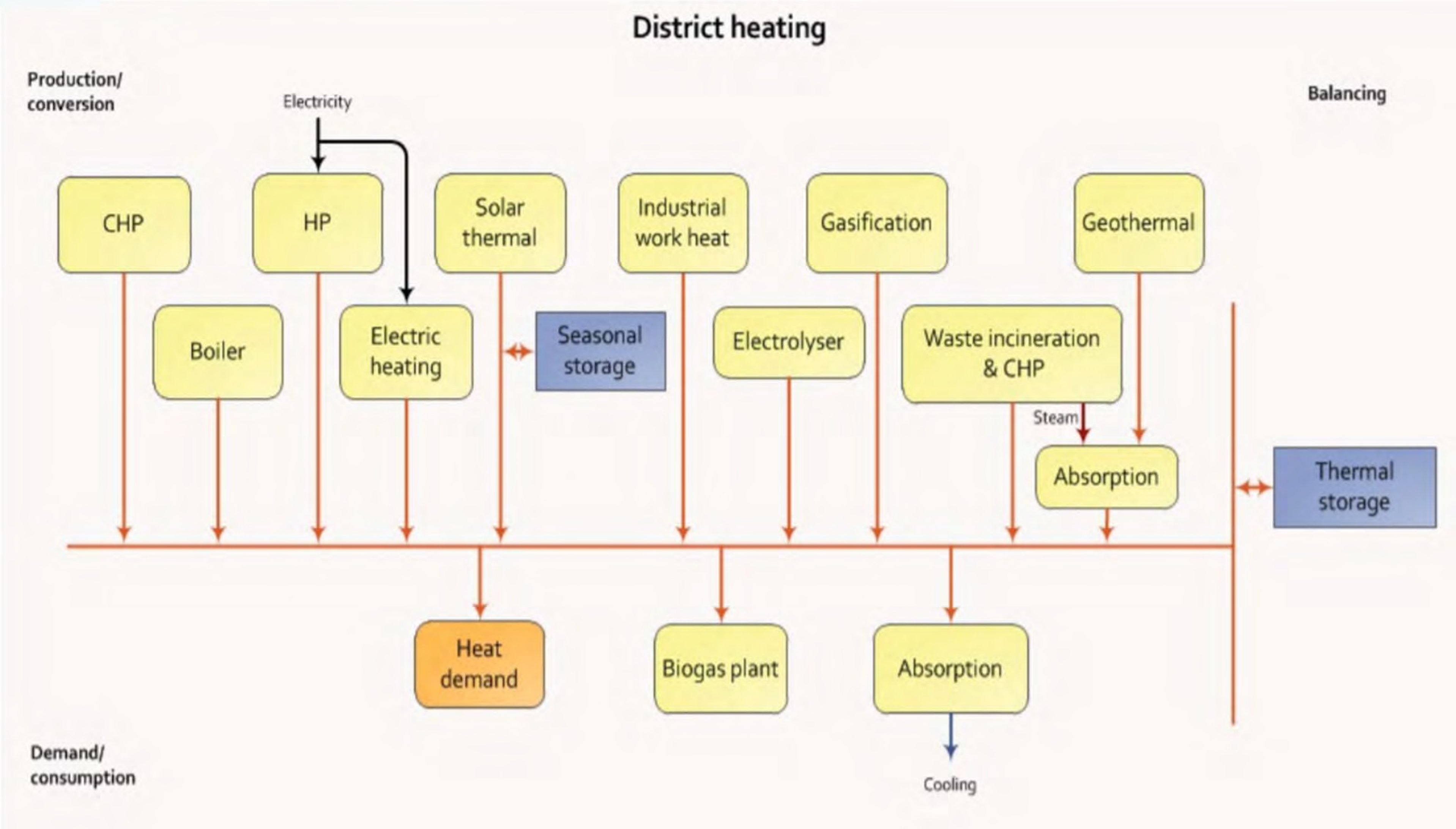
4th Generation DH systems



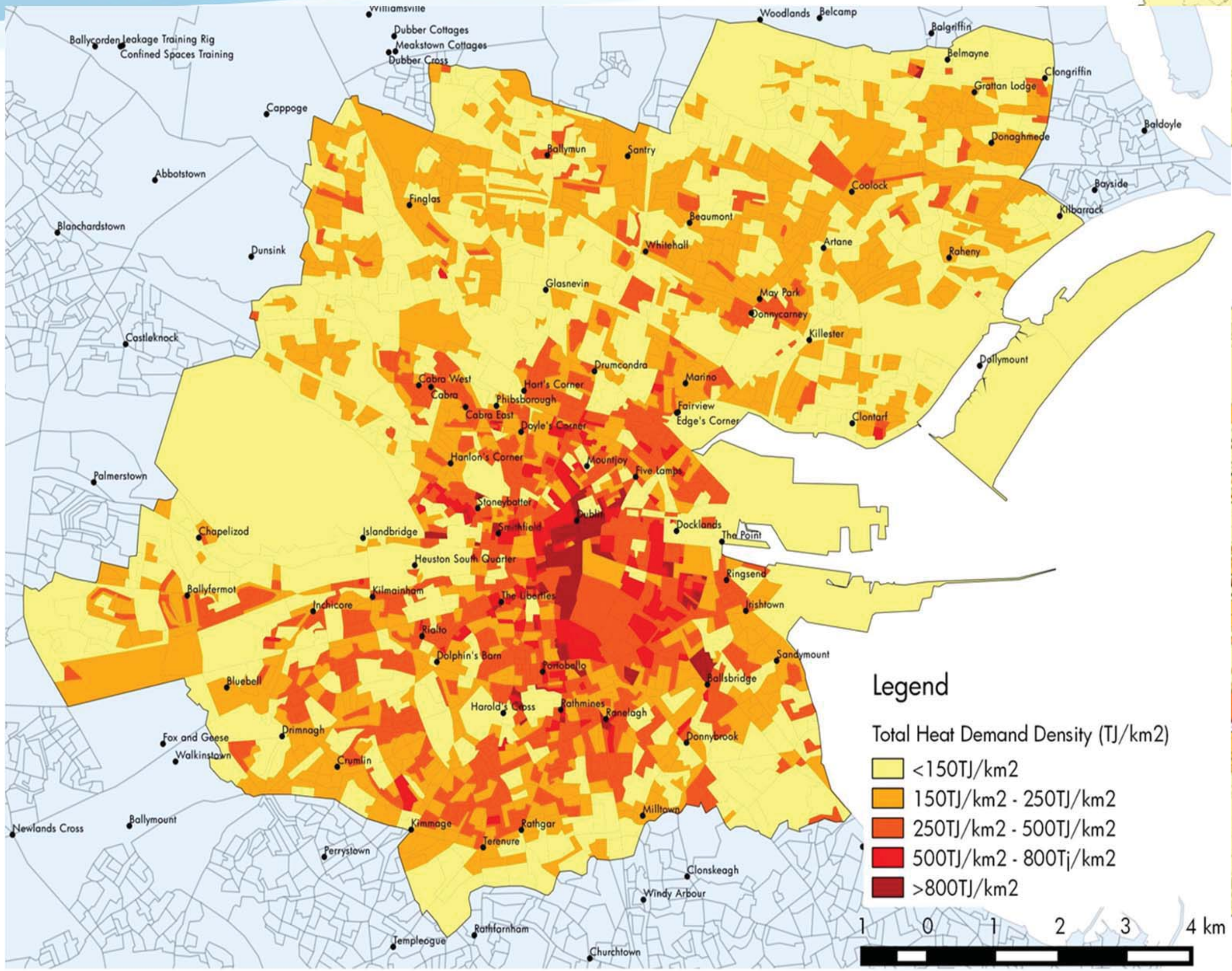
- Low temperature supply (40-50° C)
- Move away from fossil fuel supply
- Plastic pipes
- Smart Energy System

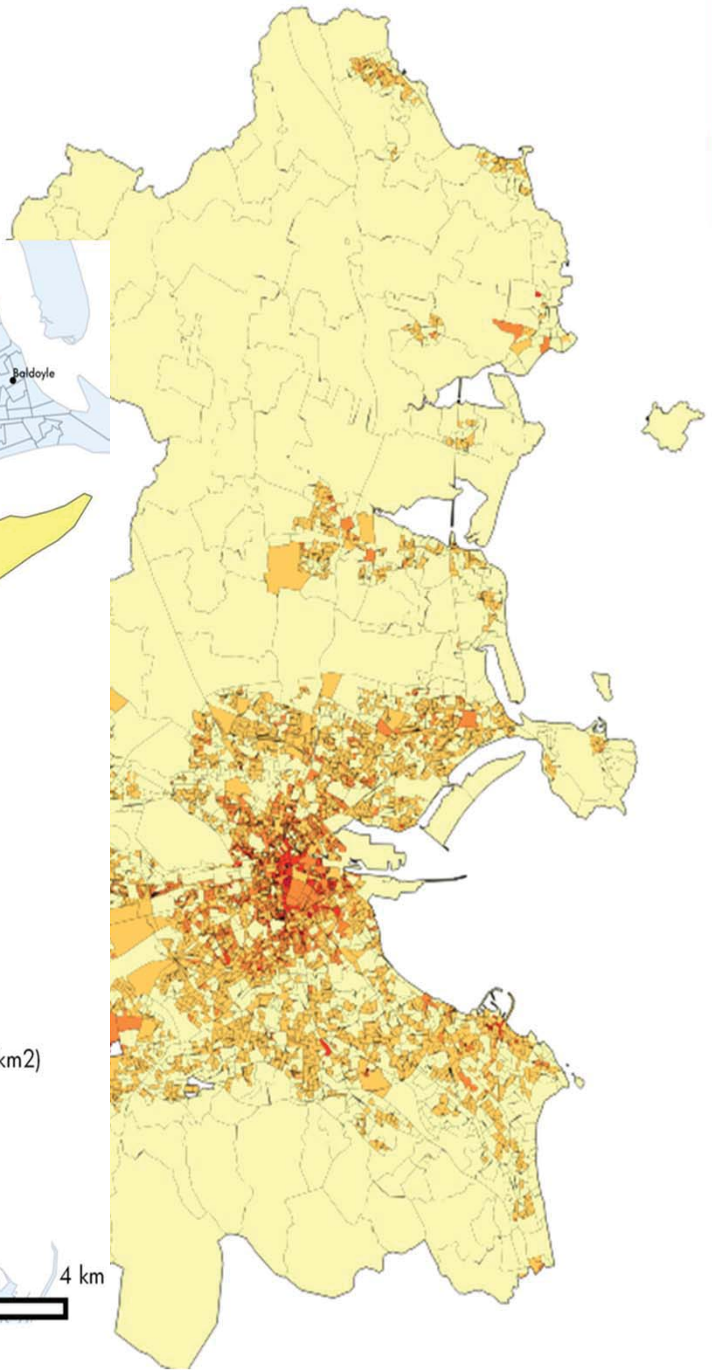
Source: 4DH Centre, Denmark

Smart **District Energy** Systems



Heat Demand **Densit**





Dublin Region **Energy Masterplan**

codema
Dublin's Energy Agency

- Funded by SEAI RD&D 2018 call
- Evaluate the **cost-optimal, spatially possible and technically feasible** low-carbon scenarios for Dublin to meet its 2030 and 2050 CO_2 reduction targets
- From the **perspective of society, energy consumers and the energy sector**
- Detailed **local-level, spatially-driven energy scenario modelling**

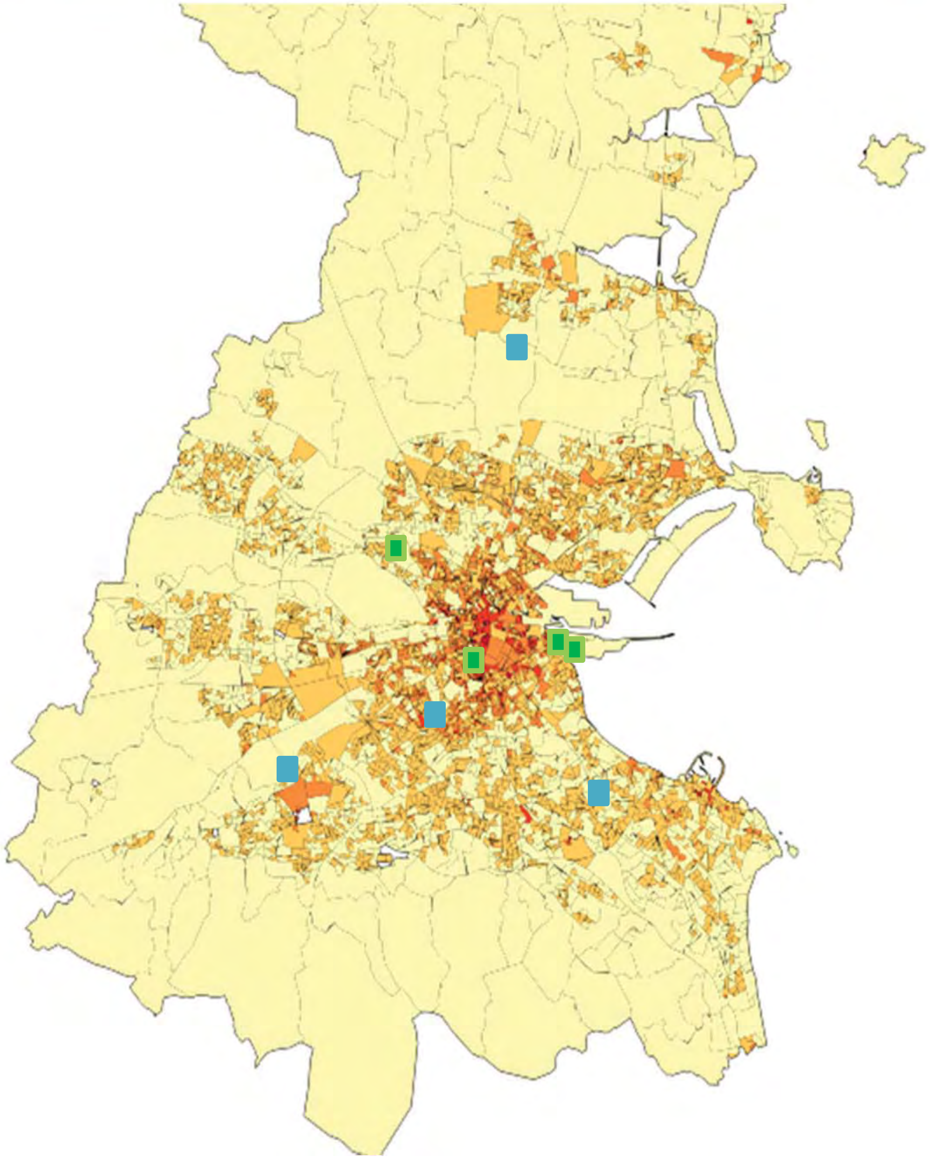
Dublin Region **Energy Masterplan**

codema
Dublin's Energy Agency

- High temp Heat Sources
- Low Temp Heat Sources

matching
with
suitable

- High temp Heat Demands
- Low Temp Heat Demands



Help us!
Where & what type of Geothermal resources available in Dublin?

FOR MORE **INFORMATION**

Email donna.gartland@codema.ie

Phone (+353) 01 707 9818

Web www.codema.ie

Geothermal research at Geological Survey Ireland – past and current

Taly Hunter Williams

Geological Survey Ireland (GSI) has been involved in geothermal activities since the 1970s in a relatively modest way. Warm springs monitoring was undertaken during the 1970's, 80's and 2000's. GSI was involved with deep geothermal studies in the 1980's, 2000's and 2010's. In the 2010's, shallow geothermal collector type suitability maps and a homeowner manual were also produced.
Currently, GSI is involved in the geothermal sector as both funders, and as collaborators. The two major projects underway currently are EU H2020 ERANet funded, and are being undertaken with multiple European Geological Survey partners: HotLime, which is concerned with low-enthalpy deep limestone geothermal reservoirs, and MUSE, which is focussing on urban ground source heat resources and management. There are 16 National/Federal Geological Survey project partners in HotLime, which has a total project budget of €1.65 Million. MUSE also has 16 National/Federal Geological Survey project partners, and a total project budget of €1.31 Million.
Hydrothermal systems in deep carbonate bedrock among most promising low-enthalpy geothermal plays across Europe. However, these prospects have received little attention, and are perceived as 'tight'. The HotLime project aims to improve mapping and assessment of geothermal plays in deep carbonate rocks in Europe in order to de-risk geothermal exploration in such plays. The project will do this through identifying the generic structural and geological controls on fractures and karst conduit development in deep carbonate formation. This will be achieved by comparing geological situations and their structural inventory, and through collating deep borehole data and their petro- and hydro-physical characteristics. Outcomes from HotLime include: spatial resource assessments in focussed areas (the study areas within Ireland are: the Dublin Basin, the Clare Basin, and Lough Allen Basin), best practice workflow and guidelines for characterisation and mapping of deep carbonate hydrothermal plays; web-based classification system for plays and prospects; assessment tool for doublet performance.
The MUSE (Managing Urban Shallow geothermal Energy) project aims to provide tools and services to assist uptake and sustainable and efficient use of shallow geothermal energy in European urban areas. The MUSE project will identify, summarise and develop state-of-the-art methods for SGE assessment, management and monitoring; develop strategies for efficient and sustainable use in urban areas; and, transfer methods and integrate strategies into specific urban pilot areas. The current pilot area in Ireland is the city of Cork.

Project website: http://geoera.eu/projects/
Contact: Natalya Hunter Williams, taly.hunterwilliams@gsi.ie

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Geothermal Energy Research in GSI

Taly Hunter Williams

Geological Survey Ireland

Deep Geothermal in Ireland – Past, Present and Future

Thursday September 6th, GSI Beggars Bush

GSI geothermal research

Background

- Warm springs monitoring in 1970's and 80's, and 2000's
- Involvement in deep geothermal studies in 1980's
- Contribution to SEAI geothermal resource study in 2000's
- Produced ground source heating suitability maps and homeowner manual in 2010's

Current work – GeoERA (EU Horizon2020 funded)

- HotLime – deep limestone low-enthalphy geothermal reservoirs
- MUSE – Urban ground source heat resources and management

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

GeoERA
GEO-ENERGY

HotLime

- Mapping and Assessment of Geothermal Plays in Deep Carbonate Rocks
  - Hydrothermal systems in deep carbonate bedrock among most promising low-enthalpy geothermal plays across Europe
  - Because perceived as ‘tight’, have received relatively little attention
  - To de-risk, crucial to improve understanding of geological conditions that determine distribution and technical recoverability of potential resources
    - fractures and karst conduits crucial
- Project will
  - identify the generic structural controls in deep carbonate formations, by comparing geological situations and their structural inventory
  - collate deep borehole data and their petro- and hydro-physical characteristics.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731166

GeoERA GEO-ENERGY

HotLime

16 National/Federal Geological Survey project partners from:

- Germany, Ireland, Netherlands, Belgium, Austria, Italy, Slovakia, Hungary, Malta, Ukraine, Croatia, Spain, Czech Republic
- + 1 associate (Belgium)

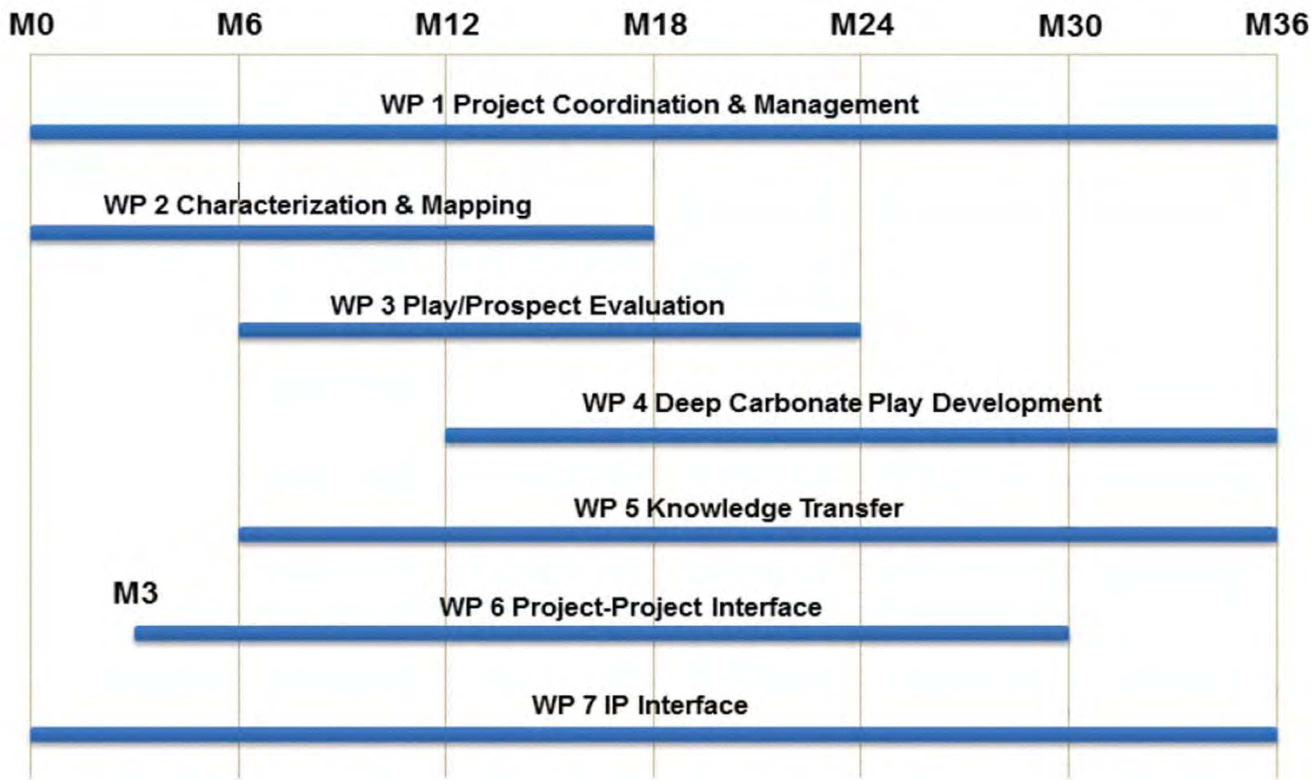
Total budget

- € 1.65 Million (In-kind € 1.16 Million)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

HotLime

Workpackages



GSI input

2 months

18 months

6 months

8 months (lead)

2 months

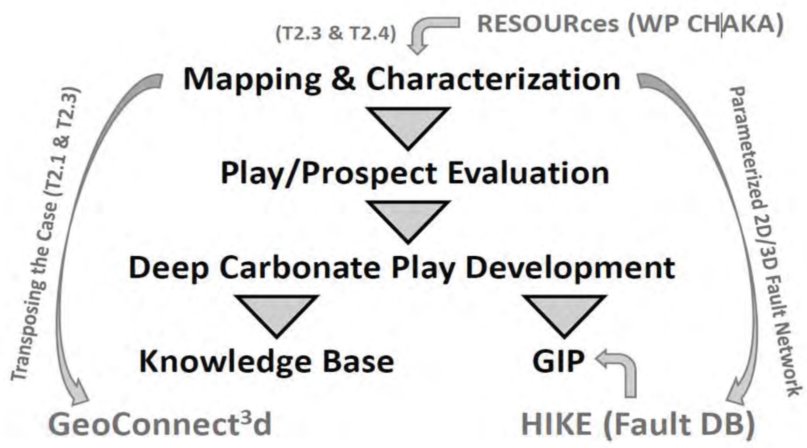
2 months

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

HotLime

Methodology

- subsurface characterisation: lithological, geochemical & mechanical properties
  - borehole data, seismics, existing 3D models, map (series), and cross-sections, descriptive reports/publications)
- seismic interpretation, 3D-modelling, temperature modelling
- compare different modelling methods target areas
- knowledge transfer from well investigated to less developed areas
- assess risk of induced hazards and of project failure from inadequately constrained geological data
- seek transfer of geo-science based recommendations into national regulatory frameworks and EU level in order to increase the sustainability of subsurface utilisation

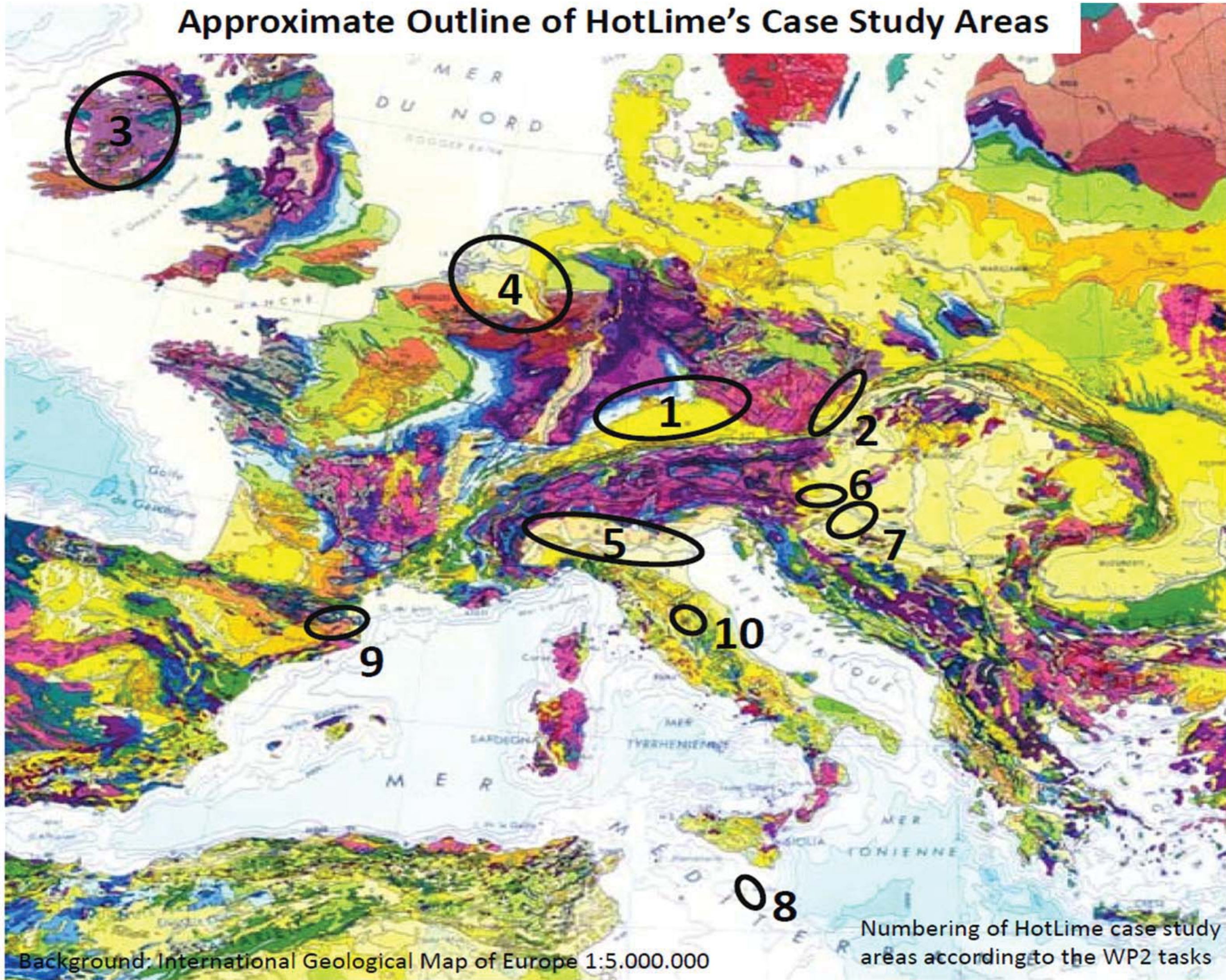


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

HotLime study areas (WP2)

10 pilot areas across Europe

3 areas in Ireland: Dublin, Clare & Lough Allen Basins



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

GeoERA GEO-ENERGY

HotLime

Principal outcomes

- Spatial resource assessments (maps, 3D models) in areas of focus complemented by a report on best practice workflow & guidelines for characterization & mapping of deep carbonate hydrothermal plays.
- Classification system for plays and prospects (web based)
- Quantitative assessment tool for doublet performance and the resources.
- Common knowledge-base grounded on the Linked Data Semantic Web, including methodology, full glossary of technical terms, and a user manual for the proper use of spatial information in subsurface in subsurface planning and management.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

MUSE

- **M**anaging **U**rban **S**hallow geothermal **E**nergy
  - More than 75% of European population live in urban areas
  - Shallow geothermal energy (open loop systems, closed loop systems) a key technology for future heating, cooling and seasonal heat storage
  - At present, has low visibility
  - Potential for conflict of use and impact on groundwater
    - Services to assist uptake and sustainable and efficient use of shallow geothermal energy are needed
- Project will
  - Identify, summarise and develop state-of-the-art methods for SGE potential, assessment, management and monitoring
  - Develop strategies for efficient and sustainable use in urban areas
  - Transfer methods and integrate into strategies in specific urban pilot areas with external stakeholder involvement via a user-friendly web platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

MUSE

16 National/Federal Geological Survey project partners from:

- Austria, Sweden, Spain, Ireland, Netherlands, Croatia, Czech Republic, France, Belgium, United Kingdom, Slovenia, Poland, Ukraine, Denmark

Total budget

- € 1.31 Million (in-kind contribution € 0.92 Million)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

MUSE

WP1:Project management and general dissemination

WP2: Technical aspects of shallow geothermal energy use in urban areas

WP3: Management strategies and action plans for a sustainable and efficient use of SGE

Partner workshops

WP4: Testing and implementation of developed methods and workflows in urban pilot areas across Europe

Stakeholder workshops, and surveys

Partner workshops

WP5: Information system, targeted communication and stakeholder interaction

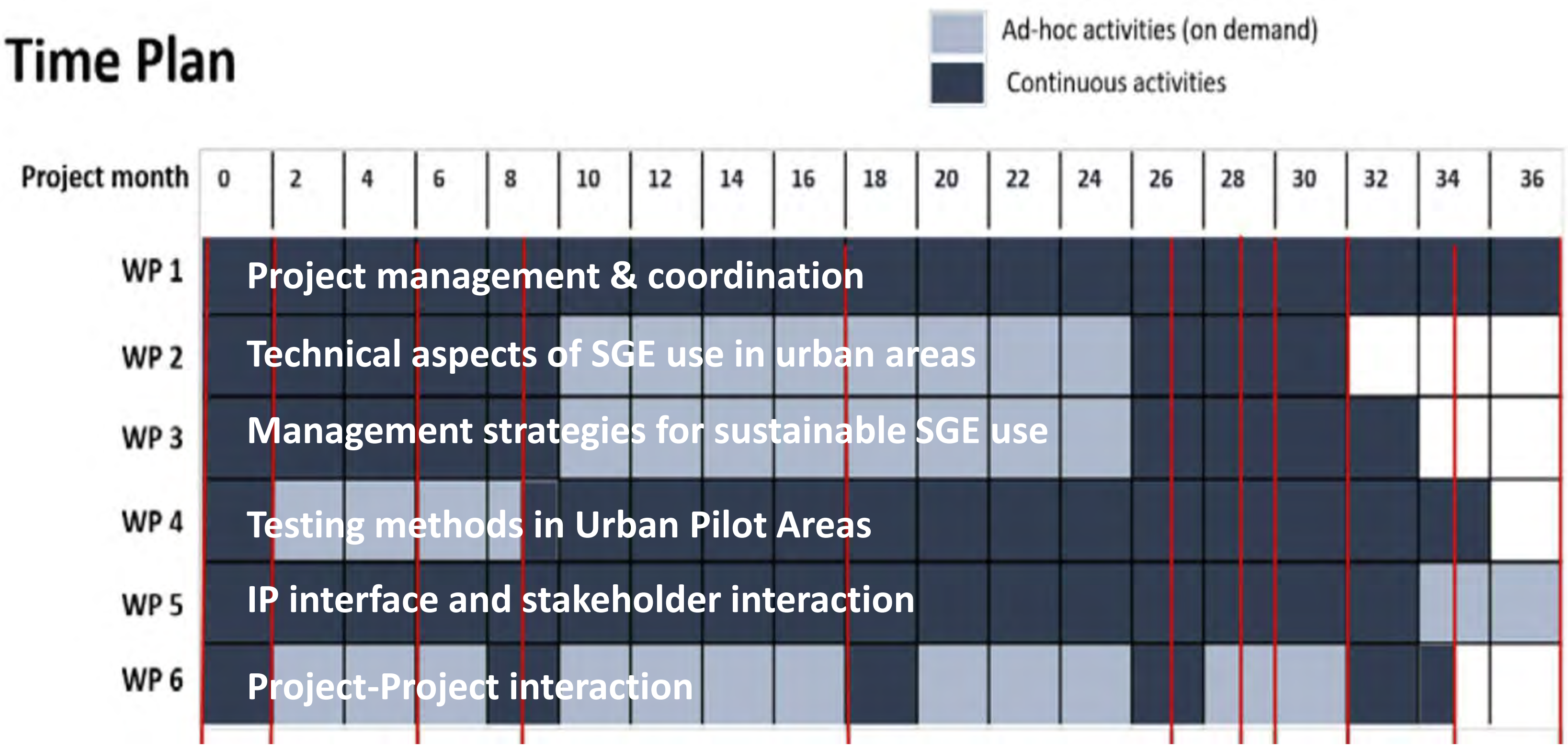
WP6: Cross-cutting issues and inside GeoERA

Knowledge Exchange Workshops

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

MUSE

Workpackages



Recoupable GSI input

0.25 months

0.25 months

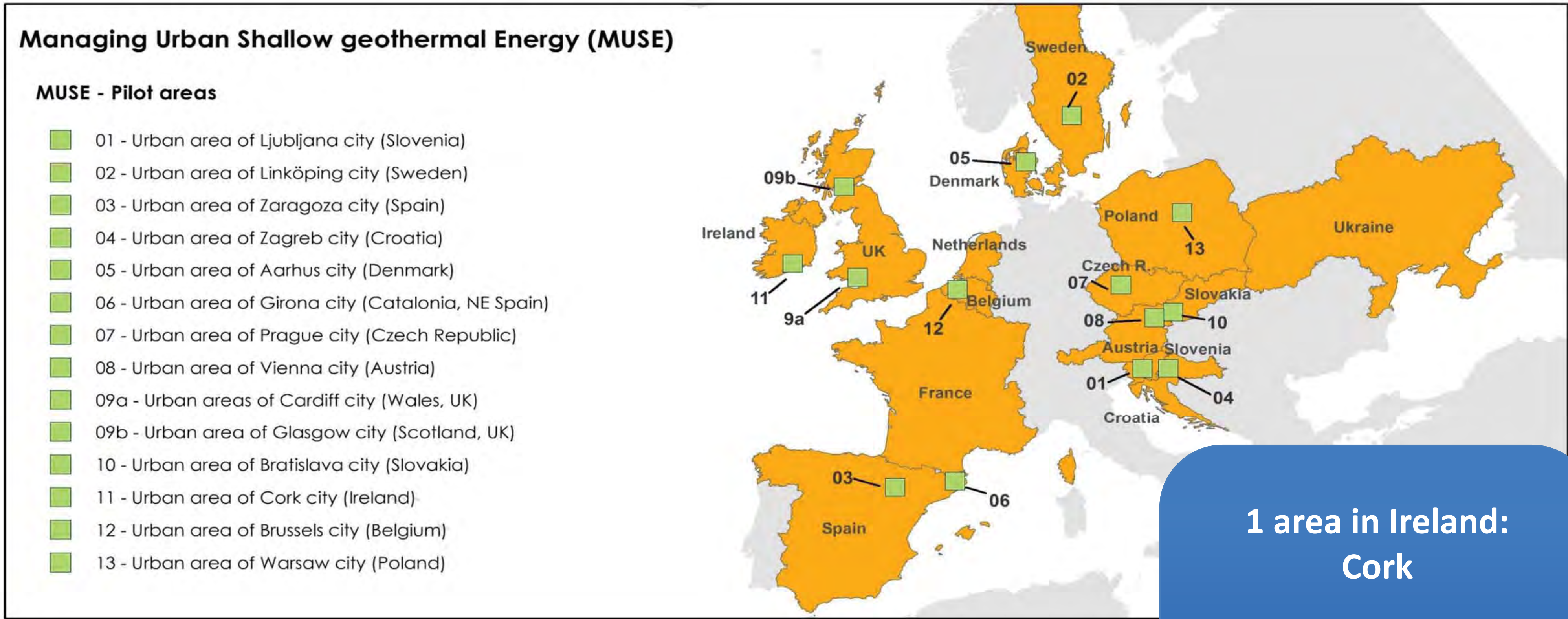
4 months

0.5 months

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

MUSE pilot areas (WP4)

14 urban pilot areas across Europe



1 area in Ireland: Cork

(would like to add Dublin if additional funds available)

- **Involving LAs, energy planners, environmental offices & municipality administration units, installers & (public) investors**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

MUSE

Principal outcomes

- A comprehensive and integrated set of methods, concepts and strategies allowing for local-scale management of shallow geothermal energy in European urban areas
- Identifying and describing proven and promising technical concepts of SGE use and describing technical and environmental risks related to inappropriate SGE use and providing risk intervention and mitigation measures
- Demonstrating the developed methods, workflows and concepts in 14 urban pilot areas across Europe
- Developing modern web-based information- and decision-support systems for investors and regulators for local-scale assessment of resources and possible conflicts related to shallow geothermal energy in cities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166

Guest speaker:

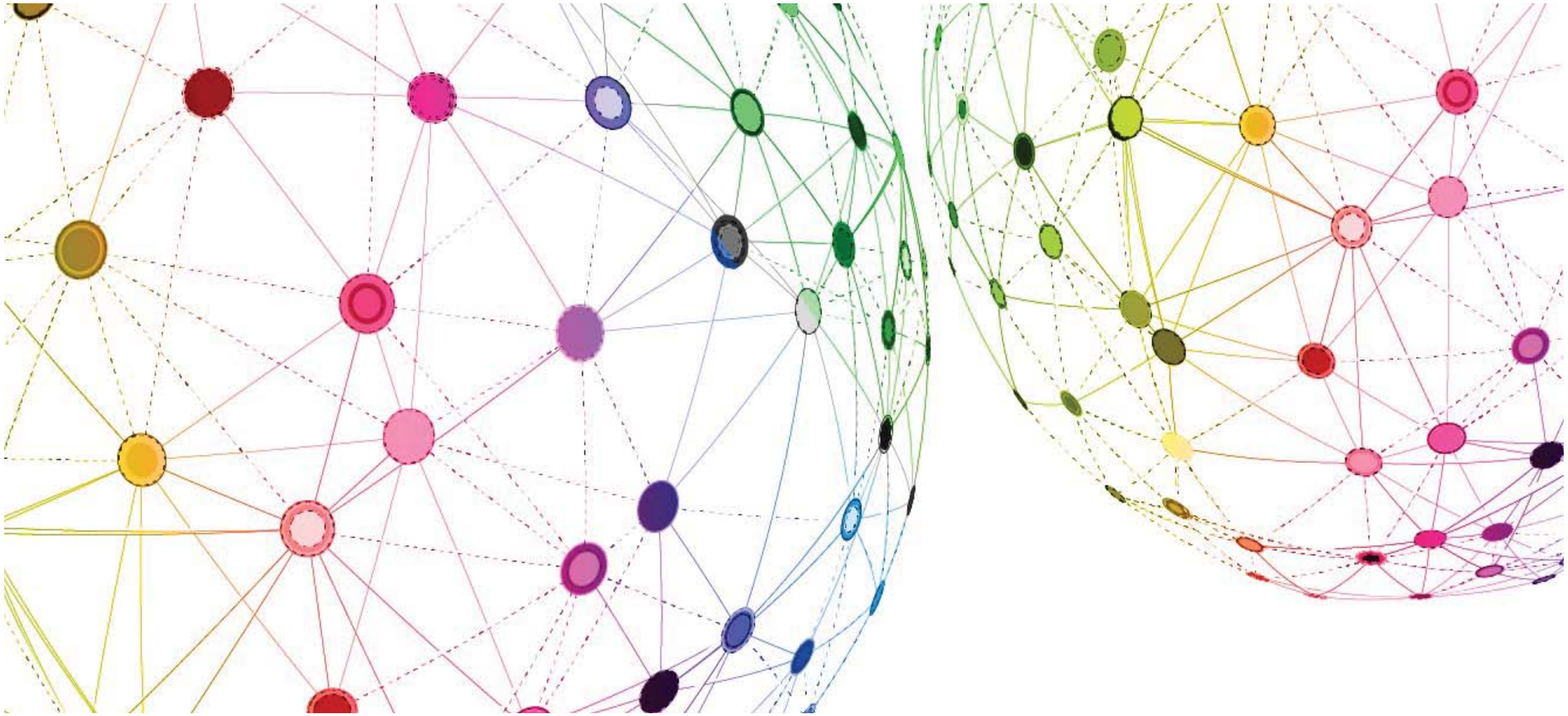
Dr Gunter Siddiqi, Swiss Federal Office of Energy – Section Energy Research

Gunter Siddiqi is the deputy head of the Section Energy Research in the Swiss Federal Office of Energy. As part of his role, Gunter coordinates federally sponsored research and development, and pilot- and demonstration projects related to geo-energies with a particular focus on geothermal energy. He also develops and implements policy instruments relevant for geothermal energy within the context of Switzerland's 2050 Energy Strategy.

A geologist and geophysicist by training, he obtained a BSc (Hon) from Imperial College, London (UK) and a Sc.D. from MIT, Cambridge (USA). Prior to joining government service, he has worked as a production engineers in the Exploration and Production upstream business on Enhanced Geothermal Systems, in-situ conversion of oil shales and in-situ upgrading of extra heavy oil. Gunter represents Switzerland in the International Energy Agency's Geothermal and Greenhouse Gas R&D Technology Collaboration Programs, in the Working Parties on Fossil Fuel and Renewable Energy as well as various European working and steering groups (SET-Plan Steering Group, Implementation Working Group for Deep Geothermal Energy, GEOTHERMICA).

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE
Office fédéral de l'énergie OFEN
Ufficio federale dell'energia UFE
Swiss Federal Office of Energy SFOE



Deep Geothermal in Ireland – Past Present and Future
Swiss national research policy & strategy

Gunter Siddiqi (Swiss Federal Office of Energy)

1A. ENERGY CONSUMPTION IN SWITZERLAND (2016)

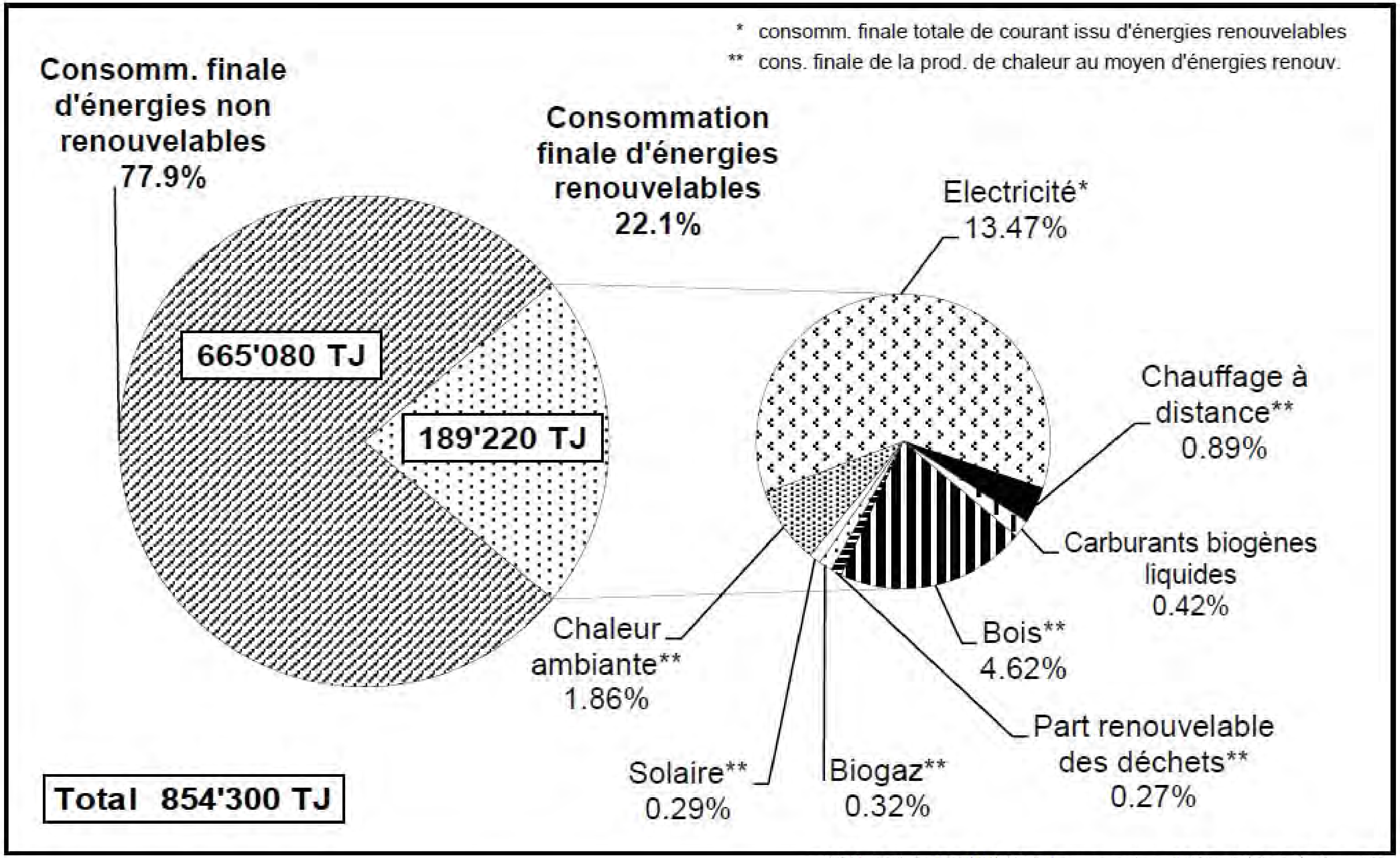


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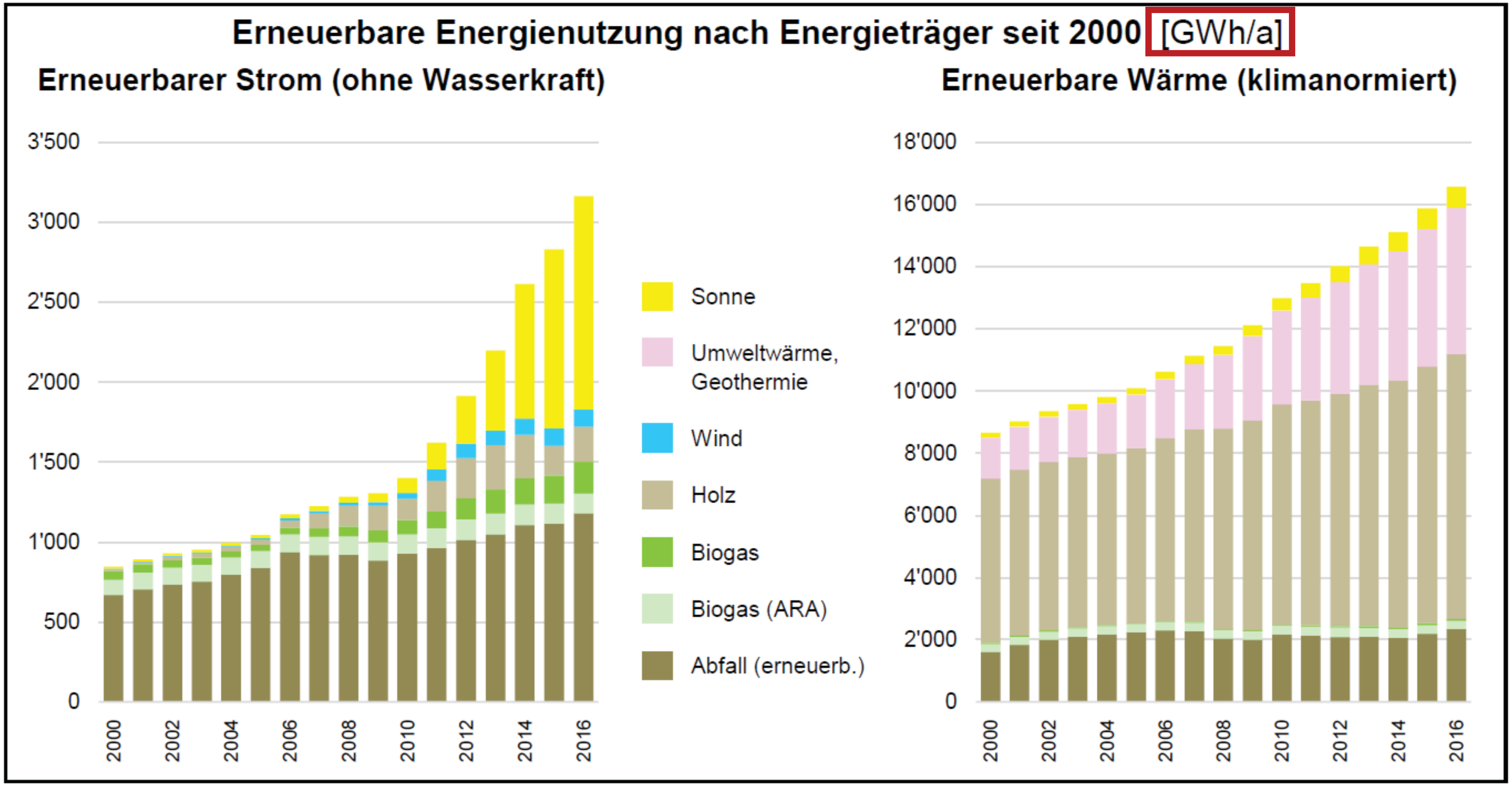
Tableau 1.4 **Consommation finale d'énergie en Suisse pour 2016, y compris la part des énergies renouvelables** (détail en fonction des agents énergétiques)

÷ 3.600 = TWh

1B. RENEWABLES FOR POWER (EXCL. HYDRO) AND HEAT SUPPLY



Gliederung nach Energieträgern (Anhang E)

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2A. HISTORY OF ENERGY STRATEGY 2050: KEY FOR SUPPORT FOR GEOTHERMAL DUE TO REVISIONS OF A NUMBER OF ACTS

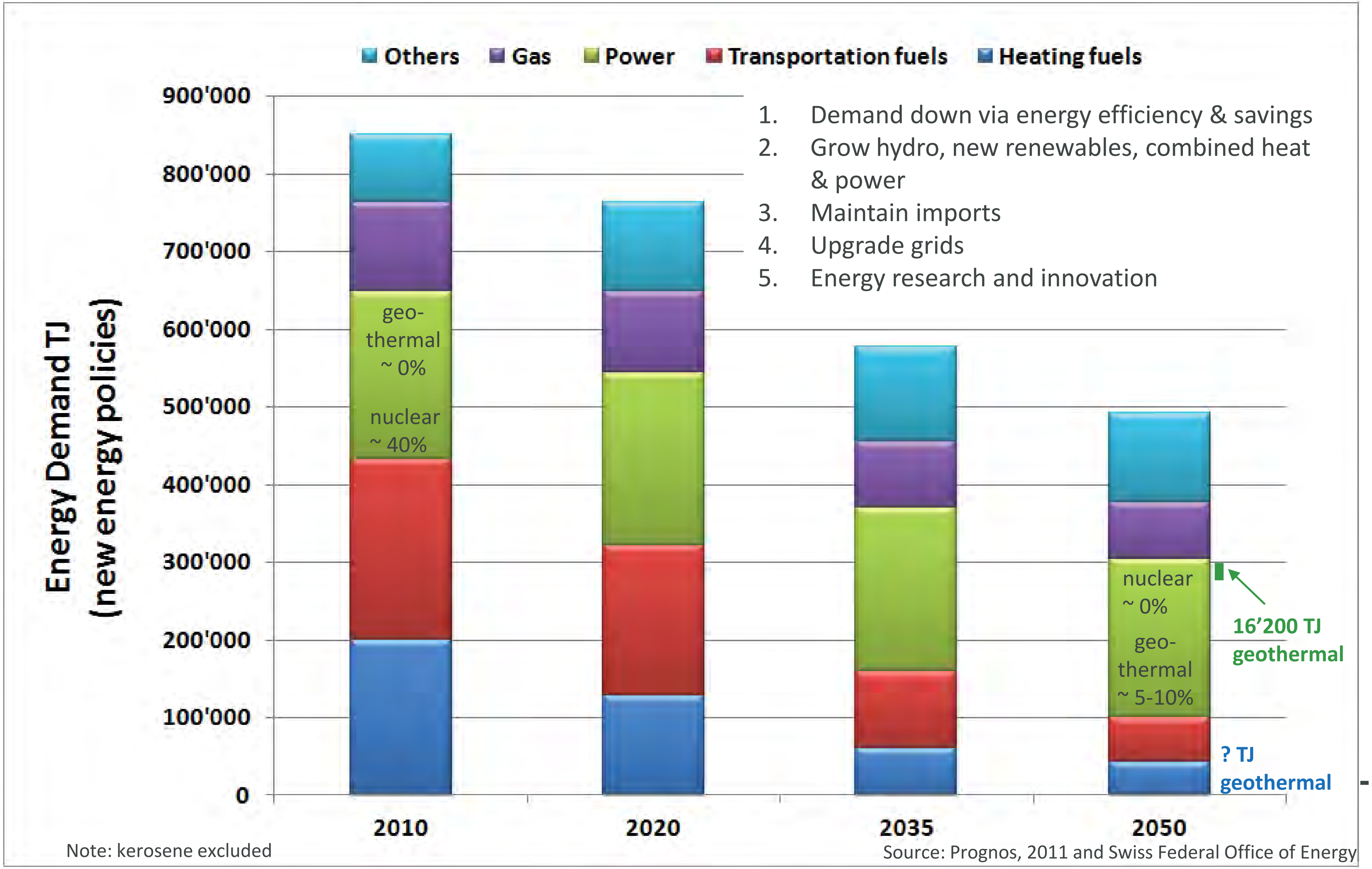
- June 2011: Government with approval of parliament develops a new energy strategy
- Trigger: Fukushima plus convergent trends (cost reduction renewables, climate change, political instability in Middle East and North Africa...)
- Sept 2013: Gov't sends bills to parliament
- Features: exit nuclear when no longer technically safe, up efficiency & savings, decrease fossils, increase renewables
- 30. Sep 2016: both chambers approve the Energy Act (optional referendum if 50'000 signatures are collected within 3 months against the Act)
- Nationalist conservatives successfully launched collection of 68'000 signatures

-> 21 May 2017 Swiss population has voted and approved with a 58% majority the revised Energy Act

- In parallel, a people's initiative (100'000 signatures) called for the shut-down of nuclear after 45 years of operation
- 45 years means that 3 of 5 plants to be shut in by the end of 2017
- But, Swiss voters rejected «accelerated» phase-out vs. «orderly» phase-out on 27 November 2016 with a solid majority of 54%.

- In parallel, 1 February 2017: Federal Administration launches the consultation process of ordinances (implementation rules of policy support measures)
- Energy Act and various ordinances will enter into force on 1 January 2018

2B. SWITZERLAND'S ENERGY STRATEGY 2050 SCENARIO: GEOTHERMAL ENERGY HAS A ROLE TO PLAY



2C. PARALLEL TO SWITZERLAND'S ENERGY STRATEGY 2050: IN PARLIAMENT: MEMBER'S INITIATIVES FOR/AGAINST GEOTHERMAL

- Mo. 11.3562
  SR Gutzwiller: *Deep Geothermal Energy. Masterplan*: «more risk coverage; more international research and innovation; more seed funding; simplified and accelerated permitting; clear regulatory framework; political support for geothermal»
- Mo. 11.3563
  SR Gutzwiller: *Deep Geothermal Energy. Exploring Switzerland*: «organize and finance geothermal exploration in Switzerland»
- Mo. 11.4027
  NR Riklin: *Action Plan Geothermal Energy*: «explore Switzerland by running seismic campaigns and drilling wells; develop regulatory guidelines including for managing induced seismicity risks»
- Po. 13.3103
  NR Trede: *Hydraulic Stimulation in Switzerland*: «ban Fracking and get neighboring countries to do the same»

3A. HEADLINES: 1ST SET OF MEASURES TO IMPLEMENT SWITZERLAND'S ENERGY STRATEGY 2050

No new nuclear (ea. of the 5 existing ones [20 TWh in 2016] retire at end of their technical/safe lifetime)

All energy targets are non-binding!

New renewables (excl. hydro) for electricity production:

2016: 3.2 TWh; 2020: 4.4 TWh; 2035: 11.4 TWh

Energy consumption relative to the year 2000:

2000: 854 970 TJ, 2016: 854 300 TJ

2020: -16% and 2035: -43% (rel. 2000)

Of which electricity consumption:

2000: 52.4 TWh, 2016: 58.2 TWh

2020: -3% and 2035: -13% (rel. 2000)

CO_2 binding targets remain unchanged:

-20% by 2020 rel. to 1990

Revision of CO2-Act has been initiated

Proposed target:-50% by 2030 rel. to 1990
-30% domestic and -20% foreign

Geothermal energy policy measures (enforcement date: 1.1.2018)

Geothermal guarantee scheme (until 2031)

Increase coverage to 60% of total sunk subsurface development cost, if the subsurface does not live up to expectations

Exploration support scheme (until 2031)

Max. 60% towards pre-spud exploration activity and first wells to confirm the presence of a reservoir (CHF 50 mln p.a.)

Feed-in tariffs (15 years) for project with first power before 2023

Support for direct use geothermal energy (to 2025)

CHF 30 mln p.a. for upstream exploration and development activities that lead to uptake of geothermal energy for direct heating

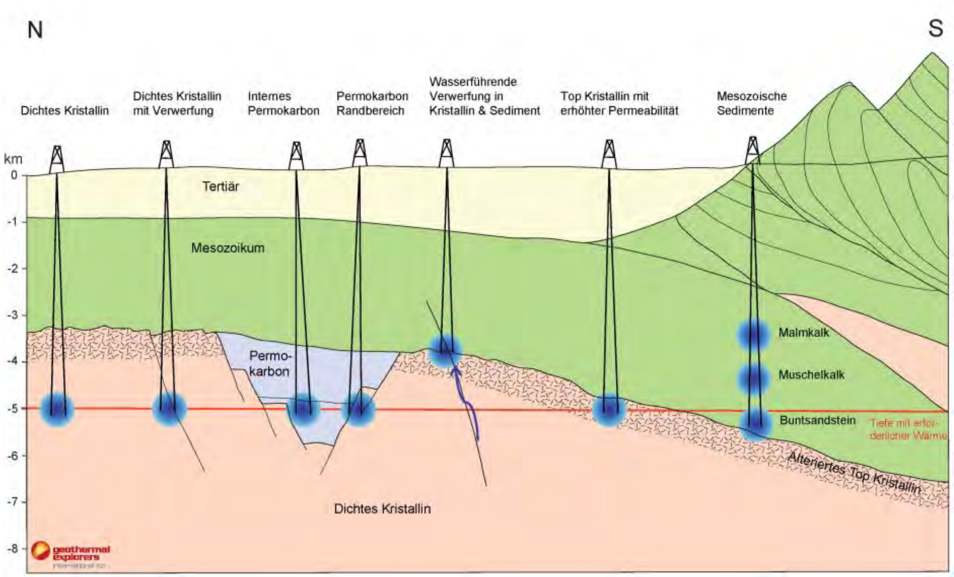
Geothermal in the "national interest"

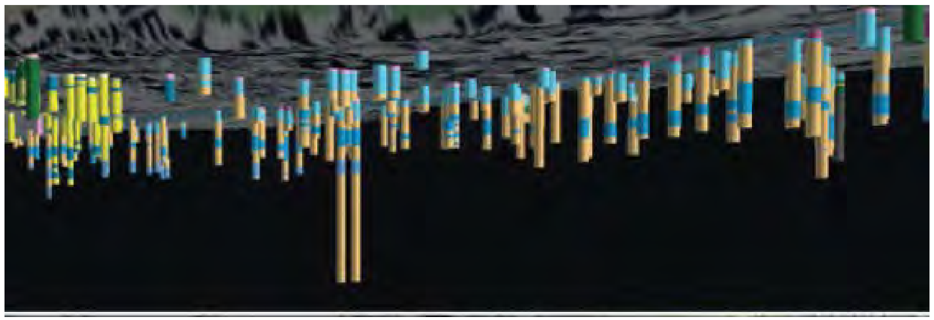
Cantons should accelerate planning and permitting

1 € = 0.9 CHF

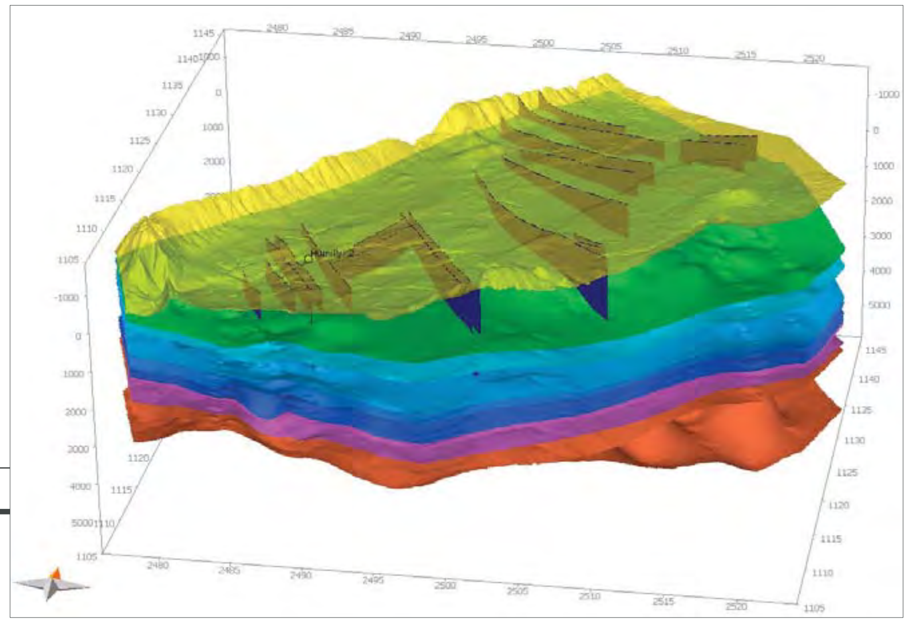
3B. «PLAY-TYPE» EXPLORATION

- Geothermal «play types»: specific geologic conditions, **where geological conditions of geothermal resources are «homogeneous**
- Industry actors estimate at least **8 «play types» in Switzerland**.
- To confirm a play, one might need **3 to 10 projects**.
- ***Swiss Federal Office of Energy and swisstopo (Swiss Geological Survey estimate that 25-50 exploration projects are necessary to confirm whether or not Switzerland's subsurface is suitable for geothermal energy supply***





Bundesamt für Landestopografie swisstopo



3C. SWITZERLAND'S SUPPORT PROGRAMS THROUGH THE PROJECT ECONOMICS LENS

Expected monetary value (EMV) = Probability of Success (POS) * $NPV_{Success}$ + Probability of Failure * $NPV_{Failure}$

$$EMV = POS*NPV_{Success} + (1\text{-}POS)*NPV_{Failure}$$

Installed capacity (Pel)	Feed-in tariff / for EGS (Rp./kWh)
≤ 5 MW	40.0 / 47.5
≤ 10 MW	36.0 / 43.5
≤ 20 MW	28.0 / 35.5
> 20 MW	22.7 / 30.2

Exploration grants

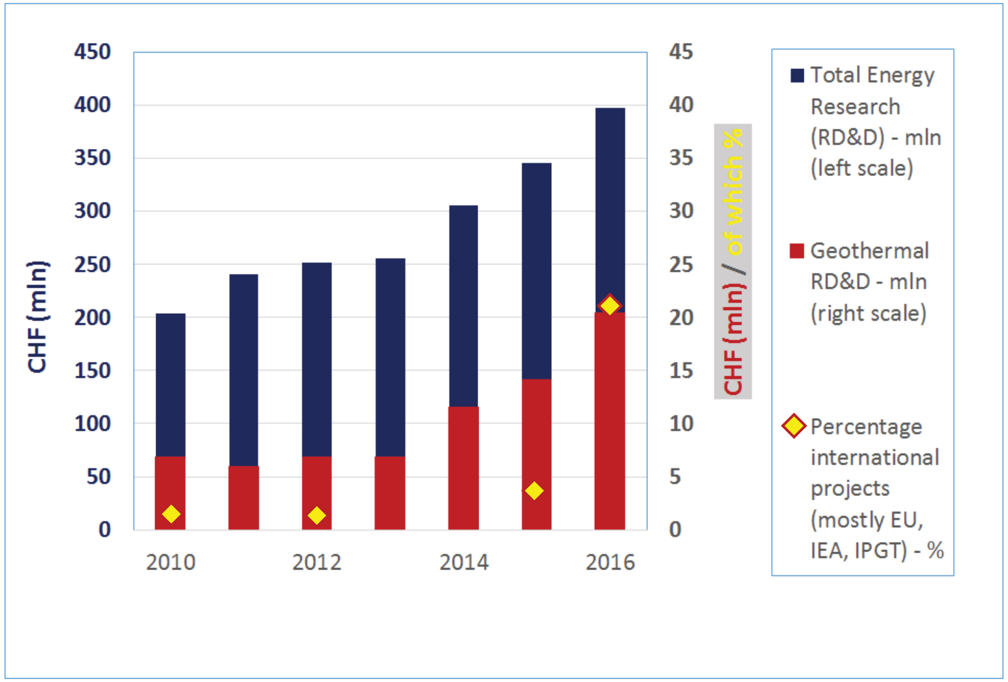
Geothermal Guarantee

- Feed-in tariffs are difficult to come by:
  Lavey-les-Bains (VD),
  possibly Haute-Sorne (JU),
  one other
- Feed-in tariffs can be adjusted if new information becomes available

- Currently in consultation: increase FITs by Rp. 6.5 / kWh to account for higher than expected cost of capital

4A. KEY IS PARTICIPATION IN INTERNATIONAL RESEARCH AND INNOVATION ACTIONS

Public investment in research and innovation



V. International Energy Agency (IEA)

- longest standing international collaboration with proven track record: direct use geothermal energy, emerging technologies, statistics

I. ERANET GEOTHERMICA 2017-2021: 15 European funding agencies and the European Commission pool financial resources for pilot and demonstration projects – Switzerland contributes CHF 6 million

- Geothermal heat coupled with aquifer thermal energy storage
- Real-time monitoring and risk management of induced seismicity from geothermal operations
- Geothermal stimulation technologies

II. EU Horizon 2020 & Swiss State Secretariat für Education, Research and Innovation (2014-2016)

- Projects related to drilling and stimulation technologies

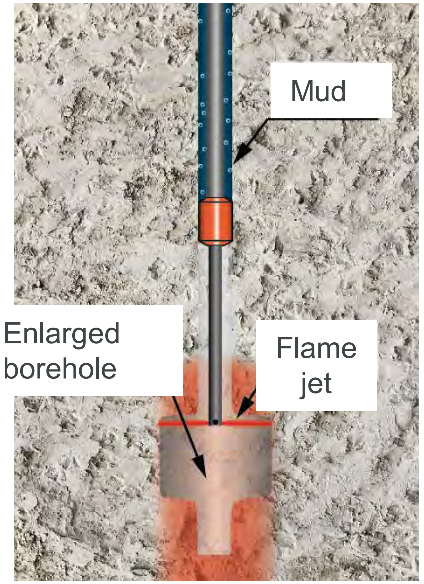
III. International Partnership for Geothermal Technology (USA, Iceland, Switzerland, Australia, New Zealand) –

- Cooperation on reservoir modeling and induced seismicity; soon to come sustainability concepts of geothermal energy and regulations

IV. Global Geothermal Alliance (Secretariat managed by IRENA)

- Placing high-level policy messages in the IRENA community

4B. INVESTIGATING HYDROTHERMAL SPALLATION DRILLING



Drilling process

A pilot for spallation-drilling in the Grimsel test site (Swiss Alps)

+ more projects related to spallation and plasma drilling (Saar, ETH-Zurich) and
independently high power electronics (solid-state modulators) for pulsed plasma drilling (Biela, ETH-Z)

4C. FRACTURE DESIGN FOR GEOTHERMAL RESERVOIRS (EDGAR)

The design of hydraulic stimulation programs that activate and create not only opening, but also in- and out-of-plane shear fractures relies on HighSTEPS (rock deformation lab at EPF Lausanne).

HighSTEPs performs high strain-rate, high temperature and pressure in-situ experiments on faulted and intact rock.

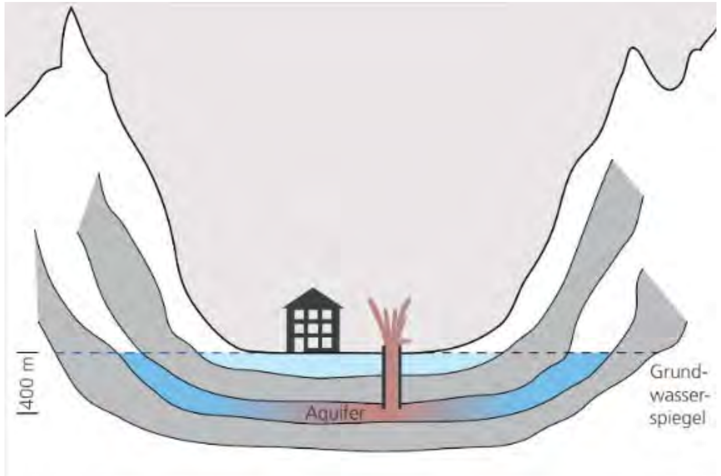
Goal: Develop engineering principles to reliably engineer topologically complex 3-D sets of fractures for EGS reservoirs; so that heat exchange area is maximized, reservoir impedance is minimized and finally micro-seismic events are limited.

Activity: experiments to establish the influence of loading configurations as well as rock and fluid properties on fracture creation.

Outcomes: Procedures via laboratory pilot studies, to stimulate mode II (shear) and mode III (out-of-plane shear) fractures

EDGAR is linked to Grimsel/Bedretto in-situ tests, and see also STIMDESIGN (Paul Selvadurai's presentation)

4D. PRINCIPLES OF SUSTAINABLE GEOTHERMAL EXPLOITATION OF ALPINE AQUIFERS (400-1000 M DEPTH)



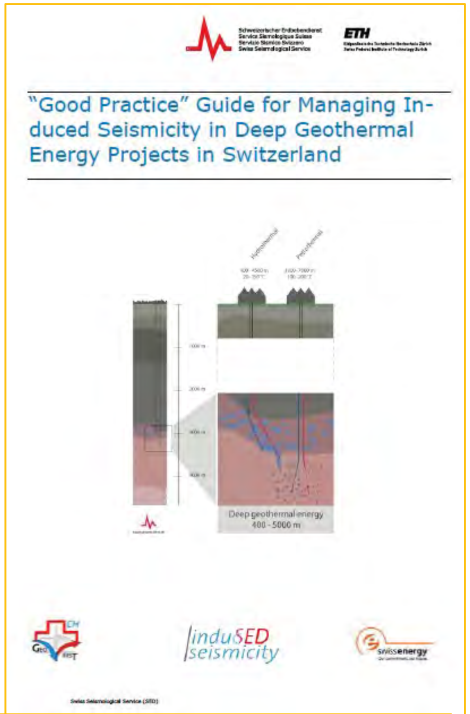
Host aquifer: Arosa Dolomite in Davos

Mode of operation: pumped production well to extract thermal energy that, integrated with process heat from a nearby ice-rink, heats the Davos congress center (of World Economic Forum fame).

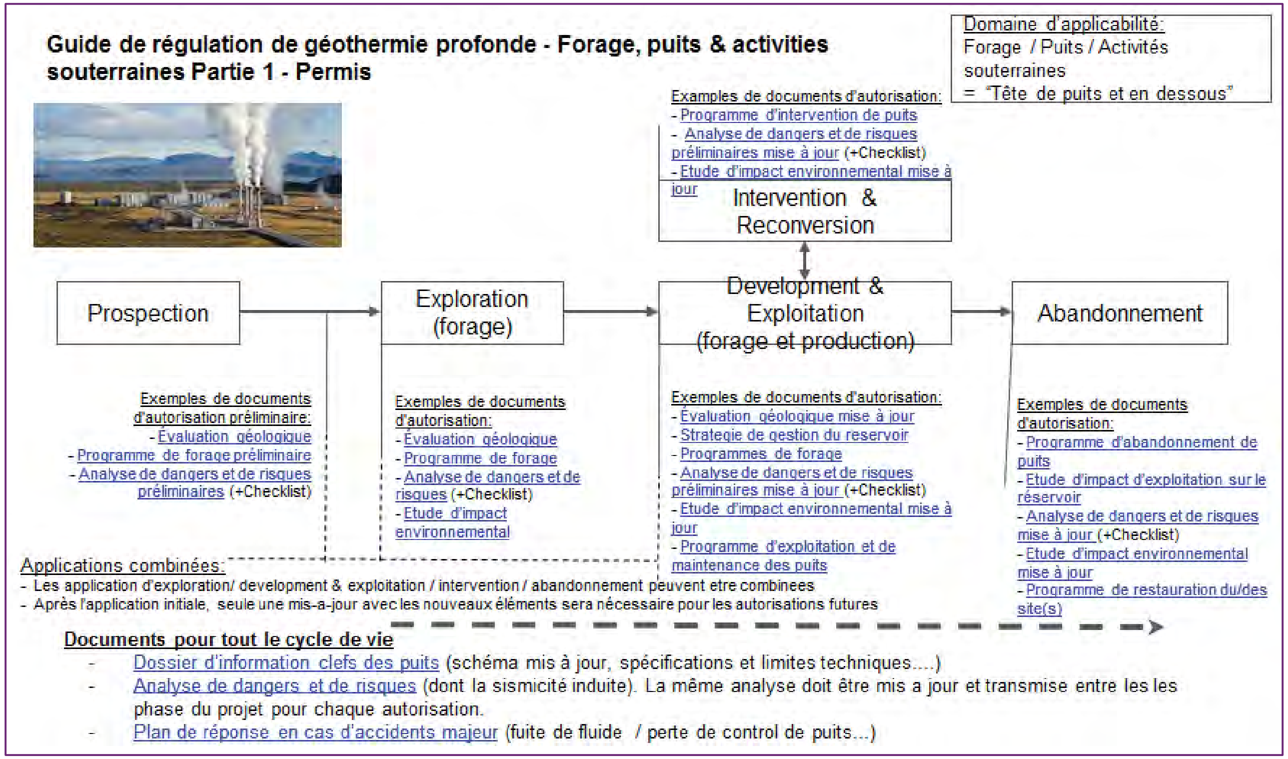
Outcome: define a sustainable production envelope for the Arosa Dolomite and monitor impact on existing ground source heat pumps

Goal: subsequent projects utilizing Alpine aquifers

4E. SCIENCE IN REGULATORY AND SAFETY AFFAIRS



Currently in use in the Cantons of GE, VD and JU



MEANWHILE BACK IN GLOVELIER (CANTON OF JURA), HOME OF SWITZERLAND'S EGS PROJECT

And now, what are we supposed to: twin with Pohang?!

NO! to deep geothermal

Deep geothermal "pigheadedness"

When earthquakes bring together people

Questions: now or later (send email to gunter.siddiqi@bfe.admin.ch)

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
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