Department for Energy Security & Net Zero ARUP

UK Geothermal Heat and Power Cost Models - Stakeholder Survey

The Department for Energy Security and Net Zero (DESNZ), supported by Arup, are updating their electricity generation cost and heat cost in addition to technical assumptions for geothermal.

The current geothermal evidence base for costs is from 2016 and based on very limited data. The recent Geothermal White Paper by the British Geological Survey (BGS) and Arup, commissioned by the North East Local Enterprise Partnership (NELEP), has highlighted the need for a review of funding support schemes for geothermal heating projects.

This research project aims to:

- Prepare techno-economic use cases for geothermal energy in the UK;
- Research updated costs and technological developments to enable a more accurate (LCOE) calculation;
- Research costs and technological developments for geothermal in heat networks;
- Include costs for different types of geothermal systems;
- Assess the technological requirements to achieve cost reductions;
- Provide costs for geothermal systems that also include extraction of lithium and other critical minerals;
- Estimate emissions of geothermal schemes;
- Research wider system costs and benefits of geothermal schemes; and,
- Calculate the cost benefit of different funding mechanisms for supporting geothermal in heat networks.

The findings of the research will be used to update DESNZ's Levelised Cost of Energy (LCOE) and Levelised Cost of Heating (LCOH). The LCOEs inform inputs to the Department's model and will inform analysis and auction parameters for Contracts for Difference (Round 7). The analysis on geothermal for heat will feed into Heat Network Zoning policy, and the development of future support for low carbon heat networks.

The purpose of this survey is to gather stakeholder input in order to achieve the following objectives:

1. **Verify Design Assumptions:** We seek to validate the design assumptions which will be utilised in the cost models.
2. **Confirm Technology Costs:** We aim to confirm the costs associated with each specific technology. A range will be used in the models.

Data Protection and Survey Privacy Notice

- Arup (Ove Arup & Partners Limited) will hold your contact details (name and email) as the data controller where you have previously engaged with us as a user or potential user of our business services or expressed an interest in being contacted to participate in network events, sector specific consultations, surveys, and whitepapers.
- We have a legitimate interest to contact you in relation to seeking participation in the above scenario's, in this case for participation in the UK Geothermal Heat and Power Cost Models - Stakeholder Survey. There is no obligation to participate, however as a stakeholder within the industry your input would be valued and appreciated.
- Should you not wish to be contacted further about this survey, please contact Lisa.Hogarth@arup.com and your contact details will be removed from our potential participants list.
- Personal data processed as submitted in the contact form is limited to contact details (name/email address). In addition, we are also asking for confirmation of your current employer and indication of sector experience.

This information will be held for the purpose of progressing your participation the UK Geothermal Heat and Power Cost Models - Stakeholder Survey.

For the UK Geothermal Heat and Power Cost Models - Stakeholder Survey itself, Arup act as a processor on behalf of The Department for Energy Security and Net Zero (DESNZ), where you consent to participate in the survey, Arup will share anonymised and aggregated responses with (DESNZ).

- As the data controller (DESNZ) will hold survey response information for up to 7 years. Arup, as data processor, will delete any personal information collected within the survey, but will retain your contact details for our legitimate business purpose as described above.
- The Department for Energy Security and Net Zero (DESNZ) have a published privacy notice relating to consultation responses, available at Link 1.
- Your personal data will be handled in line with UK data protection legislation and managed securely. If you would like to know more, including how to exercise your rights please refer to the privacy notice of the respective data controller, for contact information held by Arup (Link 2) – and for survey response data The Department for Energy Security and Net Zero (DESNZ) (Link 1).

Please contact Lisa (Lisa.Hogarth@arup.com) for any questions/ enquiries.

1. https://www.gov.uk/government/publications/desnz-consultations-privacy-notice/privacy-notice-relating-to-consultation-responses-received-by-desnz

2. https://www.arup.com/our-firm/legal

General

1. By participating in this research, you acknowledge that you have read and understood the Data Privacy and Survey Privacy Notice provided.

   You understand that the raw information will not be publicly disclosed. The data will be aggregated to provide generic costs for the technologies outlined in this assessment.

   You agree to voluntarily take part in this study.

   Please click the box below to indicate your consent.

   Please note you can withdraw consent at any time by contacting Lisa.Hogarth@arup.com

   ☐ I consent to participate in this research
   ☐ I do not consent to participate in this research

2. Please provide your name. *

3. Who do you work for? *

4. Please provide your email address. *

5. Please confirm to which of the following stakeholder groups you belong, please tick all that apply? *

   ☐ Academia
   ☐ Client/Potential end user
   ☐ Consultants
   ☐ Contractors and supply chain
   ☐ Geothermal Developers
   ☐ Energy Companies (supply/transmission)
   ☐ Finance/ Investors
   ☐ Industry Bodies
   ☐ Policy Makers
   ☐ Regulators
   ☐ Others

6. Have you been involved in developing a geothermal project in the UK? *

   ☐ Yes
   ☐ No

7. Have you been involved in developing a geothermal project outside of the UK? *

   ☐ Yes
   ☐ No

8. If you answered 'yes' to *Q6*, which countries?

9. Are you working on a live project? *

   ☐ Yes
   ☐

_____ No

Geothermal Technologies and Auxiliary Functions

As part of this research, we are specifically considering the following geothermal technologies and auxiliary functions:

Shallow Geothermal:

1. Closed Loop
2. Open Loop
3. Aquifer Thermal Energy Storage (ATES)
4. Minewater

Deep Geothermal:

1. Deep Standing Column/Coaxial Well
2. Deep Geothermal (Hot Sedimentary Aquifer Systems and Enhanced Geothermal Systems)
3. Repurposing Oil and Gas Wells
4. Advanced Geothermal Systems (AGS)
5. Lithium

The upcoming questions will be categorised into **shallow** and **deep** geothermal systems. Each technology will have a corresponding set of design assumptions and related questions. These design assumptions serve as the context and foundation for the costing models.

You do not need to answer questions on every technology.
Please respond only to questions related to technologies you are knowledgeable about.

With regards to costing questions; costs have been categorised into Phases, as below:

- **Phase 1** (pre-construction): including design, planning, permitting, licencing, health & safety documentation, environmental studies, among others.
- **Phase 2** (ground-side capital costs): including mobilisation/de-mobilisation, drilling, installation, testing, capping/well heads, among others.
- **Phase 3** (plant-side capital costs): including ground source heat pumps, pumps, plate heat exchangers, piping & trenching, energy centre construction, tanks, among others.

Closed Loop Systems (Shallow)

This study focuses on a **heating-only closed-loop borehole array system**. We will evaluate the following system scales: **a single borehole**, a **20-borehole array**, and a **100-borehole array**.

Here are the design assumptions for each well:

- **Depth**: 150 meters
- **Borehole Diameter**: 140 mm
- **Loop Configuration**: Single U-loop
- **Tubing Material**: 40 mm HDPE/PE tubing

Additionally, we consider the following operational assumptions:

- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours**: 1800 hours
- **Coefficient of Performance (COP)** for GSHP: 3.5

Timescales to get system operational:

- **Single borehole**: 3 to 6 months
- **20-borehole array**: 3 to 9 months
- **100-borehole array**: 6 to 12 months

These design assumptions serve as the context and foundation for the costing models.

10. Do you have practical or design experience with closed loop (shallow) systems? *

    ☐ Yes
    ☐ No

11. Please share any feedback or comments regarding the design and operational assumptions.

12. Do you have any COP monitoring data which you are willing to share? If so, please provide details.

13. Please provide general standard plant requirements for various closed loop system capacities, e.g. 250KW to 1.5MW system. Details may include footprint of the energy centre, GSHPs, buffer tanks, etc.

14. What is the typical cost range for Phase 1, which includes design, permitting, and permissions?

    Indicate how costs may scale for a smaller (e.g. 250kW) and larger (e.g. 1.5MW) system.

15. What are the typical range in costs for Phase 2 (Ground side - mobilisation, drilling, installation, testing, capping)?

    Please provide a breakdown and share data where possible.

    Indicate how costs may scale for a single borehole, 20-borehole array and a 100-borehole array.

16. What are the typical range in costs for Phase 3 (Plant side - civil engineering (energy centre), buffer tanks, GSHPs, Piping, etc.)? Please provide a breakdown and share data where possible.

    Indicate how costs may scale for a smaller (e.g. 250kW) and larger (e.g. 1.5MW) system.

17. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

    ☐ Yes
    ☐ No

18. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

    ☐ Yes
    ☐ No

19. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of a closed-loop system?

20. Please let us know if you have any cost data for closed loop systems that you are willing to share while ensuring confidentiality?

    Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

    ☐ Yes
    ☐ No
    ☐ Not Applicable

Open loop system (Shallow)

This study focuses on a **heating-only single doublet (2 wells) open loop system.**

Here are the design assumptions for each well:

- **Depth**: 150 meters
- **Borehole Diameter**: 12 inches (305mm)
- **Pumping**: Electrical Submersible Pump (ESP)

Additionally, we consider the following operational assumptions:

- **Electrical Submersible Pump (ESP) Life**: 5 years
- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours**: 1800 hours
- **Coefficient of Performance (COPH)** for GSHP: 4

Timescales to get system operational: 12 to 24 months

These design assumptions serve as the context and foundation for the costing models.

21. Do you have practical or design experience with open loop (shallow) systems? *

☐ Yes
☐ No

22. Please share any feedback or comments regarding the design and operational assumptions.

23. What is the typical cost range for Phase 1, which includes design, permitting, and permissions?

24. What are the typical range in costs for Phase 2 (Ground side - mobilisation, drilling, installation, testing, well heads)?
Please provide a breakdown where possible.

25. What are the typical range in costs for Phase 3 (Plant side - civil engineering (energy centre), buffer tanks, GSHPs, Piping, etc.)?
Please provide a breakdown where possible.
Additionally, indicate how costs may scale for different system sizes, such as a 500 kW system versus a 5 MW system.

26. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

☐ Yes
☐ No

27. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

☐ Yes
☐ No

28. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of an open loop system?

29. Please let us know if you have any cost data for shallow open loop systems that you are willing to share while ensuring confidentiality?

    Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements.

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Aquifer Thermal Storage System (ATES) (Shallow)

This work considers assessment of **Aquifer Thermal Storage System (ATES)** as an operational change to an existing open loop system.

Here are the design assumptions for each well:

- **Depth**: 150 meters
- **Borehole Diameter**: 12 inches (305mm)
- **Pumping**: Electrical Submersible Pump (ESP)

Additionally, we consider the following operational assumptions:

- **System Life**: 40 years
- **Annual Operational Hours**: 1800 hours
- **Coefficient of Performance (COPH) without ATES** for GSHP: 4

These design assumptions serve as the context and foundation for the costing models.

30. Do you have practical or design experience with ATES? *

- [ ] Yes
- [ ] No

31. Do you have any ATES modelling or monitoring data with regards to Coefficient of Performance (COP) which you are willing to share? If so, please provide details.

32. Please let us know if you have any cost data for ATES that you are willing to share while ensuring confidentiality?
Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Minewater system (Shallow)

This study focuses on a **heating-only Minewater GSHP System**. We will evaluate systems up to 1km depth.

We consider the following operational assumptions:

- **Electrical Submersible Pump (ESP) Life**: 5 years
- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours (heat only plant)**: 1800 hours

Timescales to get system operational: 2 to 5 years

These design assumptions serve as the context and foundation for the costing models.

33. Do you have practical or design experience with Minewater GSHP systems? *

- [ ] Yes
- [ ] No

34. Please share any feedback or comments regarding the design and operational assumptions.

35. What is the typical cost range for Phase 1, which includes design, permitting, and permissions?

36. What are the typical range in costs for Phase 2 (Ground side - mobilisation, drilling, installation, testing, capping)?

    Please provide a breakdown where possible.

    Additionally, please indicate how costs (or scalability of costs) may vary for different depths (e.g. 100m, 300m, >500m).

37. What are the anticipated range in costs for Phase 3 (Plant side - energy centre, GSHPs, etc.)?

    Please provide a breakdown where possible.

    Additionally, indicate how costs may scale for different system sizes such as a 500kW system, versus a 5MW system.

38. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

- [ ] Yes
- [ ] No

39. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

- [ ] Yes
- [ ] No

40. What is the minimum internal rate of return (hurdle rate) required to ensure the

economic viability of a Minewater GHSP system?

41. Please let us know if you have any cost data for Minewater GSHP systems that you are willing to share while ensuring confidentiality?
Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Deep Standing Column / Coaxial Well (Deep)

This study focuses on a **heating-only vertical single standing column well (coaxial well)**. We will evaluate the following system depths **1km, 2km, 4km, 5km, and 6.5km**.

We consider the following operational assumptions:

- **Electrical Submersible Pump (ESP) Life**: 5 years
- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours**: 6000 hours
- **Surface bleed rate**: 3 l/s

Timescales to get system operational: 18 to 36 months

These design assumptions serve as the context and foundation for the costing models.

42. Do you have practical or design experience with Standing Column/ Coaxial well systems? *

☐ Yes
☐ No

43. Please share any feedback or comments regarding the design and operational assumptions.

44. What is the typical cost range for Phase 1, which includes design, permitting, and permissions?

45. What are the typical range in costs for Phase 2 (Ground side - mobilisation, drilling, installation, casing, production tubing, testing, well heads)?
Please provide a breakdown where possible.
Additionally, please indicate how costs (or scalability of costs) may vary for different depths (e.g., 1km, 2km, 4km, 5km, 6.5km)

46. What are the typical range in costs for Phase 3 (Plant side - civil engineering (energy centre), buffer tanks, GSHPs, Piping, etc.)?
Please provide a breakdown where possible.
Additionally, indicate how costs may scale for different system sizes such as a 200kW system, versus a 600kW system.

47. Do you have experience of decommissioning requirements for a deep standing column/ coaxial well?

☐ Yes
☐ No

48. If yes, please provide details.

49. If yes, what are the typical range in costs for decommissioning of a deep standing column/coaxial well system?

Please provide a breakdown where possible.

Please provide costs (or scalability of costs) for different depths (e.g., 1km, 2km, 4km, 5km, 6.5km)

50. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

- [ ] Yes
- [ ] No

51. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

- [ ] Yes
- [ ] No

52. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of a deep standing column/coaxial well?

53. Please let us know if you have any cost data for deep standing column/coaxial well systems that you are willing to share while ensuring confidentiality?
Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Deep Geothermal doublet (HSA and EGS) (Deep)

This study focuses on a **heating only and heat & power** geothermal doublet. We will evaluate the following system depths **1km, 2km, 4km, 5km, and 6.5km**. We will assess the system with and without stimulation (EGS).

Here are the design assumptions for each well:

- **Geological conditions**: UK sedimentary targets, and UK granite bodies (hard-drilling) targets
- **Pumping**: Electrical Submersible Pump (ESP)

Additionally, we consider the following operational assumptions:

- **Electrical Submersible Pump (ESP) Life**: 5 years
- **Plate Heat Exchanger (PHE) Life**: 10 years
- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours (heat only plant)**: 6000 hours
- **Annual Operational Hours (power plant)**: 8585 hours (98% capacity, c. 2-weeks annual down-time)

Timescales to get system operational: 3 to 6 years

These design assumptions serve as the context and foundation for the costing models.

54. Do you have practical or design experience with Deep Geothermal systems? *

55. Please share any feedback or comments regarding the design and operational assumptions.

56. Can you share details of deep geothermal wells you have designed or installed?

    Please provide casing diameter and depth for each casing section along well profile (vertical or inclined).

    Please outline how well design would vary depending on a sedimentary basin target, and granite target.

57. Have you undertaken well stimulation?

    ☐ Yes
    ☐ No

58. If yes, do you have measured flow rate data prior to and following well stimulation that you are willing to share or discuss?

    ☐ Yes
    ☐ No

59. If yes, what are the typical costs for undertaking well stimulation (EGS) within a deep geothermal doublet system?

60. What is the typical cost range for Phase 1, which includes design, permitting, and

permissions?

Please indicate how these costs vary between a heat only and a power system.

61. What are the typical range in costs for Phase 2 (Ground side - mobilisation, drilling, installation, testing, well heads, casing, consumables, rig operation rate, ESP, logging, etc.)?

    Please provide a breakdown where possible.

    Additionally, indicate how costs may vary at depths of 1km, 2km, 4 km, 5 km, and 6.5 km (vertical or inclined well).
    We require evidence to demonstrate how costs exhibit non-linear behavior with increasing depth.

62. For a **heat only** geothermal plant, what are the typical range in costs for a Phase 3 (Plant side - energy centre design, energy centre civil engineering and construction costs, energy centre fit out (plate heat exchangers, filters, etc.))?
    Please provide a breakdown where possible.
    Additionally, indicate how costs may scale for different system sizes such as a 5MW system, versus a 15MW system.

63. For a **Power** geothermal plant, what are the typical range in costs for a Phase 3 (Plant side - energy centre design, energy centre civils and construction costs, energy centre fit out (plate heat exchangers, filters, etc.), Organic Rankine Cycle/binary plant, cooling towers, etc.)?

    Please provide a breakdown where possible.
    Additionally, indicate how costs may scale for different system sizes such as a 1MW system, versus a 3MW system.

64. What are the typical decommissioning requirements for a deep Geothermal Doublet system?

65. What are the typical range in costs for decommissioning of a deep geothermal system? Please provide a breakdown where possible.
    Please provide costs (or scalability of costs) for different depths (e.g. 1km, 2km, 4km, 5km, 6.5km)

66. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

    ☐ Yes
    ☐ No

67. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

    ☐ Yes
    ☐ No

68. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of a deep geothermal system?

69. Please let us know if you have any cost data for Deep Geothermal systems that you are willing to share while ensuring confidentiality?
    Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

    ☐ Yes
    ☐ No
    ☐ Not Applicable

Repurposing Oil & Gas Wells (Deep)

This study considers retrofit of an oil & gas well in good condition, with minimal requirements for refurbishment. We will assess this technology at **1km**, **2km**, and **4km** depths. We will assess **two end members**, completion to a **single standing column/coaxial well**, and completion to a **deep open loop doublet** system.

We consider the following operational assumptions:

- **Electrical Submersible Pump (ESP) Life**: 5 years
- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours**: 6000 hours

Timescales to get system operational: 2 to 3.5 years

These design assumptions serve as the context and foundation for the costing models.

70. Do you have practical or design experience with Retrofitting Oil & Gas wells? *

☐ Yes
☐ No

71. Please share any feedback or comments regarding the design and operational assumptions.

72. What is the typical cost range for Phase 1, which includes design, permitting, and permissions?

73. For retrofitting to a **coaxial well/standing column well**, what are the typical range in costs for Phase 2 (Ground side - mobilisation, tubing installation, testing, capping)?
Provide a breakdown where possible.
Additionally, please indicate how costs may vary for different depths (1km, 2km, 4km).

74. For retrofitting to an **open loop doublet**, what are the typical range in costs for Phase 2 (Ground side - mobilisation, tubing installation, testing, capping)?
Provide a breakdown where possible.
Additionally, please indicate how costs may vary for different depths (1km, 2km, 4km).

75. For retrofitting to a **coaxial well/standing column well**, what are the typical range in costs for Phase 3 (Plant side - civil engineering (energy centre), buffer tanks, GSHPs, Piping, etc.)?
Provide a breakdown where possible.
Additionally, indicate how costs may scale for various plant scales, e.g. 200kW to 600kW.

76. For retrofitting to an **open loop doublet**, what are the typical range in costs for Phase 3 (Plant side - civil engineering (energy centre), buffer tanks, GSHPs, Piping, etc.)?
Provide a breakdown where possible.
Additionally, indicate how costs may scale for various plant scales, e.g. 500kW to 1MW.

77. What are the typical decommissioning requirements for a Repurposed Oil & Gas well?

78. What are the typical range in costs for decommissioning a Repurposed Oil & Gas well? Please provide a range in costs for different depths: 1km, 2km, 4km.

79. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

- [ ] Yes
- [ ] No

80. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

- [ ] Yes
- [ ] No

81. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of a repurposed Oil & Gas well system?
Please provide data for a standing column well/ coaxial well geothermal system, and an open loop doublet system.

82. Please let us know if you have any cost data for a Retrofitted Oil & Gas well system that you are willing to share while ensuring confidentiality?
Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Advanced Geothermal System (AGS) (Deep)
This study focuses on a **heating-only Advanced Geothermal System**. We will evaluate the following system depths **1km, 2km, 4km, 5km, and 6.5km**.

We consider the following operational assumptions:

- **Electrical Submersible Pump (ESP) Life**: 5 years
- **Ground-Source Heat Pump (GSHP) Life**: 15 years
- **System Life**: 40 years
- **Annual Operational Hours (heat only plant)**: 6000 hours
- **Annual Operational Hours (power plant)**: 8585 hours (98% capacity, c. 2-weeks annual down-time)

These design assumptions serve as the context and foundation for the costing models.

83. Do you have practical or design experience with Advanced Geothermal Systems (AGS)? *

☐ Yes
☐ No

84. Please share any feedback or comments regarding the design and operational assumptions.

85. Please provide details of AGS anticipated energy capacity outputs, please include a range in capacity for various depths (namely 1km, 2km, 4km, 5km, 6.5km)

86. What is the typical cost range for Phase 1, which includes design, permitting, and permissions?

87. What are the typical range in costs for Phase 2 (Ground side - mobilisation, drilling, installation, testing, capping)?
Please provide a breakdown where possible.
Additionally, please indicate how costs (or scalability of costs) may vary for different depths (1km, 2km, 4km, 5km, 6.5km).

88. For a **Heat only** Advanced Geothermal System, what are the anticipated range in costs for Phase 3 (Plant side - energy centre design, energy centre civil engineering and construction costs, energy centre fit out (plate heat exchangers, etc.)?
Please provide a breakdown where possible.
Additionally, indicate how costs may scale for different system sizes such as a 5MW system, versus a 15MW system.

89. For a **Power** Advanced Geothermal System, what are the anticipated range in costs for Phase 3 (Plant side - energy centre design, energy centre civil engineering and construction costs, energy centre fit out (plate heat exchangers, etc.), Organic Rankine Cycle/binary plant, cooling towers, etc.)?
Please provide a breakdown where possible.
Additionally, indicate how costs may scale for different system sizes such as a 1MW system, versus a 3MW system.

90. What are the anticipated decommissioning requirements for an Advanced Geothermal System?

91. What are the anticipated range in costs for decommissioning of an Advanced

Geothermal System?

Please provide a breakdown where possible.

Please provide costs (or scalability of costs) for different depths (1km, 2km, 4km,

5km, 6.5km)

92. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

- [ ] Yes
- [ ] No

93. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

- [ ] Yes
- [ ] No

94. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of an Advanced Geothermal System?

95. Please let us know if you have any cost data for deep standing column/coaxial well systems that you are willing to share while ensuring confidentiality?
Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Lithium (Deep)

This study considers **Lithium** as an **auxiliary component** to an **existing deep geothermal system**.

We consider the following technical assumptions:

- **Lithium brine concentrations**: 50 mg/l, 150mg/l, and 300 mg/l
- **Process flow rates**: 10 l/s, 25 l/s, 50 l/s
- **End Product**: Battery grade Lithium Carbonate (Li2CO3)
- **Plant equipment Life**: assume 100% replacement at end of life
- **System Life**: 40 years
- **Annual Operational Hours (power plant)**: 8585 hours (98% capacity, c. 2-weeks annual down-time)

Timescales to design, construct and commission lithium plant: 3 to 5 years

These design assumptions serve as the context and foundation for the costing models.

96. Do you have practical or design experience with Geothermal Lithium extraction? *

☐ Yes
☐ No

97. Please share any feedback or comments regarding the design and operational assumptions.

98. Please provide a general process workflow for your proposed direct lithium extraction technique.

99. Considering the lithium plant only, what is the additional typical cost range for Phase 1, which includes design, permitting, and permissions?

100. Considering the lithium plant only, what are the typical range in costs for Phase 2 (Plant - tanks, piping etc.).

Provide a breakdown where possible.

Please provide costs (or scalability of costs) for various plant scales (e.g., Low production of 10 l/s with 50mg/l Li brine; and High production of 50 l/s with 300 mg/l Li brine)

101. What are your anticipated annual operational costs and plant replacement costs and equipment life?

102. For each stage stage of the lithium extraction process please provide indicative operational power requirements to run a plant of various scales? (e.g., Low production of 10 l/s with 50mg/l Li brine; and High production of 50 l/s with 300 mg/l Li brine).

Please provide a breakdown per plant equipment where possible.

103. Have you undertaken a Whole Life Carbon (WLC) assessment on a geothermal energy project considering aspects such as construction, operation, and decommissioning phases?

☐ Yes
☐ No

104. If yes, are you willing to share or discuss your Whole Life Carbon (WLC) assessment?

- [ ] Yes
- [ ] No

105. What is the minimum internal rate of return (hurdle rate) required to ensure the economic viability of a geothermal Lithium extraction system?

106. Please let us know if you have any cost data for a geothermal lithium system that you are willing to share while ensuring confidentiality?

Note. We are happy to engage with you and discuss Non-Disclosure Agreements (NDAs) or any other requirements. *

- [ ] Yes
- [ ] No
- [ ] Not Applicable

Finally.

107. After reviewing the responses, Arup and DESNZ may contact some participants for further discussion. Would you be open to discussing this research further?

- [ ] Yes
- [ ] No

108. Please let us know if you have any further comments?