# Energy Harvesting Processes

## *Geothermal Energy Lab*

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# Preamble

- In the 2021 workshop we proposed a new research program in the understanding of heat transfer and in finding ways to harvest as much as possible whether underground or at the surface.
- This led to a multisector proposal that is currently under evaluation by NSERC and Mitacs.

| **Project One: Transport Phenomena in Enhanced Geothermal Systems** |
|---|
| **Milestone 1.1 Thermal Property Measurements** *(Kantzas, Bryant, Shor)* |
| *Activity 1.1.1: Conduction only* |
| *Activity 1.1.1: Introduction of Convection* |
| **Milestone 1.2 Thermal Properties of Nanofluids** *(Kantzas, Bryant)* |
| *Activity 1.2.1: Thermal Conductivity of Nanofluids* |
| *Activity 1.2.2: Nanofluid Injection in Geothermal Targets* |
| **Milestone 1.3 Working Fluids** *(Kantzas, Shor)* |
| *Activity 1.3.1: Working Fluid Geochemistry* |
| *Activity 1.3.2: CO2 as a Geothermal Fluid* |
| *Activity 1.3.3: Combining Carbon Capture in the process* |
| **Milestone 1.4 Pore Level Predictive Modelling** *(Kantzas, Shor, Bryant)* |
| *Activity 1.4.1: Heat Transfer in Porous Media* |
| **Milestone 1.5 Wellbore and Reservoir Flow Modelling** *(Kantzas, Shor)* |
| *Activity 1.5.1: Heat Transfer in Formation and Wellbore* |
| *Activity 1.5.2: Basin Scale Thermal Flow Modelling* |
| **Milestone 1.6 Drilling Mechanics** *(Shor, Kantzas)* |
| *Activity 1.6.1: Hard Rock Drilling Bit* |
| *Activity 1.6.2: Material Properties* |
| **Project Two: Alberta Waste Heat to Power** |
| **Milestone 2.1 Inventory** *(Kantzas, Shor)* |
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| **Milestone 2.3 Miniaturization** *(Kantzas, Shor)* |
| *Activity 2.3.1: Generate Miniature Power Generators* |
| **Milestone 2.4 Sequestration** *(Kantzas, Shor)* |
| *Activity 2.4.1: Flue Gas Utilization* |
| **Milestone 2.5 Applications** *(Kantzas, Shor)* |
| *Activity 2.5.1: Increase Process Efficiency* |
| *Activity 2.5.2: New Processes with Harvested Energy* |
| **Milestone 2.6 Integration** *(Kantzas, Shor)* |
| *Activity 2.6.1: Chemical Plant Waste Heat* |
| **Milestone 2.7 Sustainability, Social License and Regulation** *(Kantzas, Shor)* |
| *Activity 2.7.1: Sustainability and Social License* |
| *Activity 2.7.2: Regulation of Distributed Power* |

# Transport Phenomena in Enhanced Geothermal Systems

**Research Areas**

- Thermal energy flow at the reservoir, well and pore scale to understand thermal conductivity of heterogenous materials and the role of convection.
- Effects of scaling and corrosion on equipment and reservoir performance.
- The geochemistry of hot fluid transfer.
- Nanofluids and nano-conducting materials.
- $CO_2$ capture and geothermal utilization.
- Pore level modelling of heat transfer.
- New experimental techniques for heat transfer measurements.

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# Transport Phenomena in Enhanced Geothermal Systems

**Thermal Property Measurements**

- Study the mechanisms of conduction and convection (natural or forced) in geothermal systems.
- Perform systematic measurements of thermal conductivity and heat capacity in different rock/fluid systems.
- Remove, as much as possible, the inconsistencies and discrepancies found in the literature.
- Generate correlations for different geological formations.
- Study the possibility of generating more complex models than the "thermal gradient".

# Transport Phenomena in Enhanced Geothermal Systems

**Thermal Properties of Nanofluids**

- What is the thermal conductivity and heat capacity of nanofluids?
- Can we find nanofluids that enhance heat transfer at a moderate cost?
- Can we use said nanofluids as circulation fluids for geothermal applications?
- How can we overcome problems such as particle loss or facility damage ?

# Transport Phenomena in Enhanced Geothermal Systems

**Working Fluids**

- What is the interaction of circulation fluids or working fluids with the formations where heat is exchanged?
- What geochemistry needs to be incorporated in the design?
- Can we use $CO_2$ as a geothermal fluids and what will be the limiting factors?
- If $CO_2$ is an acceptable fluid (and there is evidence of this being already used) can we incorporate carbon capture in Geothermal cycles?

# Transport Phenomena in Enhanced Geothermal Systems

**Pore Level Predicting Modelling**

- The problem of heat transfer at the pore level has seen limited attention.
- Our preliminary work (as described in the earlier presentation) shows that we have limited capabilities to model complex effects such as:
    - Contact points between crystals or grains
    - Wettability effects
    - Mineralogy effects
    - Interfacial effects
- Our expertise in momentum and mass transfer will be extended to the field of heat transfer.

# Transport Phenomena in Enhanced Geothermal Systems

## Wellbore and Reservoir Flow Modelling

- Scaling up from the pore level to the wellbore level will require scale up of the thermal properties as well as their change with change in saturation and mineralogy.
- This can be extended to the formation level using conventional simulation tools and scaled up properties.
- Extending this to basin scale will be attempted using statistical rather than detailed microscopic rules to be used as a tool for longer (geological?) time scales.
- This last one is more of an indicator rather than a detailed simulation tool.

# Transport Phenomena in Enhanced Geothermal Systems

**Drilling Mechanics**

- We will use experimental and modelling tools to study the mechanisms of drilling of hard rocks.
- The drilling group will use this work as part of their intelligent drilling program.
- Modelling of the drilling progress with computer tomography.
- Simulation using DEM and other sophisticated tools will also be used to match the experimental observations.

# Alberta Waste Heat to Power

**Research Areas**

- Thermodynamic energy recovery optimization.
- Use of residual heat.
- Surface facility design for minimal footprint and reduced noise.
- Miniaturization, integration and optimization.
- Alternative uses of how enthalpy heat.

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# Alberta Waste Heat to Power

- In oil and gas production, whether there are hydrocarbons from hot formations (80$^{o}$C+) or thermal production (~200$^{o}$C) they generate an enormous amount of heat that needs to be cooled for further processing.

- As an example, Alberta generates over 520,000m$^3$ of bitumen daily. At an average Steam to Oil Ratio of 5.1, 2,652,000m$^3$ per day of hot emulsion is produced per day which is cooled to approximately 60$^{o}$C prior to further processing. This corresponds to 15.5*10$^8$MJ/day or 22*10$^5$MW of sustained energy that is essentially let to waste.

- The equivalent number of light hydrocarbons produced from Alberta alone is 50,000m$^3$ and with an average amount of water oil ratio to 6-10 this corresponds to an additional 1.2-3*10$^5$MW.

- The wasted energy out of all the chemical plants, power plants, refineries, etc. is not even considered. And it should.

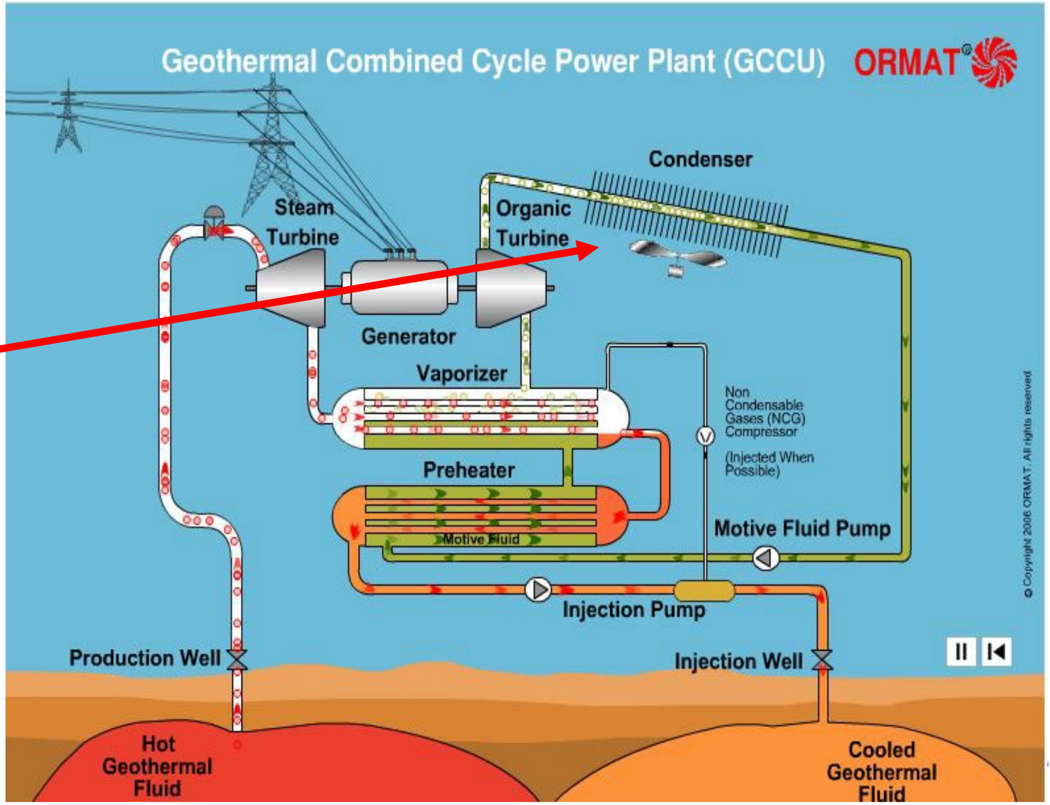
- Even if I am off by a factor of 100 the numbers are still very large. **So, the first thing to do is the generate a reliable inventory of these resources.**

# Alberta Waste Heat to Power

- The problem is that there is no single source for all this energy but it is dispersed all over the province.
- **The traditional thinking in plant design says that the larger the better, so companies that build power plants walk away from this opportunity.**
- **But if we can build a single solar panel, why can't we build an equivalent geothermal panel?**
- Nonetheless, there are many low hanging fruits, such as SAGD plants, refineries, chemical plants, etc. that they are generating enough heat for harvesting an power generation.
- And then, of course, we have the geothermal energy.

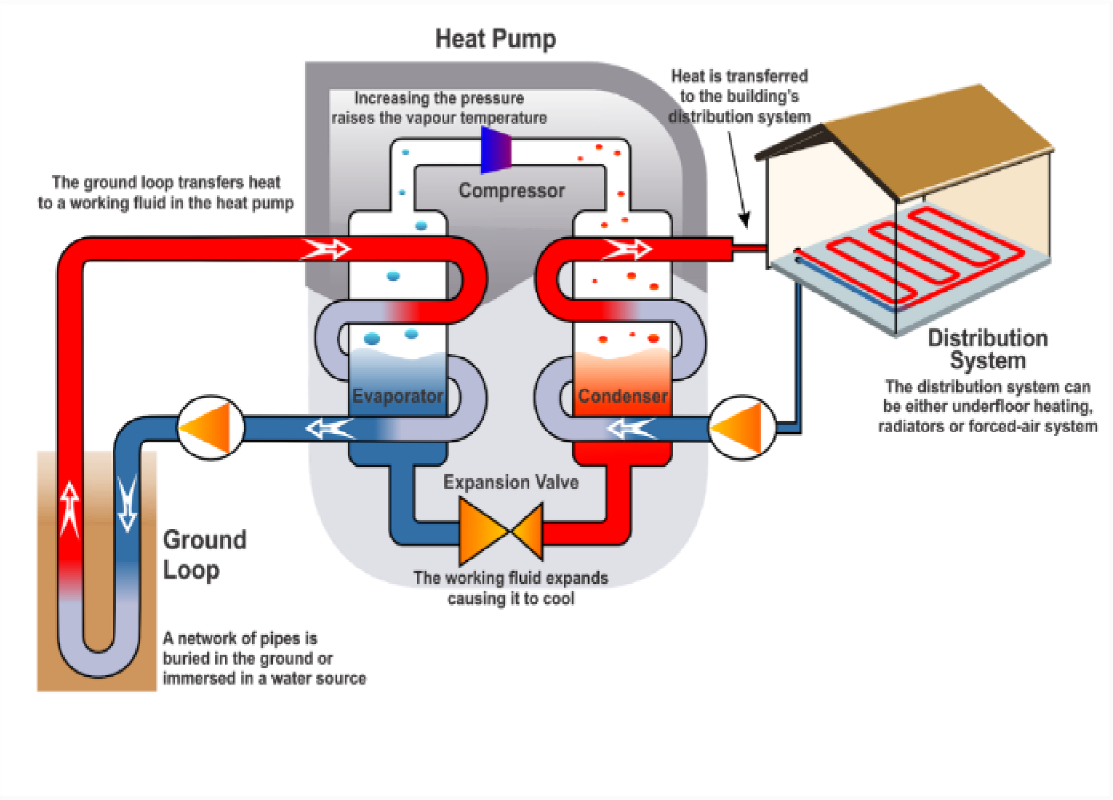
# Alberta Waste Heat to Power

- The traditional approach is to get a heat source and the use the energy from that source to feed a power generator to generate electricity.
    - Geothermal source
    - Thermal bitumen source
    - An exothermic reactor
- The process efficiency is very low due to having to condense the steam in the "condenser".
- The condensing process "wastes" around 80% of the produced energy.
- All these issues need to be quantified as they are design parameters for future R&D.



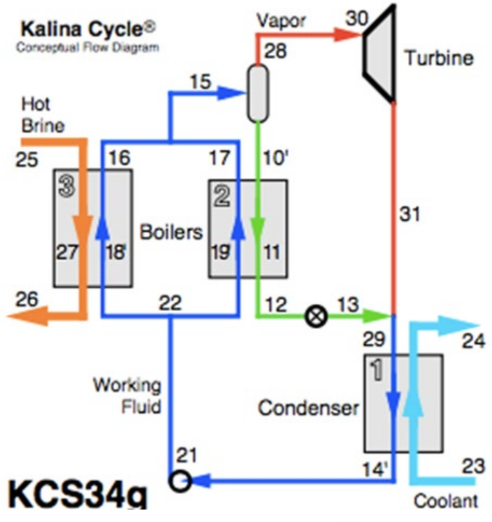
# Alberta Waste Heat to Power

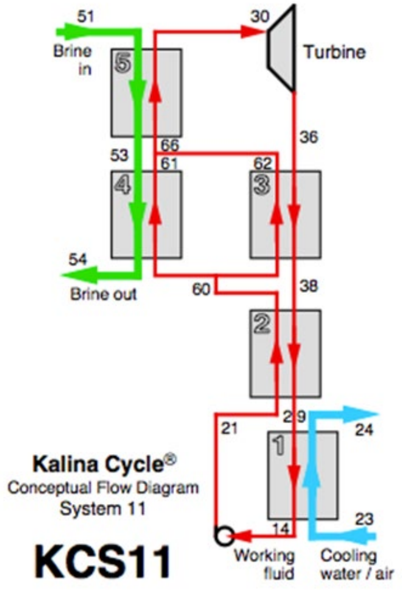
- So one way to get the overall energy efficiency to a more acceptable level is to find other processes that can make good use of the energy dispersed in the "condenser".
- The idea of house heating, roman baths, green houses, etc. can benefit the community and supply energy where it is otherwise wasted.
- Revenue can be generated for the protagonists in the same way that revenue is generated in the internet (which for those who are older was supposed to be "free access for all").
- A more holistic approach than the "core business" must be adopted.

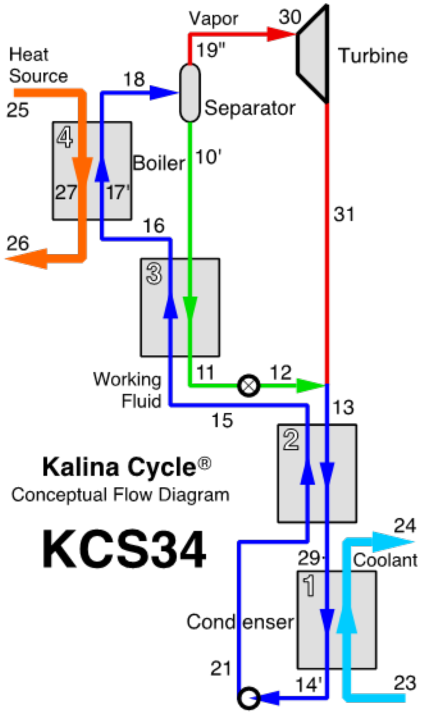


# Alberta Waste Heat to Power

- There are many different power cycle systems.
- One of them is the Kalina Cycle (water ammonia working fluid).
- Some of the designs are presented here and they have advantages or disadvantages compared to other cycles.
- The Kalina cycle is the first cycle we will work on, but we are not bound to work only on this cycle.
- This is especially valid in our effort to generate a Geothermal Panel.




Source: Kalina Energy



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# Alberta Waste Heat to Power

- **KEY QUESTIONS TO START ARE:**
- INVENTORY: How much, how dispersed, can be integrated, what options?
- ENERGY BALANCE MODELS: Quantify exactly how much energy per plant or unit operation.
- MINIATURIZATION: Build a system of a few kW or even less?
- SEQUESTRATION: Can we integrated CCS as part of our process?
- APPLICATIONS: Can we replace the condenser with some other energy harvester?
- INTEGRATIONS: Can we integrate multiple processes to replace the term “power efficiency” with a “process efficiency”?

Our vision of the future chemical plant

# Thank you to the Sponsors

Ashaw Energy
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