Calgary Geothermal Workshop

Tuesday, May 14, 2024
Calgary, AB

Workshop Program and Abstract Book

energi SIMULATION

GeoS
ENERGI SIMULATION CENTRE FOR GEOTHERMAL SYSTEMS RESEARCH

UNIVERSITY OF CALGARY

This is the digital publication of the conference program with abstracts
for the 2024 Calgary Geothermal Workshop.

Presentations may be found at:
`https://ucalgary.ca/labs/geothermal-energy/industry-partnerships/2024-workshop`

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Contents

Welcome

Evolving from the **Geothermal Energy Laboratory** launched in 2021 at the University of Calgary, the **Energi Simulation Centre for Geothermal Systems Research** was established in 2022 under a transformative investment in research funding from **Energi Simulation**.

The morning's agenda will include technical updates on work being conducted by researchers at the University of Calgary, followed by technical presentations from members of industry and a discussion of new research directions and opportunities in the afternoon.

The workshop will be chaired by Dr. **Apostolos Kantzas** and Dr. **Aggrey Mwesigye** co-leads of the **Energi Simulation Centre for Geothermal Systems Research (GeoS)** and members of the Chemical and Petroleum Engineering and Mechanical Engineering Department at the University of Calgary, while moderated in parts by Dr. **Roman J. Shor**, previous director of the center and now a member of Texas A&M University.

Academic Leadership Team

Dr. **Apostolos Kantzas** is a professor in the Department of Chemical and Petroleum Engineering at the University of Calgary and held a Canada Research Chair (CRC) in Energy and Imaging and is currently an Industrial Research Chair (IRC) in Fundamentals of Unconventional Resources. Dr. Kantzas has extensive experience with transport phenomena in porous media and is a co-director of the GeoS center.

Dr. **Aggrey Mwesigye** is an assistant professor in Mechanical Engineering Department and the co-director of GeoS and has broad research interests in the modeling, design, and optimization of sustainable thermal energy systems. Current research focuses on concentrating solar thermal systems, alternative heating and cooling systems, including geothermal, heat transfer enhancement, thermodynamic optimization, and thermal energy storage.

Timetable

Overview

8:00–8:30	**Breakfast & Coffee**	
8:30–8:50	**Opening Remarks**	
8:50–10:30	CT	**Technical Talks**
10:30–11:00	**Coffee Break**	
11:00–12:00	CT	**Technical Talks**
12:00–13:00	**Lunch**	
13:00–16:00	IS	**Industry Talks**
16:00–16:15	**Closing Remarks**	
16:15	**Energy Beers at The Banquet, University District**	

CT: Contributed Talk, IS: Invited Speaker, KL: Keynote Lecture

Technical Program

Presentations of selected recent work from researchers at the Energi Simulation Centre for Geothermal Systems Research at the University of Calgary, University of Alberta, Institut national de la recherche scientifique (INRS) and ETH Zurich.

8:50–9:10	CT	**Ali Madani** University of Calgary	Towards a Thermal Conductivity Log
9:10–9:30	CT	**Shahab Ghasemi** University of Calgary	A New Algorithm for Optimizing Closed Loop Systems
9:30–9:50	CT	**Saeid Khasi** University of Calgary	Semi Analytical Modelling of Well-Reservoir Coupling in COMSOL
9:50–10:10	CT	**Gordon Meehan** University of Calgary	Co-Axial, Closed Loop Geothermal System Modelling
10:10–10:30	CT	**Amirhossein Darbandi** University of Calgary	Solar-Assisted Thermo-Active Foundations Coupled With Heat Pumps for Space Heating and Cooling in Cold Climates
10:30–11:00	**Coffee Break**		
11:00–11:20	CT	**Philip Adebayo** University of Calgary	Solar-Assisted Low-Temperature Underground Thermal Energy Storage Systems Coupled With a Ground Source Heat Pump in a Cold Climate – Effect of Soil Lithology
11:20–11:40	CT	**Aggrey Mwesigye** University of Calgary	Solar-Assisted Ground Source Heat Pump System for a Multifamily Residential Building in SW Calgary
11:40–12:00	CT	**Nick Fry** Organization	A System Dynamics Model for Geothermal Heating and Cooling Networks
12:00–13:00	**Lunch Break**		

CT: Contributed Talk

Industry Talks Updates

Keynote presentations highlighting recent industry achievements and ideas.

13:00–13:30	IS	**Emily Smejkal** Cascade Institute	Deep Geothermal Superpower: Canada's Potential for a Breakthrough in Enhanced Geothermal Systems
13:30–14:00	IS	**Mazda Irani** E2E	Rainbow Lake Project
14:00–14:30	IS	**Koen van der Maaten** Thermal Creek	Geo-Exchange in Alberta – a Clean Energy Journey
14:30–15:00	IS	**Jeff Messner** Novus Earth	Direct-use Geothermal for Canada
15:00-15:30	IS	**Catherine Hickson** Alberta No.1	Decarbonizing the North: Heat and Thermal Solutions "Right Fit" for Communities
15:30-16:00	IS	**Vlad Zatonski** Eavor	Rock Pipe Drilling Completion Technology
16:00–16:15	**Closing Remarks**		
16:15	**Energy Beers @ Banquet (University District)**		

IS: Invited Speaker

Abstracts

Towards a Thermal Conductivity Log

Ali Madani, Apostolos Kantzas CT

Department of Chemical and Petroleum Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4

Assessing thermal conductivity is a critical factor in enhancing thermal management practices across various industries, including geothermal energy production. Achieving precise measurements of thermal conductivity presents challenges in both field and laboratory settings, making the estimation of this property from other known characteristics highly beneficial. This study explores the relationship between thermal and acoustic properties through a frequency domain analysis across various porous media models, which differ in their geometry, matrix mineralogy, and saturation conditions to leverage these insights in both laboratory and field applications. This research not only aims to facilitate laboratory assessments of thermal conductivity but also proposes a workflow for determining the thermal conductivity of various formations in geothermal operations using existing acoustic field data.

A New Algorithm for Optimizing Closed Loop Systems

Shahab Ghasemi, Saeid Khasi, Apostolos Kantzas CT

Department of Chemical and Petroleum Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4

To optimize geothermal energy extraction, it is crucial to simulate temperature variations within a wellbore during production. Due to the large disparity between the well's radius and length, an accurate simulation requires complex numerical models and extensive computational resources. An innovative modeling approach led to high correlations without compromising accuracy. In addition, various parameters affecting the temperature control and energy extraction within the well were examined. A number of factors were considered, including the method of fluid injection as well as the effects of well depth. Energy output is optimized when injection rates are lower and area ratios are smaller in annulus injection conditions. Tubing injection, on the other hand, can significantly increase energy extraction with higher injection rates. It is crucial to refine geothermal well operation strategies based on these insights. Finally, different conditions were considered for comparing geothermal heat extraction efficiency, highlighting how the environment affects the performance of the system.

Modeling of Deep Closed Loop Geothermal Systems

Saeid Khasi, Apostolos Kantzas

CT

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Simulating deep closed loop geothermal systems, as zero-emission and scalable alternative energy technologies, is essential for their designing and performance predictions. In these applications, modeling heat fluxes across the reservoir-well boundaries as well as non-isothermal fluid flow near the boundaries are challenging due to significant scale mismatches. The latter challenge makes it infeasible to directly solve for heat and flow processes using conventional numerical methods in complex well configurations drilled in deep subsurface systems. Here, we investigated different scenarios for modeling the latter processes and developed a model with an efficient well-reservoir coupling approaches for such large-scale applications. The latter approach approximates the well flow profile using one-dimensional assumption in curve segments and compute the temperature, velocity, and pressure fields while coupled with geothermal reservoir properties. The numerical simulations are solved using finite elements and they seem to be applicable for any design configurations and reservoir characteristics. As an example of deep closed-loop geothermal systems, we simulated systems similar to Eavor-Loops to examine their scalability and expected output powers. Our model is also capable of integrating surface facilities such as thermodynamic cycles to generate electricity. The latter integration is also done in COMSOL to seamlessly predict the performance of the geothermal systems. The reason behind previous discrepancies in simulating geothermal systems seem to be due to adopting different well-reservoir coupling methods. The simulation results in this study showed that the claims on thermal and electric gross energy yields are plausible, although the natural circulation of the working fluid for a reliable delivering of the energy could not be verified. The developed model can be presented as a generic simulator application for designing geothermal systems.

Co-Axial, Closed Loop Geothermal System Modelling

Gordon Meehan[1]**, *Roman Shor***[2]

CT

[1] Department of Chemical and Petroleum Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4
[2] Harold Vance Department of Petroleum Engineering, Texas AM University, 3116 TAMU, College Station, TX, USA

The Earth's interior contains considerable unused thermal energy, far exceeding the current global energy demand. Using shallow geothermal sources for direct heating is a historically viable option. The use of a system of deep Coaxial Borehole Heat Exchangers (CBHEs) was investigated to see if it would be a viable replacement for the University of Calgary's gas-powered heat plant system for district heating.

A computer model was developed to simulate the subsurface operation of a single CBHE. It utilized COMSOL Multiphysics 6.1, which solved the fluid flow and heat transfer physics equations using the finite element method. The CBHE's geometry consists of a 2000 m deep well with a 2000 m lateral. The inner tubing of the well was seated concentrically within the outer casing. Various assumptions were made to simplify the model to decrease computation time and ease the convergence of a solution. These include modelling the entire geometry as one long axisymmetric system in two dimensions, neglecting the effects of the area under the tubing, and neglecting the gravity effects. The model's accuracy and assumptions were verified against experimental data and analytical derivations.

The system's sensitivity to parameters such as the radii of the borehole and tubing, the fluid flow rate, tubing insulation properties, the number of wells, and the bottom hole temperature were investigated. Variations in these parameters directly influenced the injected and produced temperatures, impacting the system's thermal performance. Most surprisingly, it was found that the CBHE performs better with uninsulated inner tubing when unused heat is reinjected. However, when keeping the injection temperature constant, the thermal performance was optimal with fully insulated tubing.

Solar-Assisted Thermo-Active Foundations Coupled with Heat Pumps for Space Heating and Cooling in Cold Climates

***Amirhossein Darbandi*[1], *Charaka Beragama Jathunge*[1], *Shayan Davani*[2], *Aggrey Mwesigye*[1]** CT

[1] Department of Mechanical and Manufacturing Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4 [2] Department of Mechanical and Industrial Engineering, University of Minnesota Duluth,Duluth, USA

In this study, comprehensive transient computational fluid dynamics models of both vertical (borehole) and horizontal (serpentine) solar-assisted thermo-active foundation systems, validated against experimental studies, were developed using a finite volume computational fluid dynamics tool, ANSYS® Fluent. The models incorporate actual building energy loads determined from building energy modelling studies, and hourly solar thermal profiles to assess heat transfer rates, heat pump coefficient of performance, and soil temperature. Results show that coupling solar collectors' thermal loads to the ground significantly improved the system's thermal performance since a properly sized solar collector array can prevent ground overcooling. Results further demonstrate that these systems can resolve ground thermal imbalance, and the heat pump entering fluid temperature does not go below the minimum recommended value for both systems. Moreover, for the horizontal and vertical systems, the heat pump coefficient of performance improves by 11% and 12.3%, respectively. Furthermore, energy and economic analyses reveal that compared to a conventional natural gas furnace + AC system, the vertical system consumes 90% less energy and reduces GHG emissions by 82% with the optimum collector size.

Solar-Assisted Low-Temperature Underground Thermal Energy Storage Systems Coupled with a Ground Source Heat Pump in a Cold Climate – Effect of Soil Lithology

Philip Adebayo, Aggrey Mwesigye

CT

Department of Mechanical and Industrial Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4

Underground thermal energy storage and ground source heat pump systems offer promising solutions for decarbonizing building heating and cooling. Soil lithology characteristics play a critical role in the precise design and overall effectiveness of underground thermal energy storage systems and ground source heat pumps. Hence, accurate estimation of soil properties and layouts is essential. This study examines the thermal performance of a solar-assisted ground source heat pump using two boreholes in the same location in Calgary, Alberta but with different thermal response test (TRT) results. A finite-volume computational fluid dynamics model is meticulously developed, validated, and integrated with dynamic building energy load profiles and solar radiation profiles, considering a solar collector tilted at a 45-degree angle. The analysis focuses on a single 150 m deep borehole heat exchanger equipped with two independent u-loop pipes—one connected to the solar collector and the other to the heat pump. Additionally, the study experimentally investigates the thermal storage potential of the borehole. The insights gleaned from this research will be invaluable in guiding the design and advancement of underground thermal energy storage and ground source heat pump systems in Alberta.

Solar-Assisted Ground Source Heat Pump System for a Multifamily Residential Building in SW Calgary

***Dick Van Grieken*[1], *Aggrey Mwesigye*[2]**

CT

[1] Telsec Property Corporation, Calgary, AB, Canada
[2] Department of Mechanical and Industrial Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4

Ground source heat pumps are the most efficient means for space heating and cooling in cold climates. However, when building energy loads are imbalanced, with higher heating loads than cooling loads, the heat pump performance degrades as the ground temperature reduces over time. This degradation increases the heat pump's energy consumption and can lead to eventual failure. Coupling ground source heat pumps with solar thermal energy provides a means of recharging the ground by injecting back the heat extracted for heating and thus helping alleviate the ground thermal imbalance problems. Moreover, using photovoltaic thermal (PVT) collectors that simultaneously generate both electricity and heat can further increase the energy and economic performance of these systems. The heat generated by the PVT collectors is injected back into the ground to provide thermal balance, while the electrical energy can be used to run the heat pump, offsetting the electricity required from the grid. In this presentation, an overview of solar-assisted ground source heat pumps is presented. Then, an overview of a planned solar-assisted ground heat pump system with Telsec Property Corp in the SW of Calgary is presented.

A System Dynamics Model for Geothermal Heating and Cooling Networks

Nick Fry[1], ***Roman Shor***[2]

CT

[1] Department of Chemical and Petroleum Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB T2N 1N4
[2] Harold Vance Department of Petroleum Engineering, Texas AM University, 3116 TAMU, College Station, TX, USA

In geothermal systems of many kinds there are shared system parameters which define the technical and economic feasibility of heating and cooling developments. These parameters exist in non-linear complex system interactions. It is often true that design and feasibility assessments take place in linear space without considerations for demand divergence, reservoir sustainability, or varying performance of equipment efficiency, among others. For example, future geothermal system assessment should operate in a space which allows developers to quickly quantify the impacts of climate change, grid emissions impacts, parasitic loads, or equipment lifetimes. This effort employs a preliminary working model of techno-economic assessment using System Dynamics. System Dynamics is a modeling framework developed by Massachusetts Institute of Technology staff in the 1950s which allows analysis to take place cyclically with dynamic feedback loops across component parts. In the context of geothermal heating and cooling systems, this preliminary work showcases component System Dynamics groups for aquifer characteristics, production and injection, central plants, cost and economics, demand models, pipe sizing, pipe flow, and heat exchangers. Together, the component groups allow users to perform broad sensitivity analysis and optimization within operational system boundaries or reality checks. This presentation will discuss the current component groups, benefits and limitations of the modeling framework, and a brief roadmap for future development of the model.

List of Speakers

Ali Madani	University of Calgary, Calgary, AB, Canada
Shahab Ghasemi	University of Calgary, Calgary, AB, Canada
Saeid Khasi	University of Calgary, Calgary, AB, Canada
Gordon Meehan	University of Calgary, Calgary, AB, Canada
Amirhossein Darbandi	University of Calgary, Calgary, AB, Canada
Philip Adebayo	University of Calgary, Calgary, AB, Canada
Aggrey Mwesigye	University of Calgary, Calgary, AB, Canada
Nick Fry	University of Calgary, Calgary, AB, Canada
Emily Smejkal	Cascade Institute, Victoria, BC, Canada
Mazda Irani	E2E, Calgary, AB, Canada
Koen van der Maaten	Thermal Creek, Calgary, AB, Canada
Jeff Messner	Novus Earth, Calgary, AB, Canada
Catherine Hickson	Alberta No.1, Edmonton, AB, Canada
Vlad Zatonski	Eavor, Calgary, AB, Canada

Useful Information

Joining the Workshop remotely?

To join the Workshop virtually, please use the following **Zoom link**.
The meeting ID is: 973 5007 6791.
The meeting passcode is: 260778.

Upon entry, please keep your microphone muted.

Questions during the talks will be enabled through Slido, details of which will be provided before the talks start.

Joining the Workshop in person?

Talks will be held on the basement level of Engineering Block C building (ENC, floor B1) of the **Schulich School of Engineering** in room **ENC 070**. The room can be accessed from multiple entrances - CCIT building access point, ENG building access point, or ENC building itself. Signage will be posted throughout the engineering complex to guide the attendees to the right location.

Breakfast and coffee breaks will be offered on the platform of ENC 070 theatre.

Lunch will be served on the second floor of the main engineering building (G Block) in room **ENG 207**. The **G Block** is the new part of the building with predominantly yellow walls, and the room can be accessed from multiple entrances - CCIT building access point, ENB building access point, ENC building access point, or ENG building itself. Signage will be posted throughout the engineering complex to guide the attendees to the right location and volunteers will be available for additional guidance.

Interactive room finder is available on the following **link** for ease of finding different buildings on campus.

Wi-Fi will be available during the Workshop at the University of Calgary campus via the **airuc-guest** and **eduroam** networks.

Energy Beers

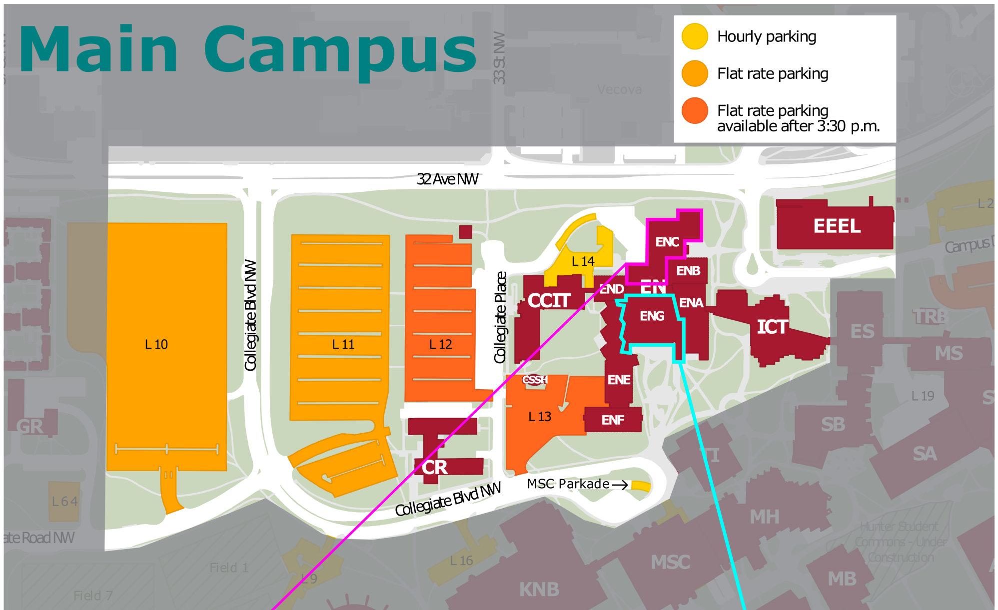
Networking will start after the technical program of the day is over at 16:15 in the afternoon. It takes place at The Banquet at University District, the new urban area across from campus, a short walk or drive from the Engineering complex. The address of the bar is 3953 University Ave NW 220, Calgary, AB T3B 6K3, and the exact location on Google maps can be accessed **here**.

How to get to the Schulich School of Engineering?

The engineering complex is located on the north side of campus, within walking distance of the University CTrain station.

Parking is available at several locations, on hourly or flat rate basis (see the map on the next page for exact locations on campus):

- **Lot 10**: public flat rate, $9/day. Payment available at parking pay station or through the Parkedin app (**Zone ID: 1368**)
- **Lot 11**: public flat rate, $9/day. Payment available at parking pay station or through the Parkedin app (**Zone ID: 1369**)
- **Lot 12**: public parking starts at 3 p.m., flat rate, $9. Payment available at parking pay station or through the Parkedin app (**Zone ID: 1377**)
- **Lot 13**: public parking starts at 3 p.m. Payment available at parking pay station or through the Parkedin app (**Zone ID: 1375**)
- **Lot 14**: public parking starts at 3 p.m., flat rate, $9. Payment available at parking pay station.


Main Campus
Hourly parking
Flat rate parking
Flat rate parking available after 3:30 p.m.
32 Ave NW
33 St NW
Collegiate Blvd NW
Collegiate Place
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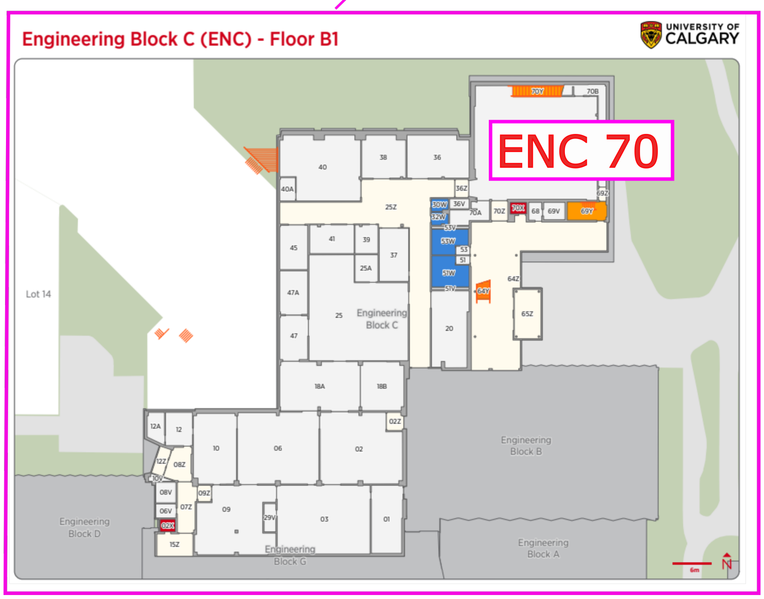
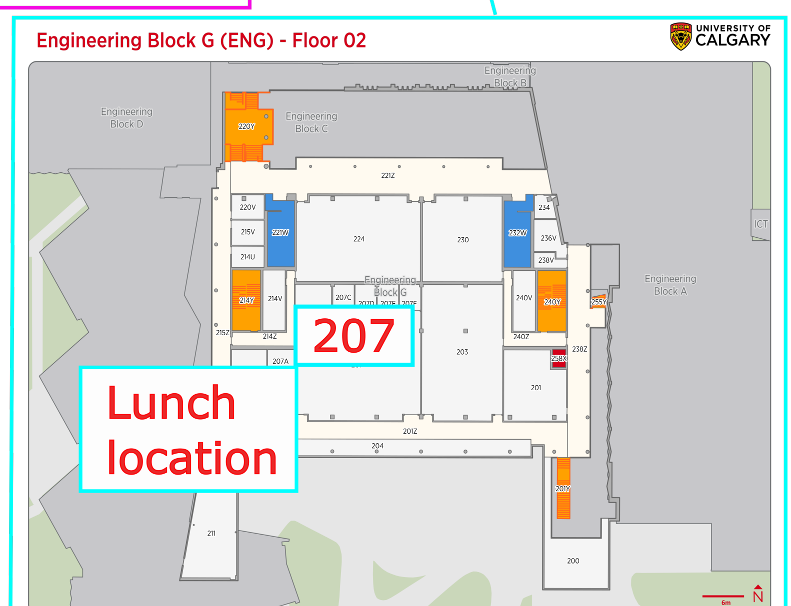

Engineering Block C (ENC) - Floor B1
UNIVERSITY OF CALGARY
ENC 70
Engineering Block C
Engineering Block B
Engineering Block D
Engineering Block A
Engineering Block G
Lot 14


Engineering Block G (ENG) - Floor 02
UNIVERSITY OF CALGARY
207
Lunch location
Engineering Block G
Engineering Block D
Engineering Block C
Engineering Block B
Engineering Block A
ICT

Funding Agencies and Industry Partners

GeoS would like to thank our industry partners and funding agencies for their generous support of our research program.

Special thank you to this year's industrial sponsors of the Geothermal Workshop.

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