Report No. SPIRE20150630 Provided by Gaelectric Energy Storage Ltd to University of Ulster June 2015. Project SPIRE. University Ref project_13574. This report constitutes Commercially Sensitive Information and Confidential Information as defined in the contract between University of Ulster and Gaelectric Energy Storage Ltd dated 30th September 2013.

Gaelectric Energy Storage Ltd

PROJECT SPIRE: EXPLORATORY DRILLING FOR CAES WITHIN THE CBT AREA

FINAL REPORT TO UNIVERSITY OF ULSTER

19TH JUNE 2015

Executive Summary

Project SPIRE, a joint initiative between University of Ulster and Dundalk Institiute of Technology, aims to determine the energy storage technologies best suited to meeting the needs of the Cross-Border Territory (Ireland-Northern Ireland). Project SPIRE is funded by the European Union's INTERREG IVA Programme which is managed by the Special EU Programmes Body.

University of Ulster (UU), as lead partner of Project SPIRE, has contracted Gaelectric Energy Storage Ltd (GES) to provide drilling and related services to the project, the purpose being to assess the geological potential for compressed air energy storage (CAES) in the CBT.

The study has concluded that the Larne Halite Member is capable of hosting caverns for CAES and 3 caverns with a working net volume of 560,000m3 are required to operate a 268MW CAES plant with 6 hours production and an efficiency of 52.5%.

1 Introduction

Project SPIRE, a joint initiative between University of Ulster and Dundalk Institute of Technology, aims to determine the energy storage technologies best suited to meeting the needs of the Cross-Border Territory (Ireland-Northern Ireland). Project SPIRE is funded by the European Union's INTERREG IVA Programme which is managed by the Special EU Programmes Body.

University of Ulster (UU), as lead partner of Project SPIRE, contracted Gaelectric Energy Storage Ltd (GES) to provide drilling and related services to the project, the purpose being to assess the geological potential for compressed air energy storage (CAES) in the CBT.

This document represents the final report on work conducted by GES for the project.

University of Ulster (UU), as lead partner of Project SPIRE, contracted Gaelectric Energy Storage Ltd (GES) to provide the following services:

Activity #	Detail
1.	Geological, geophysical and geotechnical data and reports providing the basis for selection of (a) sites for drilling to confirm salt deposit characteristics for CAES and (b) potential locations for CAES caverns.
2.	Selection of appropriate sites for drilling.
3.	To allow (a) drilling and geophysical surveys within the CBT salt deposits area (b) laboratory testing of drill core samples and (c) the use of results from laboratory testing for the purposes of the SPIRE project.
4.	To secure agreements to allow surface access for drilling and geophysical equipment.
5.	To ensure compliance of drilling programme with Statutory requirements
6.	Drill core for laboratory testing for the purposes of Project SPIRE
7.	Orientation studies to select the most appropriate downhole geophysical techniques.
8.	Drilling: 2 x diamond drill holes, each of total depth 800-900m to provide PQ (3.4 inch diameter) drill core for laboratory testing
9.	Drilling supervision, core logging, supervision of geophysical surveys; core handling, storage and transport
10.	Downhole geophysical surveys to establish salt characteristics for the purposes of Project SPIRE
11.	Core analysis, leach testing and rock mechanical testing to determine salt characteristics for solution mining, cavern design and operation parameters.
12.	Cavern design and CAES technical feasibility study based on results of the above.
13.	Surface plant engineering design and optimisation work based on salt characteristics and cavern design.
14.	Infrastructure studies based on the results of the geological and geotechnical work outlined above.
15.	Operational data and optimisation studies of CAES plant based on results of the above for input to Project SPIRE modelling of CAES in the Single Electricity Market.

The time frame for delivery is set out in the following table:

Activity	Deliverable		Date Due	Date Delivered (by agreement with UU)
1-3	1	Review of CAES salt strata projects reviewing engineering constraints and how these were evaluated	31st October 2013	31st October 2013
4-9	2	Drilling completed	31st January 2014	31st May 2014
10	3	Downhole geophysics and interpretation completed and reported	30th June 2014	30th June 2014
11, 12	4	Rock Mechanics and residual rock/salt analysis and reported	31st October 2014	30th September 2014
14, 15	5	Plant Design and optimisation and reported	31st December 2014	30th November 2014
1-15	6	All final reports to be submitted	30th June 2015	19th June 2015

2 Summary of previously reported activities and results

Initial studies of the geology of the CBT, interpretation of seismic data and CAES system requirements available at commencement of the project confirmed that the Larne Region has unique potential for CAES on the island of Ireland and identified Carnduff, approximately 1km south of Larne town, as an optimum drilling location with expectation of the target Larne Halite Member (LHM) to have a vertical thickness of approximately 300m, with potential to host caverns suitable for CAES.

GES conducted drilling of two boreholes at Carnduff and geophysical surveys including acoustic televiewer, natural and spectral gamma, neutron, density, sonic, resistivity, conductivity and temperature. In addition, a borehole ground penetrating radar (GPR) survey was conducted in Carnduff No 1 and borehole seismic surveys were conducted in Carnduff No. 2 with the objective of identifying igneous intrusions that may present an obstacle to cavern development. Nitrogen injection tests and a permeability test were carried out in Carnduff No. 2 to assess the rock strength and pressure regime within the LHM and the permeability of mudstone interbeds.

The drilling programme was successful in intersecting 340m of the LHM in Carnduff No 1 (some 40m thicker than anticipated from the interpreted seismic data) and 370m in Carnduff No 2.

While the results of the GPR survey in Carnduff No. 1 were inconclusive due to low radar penetration into the sidewall, the multi-offset vertical seismic profile (VSP) in Carnduff No. 2 successfully identified steeply dipping reflectors which could be tied to two observed dolerite intrusions in both boreholes.

The nitrogen injection and permeability tests indicated that the LHM at Carnduff has sufficient lithostatic pressure, rock strength of the salt and extremely low permeability of mudstone to allow successful construction and operation of CAES caverns.

Leaching tests of the salt unit were carried out on samples selected at several intervals from Carnduff No. 1 core. Insoluble content and leaching velocities provided input to initial cavern design. Results indicated a relatively high insoluble content of 25% vol. with a high bulking factor of 2.3, reducing to < 2.0 over some days. The results of the leaching test were carried through to leaching simulation which indicated that an individual cavern volume of 150,000m3 is achievable. Solution mining simulations indicated the potential to create caverns of at least this volume, although the relatively high insoluble content would necessitate frequent workovers during solution mining process.

Rock mechanical tests including triaxial compressive tests and direct shear tests and an assessment of creep behaviour were conducted on samples of the LHM. The behavioural characteristics of a 3m thick layer of mudstone were assessed as a potential weak element of the load bearing system. Results were positive in indicating sufficient rock strength of the LHM to support CAES cavern creation and operation.

Thermodynamic simulations, based on the results of the leaching and rock mechanical tests, indicated that three caverns with a net storage volume per cavern of 150,000m3 would be required to operate a CAES facility with generation capacity of 268 MW for 6 hours at maximum output and that the required pressure cycles between 80 and 60 bar are well within the safe cavern operation parameters of 80 to 100 bar.

Continued optimisation studies considering the geological conditions and CAES plant requirements increased the total required net storage volume to 560,000m3 in order to ensure cavern integrity during operation. The required net volume can be achieved with two off caverns at 230,000m3 and one off cavern at 100,000m3. Plant efficiency of the Dresser Rand SmartCAES technology may reduce from 52.94% to 52.5% due to the higher pressures required at this location.

A three-dimensional model based on the drilling and VSP data provided an achievable and safe arrangement for three operating CAES caverns of the required volume at Carnduff, within parameters dictated by geological conditions and surface plant layout.

Results of the drilling and laboratory testing programmes indicate that the CAES production wells and caverns would have a structurally stable operational lifespan of at least 50 years.

3. Infrastructure studies

Electricity Grid Connection

TNEI, on behalf of the System Operator Northern Ireland, conducted a grid connection feasibility study, contracted by GES. This identified a number of connection options (Figure 1, Appendix). Connection to the 275kV substation at Ballylumford was identified as preferable in terms of environmental impact (overhead lines versus underground), technical issues and cost. Conclusions are summarised in Table 1 of the Appendix to this report.

Gas Supply

GES subcontracted Premier Transmission Ltd to conduct a feasibility study for connection to gas supply. The connection options are located on Islandmagee. A number of corridor routes were identified and ranked in terms of environmental impact. Results are summarised in Table 2 of the Appendix to this report.

Solution Mining Infrastructure

Consideration of water supply and brine disposal needs led to identification of preferred intake and brine disposal locations and associated pipelines. Seawater can be used for the solution mining process and a suitable location was identified north of the port of Larne. A potential site for brine disposal was identified offshore to the northeast of Islandmagee, which would allow rapid dispersal of brine due to fast-flowing currents at the location. Relevant figures are presented in the Appendix.

Access to infrastructure

The infrastructure studies outlined above show that access to electricity grid, gas supply and brine disposal to/from the drilling site at Carnduff all require crossing Larne Lough which has SPA and ASSI designations. Under contract to GES, ARUP and LMR Drilling UK Ltd have identified potential solutions to connect these infrastructure elements via horizontal directional drilling. Potential HDD routes are shown in the Appendix.

4. Conclusion

The drilling and related activities of Project SPIRE have successfully demonstrated the feasibility to create storage caverns in the Larne Halite Member for the long-term operation of a compressed air energy storage facility in the Larne region of the CBT. The installed storage capacity of such a facility would be at least 6 hours at maximum generation output of 268 MW, i.e. 1.6 GWh.

Infrastructure studies have indicated a number of route options for connection to electricity grid, gas supply, water supply and brine disposal. Environmental, technical and economic considerations indicate preferred connection routes.

This successful demonstration allows for definition and refinement of an appropriate regulatory framework for flexible, large scale energy storage in the All-Island system. Thus the results of the project can provide the basis for a business case for the first CAES facility in Europe to be optimised for the integration of high levels of variable renewable generation, to be implemented in the CBT. This has significant demonstrator impact for CAES projects under consideration in Europe and worldwide.

In addition, this first-ever demonstration that CAES caverns can be safely created and operated in bedded salt deposits with relatively high content of insoluble material substantially broadens the geological potential for deployment of CAES at many locations across Europe. This will help to promote the widespread commercial deployment of CAES, which will in turn incentivise technology improvements to increase efficiency of the technology and reduced costs.

Results have been achieved and reported within the time schedule agreed by University of Ulster. While costs associated with this element of Project SPIRE have exceeded the initial projection, the excess has been absorbed by the contractor, Gaelectric Energy Storage Ltd, allowing the contract to be completed within budget.

APPENDIX

Tables and figures on infrastructure studies: Transmission, gas and solution mining infrastructure