Real-time monitoring of the underground for researchers, industry and the public

Mike Stephenson and Carl Watson

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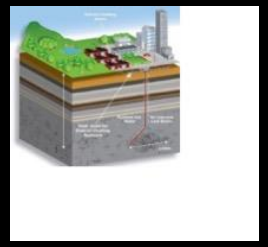
The underground is vital for the ‘low carbon transition’

Energy

Geothermal hot dry rock

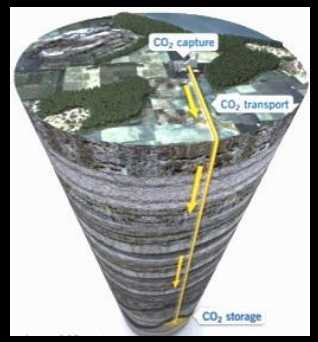


Geothermal district heating

Geothermal minewater heating

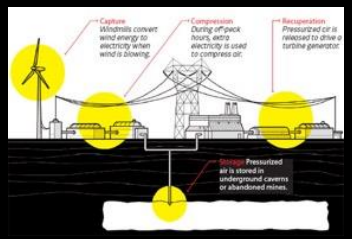
?Shale gas

Disposal



Carbon capture & storage

Storage



Compressed air energy storage

Hydrogen storage

- How much potential is there?
- Can these technologies be done sustainably?
- Both of these are science questions…So we need the facilities to answer these questions

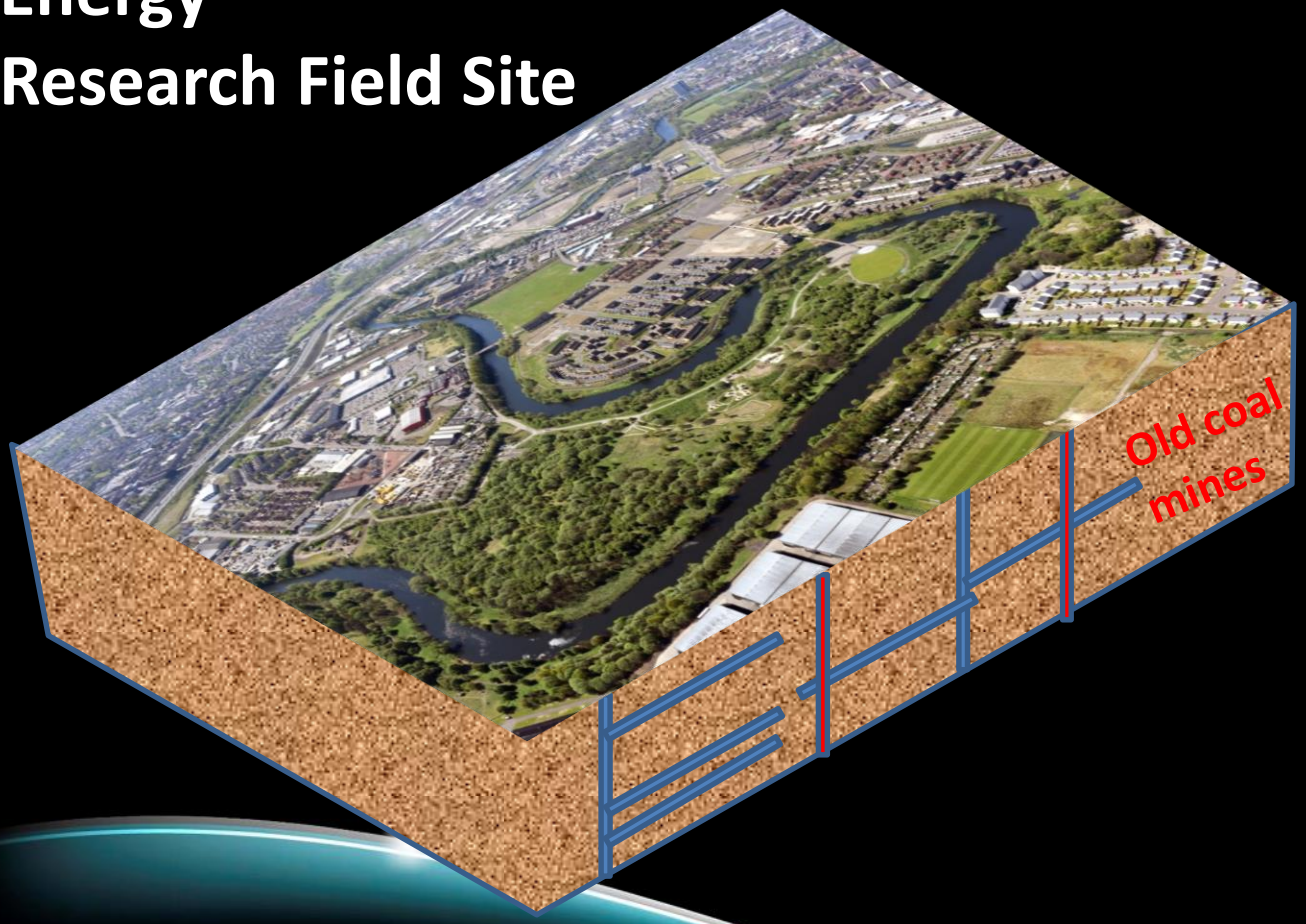
UK Geoenergy Observatories
£31 million

Glasgow Geothermal Energy Research Field Site

Cuningar Loop, looking west (photo©Claire Ferguson/Clyde Gateway URC)

Cheshire Energy Research Field Site

Glasgow Geothermal Energy Research Field Site

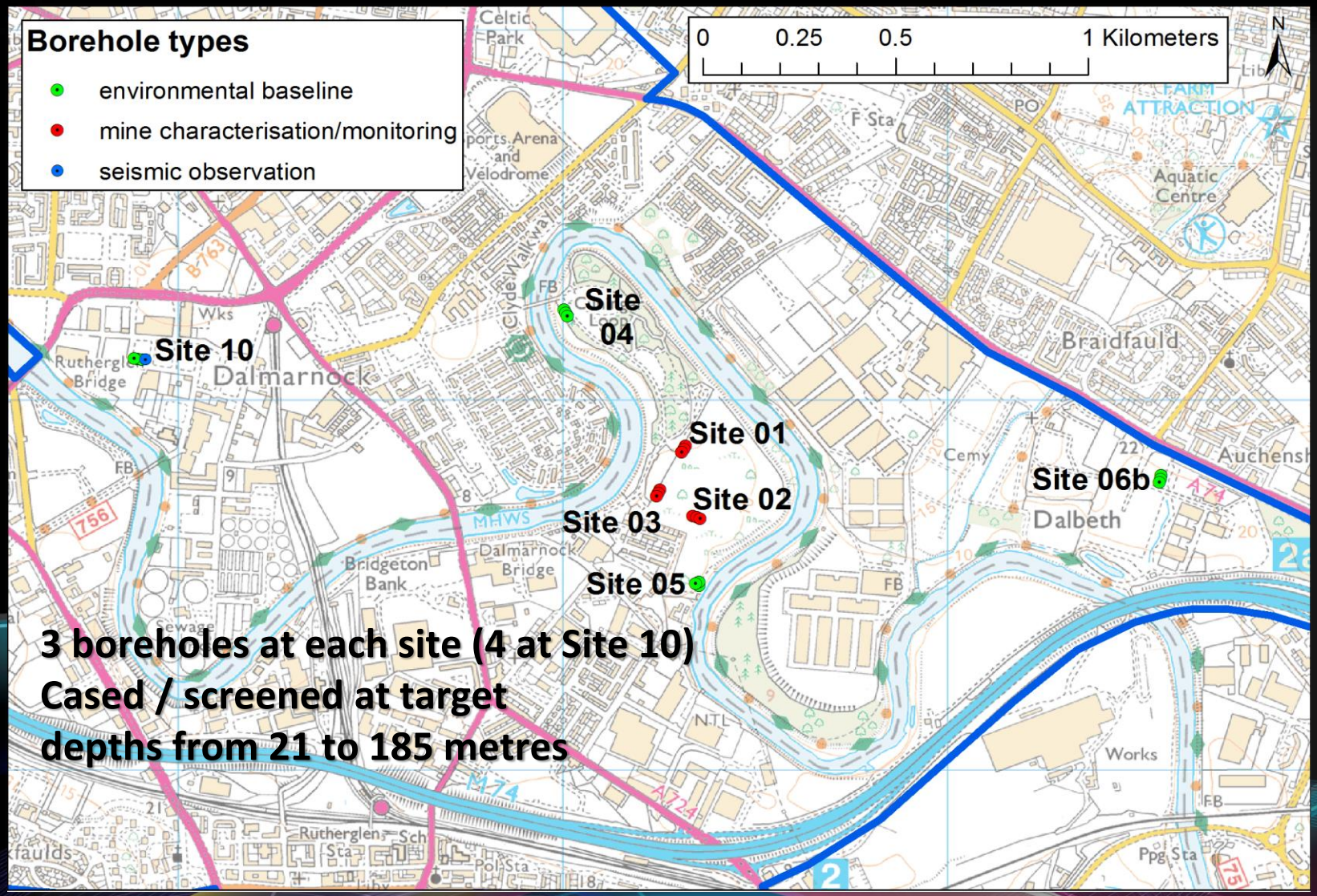


How much heat is there? Enough for houses and businesses?

What's the most efficient way of getting the heat out?

How fast does the heat get replenished?

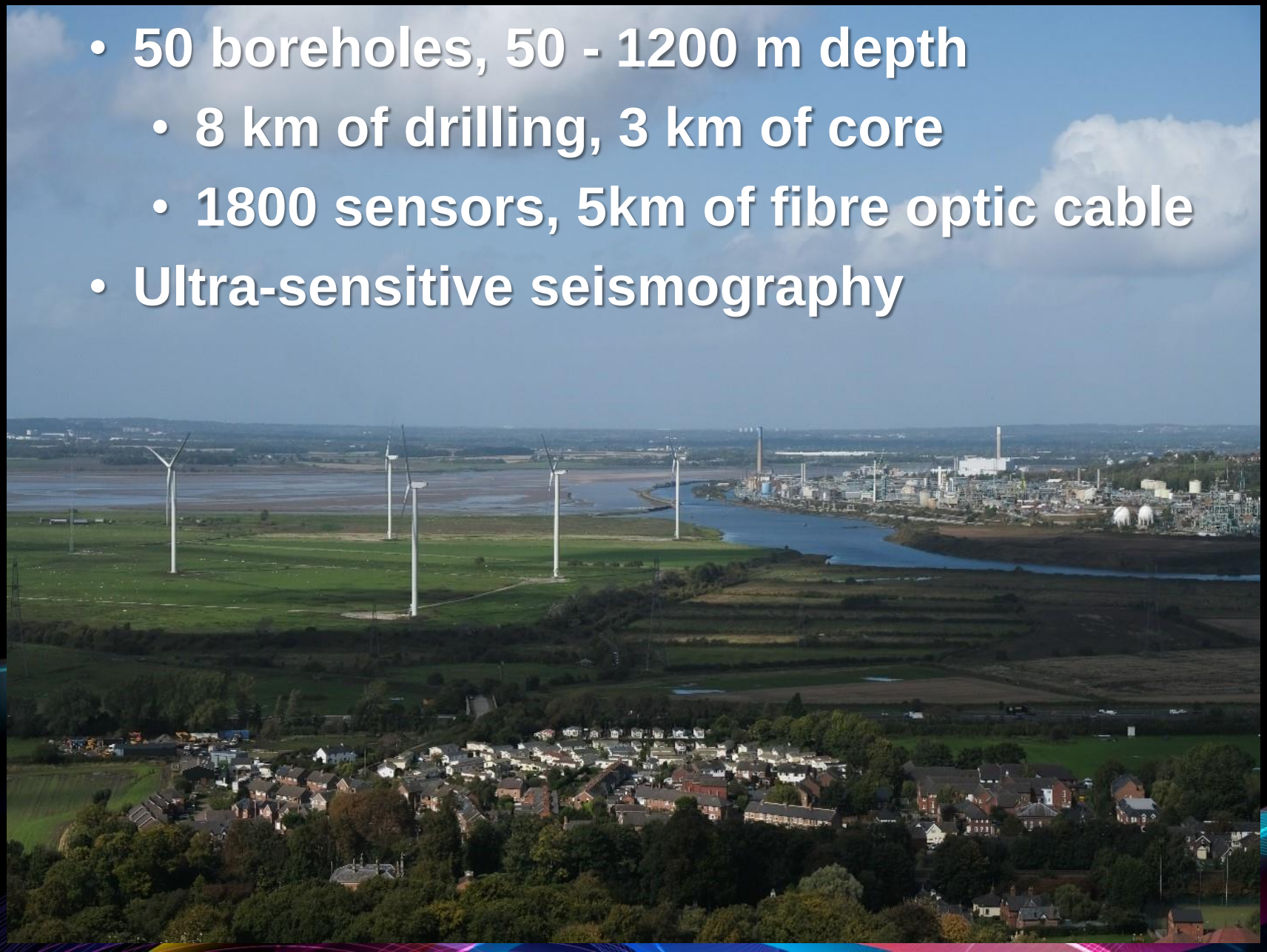
Glasgow Geothermal Energy Research Site borehole locations



3 boreholes at each site (4 at Site 10)
Cased / screened at target depths from 21 to 185 metres

Cheshire Energy Research Facility

- 50 boreholes, 50 - 1200 m depth
  - 8 km of drilling, 3 km of core
  - 1800 sensors, 5km of fibre optic cable
- Ultra-sensitive seismography



Array 1: Groundwater Baseline

Objective: Baseline to study & understand regional groundwater regime

- Array Description:
  - 15 bh at 8 sites, 100 & 50 m deep
  - 5 x 100 m boreholes cored to samplw superficial & Permo-Trias geology
  - Automated & telemetered data logging in 6 boreholes

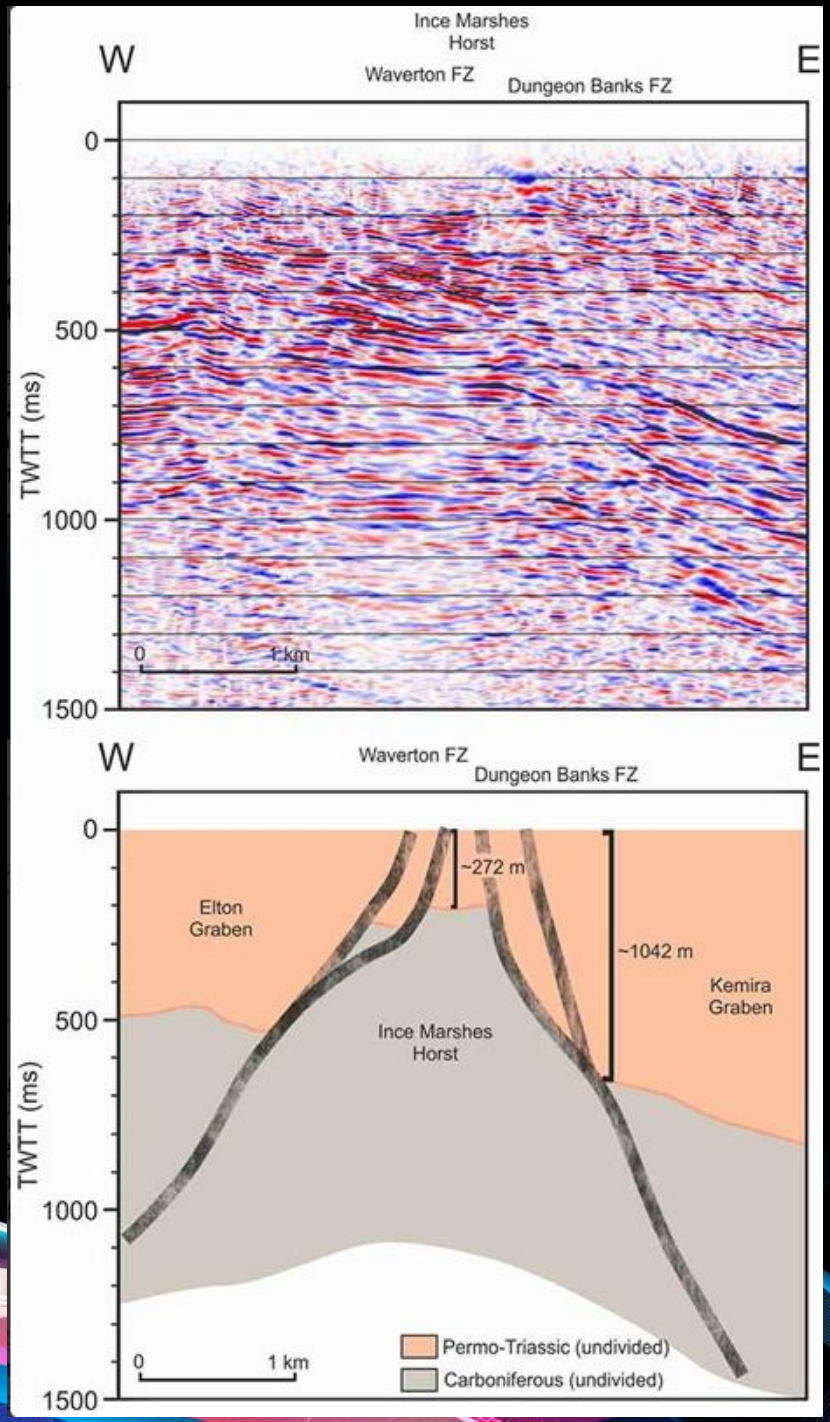
Array 2: Seismic Baseline

Objective: Seismic monitoring network that detects very small earthquakes (-0.6 to -1.0 Magnitude)

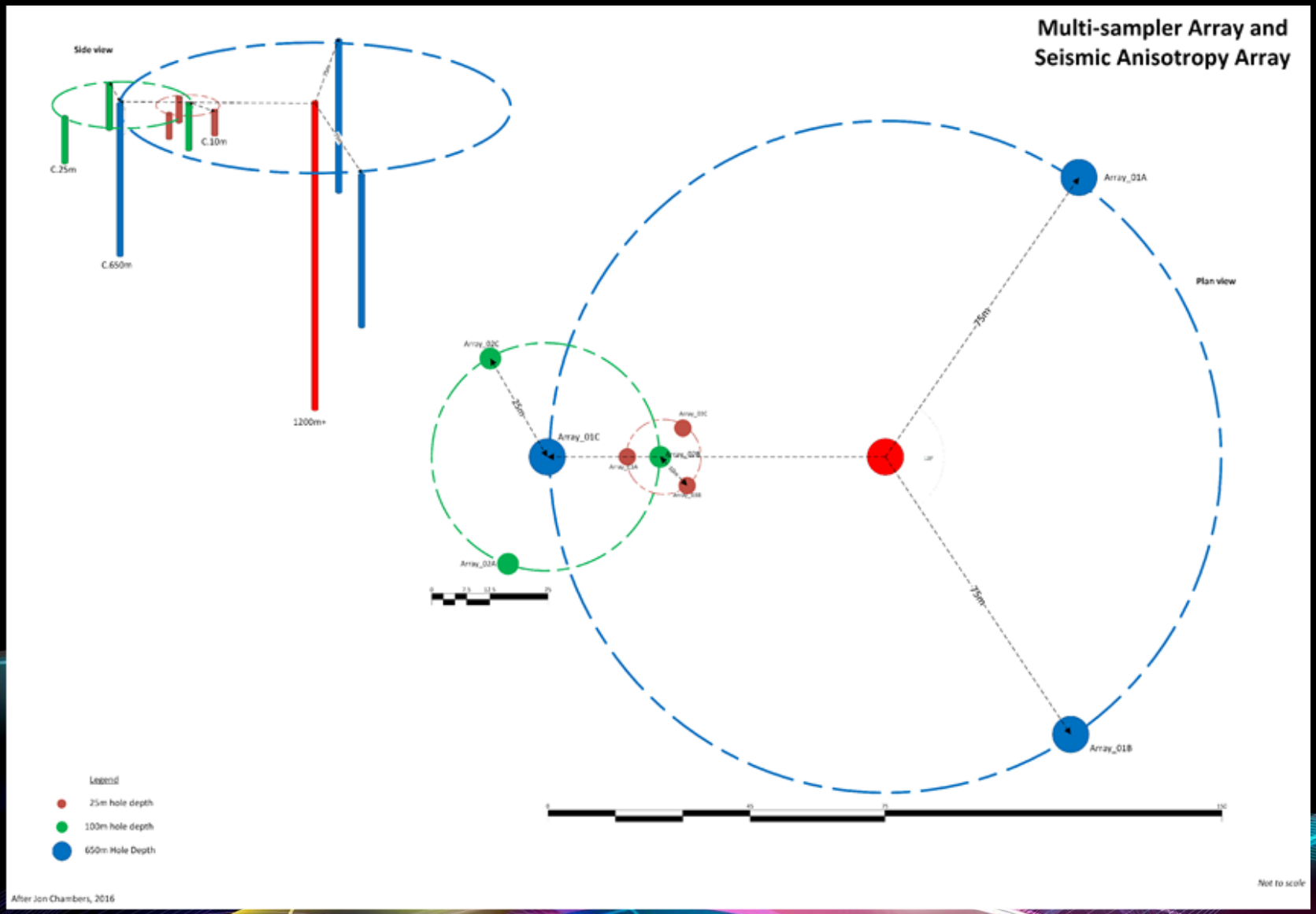
- Array Description:
- 10 seismometers installed in boreholes
  - 3 x 300 m deep
  - 7 x 200 m deep
  - 4 x 200 m boreholes also cored

Array 3: Deep well

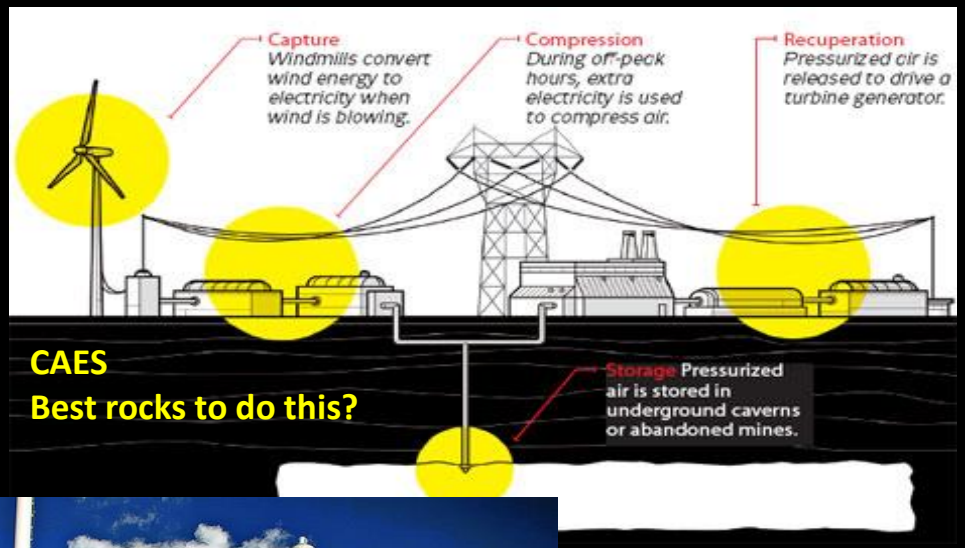
- New geological data
- Single seismometer for deep monitoring
- Other experiments

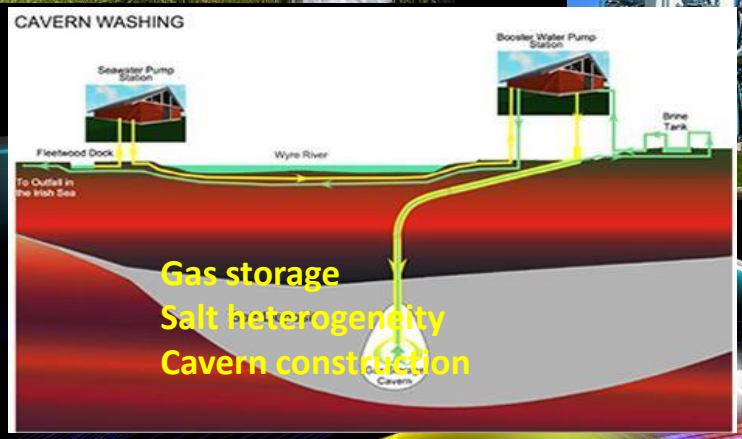


Array 4: multi-scale boreholes



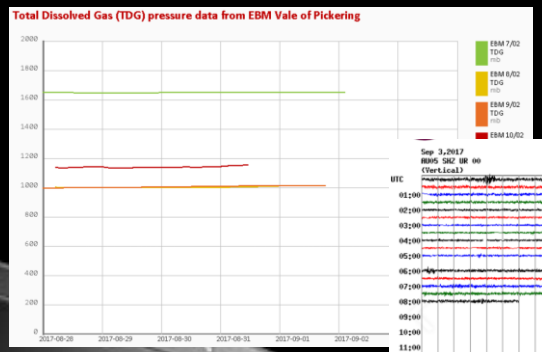
Science questions - subsurface energy



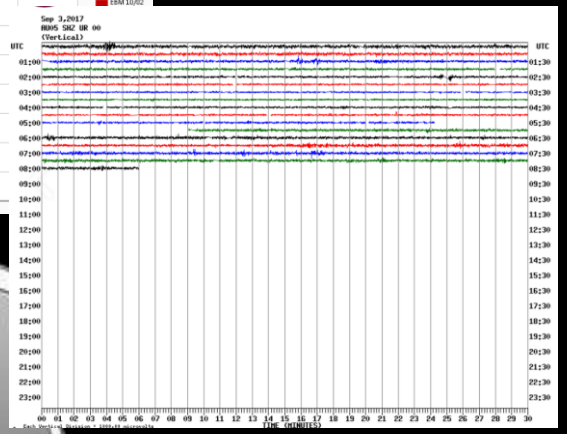


Data and science available to everyone

Groundwater quality



Seismicity



…often in real time….

For the public:
To see what's happening

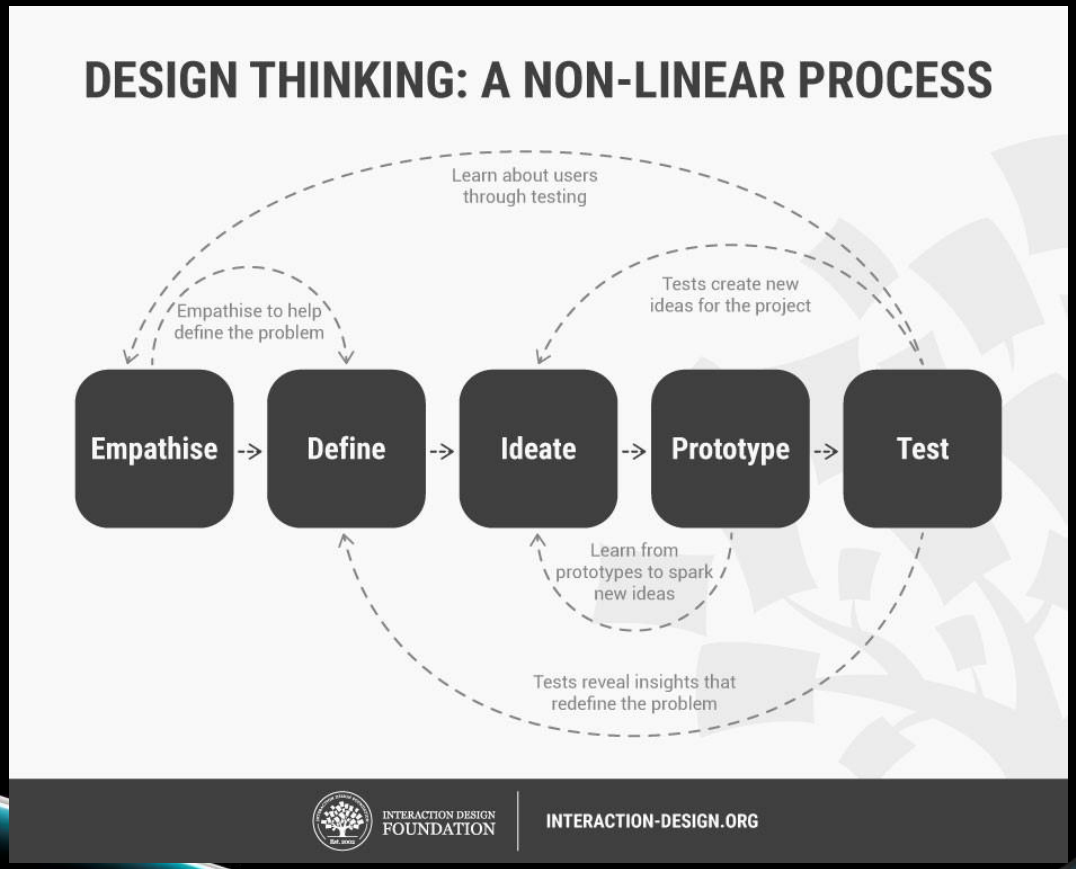
For scientists:
For research and innovation

For industry:
For new products, jobs and investment

Design-led development

Design Thinking

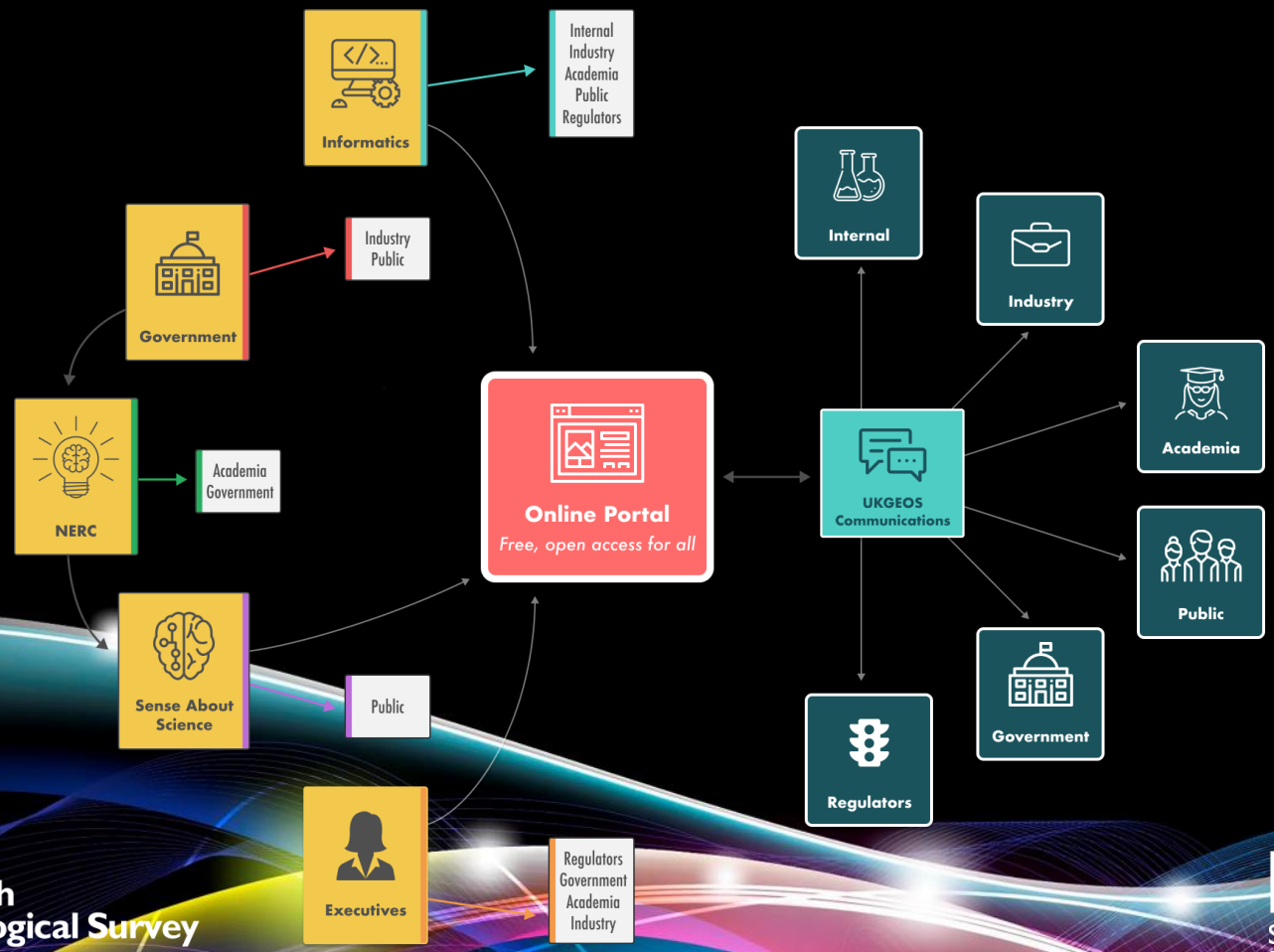
Design Thinking is a design methodology that provides a solution-based approach to solving problems. It's extremely useful in tackling complex problems that are ill-defined or unknown, by understanding the human needs involved, by re-framing the problem in human-centric ways, by creating many ideas in brainstorming sessions, and by adopting a hands-on approach in prototyping and testing.



User Groups

Designing the online portal for many stakeholder groups

|Different needs, levels of expertise, interest levels



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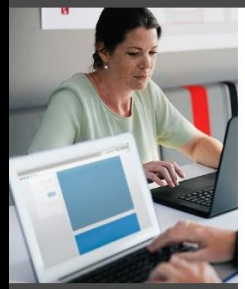
Personas

Getting to know our users

|Personas help us to imagine how different users will find, explore and use project outputs.

PALMA, *Data Scientist*



"There could never be too much data."

GOALS

Download sensor data from last year and analyse it together with datasets from other observatories.

PAIN POINTS

- Incomplete data
- Missing Data
- No metadata
- Not enough data

BEHAVIOURS

- With my personal estimate, data exploration, cleaning and preparation take up 70% of my project time.

MOTIVATION

Achievement, incentive.

TECH ■■■ **SCIENCE** ■□□ **POLITICS** ■□□

ALASTAIR, *Minecraft Expert*

"I like when teachers use games to help us learn new things. Learning doesn't seem so boring then."

GOALS

Find out whether the underground looks the same as it does in Minecraft

PAIN POINTS

- Lack of dinosaurs
- Being treated like a kid
- Websites with a lot of text - he prefers videos and info-graphics.
- Memorising things - he'd rather use google.

MOTIVATION

He is motivated by learning new things about this planet and everything else that includes dinosaurs and space travel.

TECH ■■□ **SCIENCE** ■□□ **POLITICS** ■□□

HYE, *Researcher*

"I would like the data from my research to stay private until it is published."

GOALS

- Find more information about the site, its capabilities and limitations.
- Find things to do before they can start their research
- Access the physical site
- Communicate science to the public
- Give recommendations to government agencies

PAIN POINTS

Lack of detailed explanations. Too much hand holding in modern web-apps. No access to raw data.

BEHAVIOURS

- Quickly learns new things
- Is open minded about new ideas.

MOTIVATION

Incentive, achievement, growth.

TECH ■■□ **SCIENCE** ■■■ **POLITICS** ■□□

SAMANTHA, *Developer*

"I love the challenge of building something quickly and I don't like when it takes too long to set things up."

GOALS

Work with other hackers to build an app over the weekend for environmental research.

PAIN POINTS

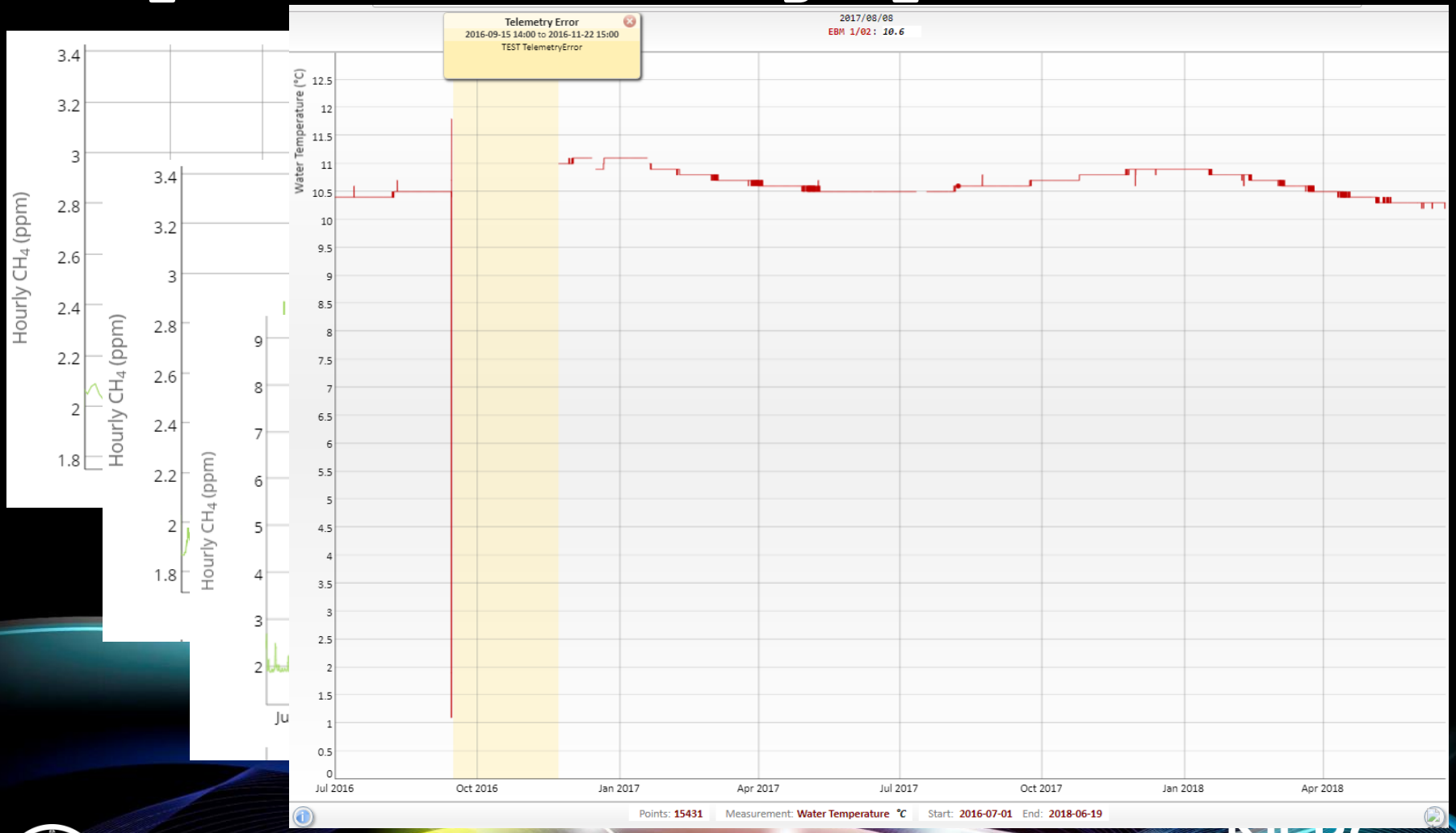
- Documentation that makes you feel stupid and incompetent
- More than 3 minutes to create a first API call
- A long sign up process before she can use the API
- Errors that don't provide sufficient assistance in debugging

MOTIVATION

She is motitaved by learning and working with others.

TECH ■■■ **SCIENCE** ■□□ **POLITICS** ■□□

Spikes and gaps



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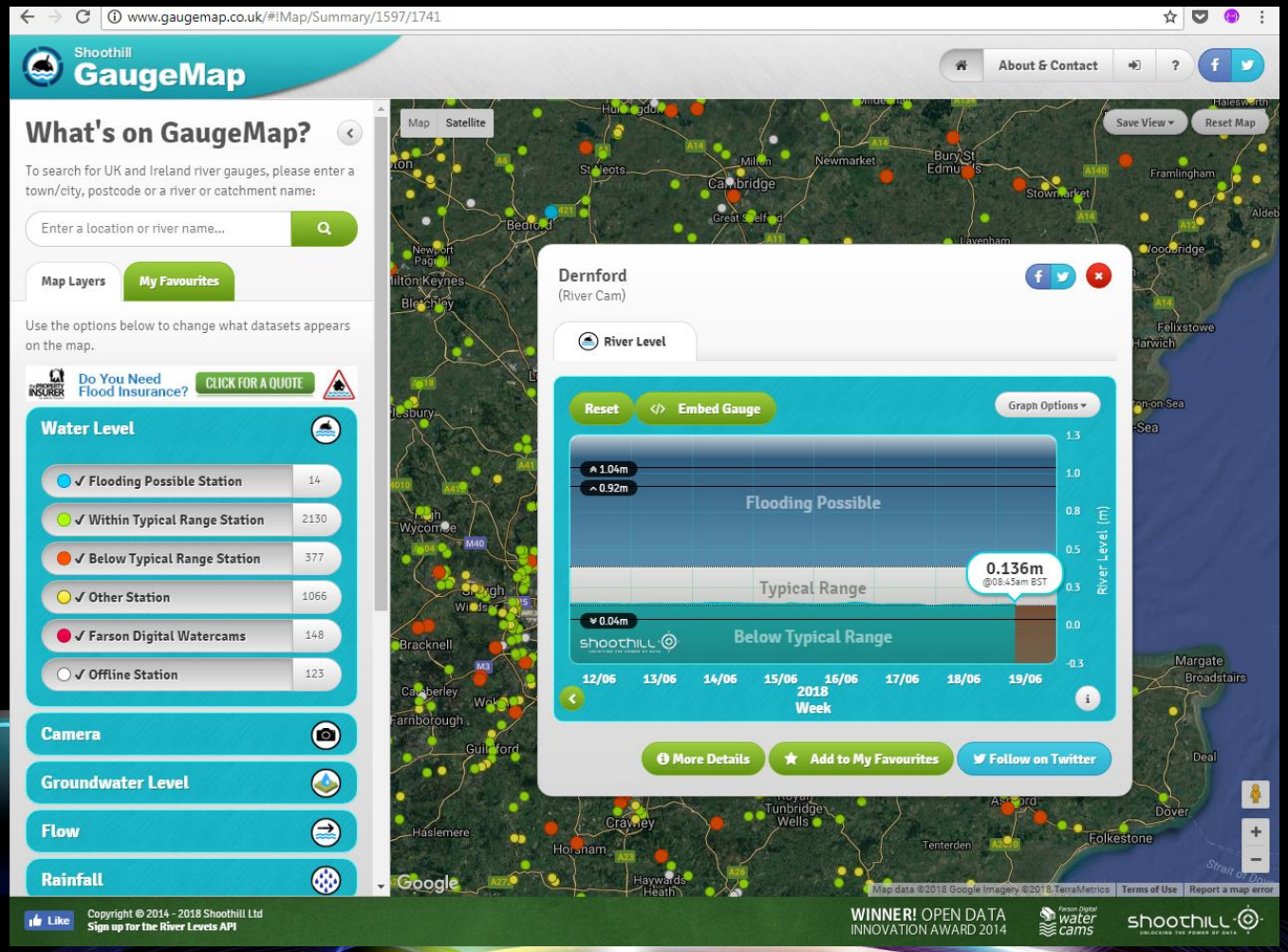
Typical ranges



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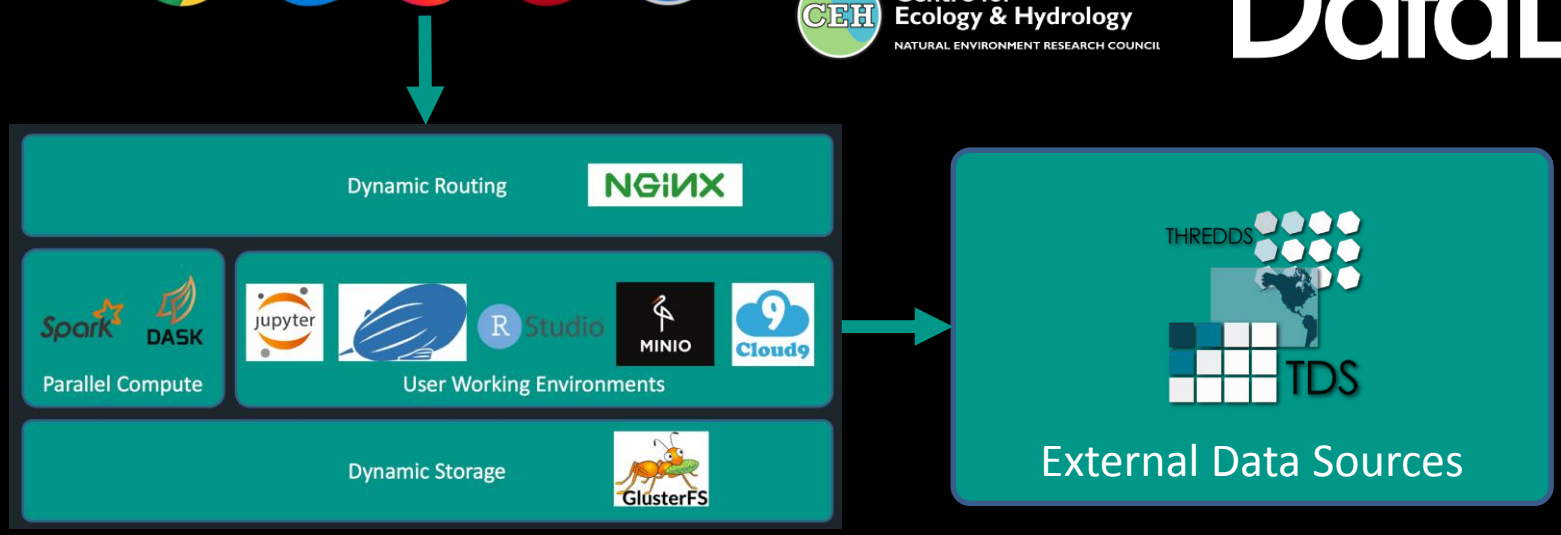
NERC DataLabs



- Dynamic creation of elements within the user working environment
- Accessible from user working environment & parallel compute
- Dynamic creation of storage
- Web-based application

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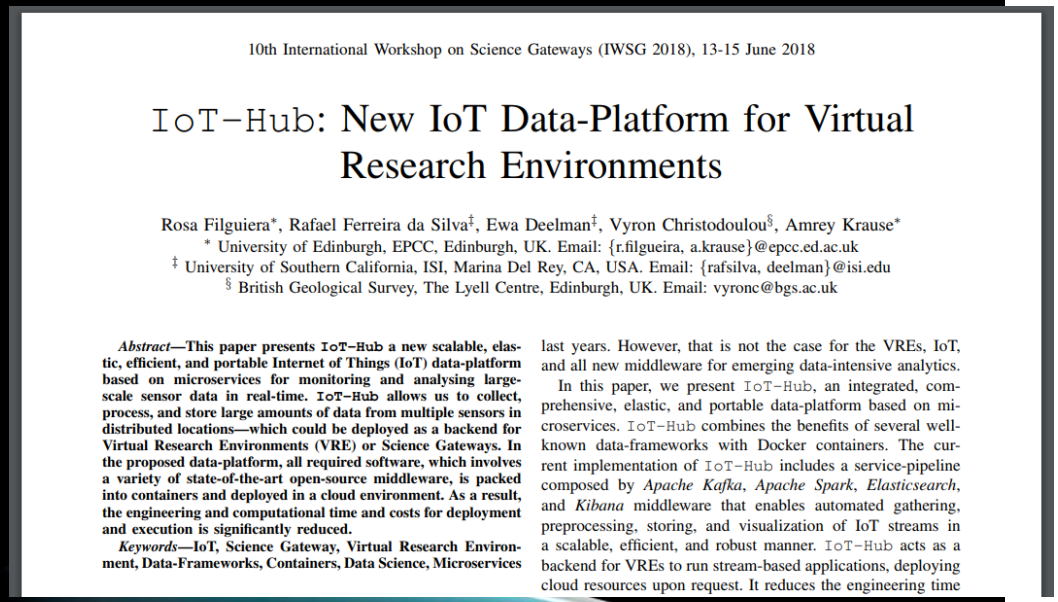
Anomaly Detection

Detecting localized anomalies can be utilized as a warning system to prevent device failures



10th International Workshop on Science Gateways (IWSG 2018), 13-15 June 2018

IoT-Hub: New IoT Data-Platform for Virtual Research Environments

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***Abstract*—This paper presents IoT-Hub a new scalable, elastic, efficient, and portable Internet of Things (IoT) data-platform based on microservices for monitoring and analysing large-scale sensor data in real-time. IoT-Hub allows us to collect, process, and store large amounts of data from multiple sensors in distributed locations—which could be deployed as a backend for Virtual Research Environments (VRE) or Science Gateways. In the proposed data-platform, all required software, which involves a variety of state-of-the-art open-source middleware, is packed into containers and deployed in a cloud environment. As a result, the engineering and computational time and costs for deployment and execution is significantly reduced.**

***Keywords*—IoT, Science Gateway, Virtual Research Environment, Data-Frameworks, Containers, Data Science, Microservices**

last years. However, that is not the case for the VREs, IoT, and all new middleware for emerging data-intensive analytics.

In this paper, we present IoT-Hub, an integrated, comprehensive, elastic, and portable data-platform based on microservices. IoT-Hub combines the benefits of several well-known data-frameworks with Docker containers. The current implementation of IoT-Hub includes a service-pipeline composed by *Apache Kafka*, *Apache Spark*, *Elasticsearch*, and *Kibana* middleware that enables automated gathering, preprocessing, storing, and visualization of IoT streams in a scalable, efficient, and robust manner. IoT-Hub acts as a backend for VREs to run stream-based applications, deploying cloud resources upon request. It reduces the engineering time

Filguiera, R., da Silva, R.F., Deelman, E., Christodoulou, V. and Krause, A., IoT-Hub: New IoT Data-Platform for Virtual Research Environments.

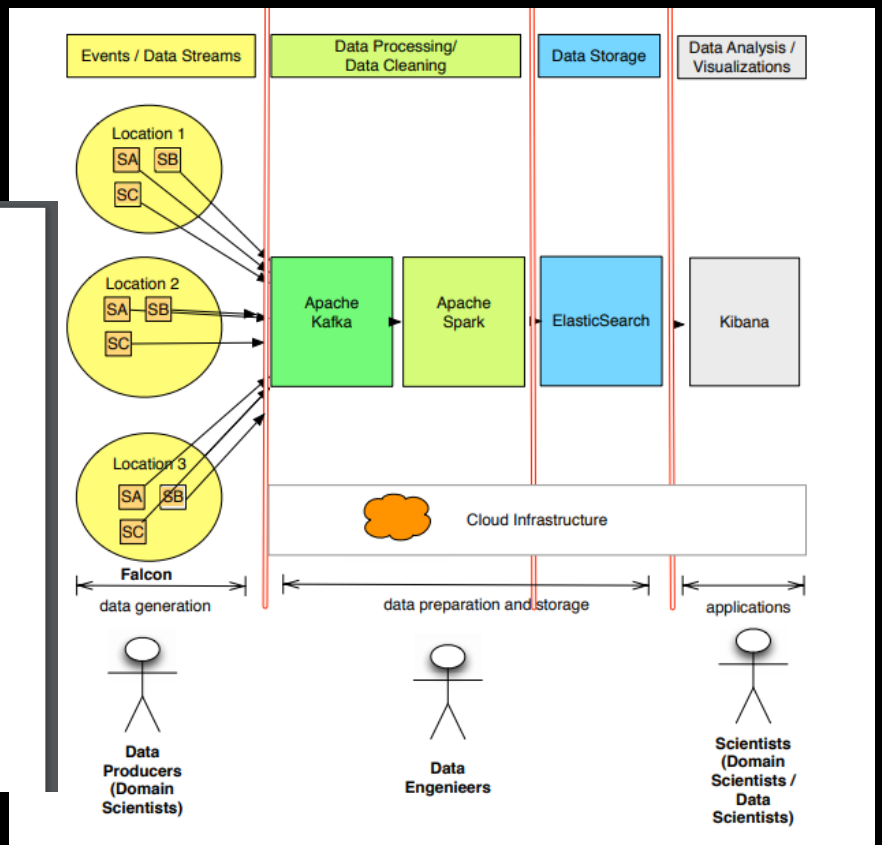

Fig. 1: IoT-Hub: Data-platform for gathering, quality checking, storing, and visualizing environmental sensors streams.

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Messy environment – messy data

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Conclusions

- UK Geoenergy Observatories is the UK's first 'geological macroscope'
- Will 'listen' to the underground, collect data, provide data to everyone for free
- Lots of new data for new science