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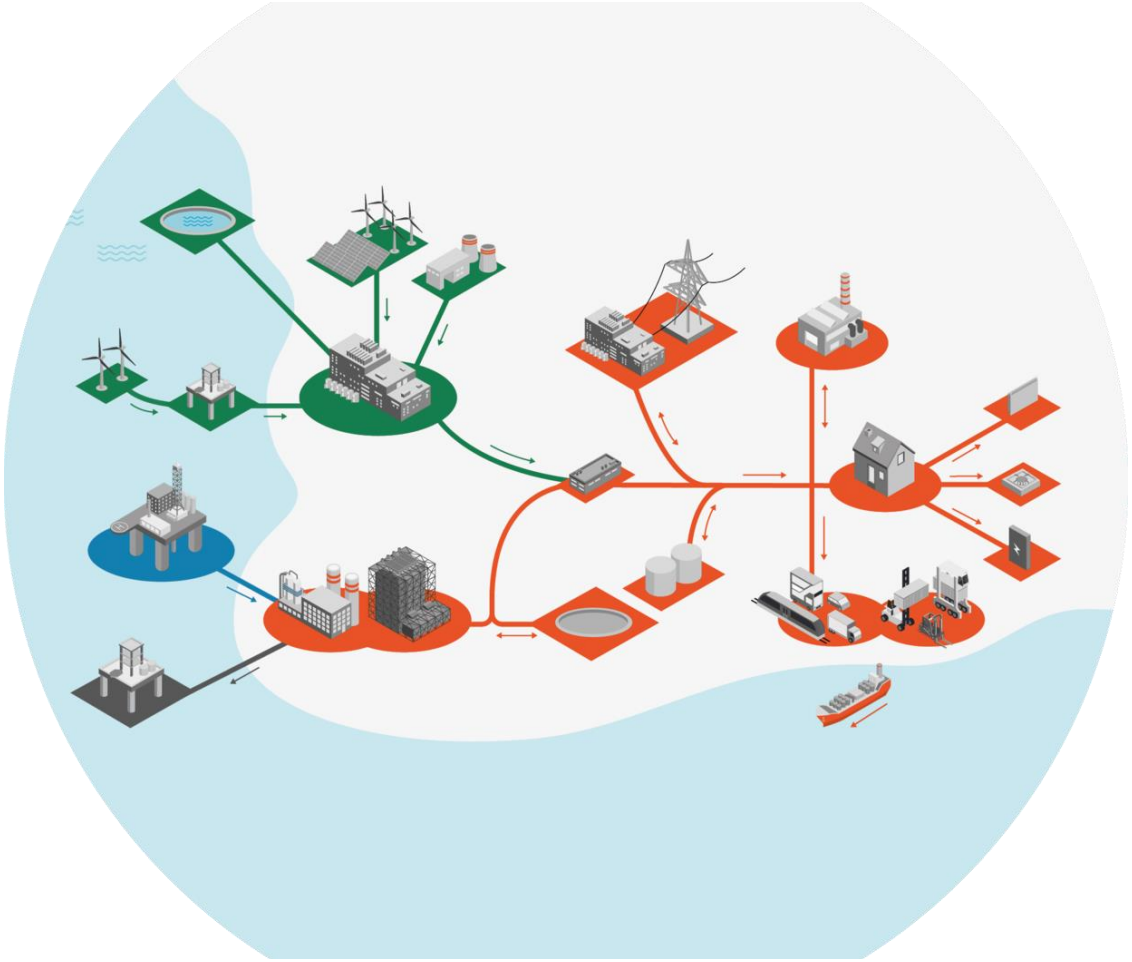

Reducing Microbial Risk During Underground Hydrogen Storage

Dr Tim Armitage

Hydrogen Consultant

Hydrogen Storage in Salt Caverns

29th March 2023

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Acknowledgements

Part of this work is extracted from the soon to be published study:

Site Selection Criteria to Reduce the Risk of Adverse Microbial Effects during Underground Hydrogen Storage in Porous Rocks

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[3] IDAEA, National Spanish Research Council

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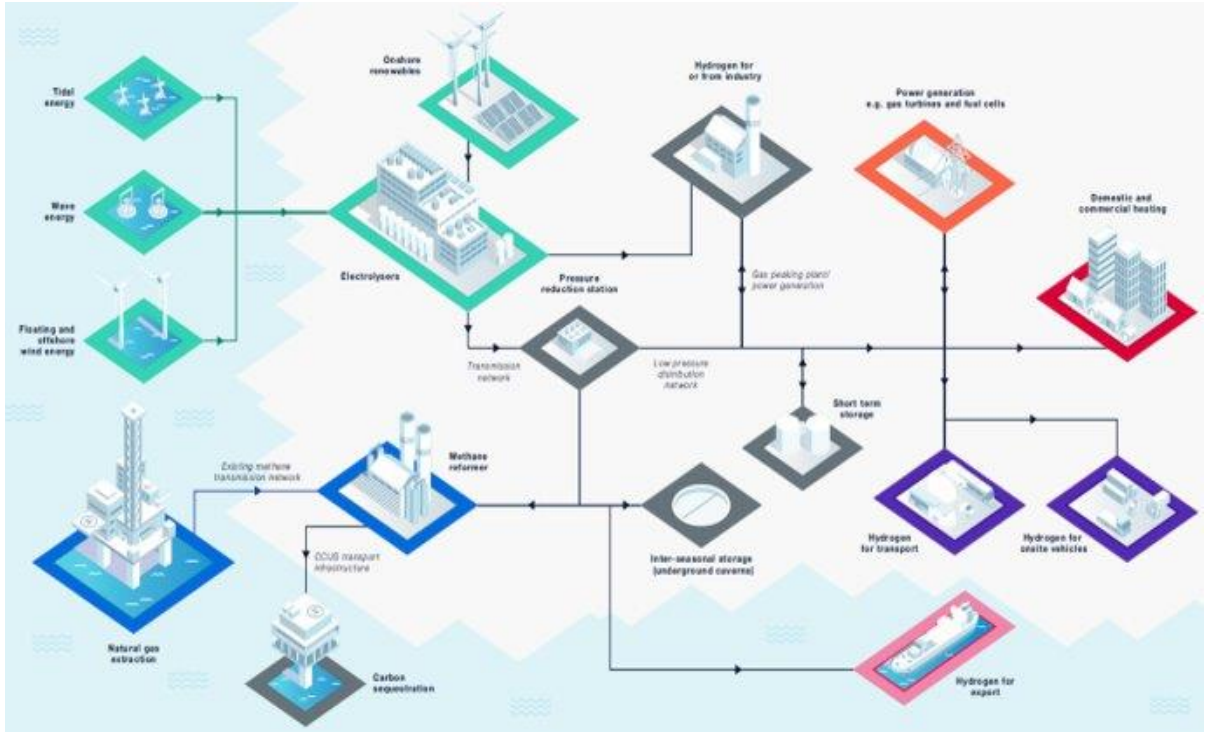
Why Arup?

Capability and Experience

The multidisciplinary nature of Arup covers the full spectrum of GeoEnergy and GeoStorage projects, from:

- Policy
- Transaction advisory
- Feasibility
- Detailed design
- Project management
- Operation
- Decommissioning and repurposing



Arup Hydrogen Projects

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Port of Auckland Hydrogen Pilot Project

New Zealand's first hydrogen energy facility, which will produce green hydrogen from electrolysis.

SGN
Your gas. Our network.

Project H100
Feasibility study determining the viability of a hydrogen gas distribution network in Scotland

Scottish Hydrogen Assessment
An assessment of the potential of using and producing hydrogen in Scotland

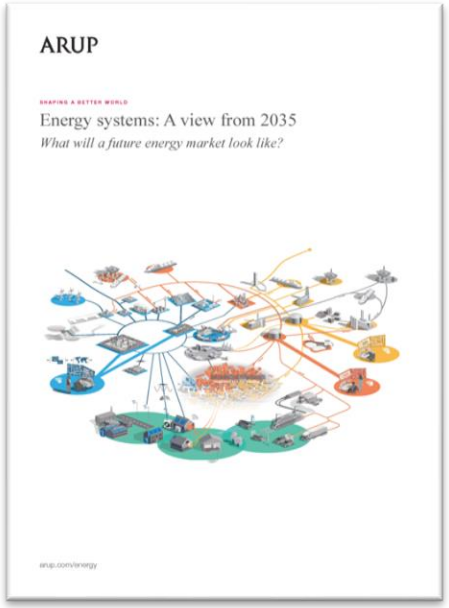
Department for Business, Energy & Industrial Strategy

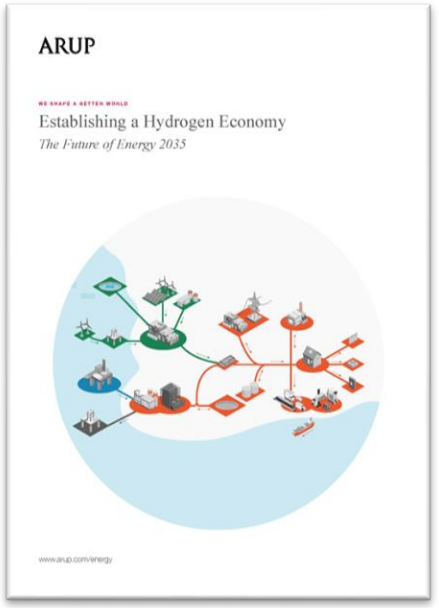
Hydrogen Grid R&D Programme
Supporting the £200m Hydrogen Grid Research & Development Programme exploring the use of hydrogen for heating

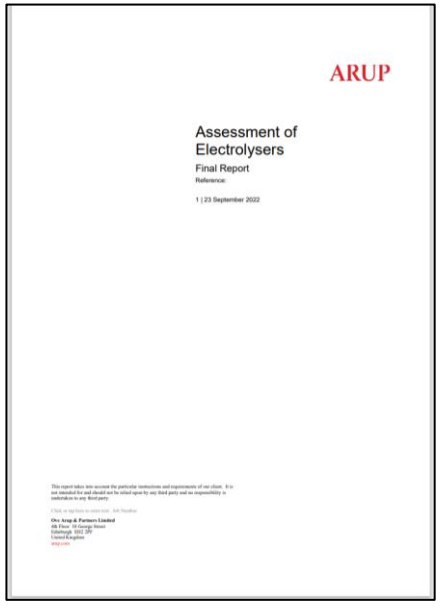
Project Cavendish
Feasibility study to examine the potential to construct a large 'blue' hydrogen production facility in Kent near London

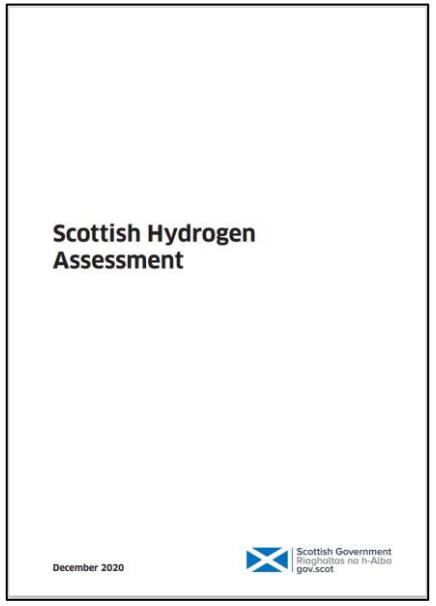
Hy4Heat

Hydrogen for Heat Programme
Managing the a £25m innovation programme on behalf of UK Govt that will demonstrate and de-risk the use if hydrogen for heating in UK homes and businesses.









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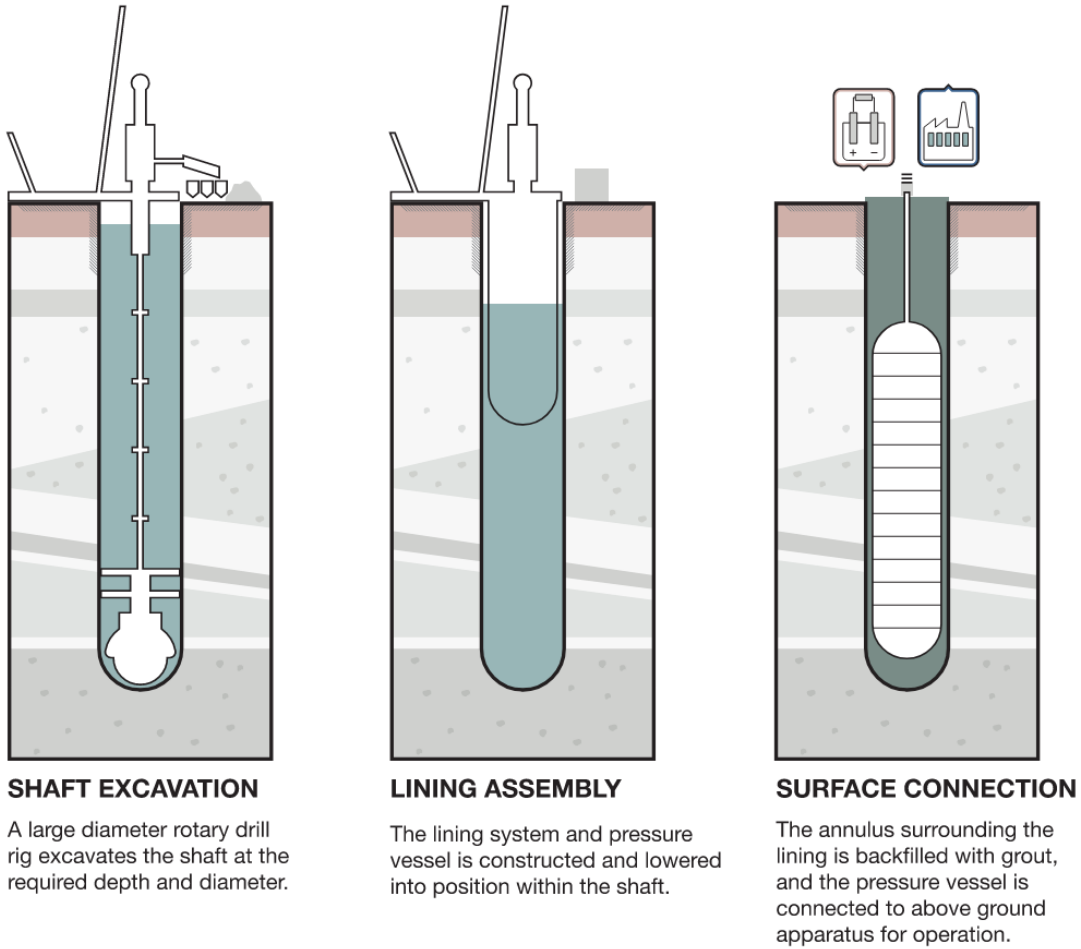
Hydrogen Storage in Lined Rock Shafts

BEIS HySupply 2 Competition – Partnership with Gravitricity

- Feasibility of storing hydrogen in purpose-built lined rock shafts
- Shaft sinking with a capping system
- Internal pressure is passed through the lining system to the rock mass, allowing high storage pressures
- Not geologically constrained
- Small above ground footprint and shaft dimensions to suit end user



SHAFT EXCAVATION

A large diameter rotary drill rig excavates the shaft at the required depth and diameter.

LINING ASSEMBLY

The lining system and pressure vessel is constructed and lowered into position within the shaft.

SURFACE CONNECTION

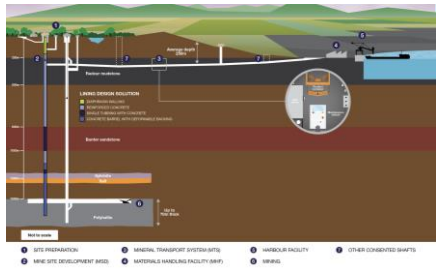
The annulus surrounding the lining is backfilled with grout, and the pressure vessel is connected to above ground apparatus for operation.

Cavern & Shaft Engineering in Evaporites

Our Experience

Jansen Project – BHP Canada

Halite and potash mine development undertaken by BHP in Saskatchewan, Canada.



Woodsmith Project – Anglo American, United Kingdom

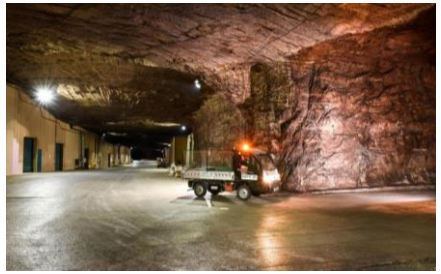
Potash mine under construction in North Yorkshire, UK. 4km of vertical shafts and 37km of tunnels and caverns.

Carrickfergus Salt Mines - DETI, NI

Arup were appointed to advise on the stability of 7 abandoned salt mines within their ownership.

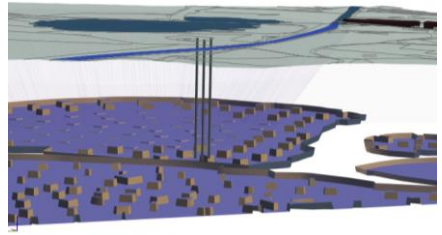
Cheshire West and Chester Council

Northwich Salt Mine stabilisation is the largest single mine infilling contract in the UK.



Winsford Salt Mine - United Kingdom

Arup were appointed to advise the Planning Authority regarding plans for duplex mining of salt at an existing salt mine.



Lion Saltworks | United Kingdom

Undertake ground investigation, assess the risk of future settlement and or instability associated with the brine extraction and mining..

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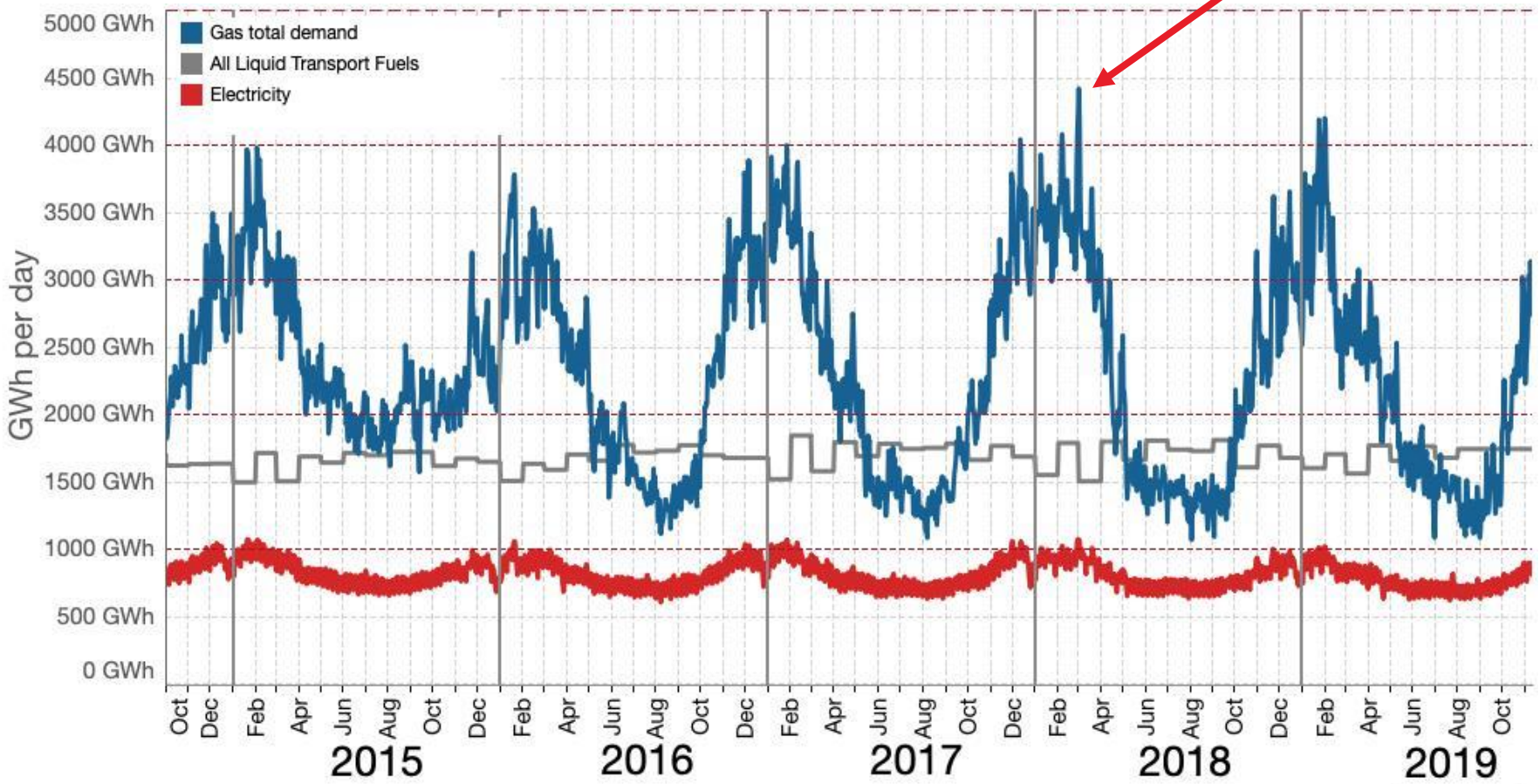
Requirement for Hydrogen Storage

Establishing the Hydrogen Economy

Beast from the East

[1]



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Underlying data are from National Grid, Elexon and BEIS
Figure created by Dr Grant Wilson: i.a.g.wilson@bham.ac.uk

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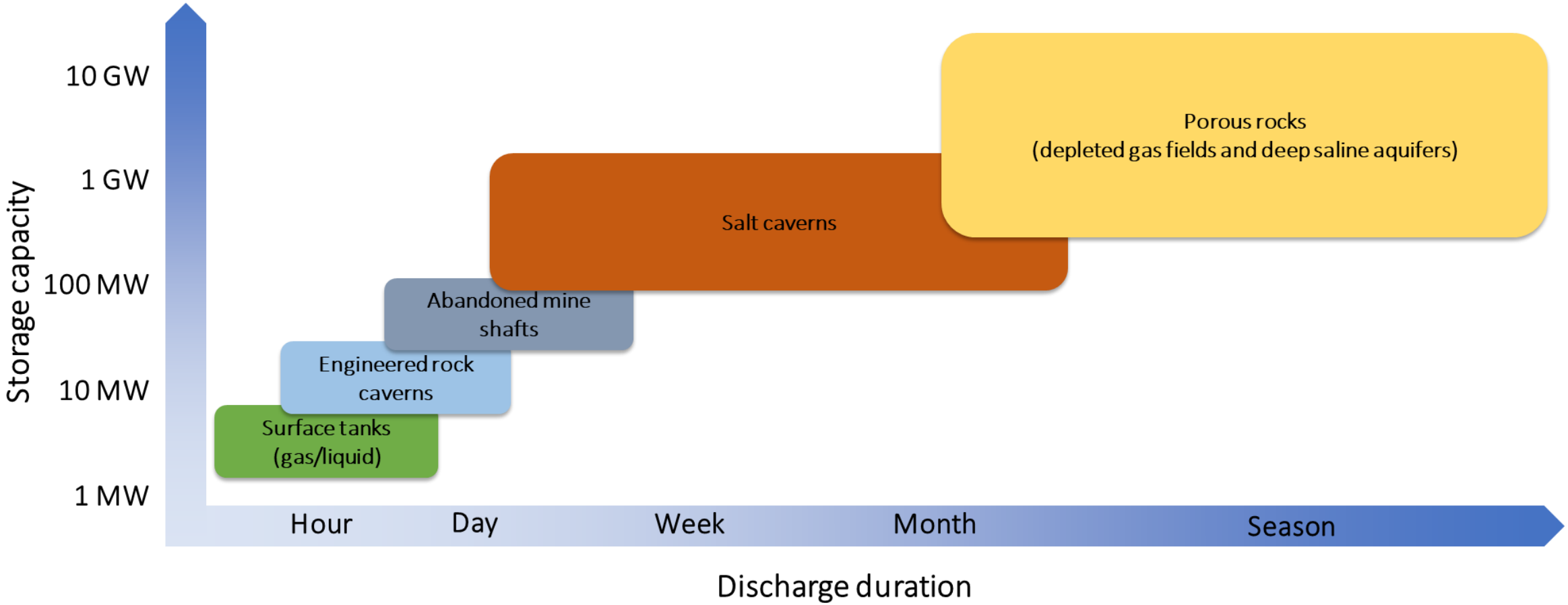
Porous Media and Depleted Gas Field



[2]

Porous Media and Depleted Gas Field

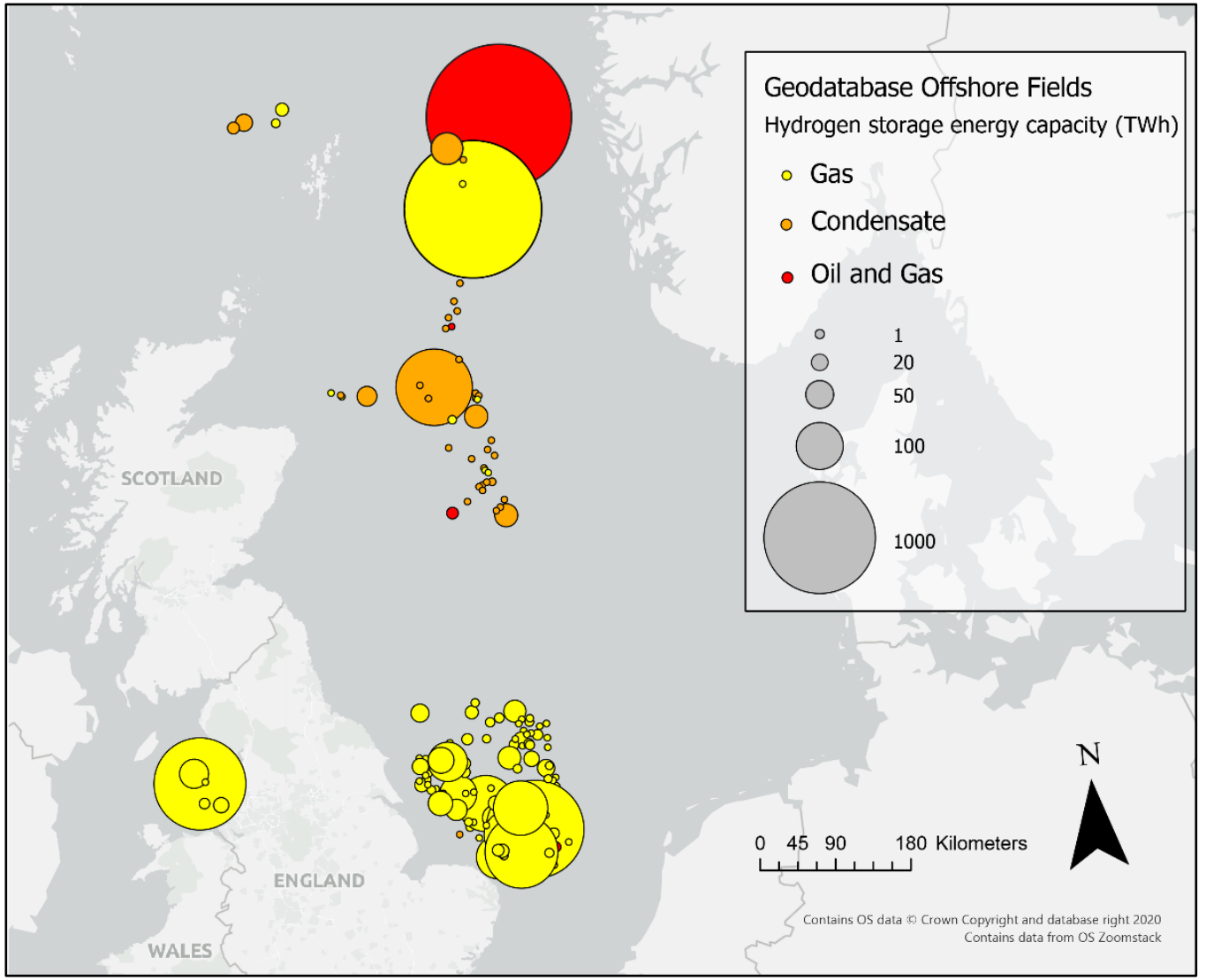
[6]

Estimated long duration energy storage needed (2035)

- 6.9 TWh [3]
- 48 TWh [4]
- 150 TWh [5]

Typical salt cavern at 500 m depth = 0.05 - 0.1 TWh [6]

- Meaning LOTS of caverns built in very short period!



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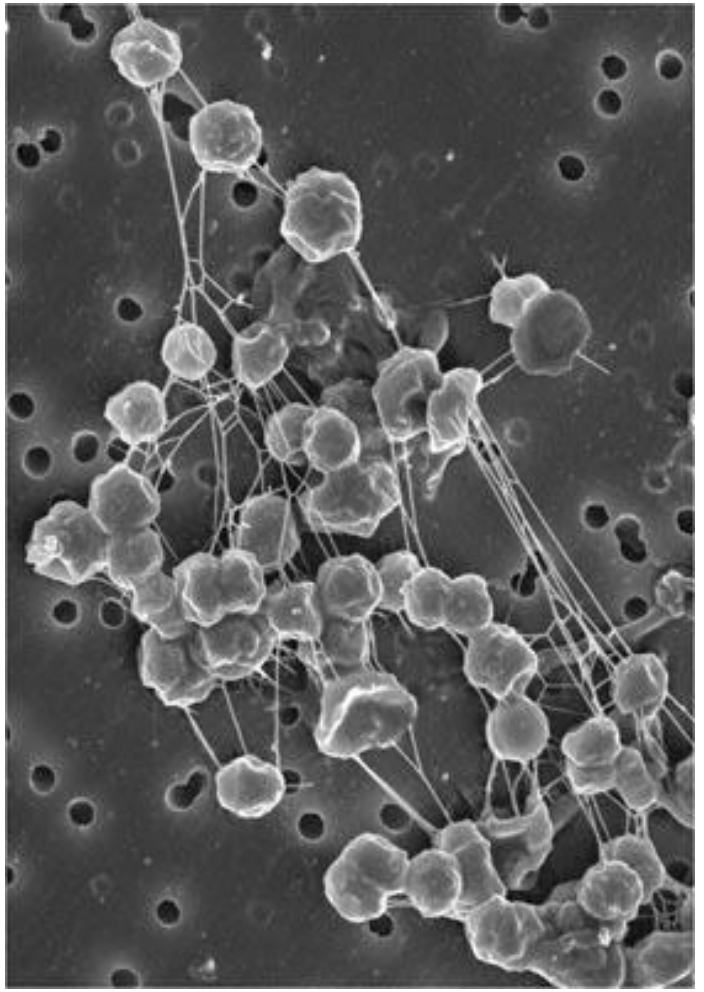
Microbial Consumption

Problems of H2-eating microbes

- Consumption of product
- Corrosion of material
- Produces hydrogen sulphide (H2S)
- Clogging of pore network and wells
- Induced geochemical precipitation



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Microbial Consumption

Methanogens

$4H_2 + CO^2 \rightarrow CH_4 + 2H_2O$

Sulphur Species Reducing Microorganisms (SSRM)

$4H2 + SO_4^{2-} + H+ \rightarrow HS- + 4H_2O$

Homoacetogens

$H_2 + CO_2 \rightarrow CH_3COOH$

Dissimilatory Iron Reducing Bacteria (DIRB)

H_2 + ferric(oxy)hydroxides → ferrous iron + H_2O

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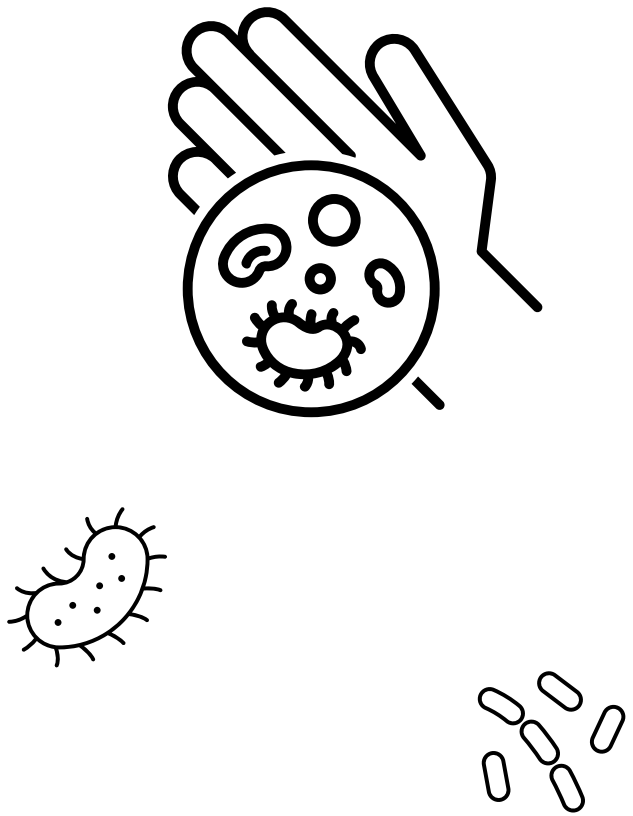
Microbial Consumption

Parameters that control microbial growth

- Temperature
- Salinity
- pH
- Pressure
- Geology
- Nutrient supply



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Depleted Gas Fields on UKCS

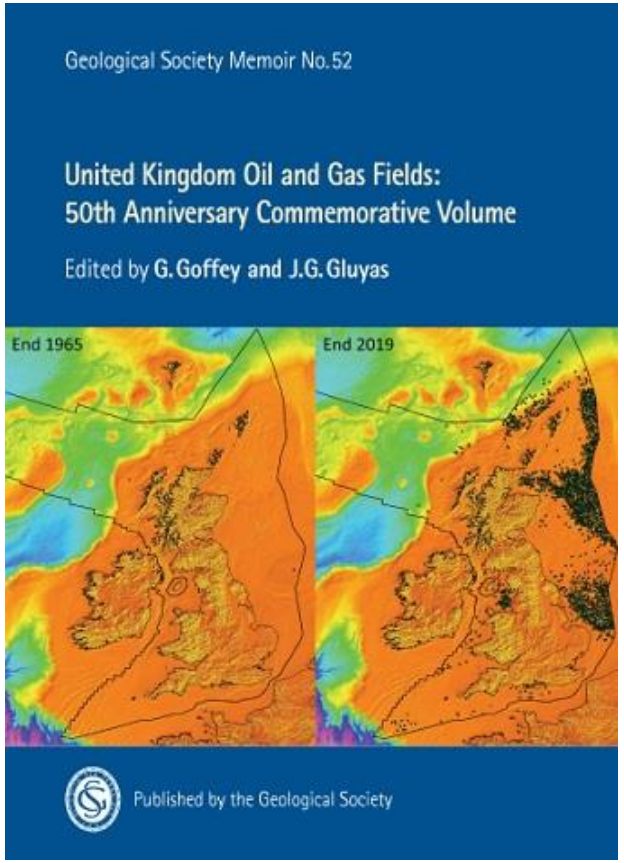
Data Collection

- Controlled for **temperature** and **salinity** for depleted gas fields on the UKCS

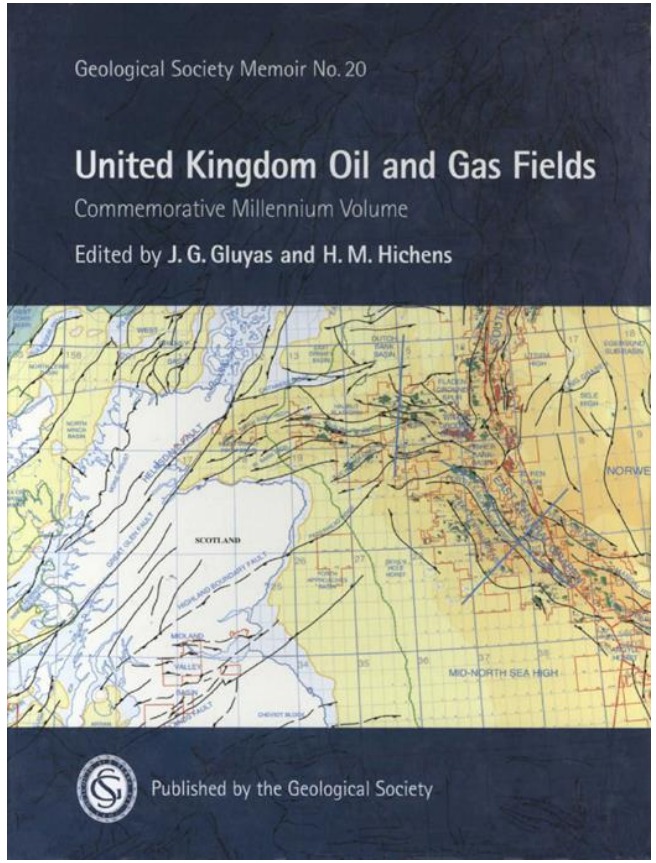
- **75/173 fields**

- By no means complete, however, gives indication of microbial risk on UKCS

[7]



[8]



Methodology

GIS-based mapping

Sterile/No Risk

Temperature > 122 °C

[7, 8, 9,]

Low Risk

Temperature >90 °C

[10, 11]

Medium Risk

Temperature >55 °C

Salinity >1.7 m NaCl

[12]

High Risk

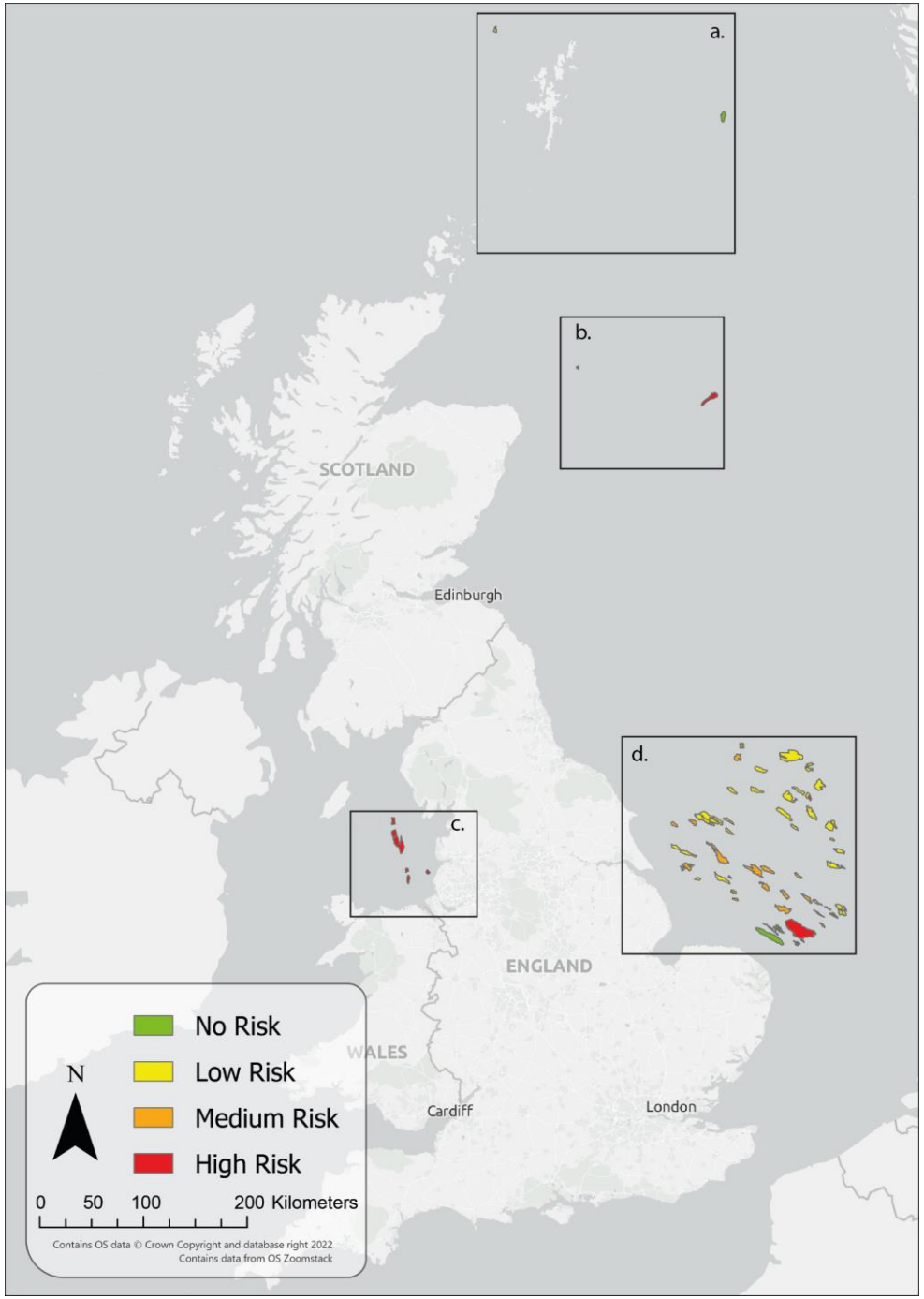
Temperature <55 °C

[7]

Results

Depleted gas field microbial risk

- Out of 75 gas fields analysed:
  - 9 No Risk/Sterile
  - 35 Low Risk
  - 22 Medium Risk
  - 9 High Risk



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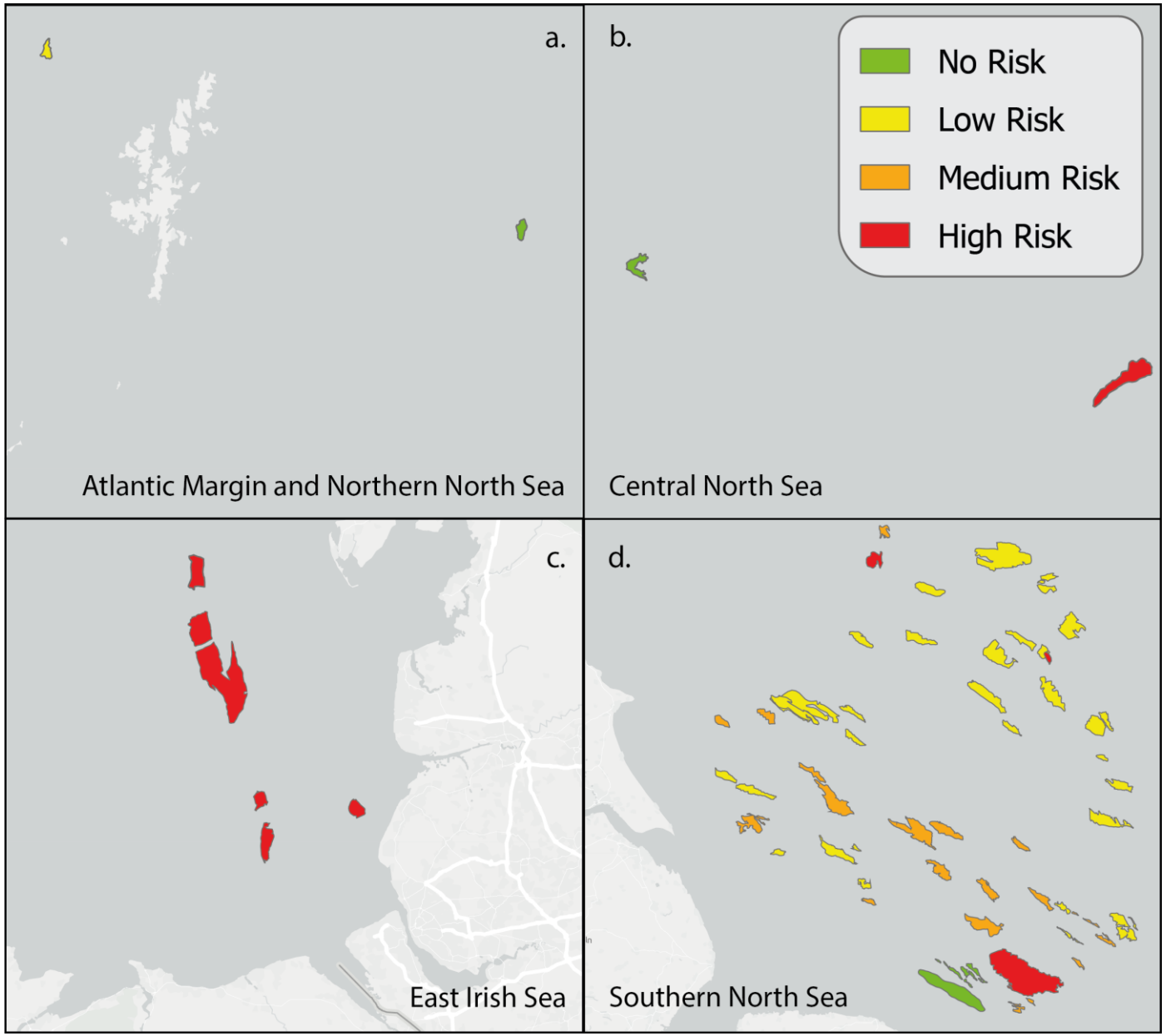
Results

Atlantic Margin, Northern, and Central North Sea

- Atlantic Margin, Northern, and Central North Sea are mainly oil fields.
- Lack of gas field data in this region.
- However, mostly high T and low salinity.



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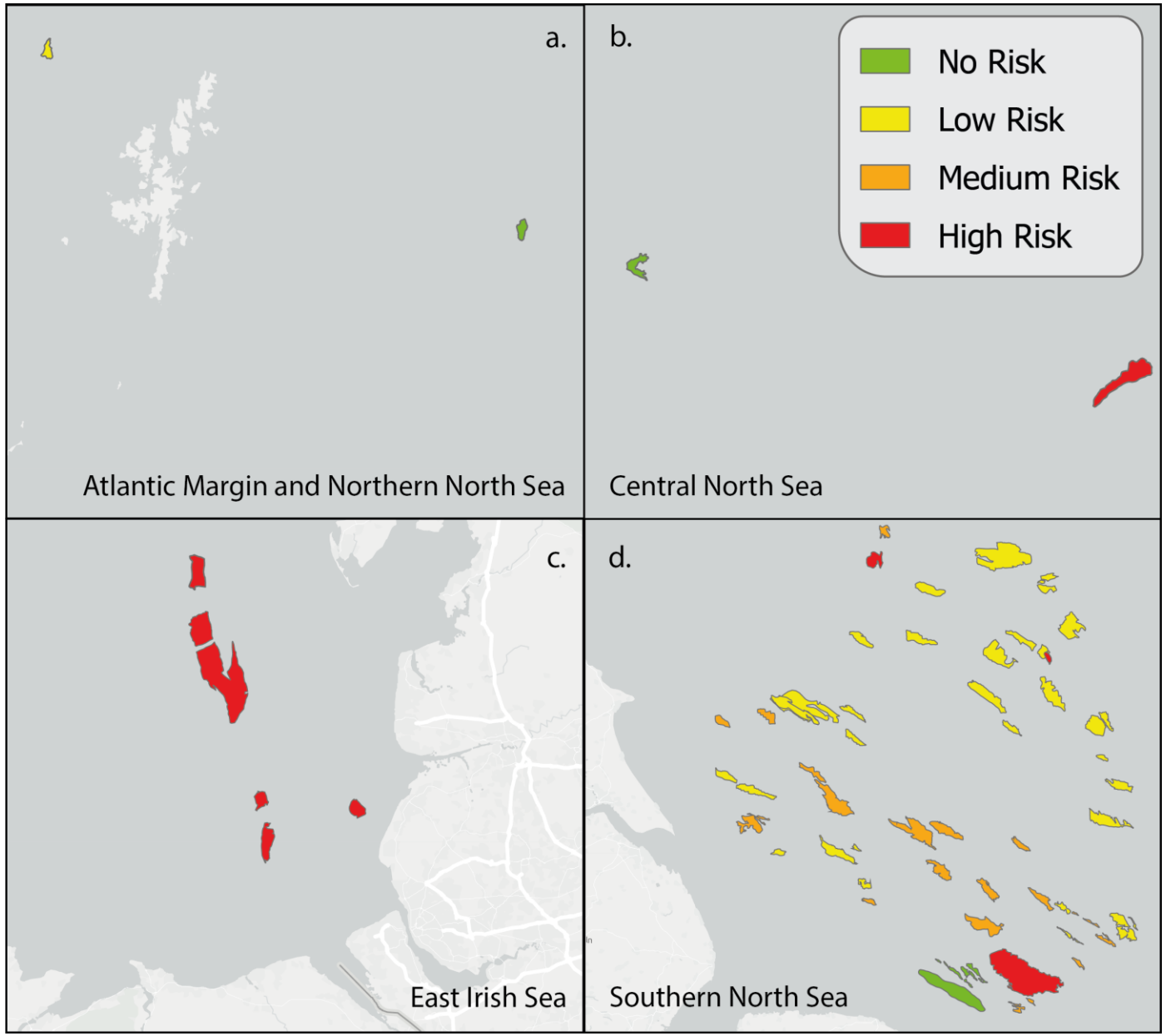
Results

East Irish and Southern North Sea

- East Irish Sea has low T (30-38 °C) and high salinity (3.4-5.1 M NaCL).
- Majority of data from SNS (65 fields), showing full range of risk.
- 7 fields No Risk, 34 Low Risk.

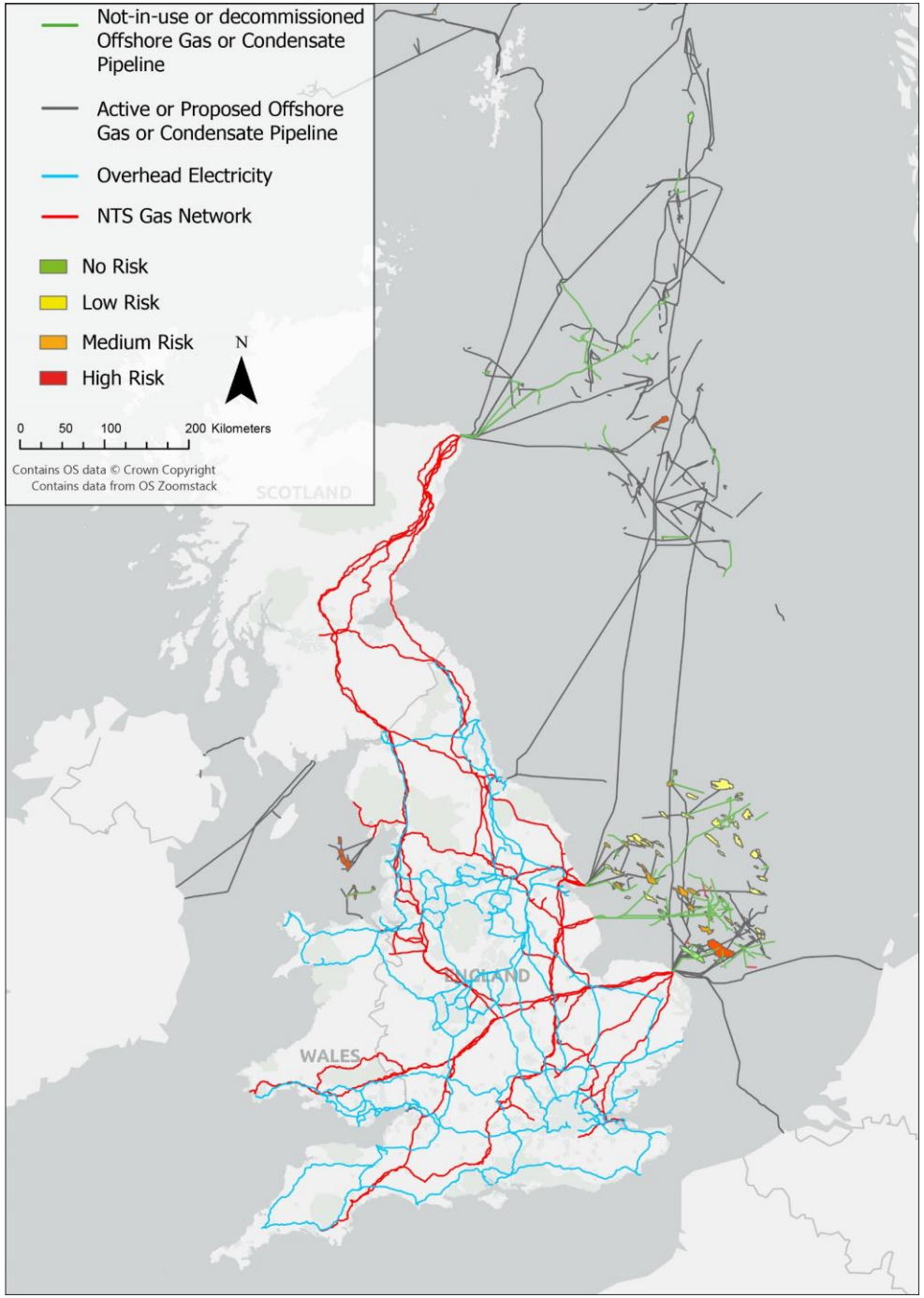


Energy Infrastructure

Context for depleted gas field microbial risk

- Repurposing offshore infrastructure

- Dense concentration of infrastructure in Southern North Sea
  - These link to No and Low Risk fields



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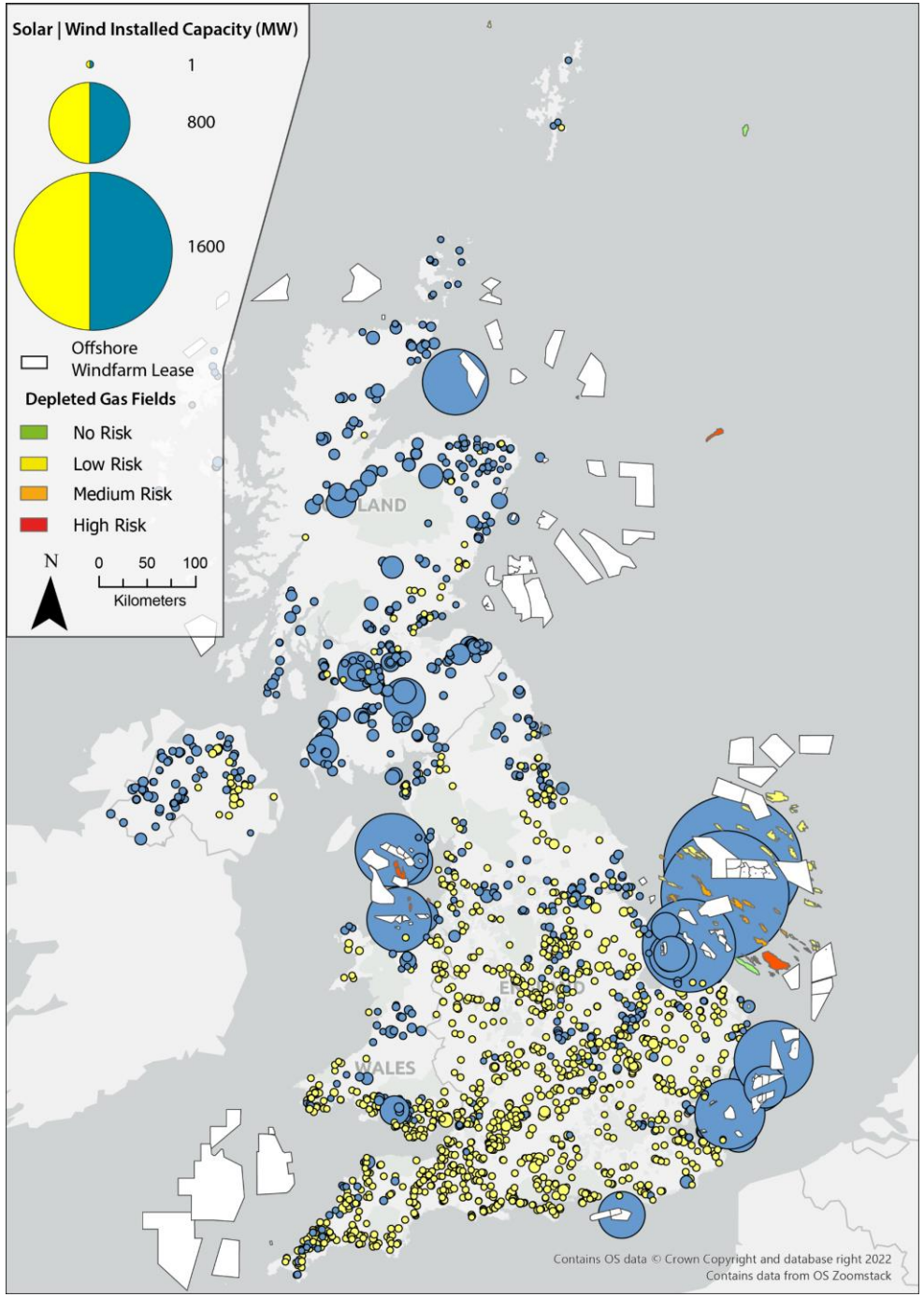
Renewable Energy

Context for depleted gas field microbial risk

- Southern North Sea has overlap of No and Low Risk gas fields and large-scale wind farms.



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Conclusions

Microbes pose a risk to hydrogen storage

Temperature and salinity can control for microbial growth

Out of 75 fields analysed, 44 are No or Low Risk

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