GEOTHERMAL ENERGY'S
ROLE IN AN EVOLVING CARBON REDUCTION WORLD

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SPE International
Aberdeen Section
www.spe-uk.org

Energy Transition in an Oil and Gas World

SPE Gaia
SUSTAINABILITY PROGRAM

https://www.listeningpays.com/how-to-deal-with-the-elephant-in-the-room/

There is an "elephant in the room" that is the world's geothermal resource endowment – how do we better understand the challenges to be able to grow this renewable energy source?

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Geothermal Fundamentals

What are low enthalpy systems and where do they occur?

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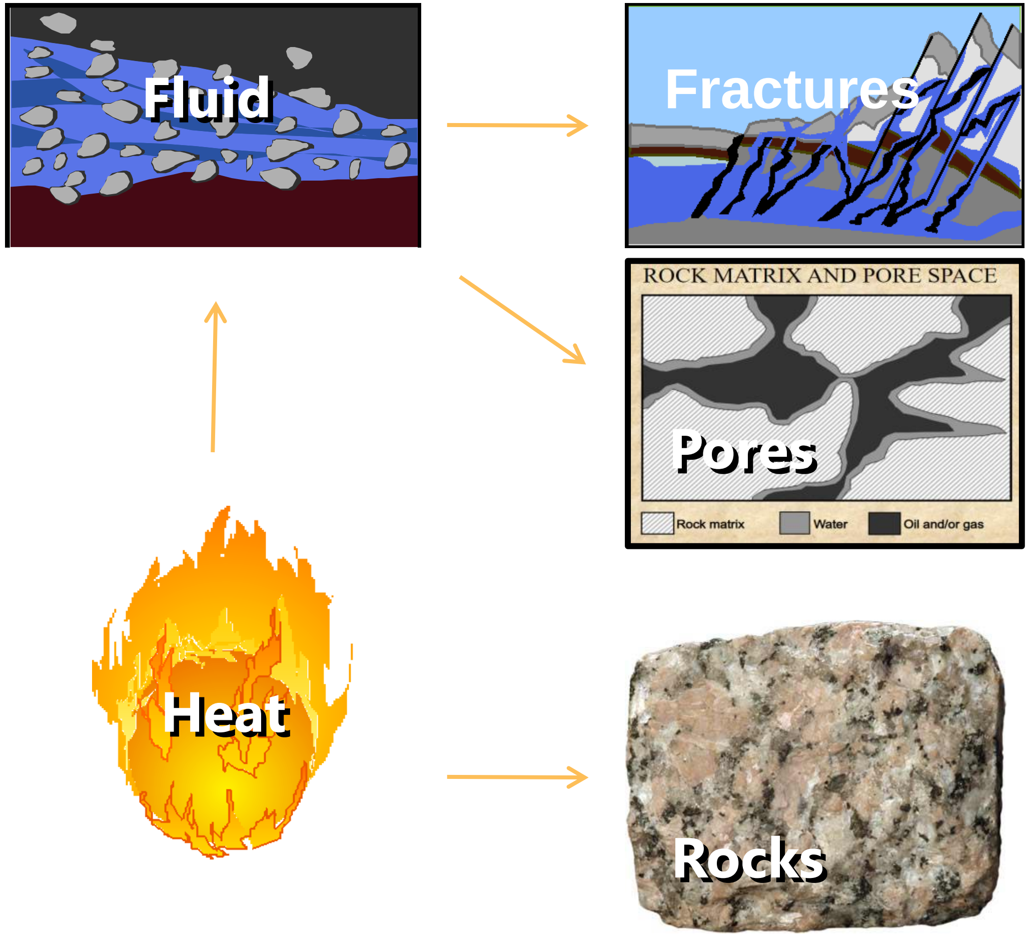
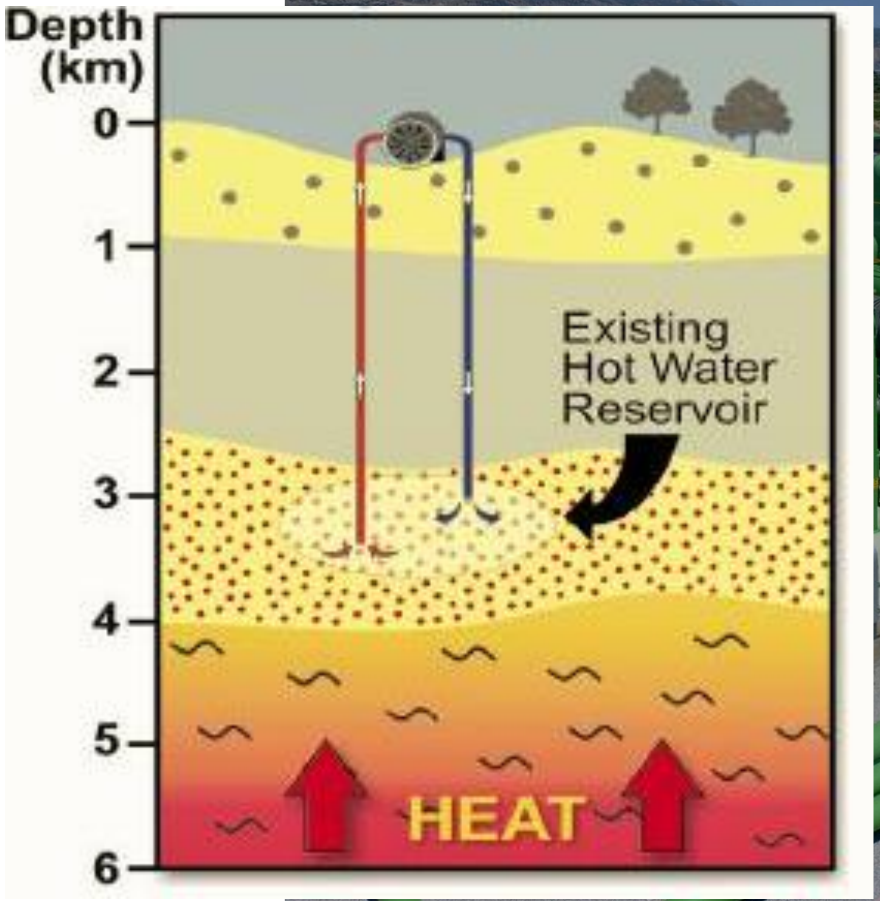
Geothermal Fundamentals





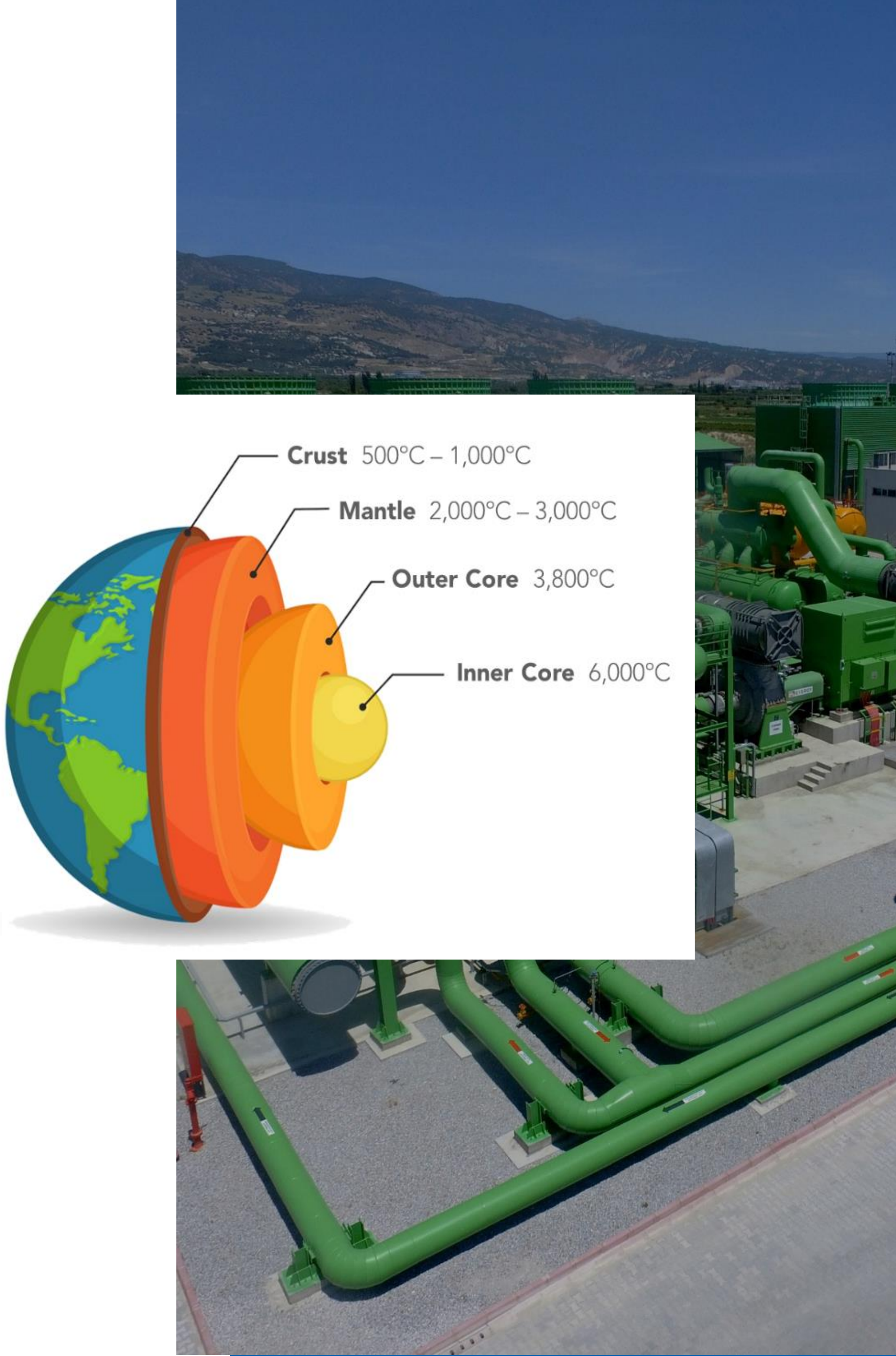
Alberta Government has defined "geothermal" as the naturally occurring heat of the earth.

Geothermal Fundamentals

- It gets hotter as we move towards the center of the earth.
- The heat is not the same everywhere.
- There are different types of geothermal systems.

A big chunk of the world has significant resources

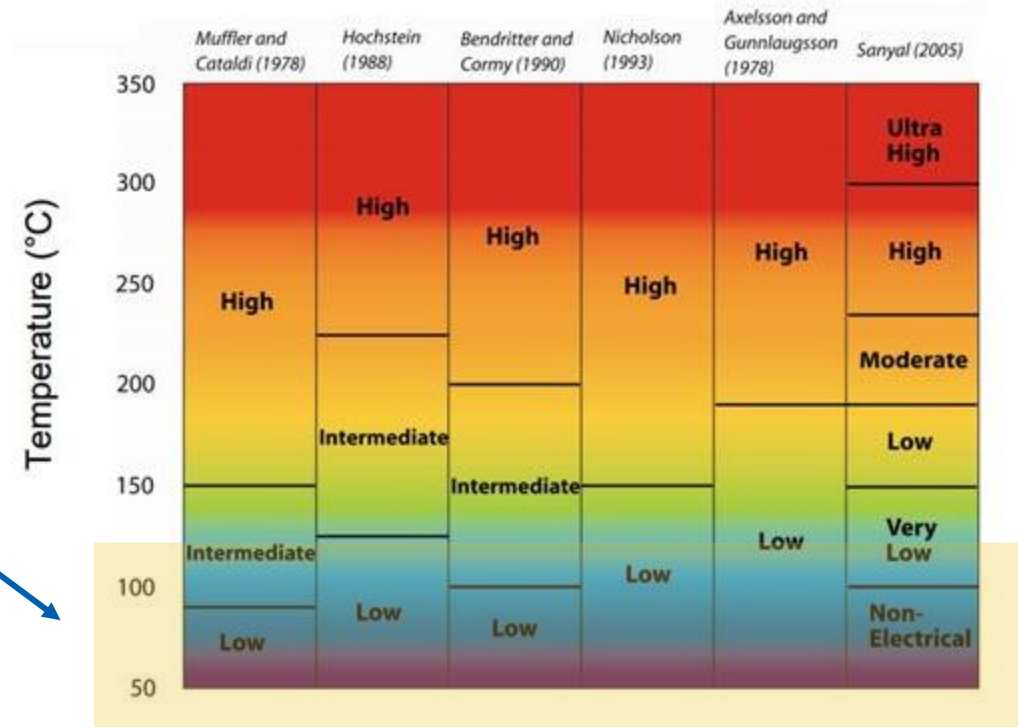
	Resource Type
1	*Convective Hydrothermal resources*
2	*Vapor dominated*
3	*Hot-water dominated*
4	*Other hydrothermal resources*
5	*Sedimentary basin*
6	*Geopressured*
7	*Radiogenic*
8	*Hot rock resources*
9	*Solidified (hot dry rock)*
10	*Part still molten (magma)*

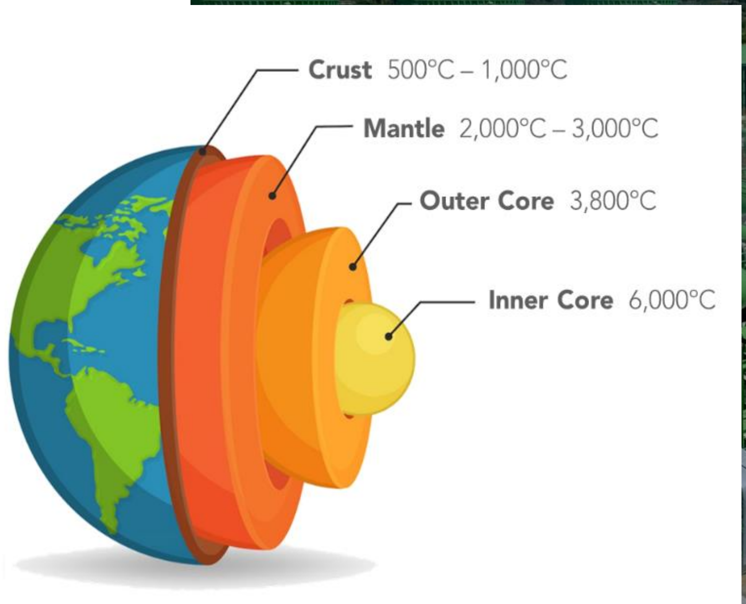


Geothermal Fundamentals

- Enthalpy is the key!
  - Low enthalpy, mostly thermal energy
  - High enthalpy, electricity plus thermal energy

Our focus



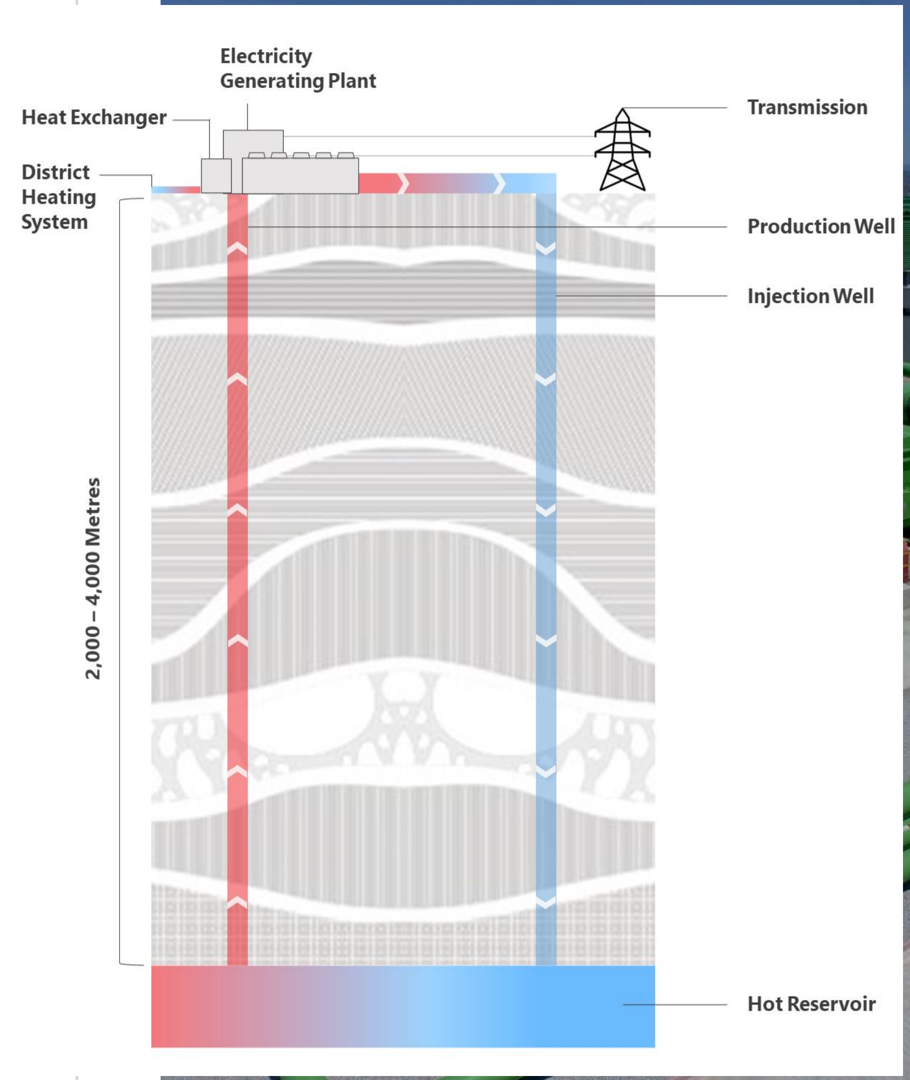


Geothermal Fundamentals

Reservoir temp.	Reservoir fluid	Common use	Technology commonly chosen
High temperature >220°C	Water and/or steam	Power generation Direct use	Flash steam Combined (flash and binary) cycle Direct fluid use Heat exchangers Heat pumps
Intermediate temperature 100-220°C	Water	Power generation Direct use	Binary cycle Direct fluid use Heat exchangers Heat pumps
Low temperature 50-150°C	Water	Direct use	Direct fluid use Heat exchangers Heat pumps

Let's get away from power only, and think about thermal/heat usage

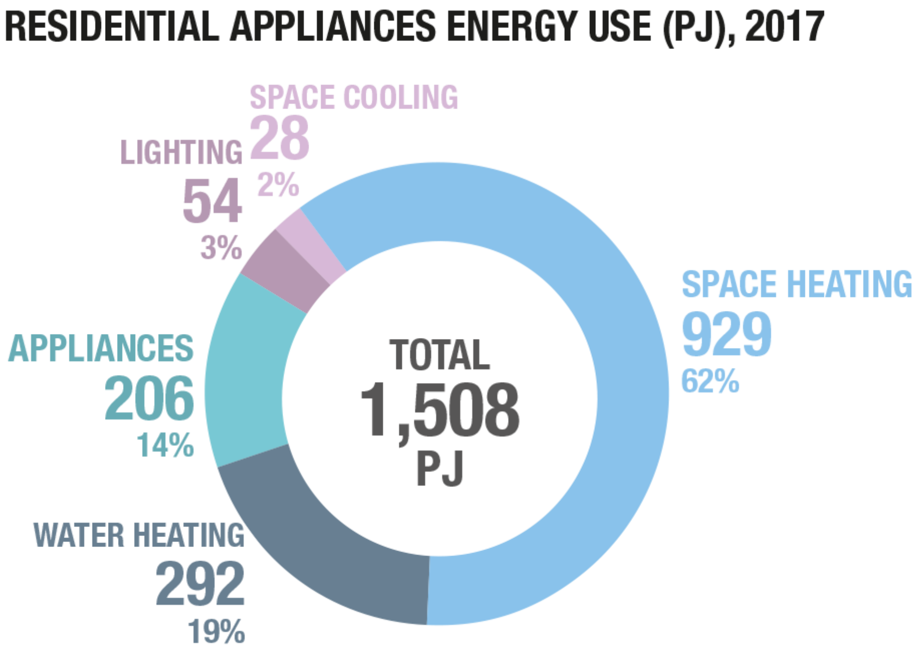
- Multiple uses for fluids in the 50°C to 120°C range
  - 70°C – 100°C range some electrical generation systems but require significant flow volumes.
  - 110°C + range expanding use of binary systems (cf., Organic Rankin Cycle technology)



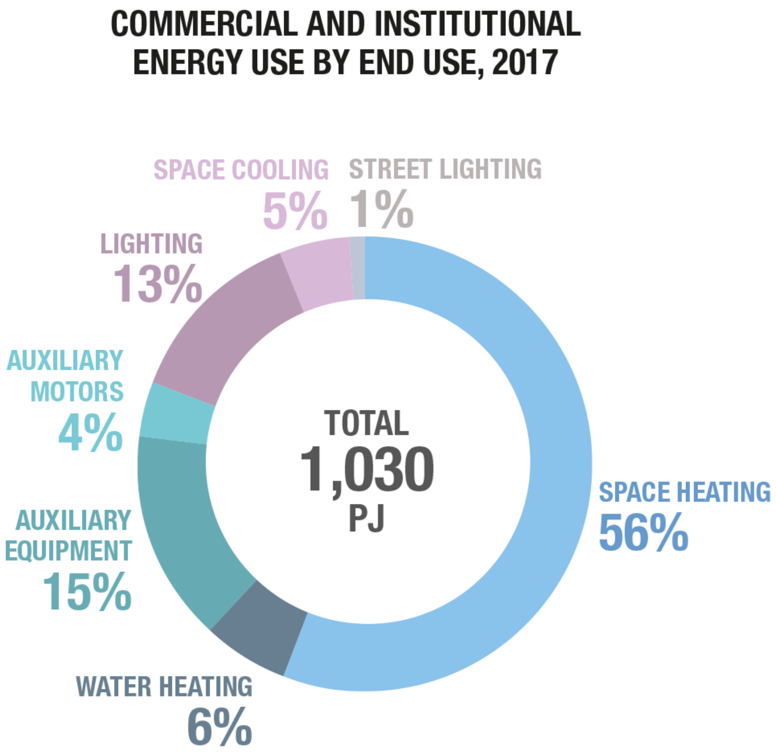
Heat is Useful Energy

The importance of heat in a cold climate

Energy consumption: Huge requirement for space heating in Canada, much supplied by natural gas.



NRCan 2020



Heat is Useful Energy

How much oil does geothermal replace?

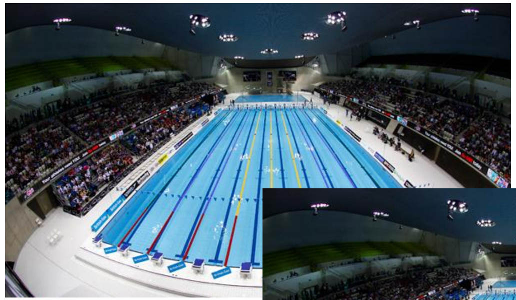
Alberta No. 1 is anticipated to flow at least 300 liters/sec. The heat value of the flow @ 120°C is the heat equivalent of 40 barrels of oil an hour or 350,000 barrels a year.

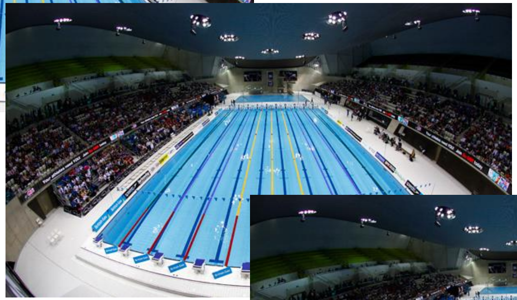
350,000 barrels a year

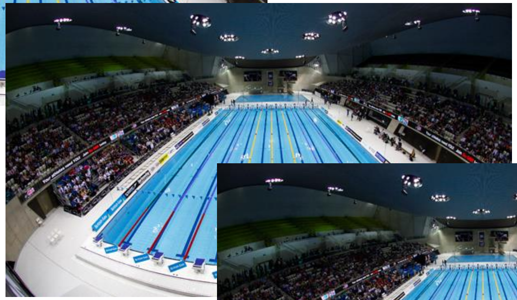
Heat is Useful Energy

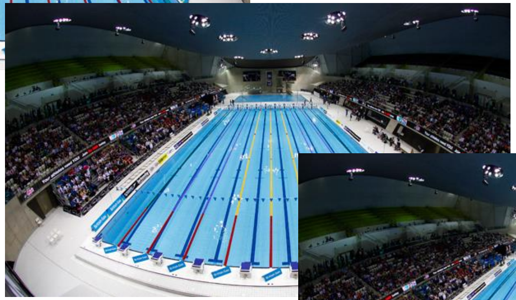
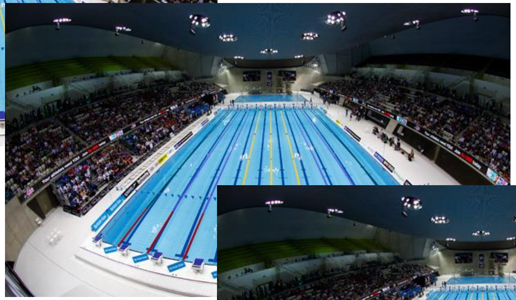
How much brine does geothermal flow?

Alberta No. 1 is anticipated to flow from multiple wells, at least 300 liters/sec. This is enough brine to fill more than 10 Olympic sized swimming pools a day.








10 pools/day

Why Geothermal?

GHG and ESG credits and other “green” advantages.

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Greenest of the Green Renewable Energy Options

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Geothermal Energy *IS* the Solution.

Baseload (24/7 – 365) capabilities and available on demand (dispatchable) and lasts more than 40 years.

Most prevalent baseload renewable resource (heat & electricity) in many jurisdictions and **excellent Environmental, Societal, Governance (ESG) values**.

Most effective renewable for **Green House Gas (GHG) reductions & lowest environmental footprint of all renewables.**

Dual commodity value (heat & electricity) plus "add-ons" such mineral extraction and CO_2 sequestration.

In areas with existing hydrocarbon industry, geothermal **utilizes oil and gas assets, expertise and data**.

Greenest of the Green Renewable Energy Options

Three times green.

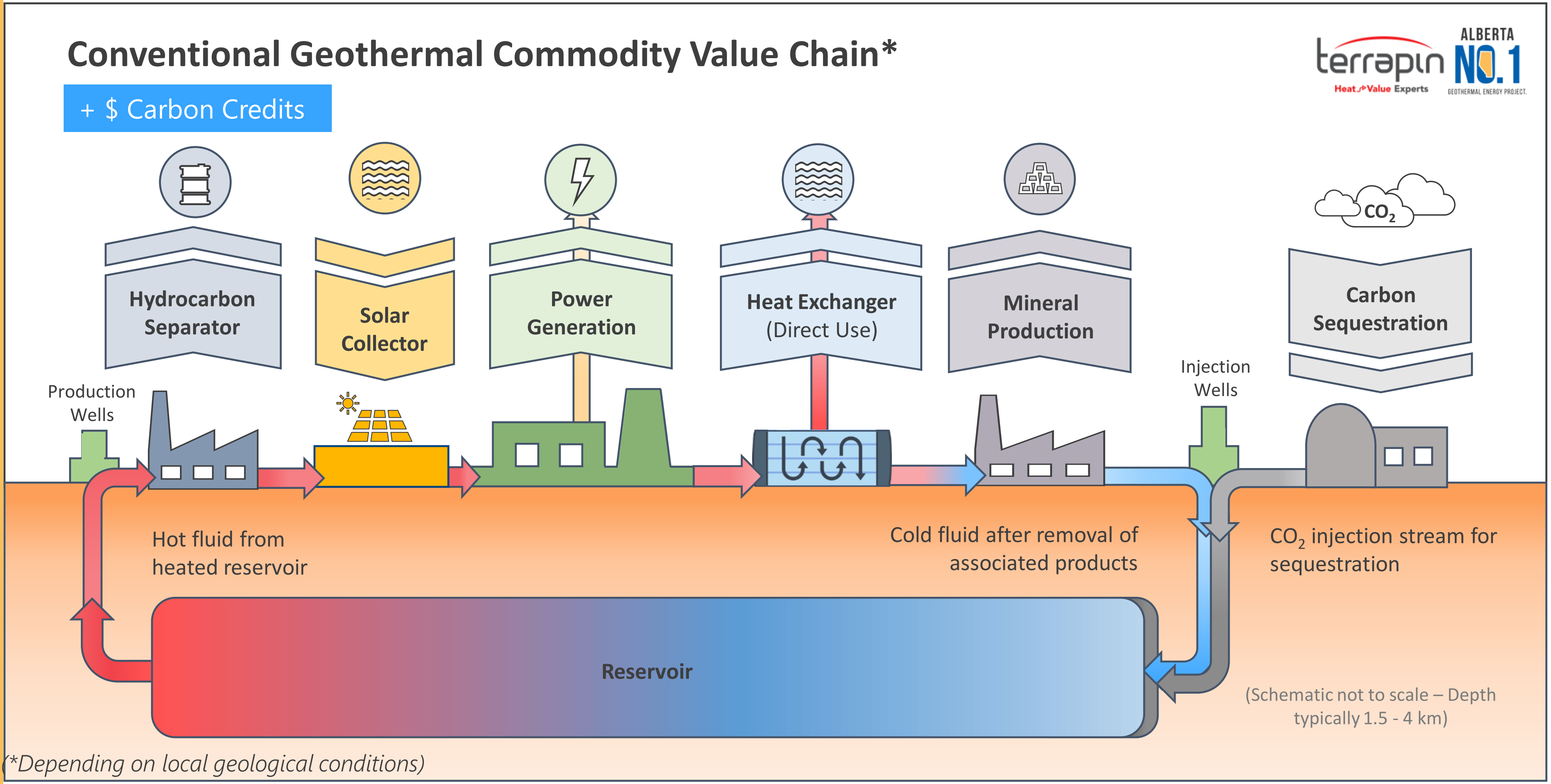
Baseload (24/7 – 365 days a year). Does not require backup peaking capacity as a carrying cost, as is required in systems with a significant intermittent renewable load in order to ensure resiliency of the grid.

Battery storage is not required. Intermittent renewables require battery storage on many grids in order to be stable. Current pricing for intermittent renewables with battery back-up is around 30-40 cent/kWhr. Typically, the battery backup is only capable of storage of a few hours of energy. Battery storage is significantly more costly per kWhr than the intermittent renewables. Batteries also add another level of complexity to the grid.

Multi-commodity value. Developments can produce heat & electricity, supporting both nearby industry (food security for example) as well as more distant industries through grid transmission. Additionally, there is an option for "add-ons" such mineral extraction and CO_2 sequestration depending on local geological conditions that would not have been commercially feasible without the geothermal development.

Promoting a Holistic Eco-industrial Development

Utilizing all the intrinsic value of the produced brine and injection capacity.



THE OPPORTUNITY

Value chain from geothermal energy production

- Helping industries thrive in a carbon neutral world.
  - Carbon sequestration
  - Carbon credits
  - Cascading use of brine
- Helping global industry get to net zero while assisting in supporting the Oil and Gas industry.
- New industry
  - Growth of greenhouses (food security)
  - Eco agricultural cluster (industrial composting, greenhouses, aquiculture, agricultural drying)
  - Eco industrial cluster (Hydrogen, ammonia/nitrogen fertilizers, petrochemical processing (Methanol, plastics and solvents)
  - Forest product manufacturing (Oriented Strand Board (OSB), timber drying)
  - Mineral extraction (Li and rare earth elements)

THE ASK *–EMBRACE CHANGE*

Financial

- Creation of financial instruments to support early entrants in order to mitigate exploration risks and up-front CAPEX concerns of private capital.
  - *Tax credits and loan guarantees.*
  - *Support of increasing carbon tax/credit*
  - *Thermal and electrical PPA that recognize the GHG reduction potential of geothermal.*

Political

- Meaningful discussion with geothermal development companies on the regulatory framework, red tape reduction and streamlining project approvals.
  - *Simplification of the process.*
  - *Reengagement on the intention of Bill 36 and the associated regulations.*

Technical

- R&D support for technical issues and transfer of skills/knowledge from the Oil and Gas industry.
  - *Recognition that the existing vast wealth of subsurface data does not answer all of geothermal's questions and technical needs.*
  - *Support R&D on industrial offtakes, such as mineral extraction, CO2 sequestration, and innovative direct use heat uses.*

Why the high CAPEX?

Flow Requirements for Conventional Geothermal

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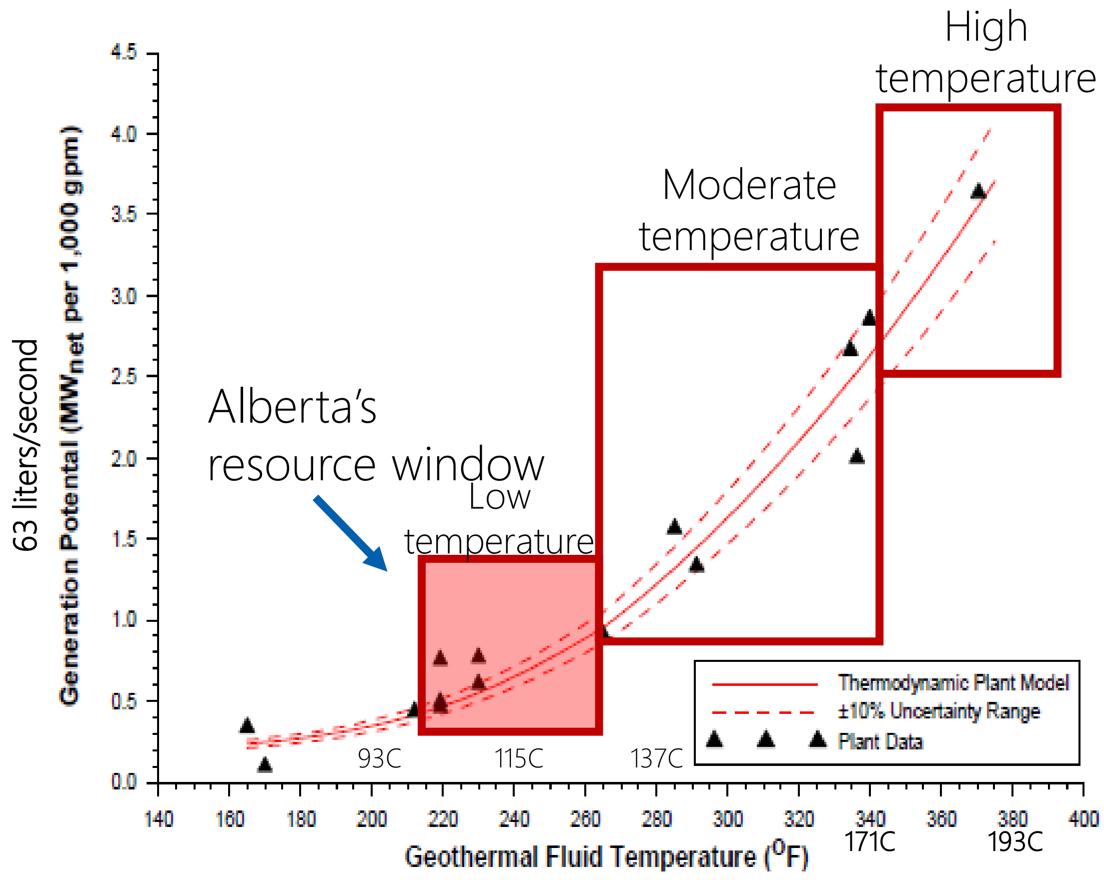
Fluid Flow Requirements for Power Generation

Power generation (electricity) fluid flow needs exceed the requirements of direct use requirements

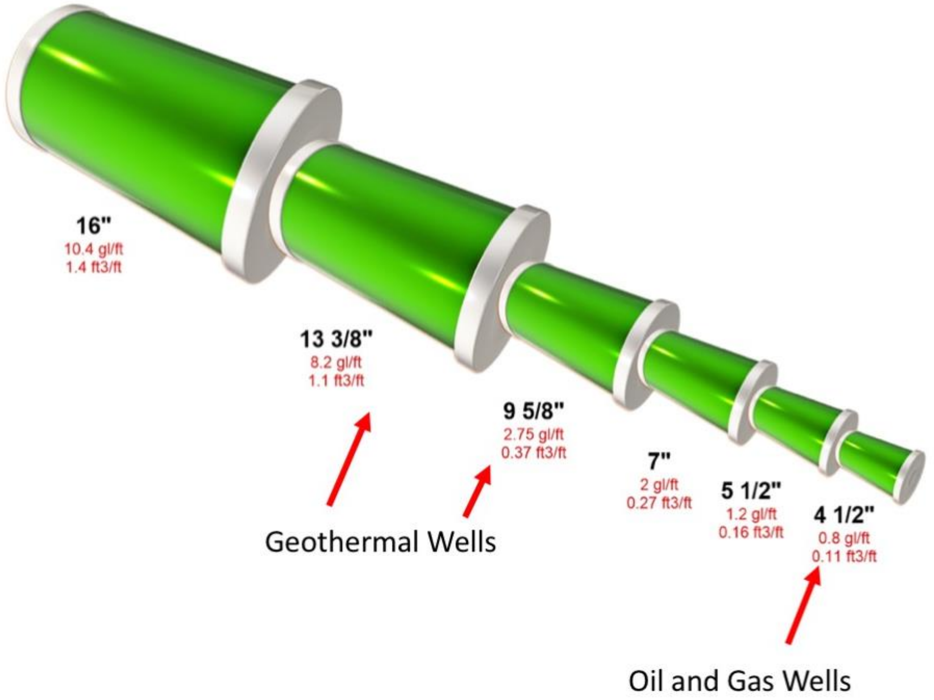
- Low enthalpy systems need very high flow rates and volumes to be commercially viable.
- Required volumetric flow rate necessitates wells with wider diameters than O&G
- **To obtain the flows required, well bores and equipment need to be significantly larger.**

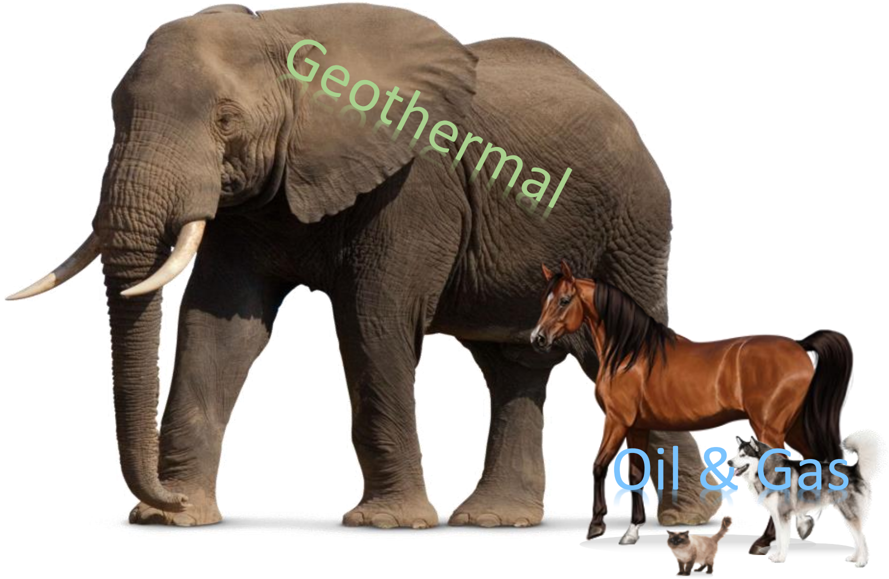


Generation potential vs. fluid temperature (Sanyal and Butler 2010).

How to flow all that fluid?

Technical requirements - Power generation requires significant flow of fluids





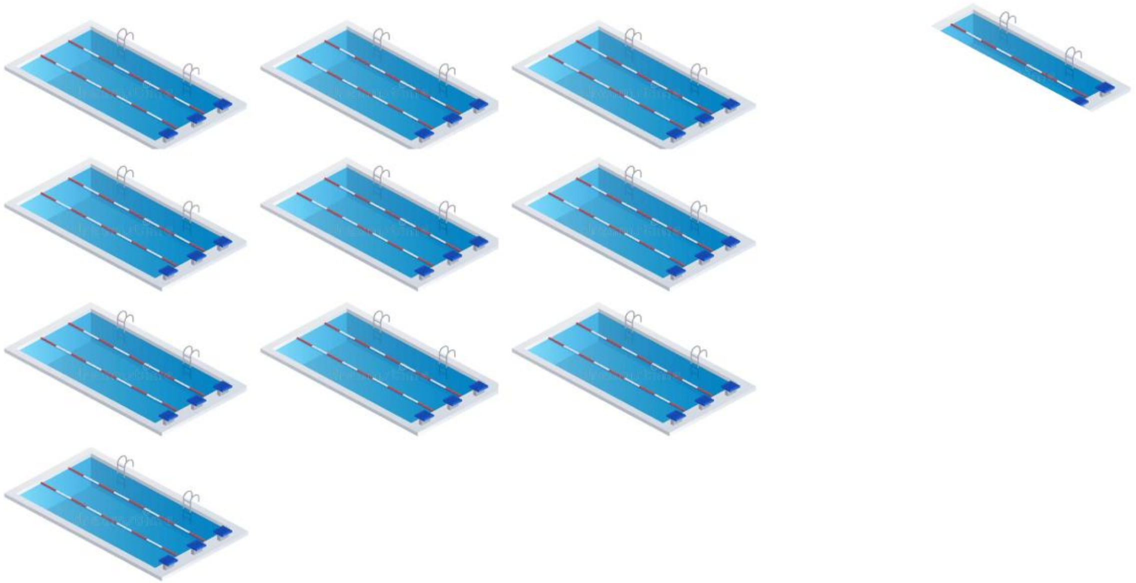
- Required volumetric flow rate necessitates wells with wider diameters than on shore Oil & Gas wells
- At 120C to produce 8MWe of power requires 300 liters per second or 4,755 gallons per minute this is 10X larger than the largest Oil & Gas operations (Arabian horse (400 kg) vs Elephant (4000 kg) and 100 times larger than many operations (cat 4 kg).
- To handle the "elephant" sized flow required for power production well bores are 9 5/8" or larger.
- Large ESP pumps required through 7" or larger tubing.

Geothermal Brine production

- Alberta No. 1 is anticipated to flow at least 300 L/sec. or 26 million L/day or 163,000 barrels/day through well bores capable of delivering ~100 l/sec
- Individual wells need to be able to flow ~100 l/s in order to justify costs.

How Much Is Produced In 24 Hours?

Alberta No. 1	Oil Well
300 L/s brine	10 L/s oil and water
26 million L/day	860,000 L/day
163,000 bbl/day	5,400 bbl/day

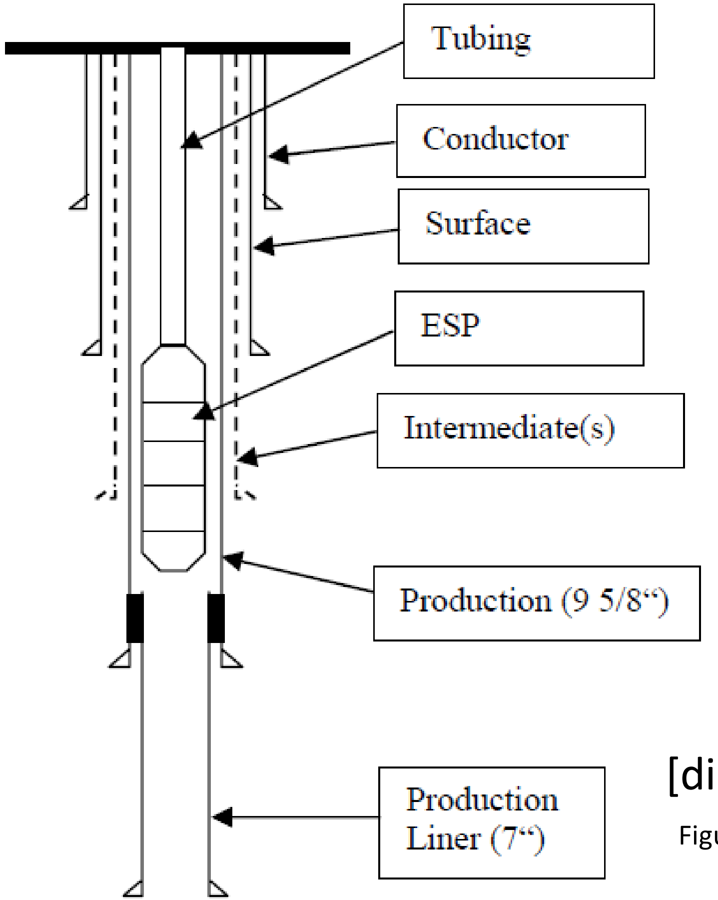


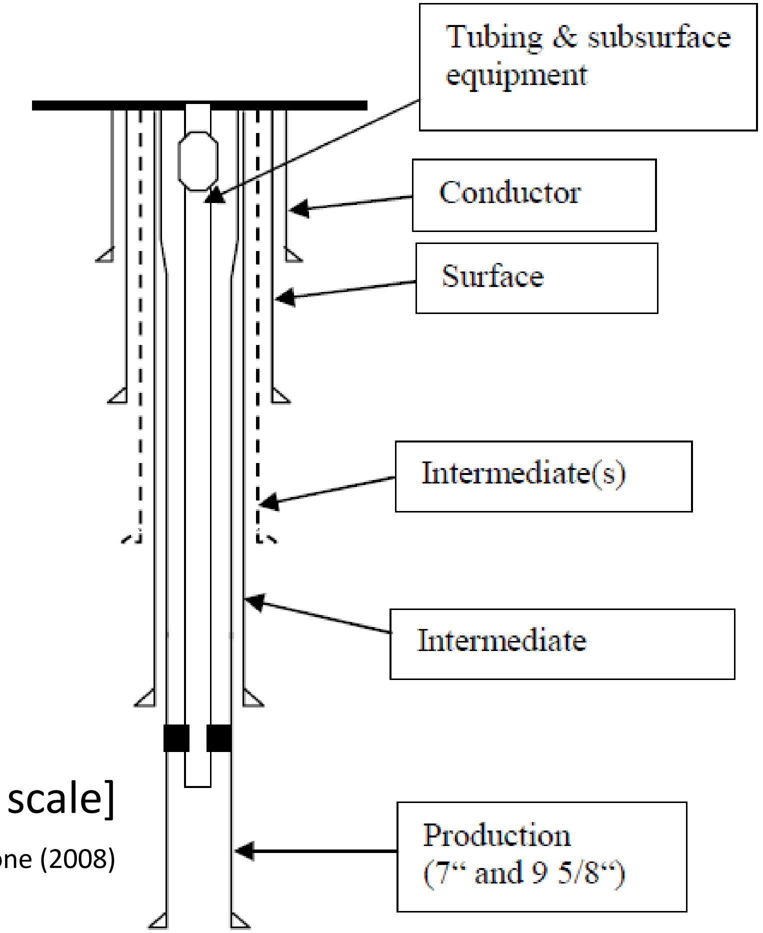
Geothermal well head at Dixie Valley, Nevada

Typical sour gas well head

Well design

Well bores larger all the way down to accommodate high flow rates and large Electrical submersible pumps.





[diagrams not to scale]

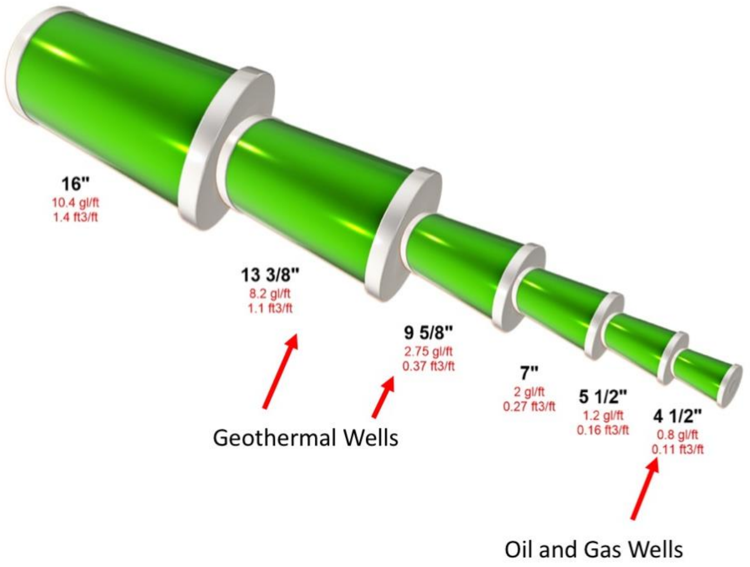
Figure: Teodoriu and Falcone (2008)

- Geothermal: wide diameter; large well bore to accommodate deep set, large capacity pump; volumes of pumped fluids >> 30 l/sec.
- Oil and Gas: narrow diameters; shallow, small pumps; small diameter tubing often to depth.; volumes of pumped fluids < 30 l/sec.

Geothermal production and injection wells

Larger sized drill bits and casings sizes

- Larger casing sizes require larger sized bits and rigs with higher handling capacity.
- Bit shown is a 609.6 mm (24 inch) TCI (Tungsten Carbide Insert) bit used for drilling the surface hole at the Clarke Lake, BC project. A more typical size for an oil or gas well in Canada would have been 444.5 mm or possibly 311.2 mm.



Geothermal wellheads

Wellheads and surface piping are larger and intended to prevent temperature drops

Typical geothermal well head in a low temperature field, Soda Lake, Nevada, USA

Typical gas well head in Alberta

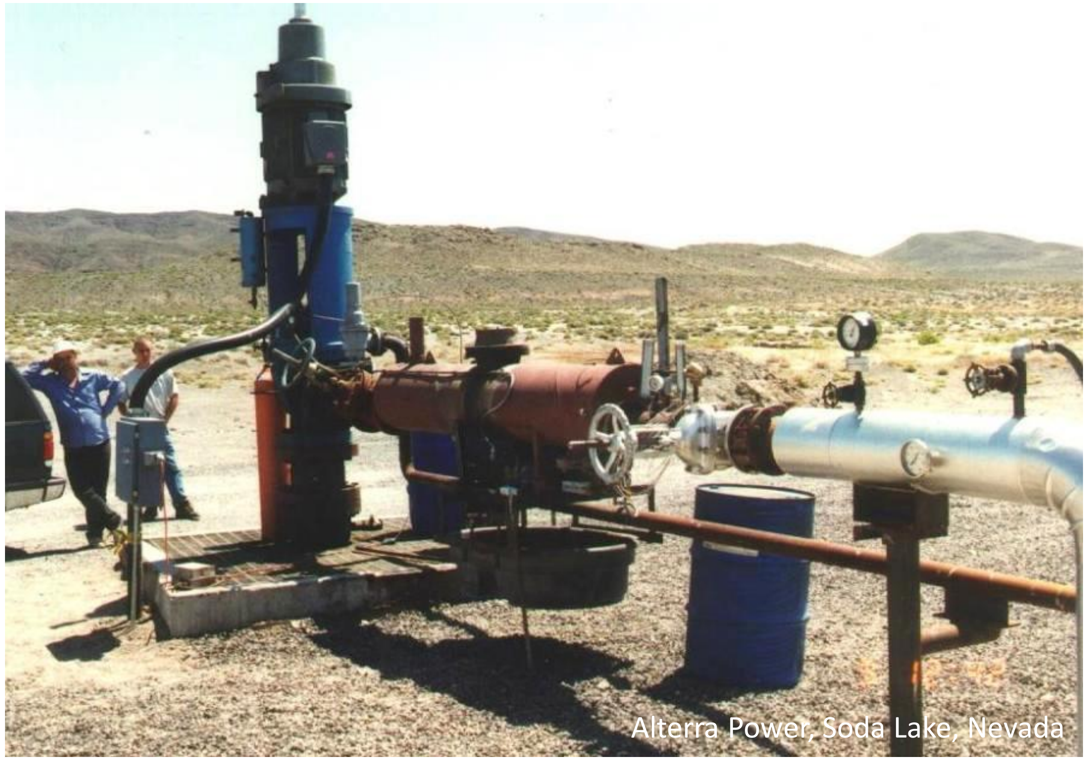
Well drilling and rigs

Alberta has some of the most experienced well drilling experts in the world

- Deep geothermal development for power production in sedimentary basins will utilize some of the largest rigs available, currently used for very deep Oil&Gas exploration and production.
- Direct use developments which are smaller and the wells are narrower in diameter, will make use of the extensive inventory of "standard" rigs. Smaller, shallower well bores and smaller pumps.

Geothermal Pumps

Wellheads and surface piping are larger and intended to prevent temperature drops

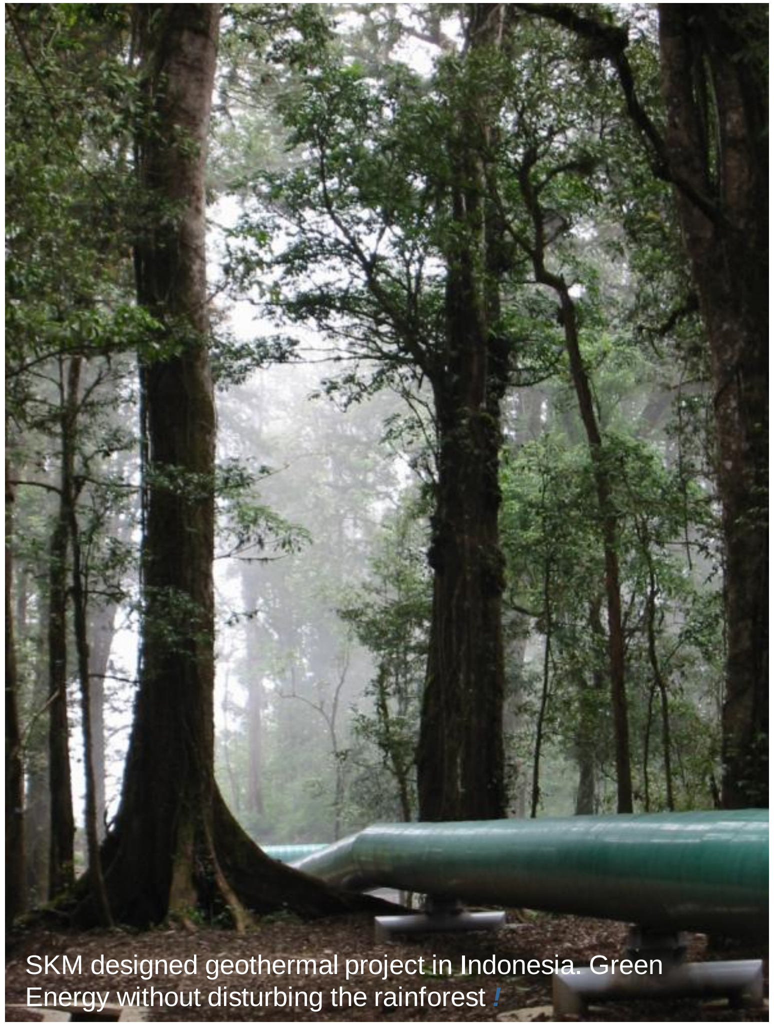


In Low temperature geothermal fields such as Alberta, large sized Electrical Submersible Pumps (ESPs) and line shaft pumps are required to move the volumes of water needed for electrical production.

Geothermal surface piping

Wellheads and surface piping are larger and intended to prevent temperature drops

Alterra Power, Soda Lake, Nevada 2009



SKM designed geothermal project in Indonesia. Green Energy without disturbing the rainforest !

All that flow requires large surface pipes, some of which could be buried using existing pipeline corridors.

Will geothermal create or trigger earthquakes?

Targeting injection
Stimulation of under performing well bores
Injection monitoring

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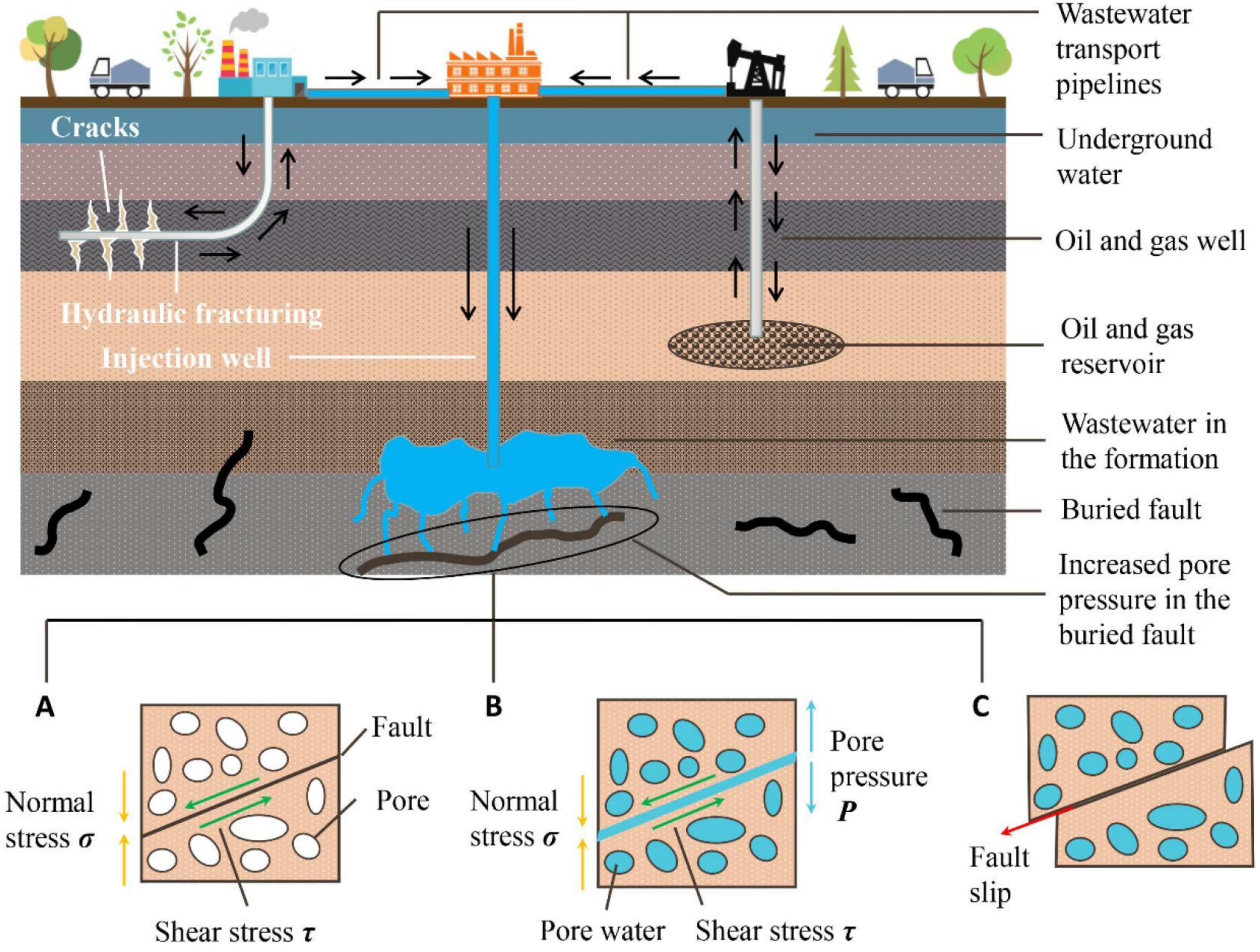
Induced Seismicity

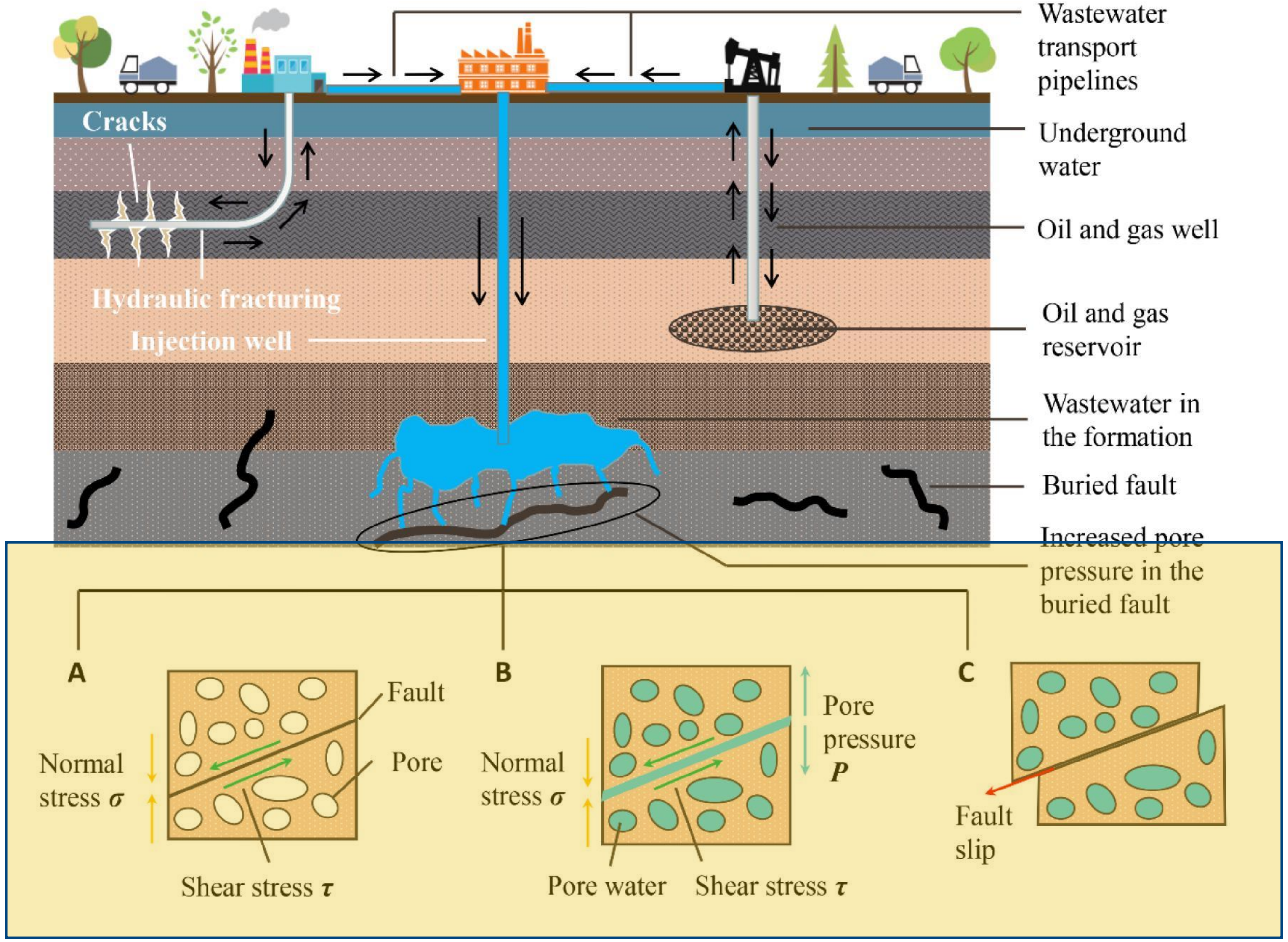
- Fluid injection is known to trigger seismic events.
- Most documented cases have resulted from re-activation of existing faults.
- Factors that impact induced seismicity:
  - Rate and volume of injection
  - In-situ stress conditions
  - Physical and mechanical host rock properties.



https://www.frontiersin.org/files/Articles/539240/feart-08-00227-HTML-r1/image_m/feart-08-00227-g001.jpg (He, Li and Li 2020 injection-induced seismic risk management using machine learning methodology – a perspective study)

Induced Seismicity - Prevention

- Understand existing in-situ stress conditions.
- Monitor rate and volume of injection (no pumping above hydraulic limit for depth)
- Physical and mechanical host rock properties.
- Alberta No. 1 is engaged in a research study with University of Waterloo researchers, Dr. Maurice Dusseault and Mr. Ali Yaghoubi to investigate the potential for induced seismicity in the ABNo1 project area.



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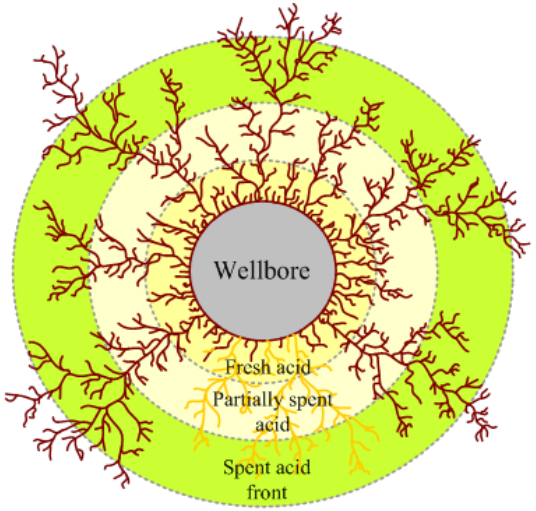
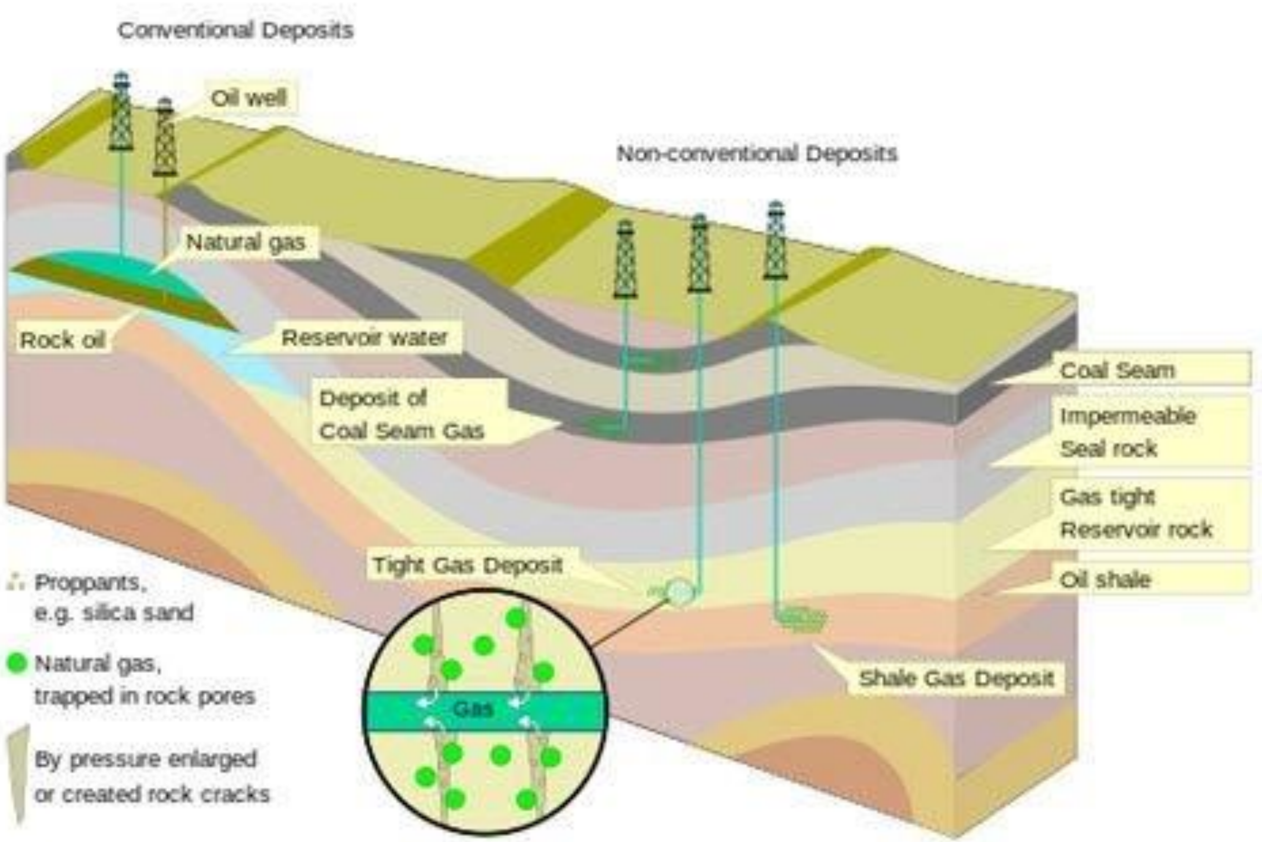
Wellbore Stimulation

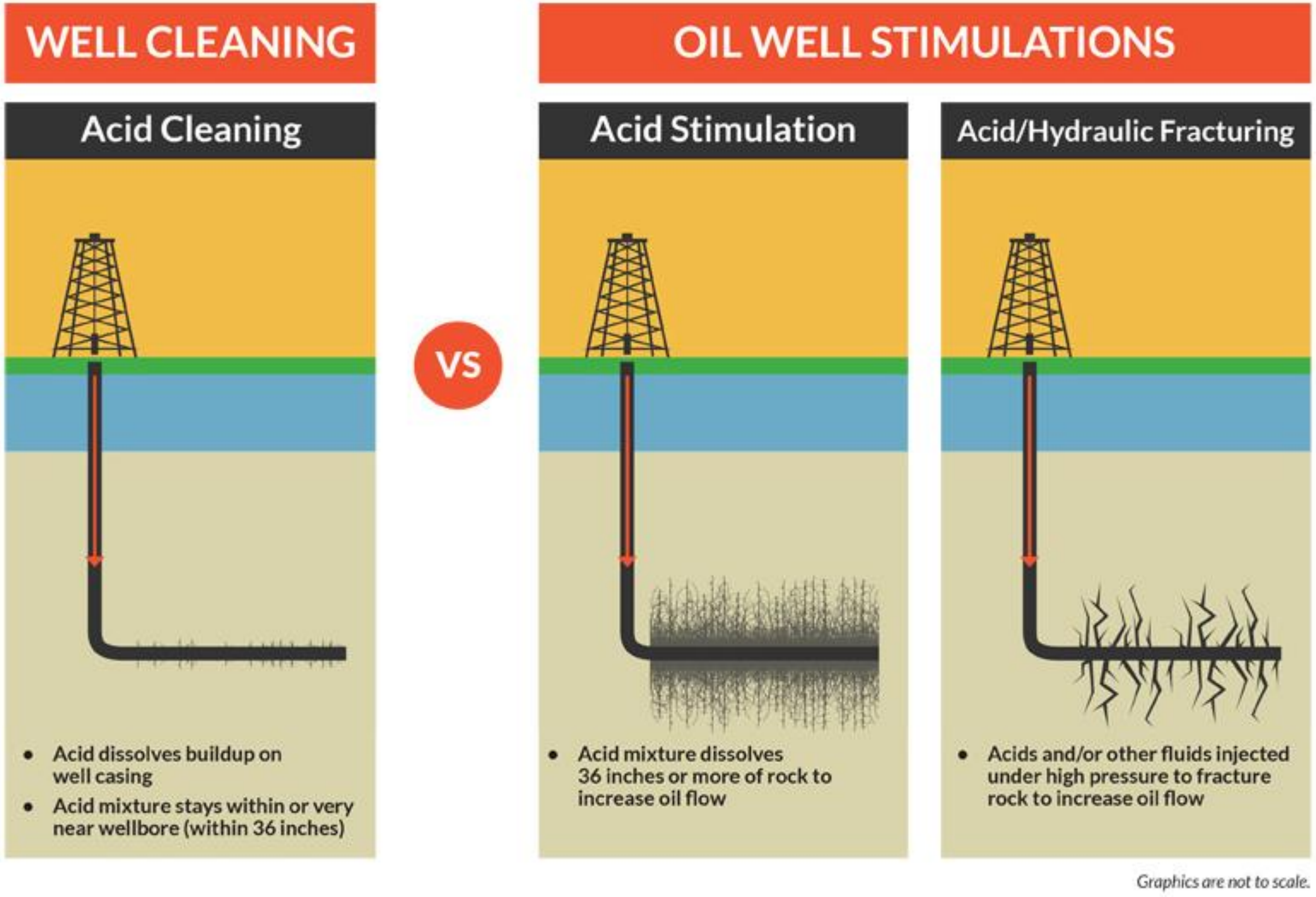
- Aim is to increase flow in a well (either for injection or production) to commercial levels.
  - Hydrofracking (hydraulic fracturing)
  - Acid “dosing” (reactive fluids)
  - Deflagration
  - Thermal fracturing





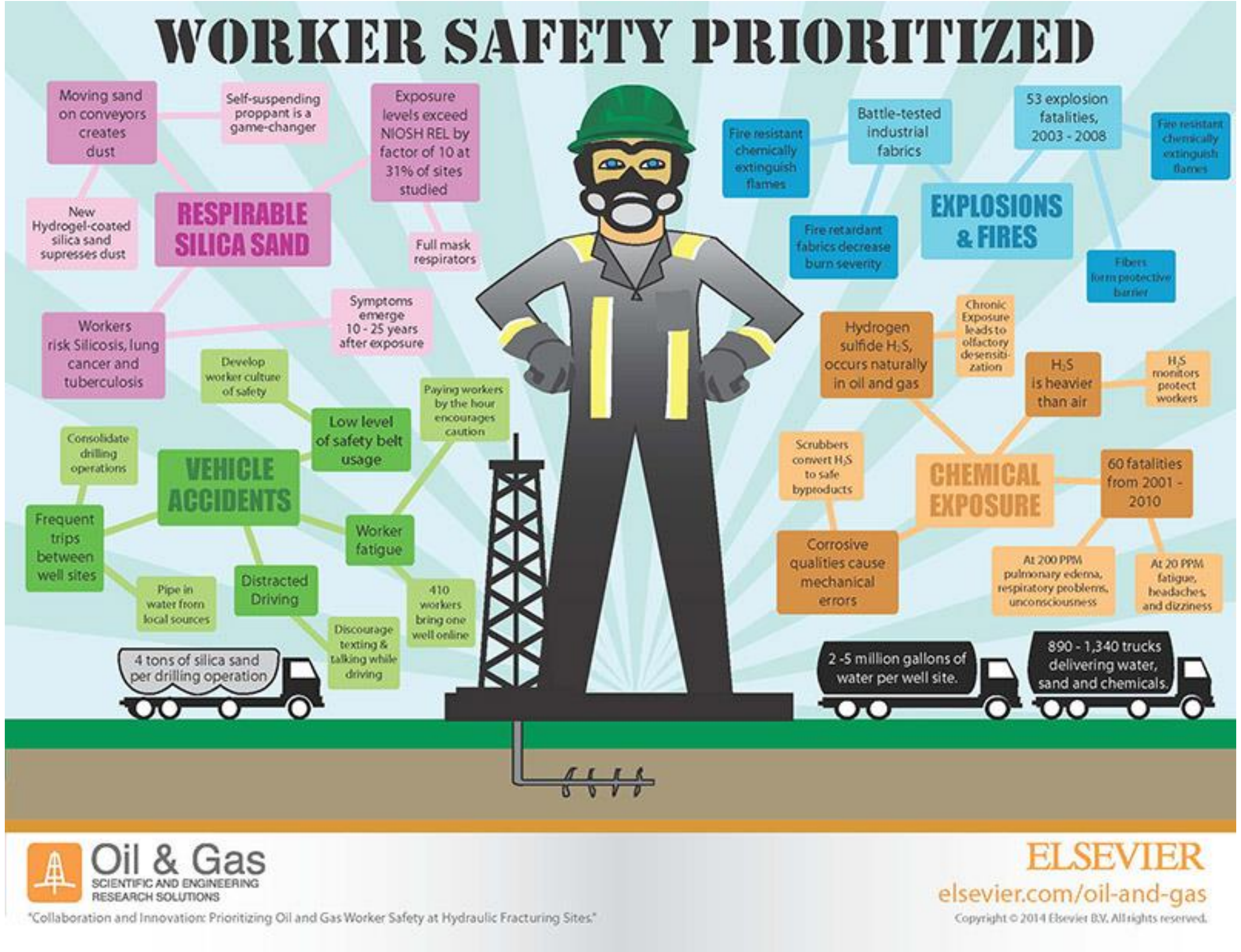
Wellbore Stimulation – Hydraulic fracturing

- Hydraulic fracturing is pumping into the formation above lithostatic pressure.
- Pumping creates stress that opens pore space and “proppants” are injected to maintain the fracture openings. Often used with acid dosing.
- PROS: in sedimentary basin plays, process is well understood from oil and gas experience.
- CONS: very expensive and hard to do in the large well bores used by geothermal. Can lead to induced seismicity if regional stress field is not understood.



Wellbore Stimulation – Hydraulic fracturing

- Hydraulic fracturing has a very poor public perception; even though it, as a technology, has enabled the USA (for example) to become self sufficient in oil and gas production.



See for example Julian Matthews and Anders Hansen, "Fracturing Debate? A Review of Research on Media Coverage of "Fracking"", Frontiers in Communication, 2018

Wellbore Stimulation - Deflagration

- Subsonic combustion propagating through the near bore formation rock that can open fractures.
- Results have been mixed, but several instances a well has been taken from sub-commercial to commercial within a few months of deflagration.
- PROS: relatively cheap; no proppants required.
- CONS: need to be very well targeted. In hot wells, well must be cooled to prevent premature ignition.

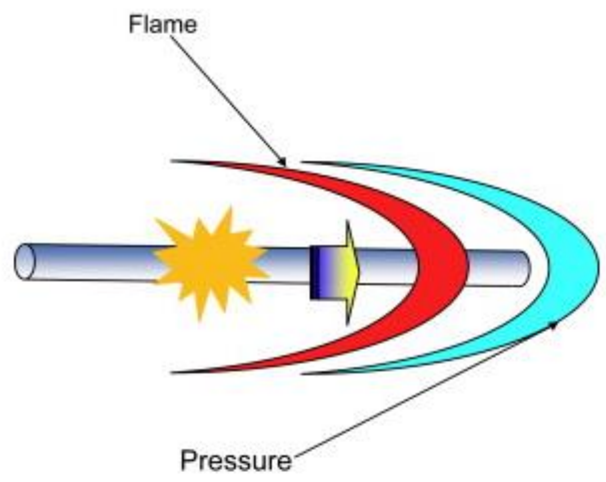


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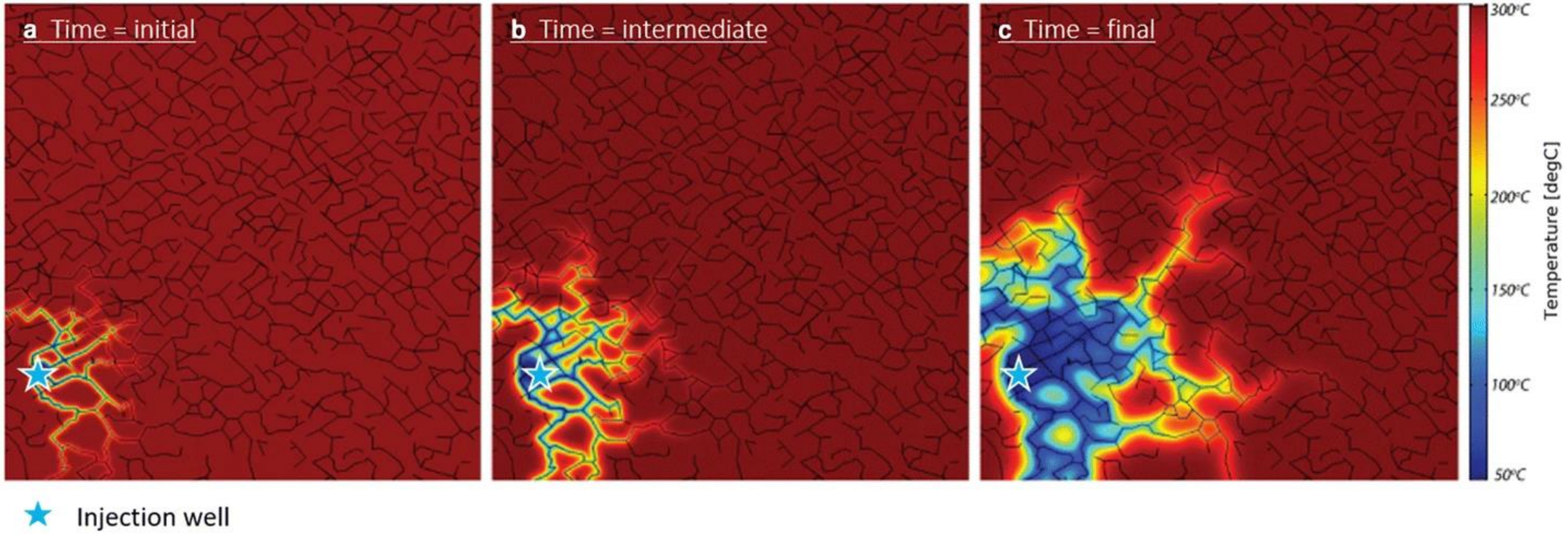
Figure 3. Illustration of the pressure front preceding the flame front in a subsonic explosion (deflagration).

Wellbore Stimulation – Thermal fracturing

- Pumping/circulation of cold water through the drill pipe over days to weeks to months.
- PROS: cheap when a source of cold water is close at hand; no proppants required.
- CONS: takes time, need to set up separate pumping system so rig can be released from site. Many well documented cases of success, especially in hot fields where the ΔT is large.



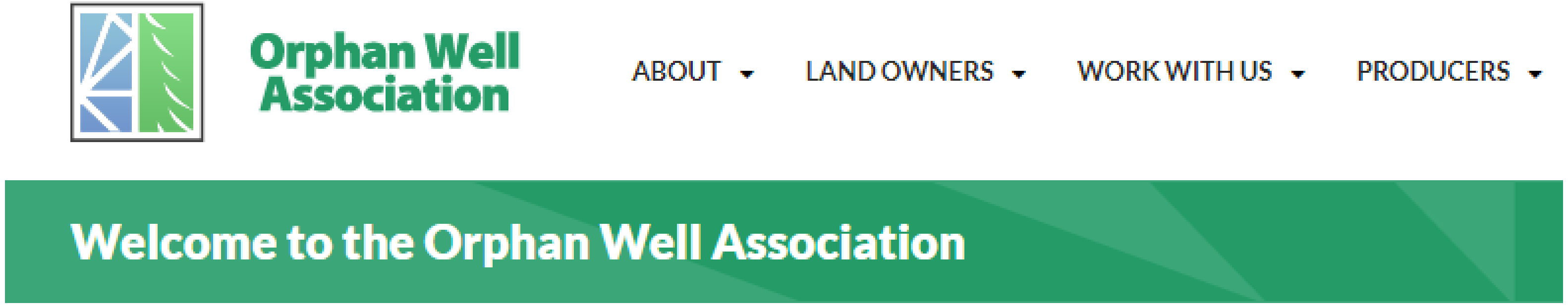
https://geothermal-energy-journal.springeropen.com/articles/10.1186/s40517-019-0141-8, Lepillier, Daniilidis, Gholizadeh, Bruna, Kummerow, and Druhn, 2019

Can existing oil and gas wells be used?

Aka abandoned and orphan wells

Orphan wells

Legacy of the Oil and Gas industry

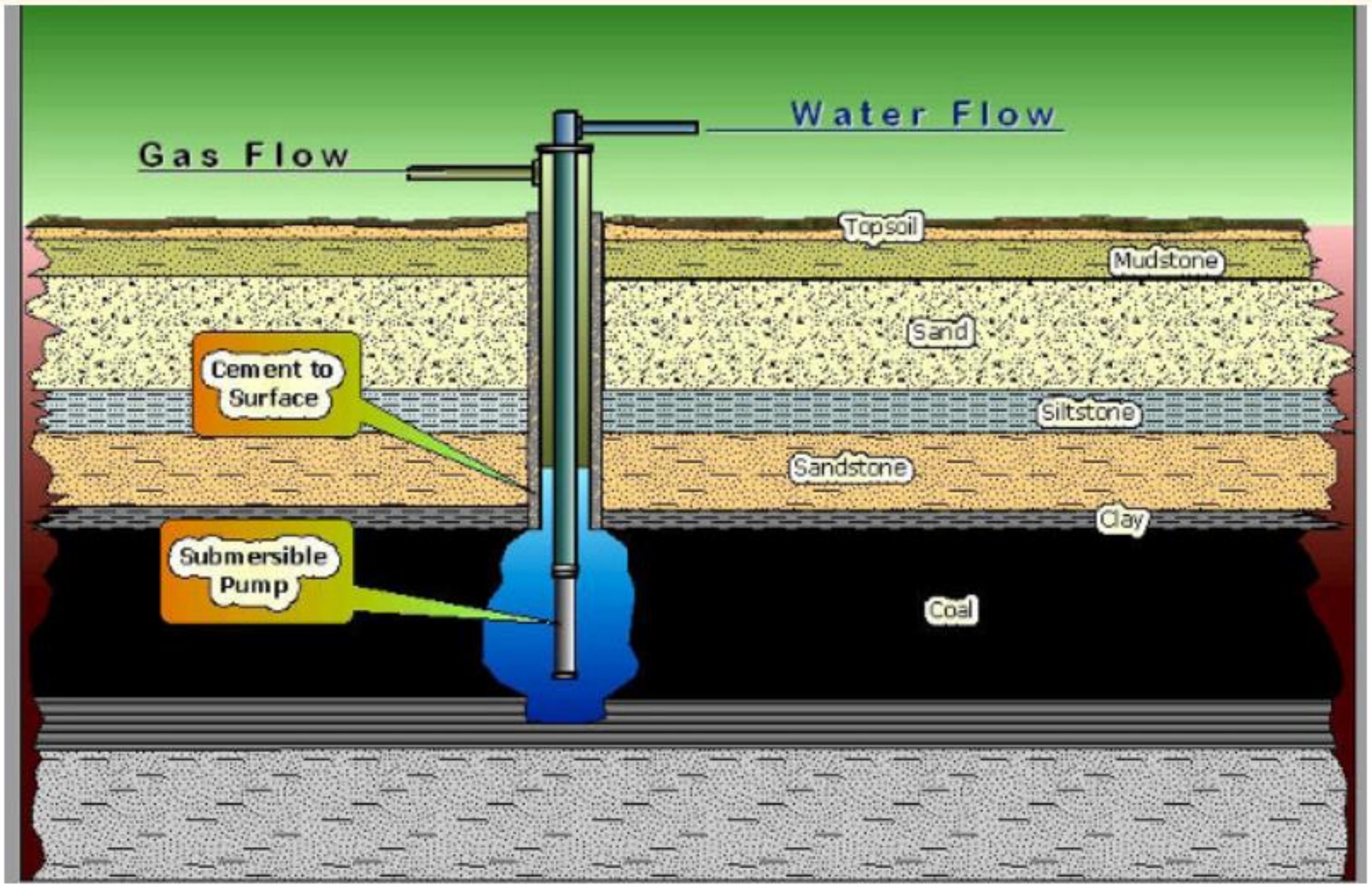


- *Orphan wells are wells that have been drilled, but now have no ownership.*
- With ownership comes the liability to plug and abandon (P&A) the well and restore the site to its original characteristics.
- Without ownership, these wells are a continued liability to complete the plug and abandon (P&A) and environmental restoration of the site.
- Geothermal companies are typically small companies created specifically to carryout geothermal operations; without the financial resources to assume potentially significant liabilities in assuming an orphan well.
- Challenge for governments is the liability issue surrounding environmental concerns.

Re-purposing wells – wellbores

Legacy of the Oil and Gas industry

- Over 600,000 wells have been drilled in Alberta
- Wells could be re-purposed as observation wells, injection wells or production wells.
- **Wells must have a high water cut and flow rate (production rate).**
- Entering a P&A well and dealing with drilling through the plug *must* be cost effective.
- Well bore conditions (corrosion, erosion or other issues arising from production (or injection) require good existing records and additional logging prior to re-entry.



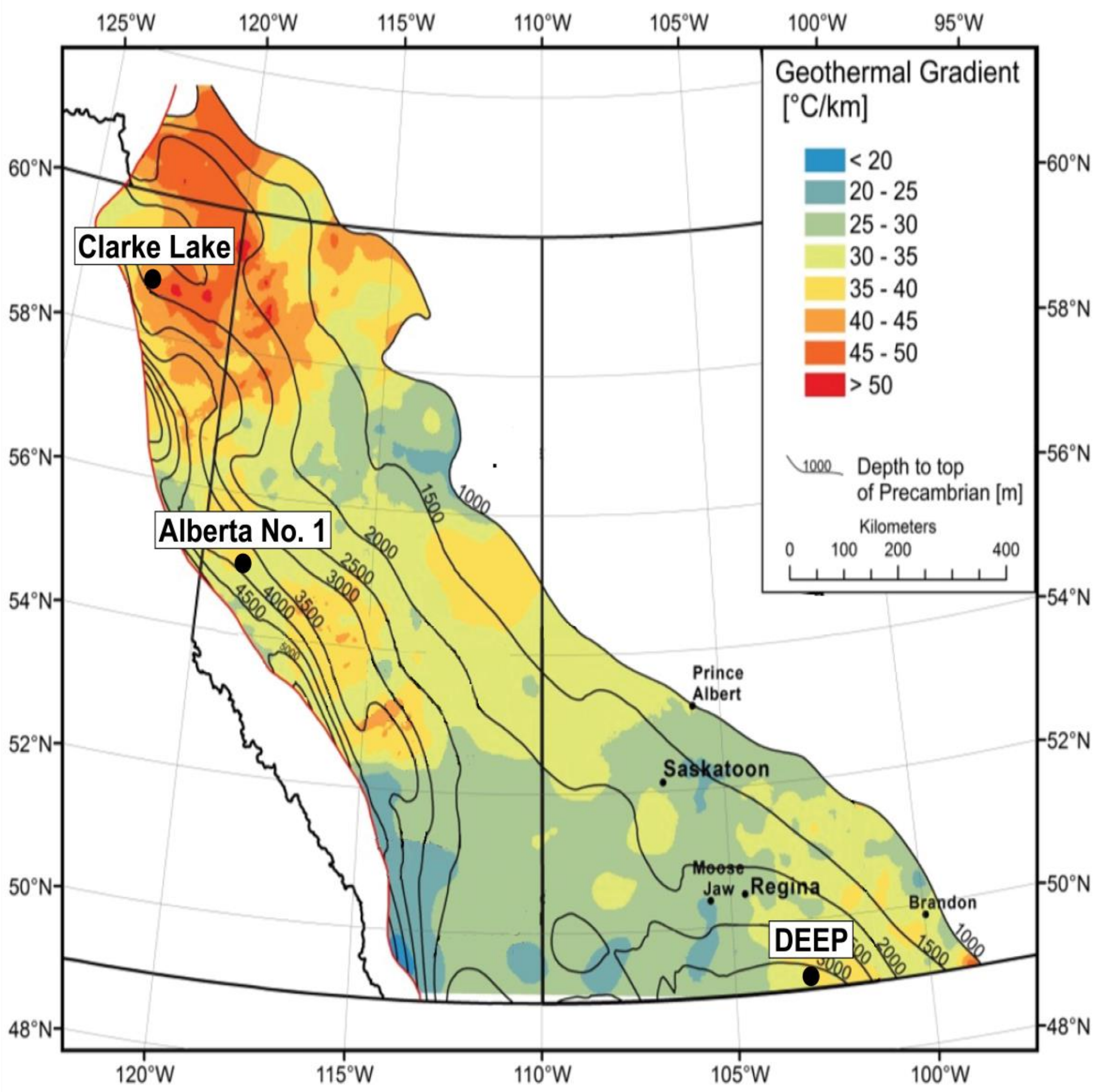
A typical energy wellbore: integrity of cement casing key to preventing leaking emissions.

https://thetyee.ca/News/2014/06/05/Canada-Leaky-Energy-Wells/

Re-purposing wells – wellbores – case study

Tu Deh-Kah Geothermal, British Columbia

- Case Study from the Clarke Lake gas field, British Columbia Project, known to be highly productive with a significant water cut, over a long time period.
- Very high water cut – termed “exceptional” by some.
- Early assessment indicated that one or more wells were worthy of consideration to re-purpose.
- C-87-gas well, originally drilled in 1997, was chosen; well was intermittently producing.
- Well and lease were acquired; re-permitted as a disposal well for reservoir characteristic testing
- Stuck packer became problematic and created cost overruns.
- Well completed with a whip stock around packer and debris. Casing evaluation suggests that well has limited commercial lifespan.
- **Outcome – cheaper than drilling an exploration well to test reservoir.**



Re-purposing wells – surface fascilities

Legacy of the Oil and Gas industry

- Use of existing sites are a quick pathway to development; saving time and money.
- Wellbores with flows (>10 l/sec), close to existing infrastructure may be considered for re-purposing for small developments (greenhouses, drying fascilities, aquiculture, etc.). Also, in some locations well pads are in close proximity to each other and can be used as a doublet (injector and producer).
  - CONS: Need to acquire existing surface rights <u>and</u> subsurface rights if there is a drilled well on the site (current AE/AER regulations). Beware of “legacy” liabilities related to previous activity. Is continued use of the well dependent on oil and gas revenue? Is there a near-by well that can be used as an injector?
  - PROS: Can speed up site acquisition process (which in some cases can take years). Often less need for additional construction costs. Less disruption of the land.

How do we make geothermal financially viable?

Regulations
Power sales
Thermal (direct use sales)
Holistic and integrated developments
Carbon credits and politics

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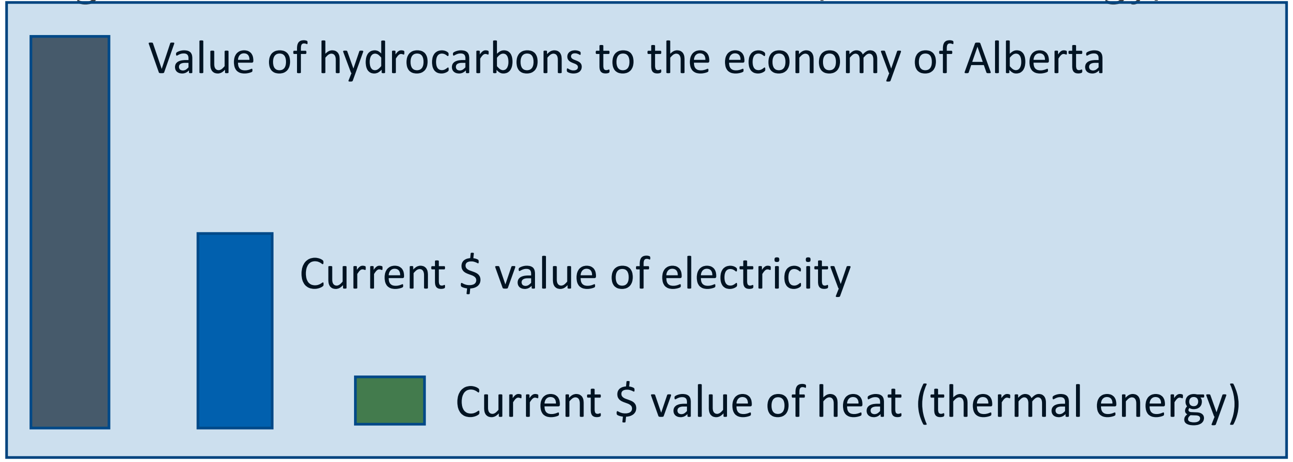
https://www.listeningpays.com/how-to-deal-with-the-elephant-in-the-room/

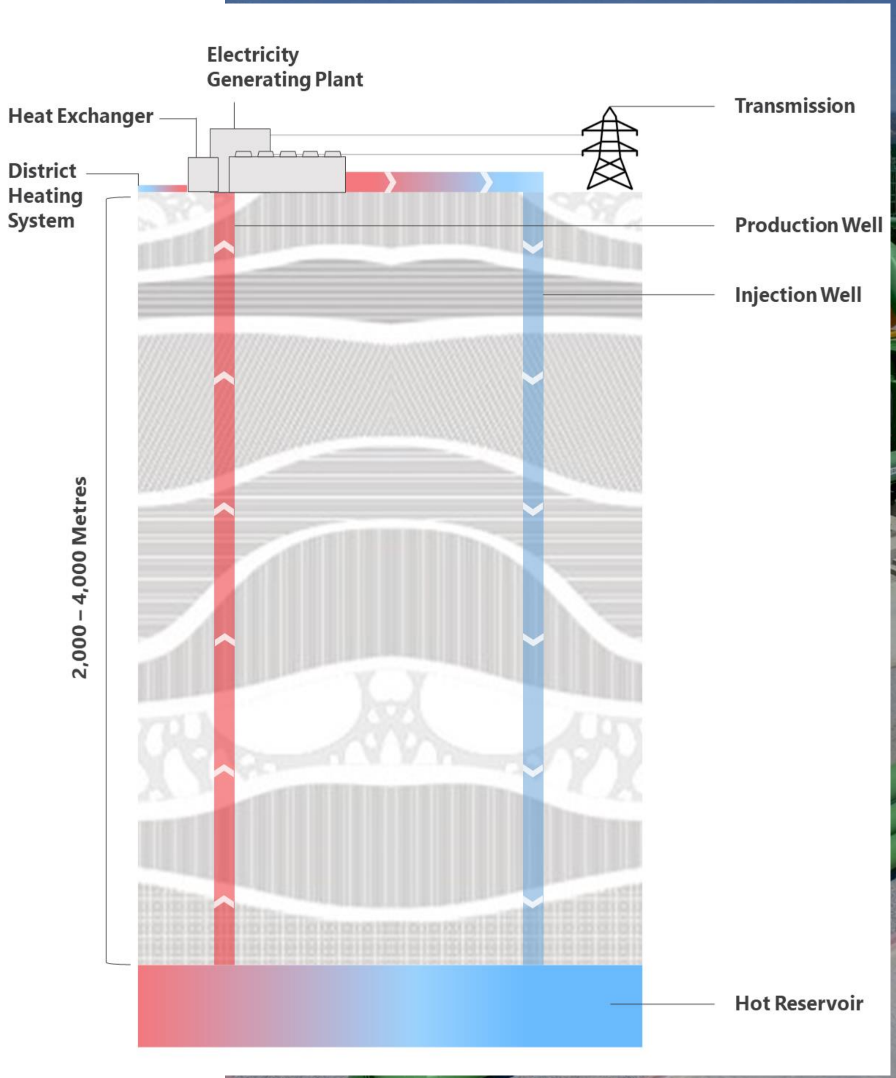
How can government and investors best take advantage of the “elephant in the room” that is the global geothermal resource endowment?

The keys to the geothermal market

- Economics of projects are very different for oil and gas investors.
- Social acceptance of a “new Industry”.
- Helping corporations increase their Environment-Social-Governance (ESG) credits.
- Technology transition while preserving core expertise in Oil and Gas.
- Moving the needle on the value of heat (thermal energy)



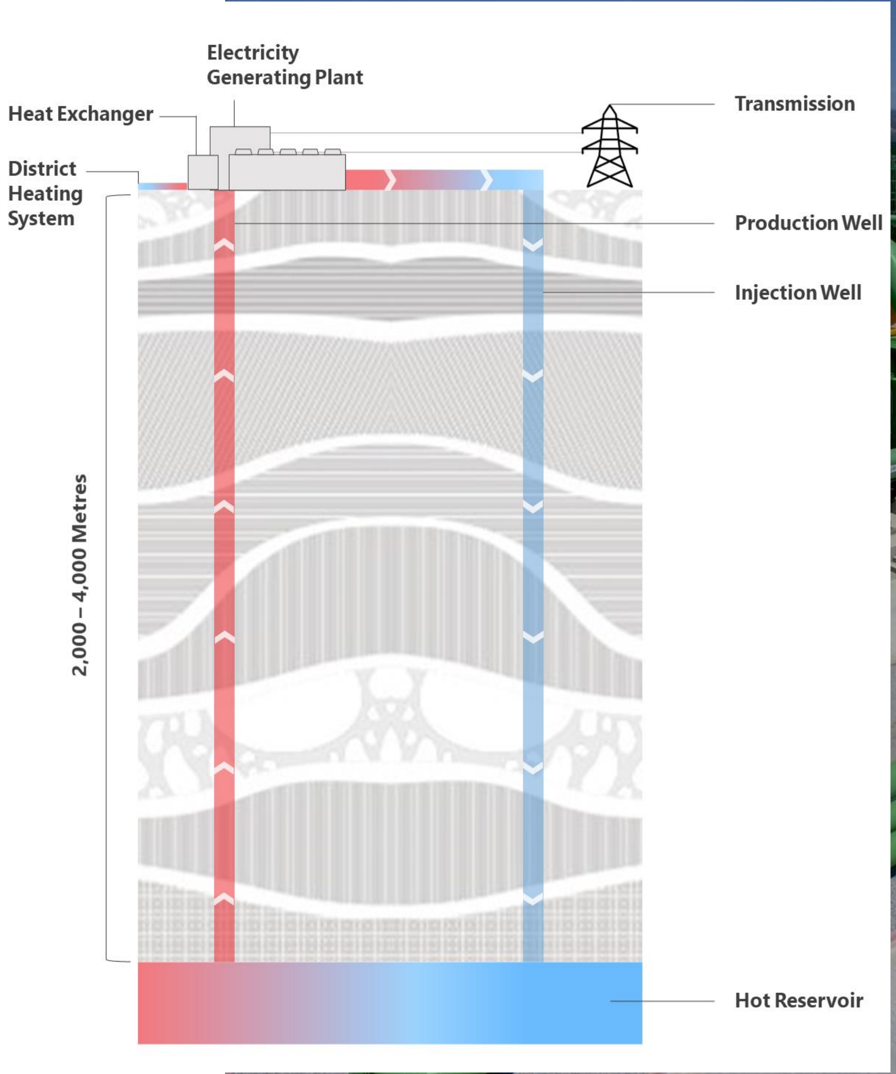
Financial **Political** **Technical**



Geothermal's commercial hurdles

- Carbon emitters have not fully grasped the long-term implications of carbon tax on the economics of their operations.
- Challenging to show early returns due to low price of power and natural gas in Alberta.
- "First in kind" seen as too risky for most/many investors.
- Institutional investment wants to come in after drilling risk is removed.
- Skepticism as to the potential for build out of projects.
- Economics of projects are very different for oil and gas investors.
- Inability to get debit financing during early phases of a project.
- Mezzanine or bridging financing very costly.

Financial **Political** **Technical**

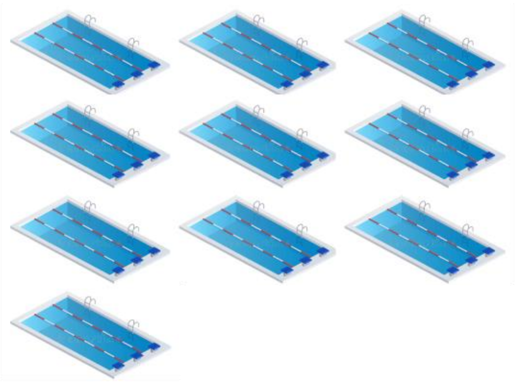


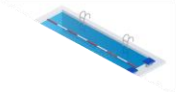
Geothermal's commercial hurdles

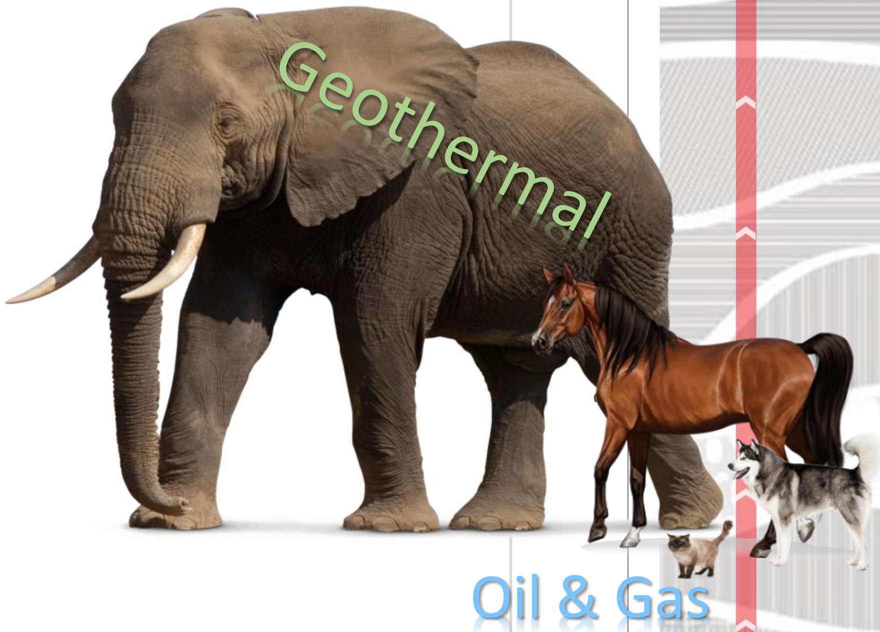
- Technical hurdles showing temperatures and flow rates.

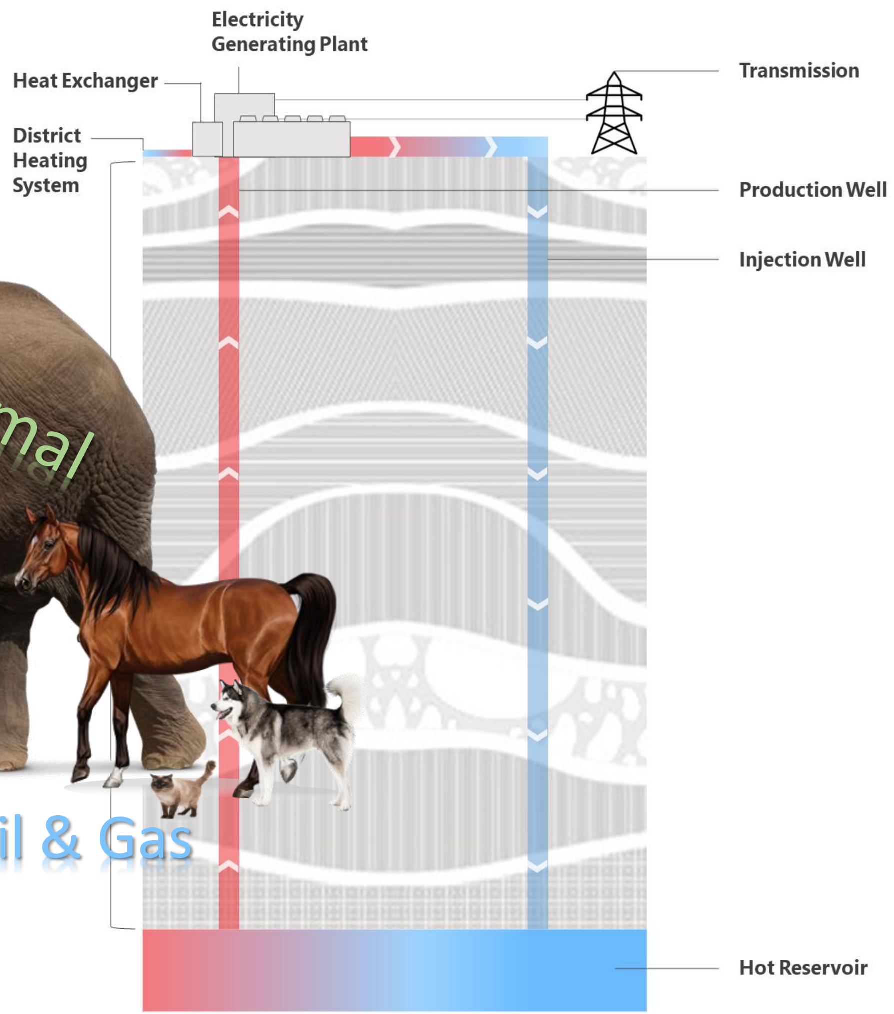
How Much Is Produced In 24 Hours?

Alberta No. 1	Oil Well
300 L/s brine	10 L/s oil and water
26 million L/day	860,000 L/day
163,000 bbl/day	5,400 bbl/day









Financial | Political | Technical

Expanding Conventional Geothermal's Value Chain

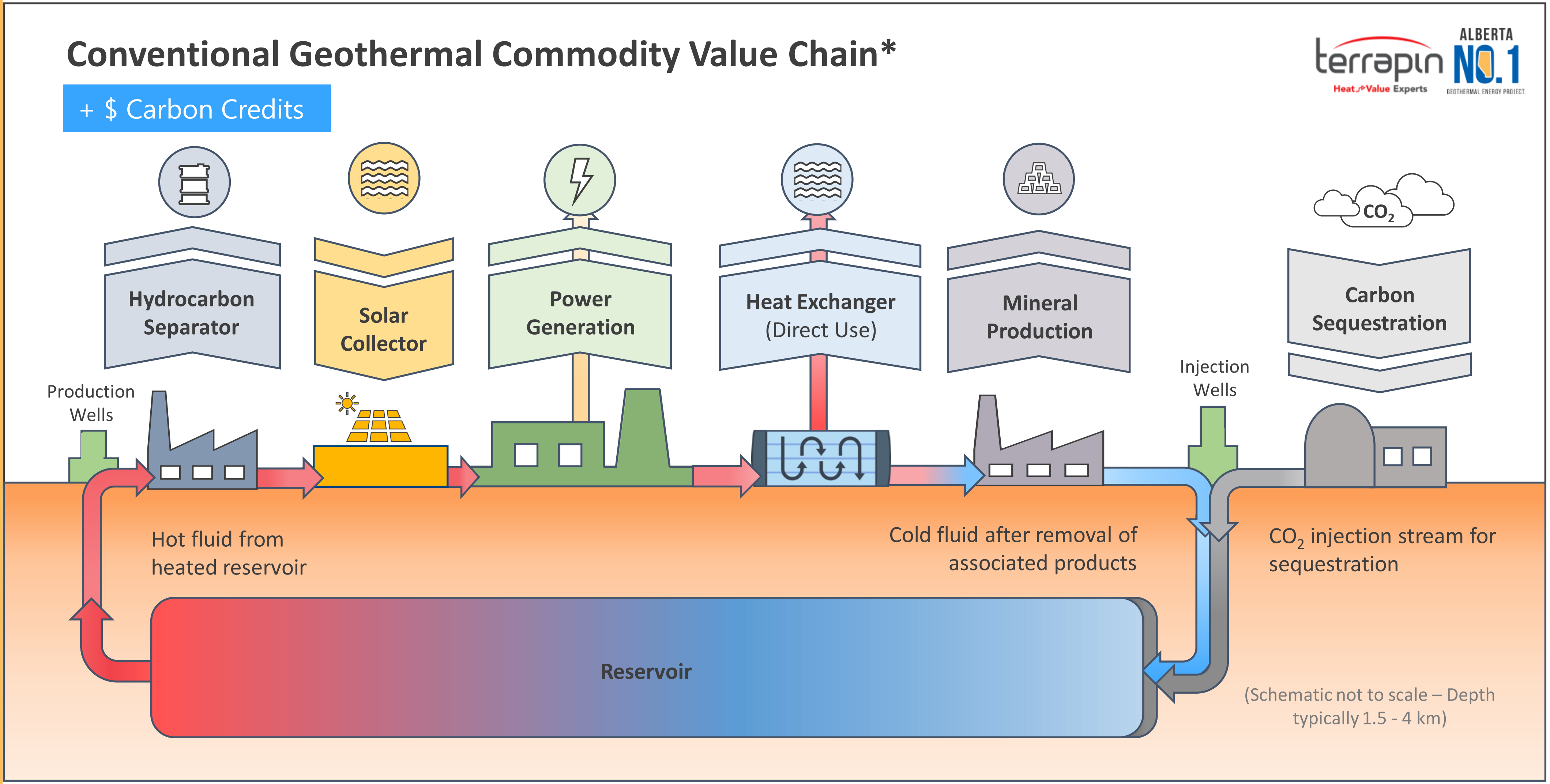
Holistic and eco-industrial development

ALBERTA NO.1 GEOTHERMAL ENERGY PROJECT.

terrapin Heat Value Experts

Promoting a Holistic Eco-industrial Development

Utilizing all the intrinsic value of the produced brine and injection capacity.

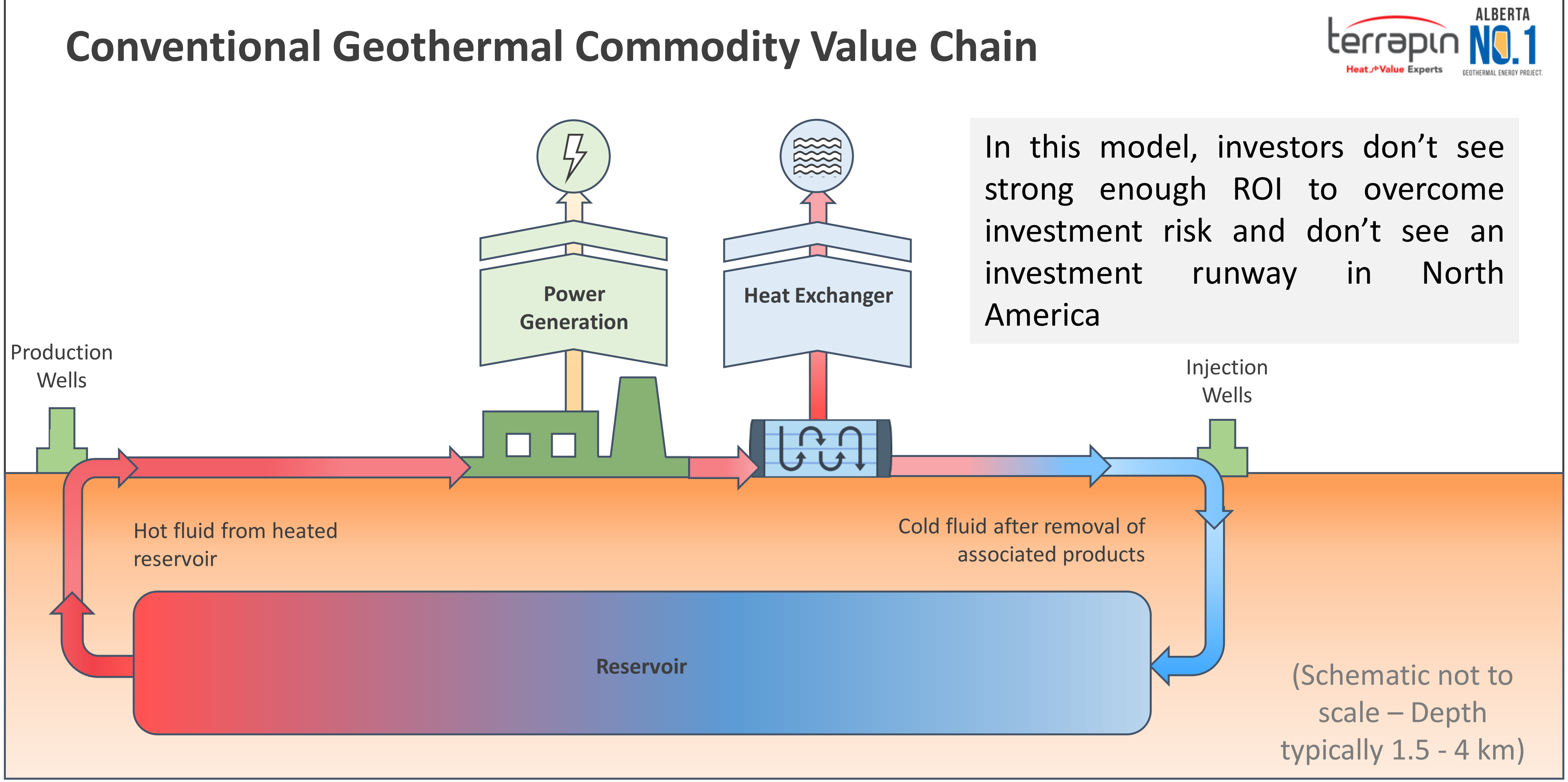


(*Depending on local geological conditions)

Power and Heat (thermal) Projects

How conventional geothermal can be competitive in the global marketplace.

Conventional Geothermal Commodity Value Chain

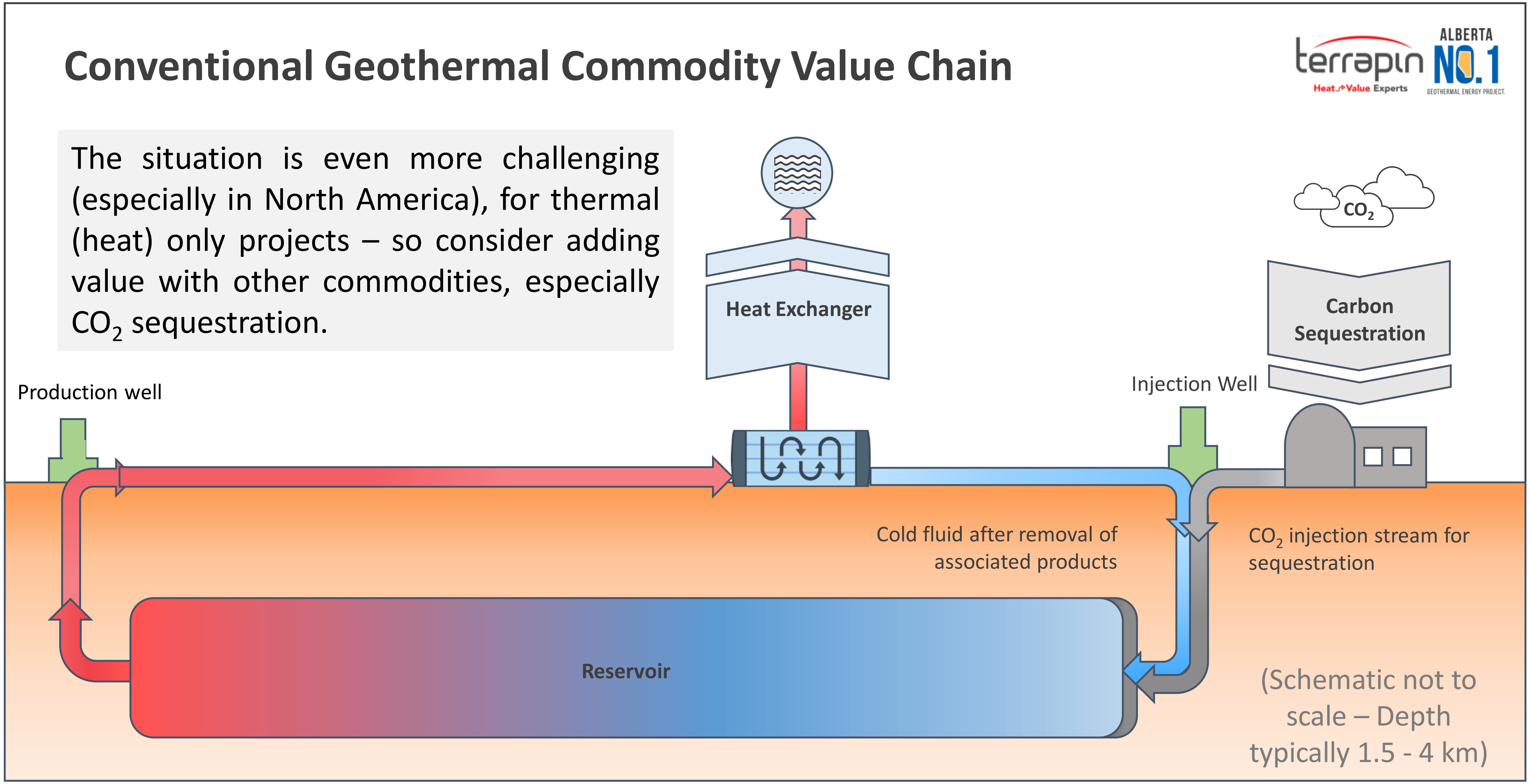


In this model, investors don't see strong enough ROI to overcome investment risk and don't see an investment runway in North America

Fundamentals of conventional geothermal are thermal heat recovery and in some place's electricity generation

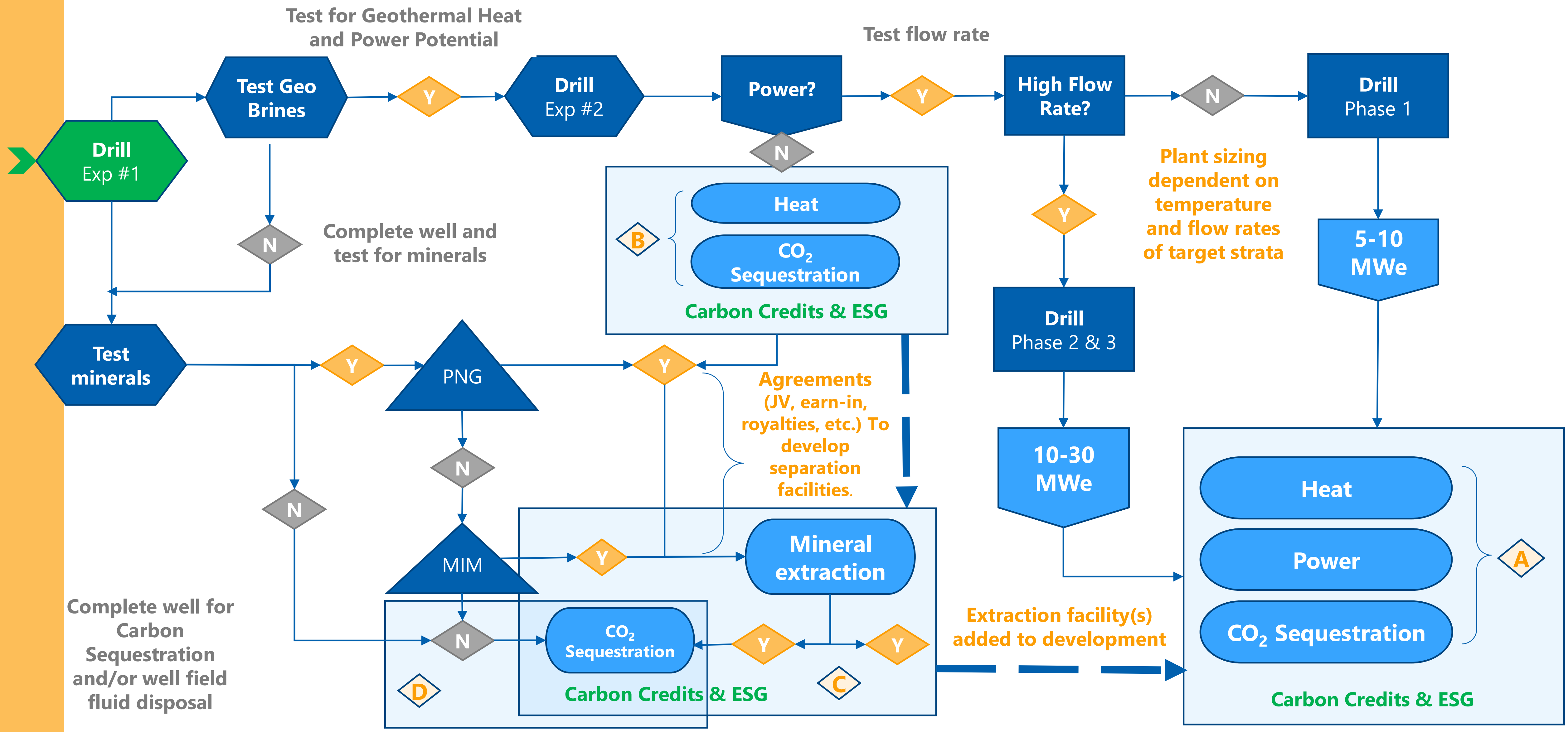
Heat (thermal) only projects

Thermal only projects may be able to get a boost by being carbon negative



Schematic Development Plans

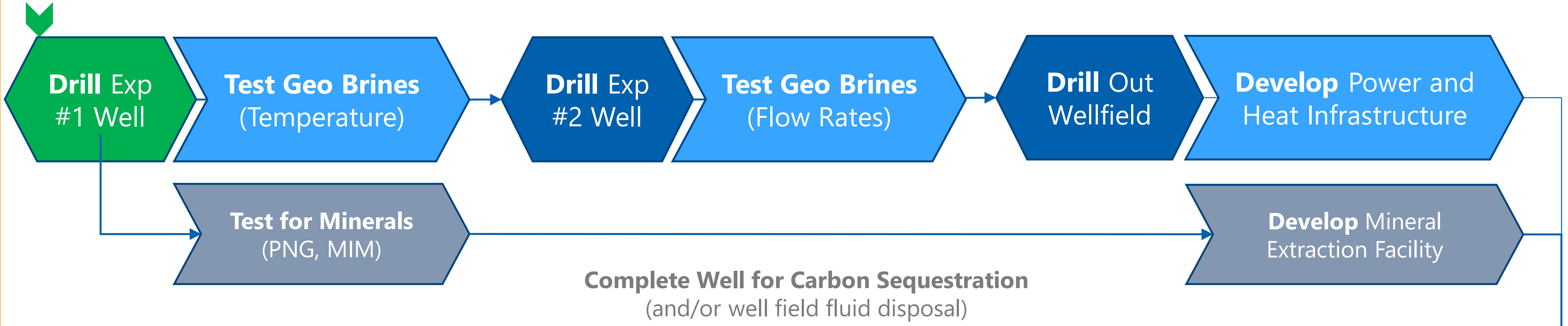
PLAN A – Heat, power, CO_2S, ±minerals
PLAN B – Heat, CO_2S, ± minerals
PLAN C – Minerals, CO_2S
PLAN D – CO_2S (and/or oil field disposal)



Schematic Development Plan A: Power

A

+ Carbon & Environmental, Societal and Governance (ESG) Credits



A

Plan A – Our Development Plan
Development Site(s) Demonstrate Power Generation Potential

Value additions of:

+ Development of heat (direct use) infrastructure
+ Mineral extraction from produced brines
+ CO_2 sequestration into injection wells
+ Sale of environmental attributes

Development Efficiencies

- Cost savings are gained with larger well field fluid flows resulting in maximization of the power plant size.
- Surface drilling locations(within 5 to 10 km) can be piped to a central generation facility, maximizing the output of the facility.

A

30 MWe* of Geothermal Power

+

District Heating

Mineral Extraction

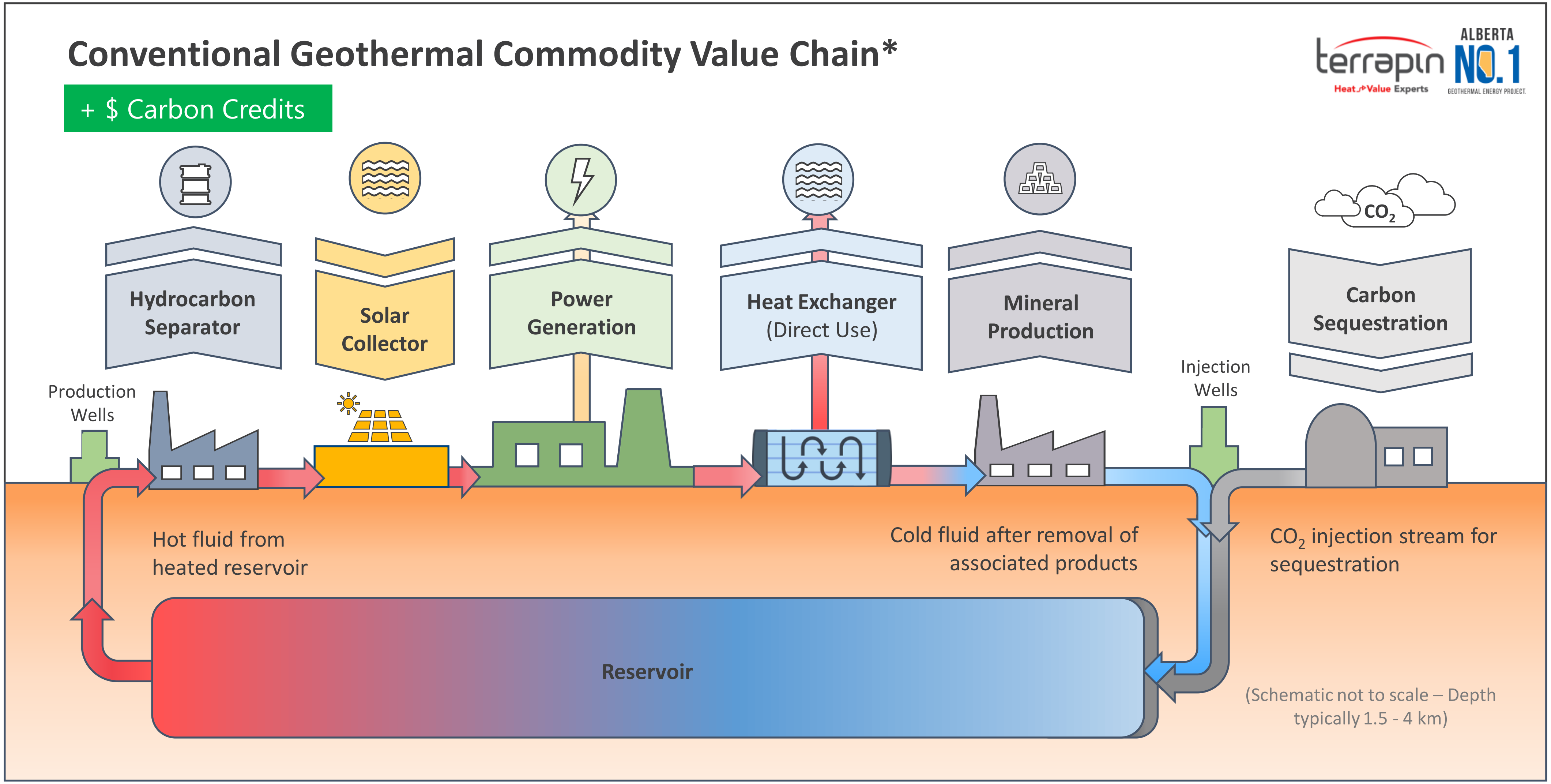
CO_2 Sequestration

**Plant sizing dependent on temperature and flow rates of target strata*

Hybrid (Holistic) Systems

*Scenario A requires geological conditions that provide the commercial viability for all commodities – **RARE!***

A

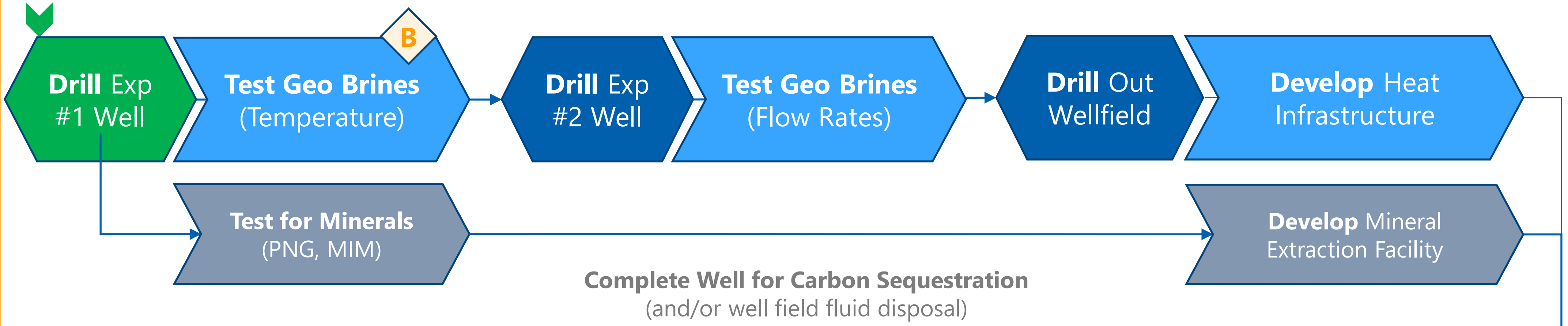


Addition of solar and other forms of hybrid systems (e.g., thermal storage, co-generation) may help economics in specific jurisdictions as well as support of offset parasitic loads providing more green geothermal power to the grid.

Schematic Development Plan B: Heat infrastructure

+ Carbon & Environmental, Societal and Governance (ESG) Credits

B



B

Plan B – Heat infrastructure

*If geothermal brines are not commercially viable for geothermal power development, revenue will be generated from **thermal energy sales**.*

Value additions of:

+ Mineral extraction from produced brines
+ CO_2 sequestration into injection wells
+ Sale of environmental attributes

Development Efficiencies

- Cost savings are gained by minimizing the piping length between optimized surface locations and the thermal load.

District Heating

Mineral Extraction

CO_2 Sequestration

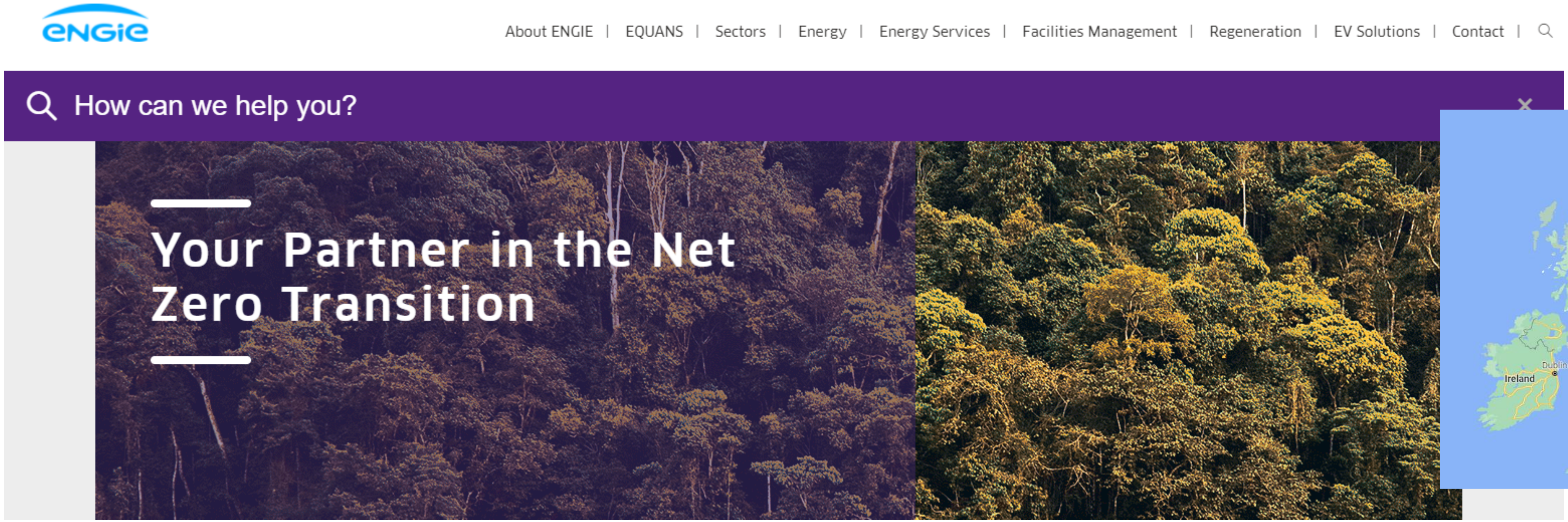
Schematic Development Plan B: Heat infrastructure

+ Carbon & Environmental, Societal and Governance (ESG) Credits

European adoption of District Heating is much more widespread than North America

- Need to grow district heating projects in areas where temperatures aren't high enough for power generation.
- **Lower CAPEX due to shallower, smaller wells and infrastructure.**
- **Possibility to repurpose existing wells and infrastructure.**
- Europe has a high-density population.
- Surface drilling locations (within 5 to 10 km) can be piped to a central generation facility, maximizing the output of the facility.

Southampton District Energy Scheme by Southampton Geothermal Heating Company Ltd.



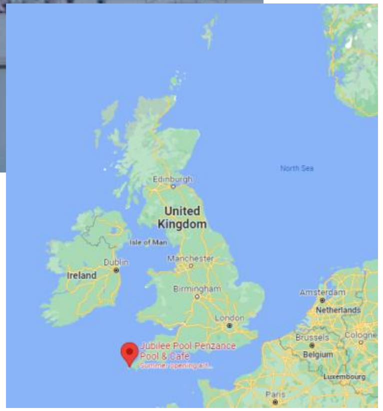
Schematic Development Plan B: Heat infrastructure

+ Carbon & Environmental, Societal and Governance (ESG) Credits

Developing Other direct use options

JUBILEE POOL

Relax, unwind and enjoy the view in our geothermal pool, the first of its kind in the UK. Bathe in natural salt water heated to between 30-35 degrees by our very own geothermal well.

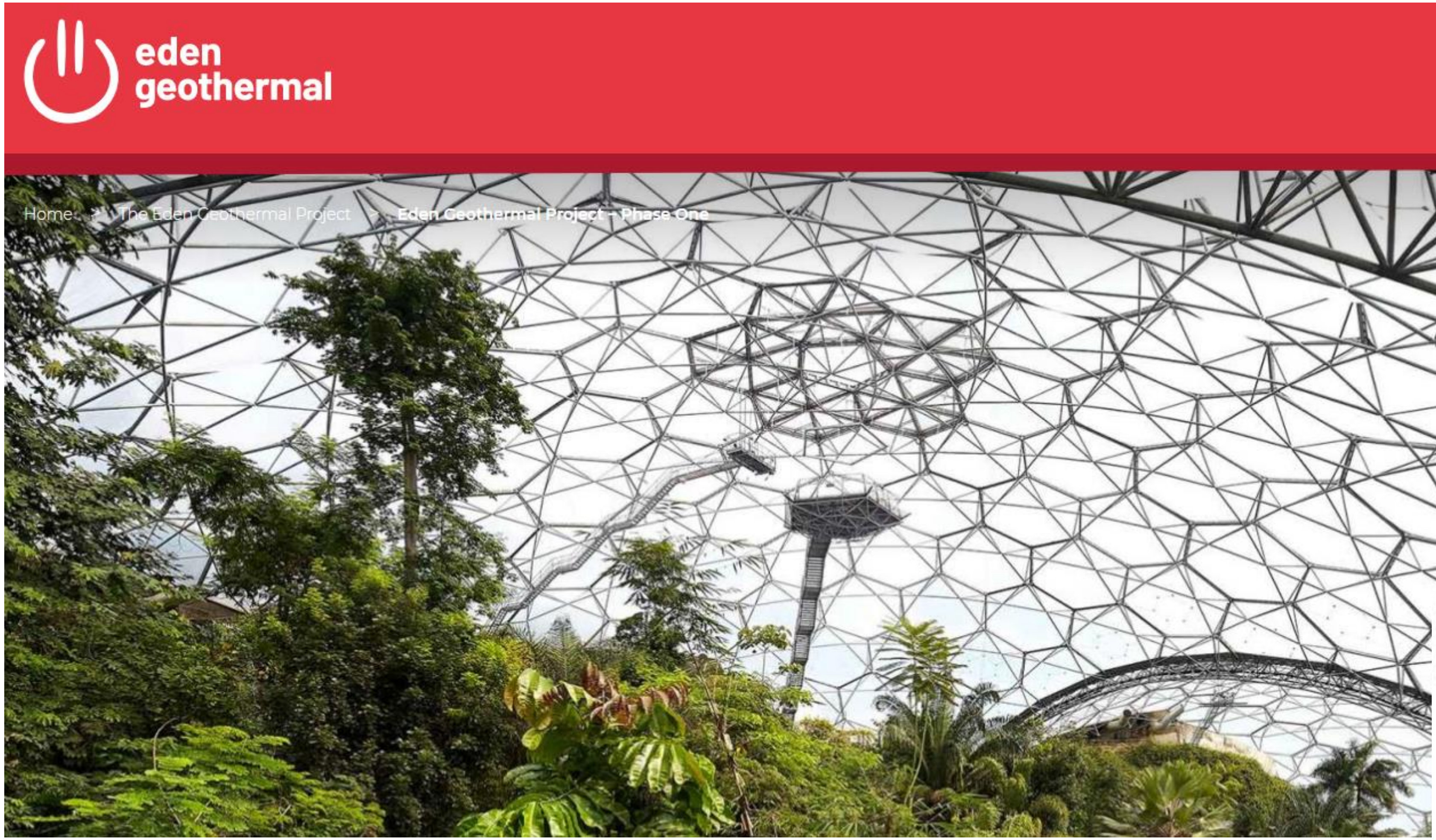


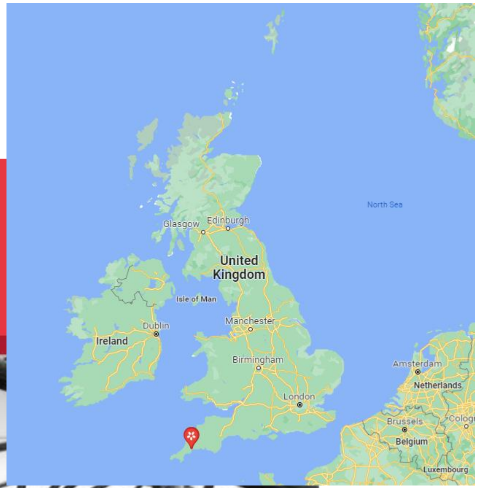
Schematic Development Plan B: Heat infrastructure

+ Carbon & Environmental, Societal and Governance (ESG) Credits

Developing Other direct use options

Eco-industrial





Schematic Development Plan B: Heat infrastructure

+ Carbon & Environmental, Societal and Governance (ESG) Credits

Developing Other direct use options

EXPLORING °CELSIUS GEOTHERMAL TECHNOLOGY

1. Sustainable Distillery Research Centre

2. Geothermal Rum Distillery

3. Geothermal Cask Maturation Pods

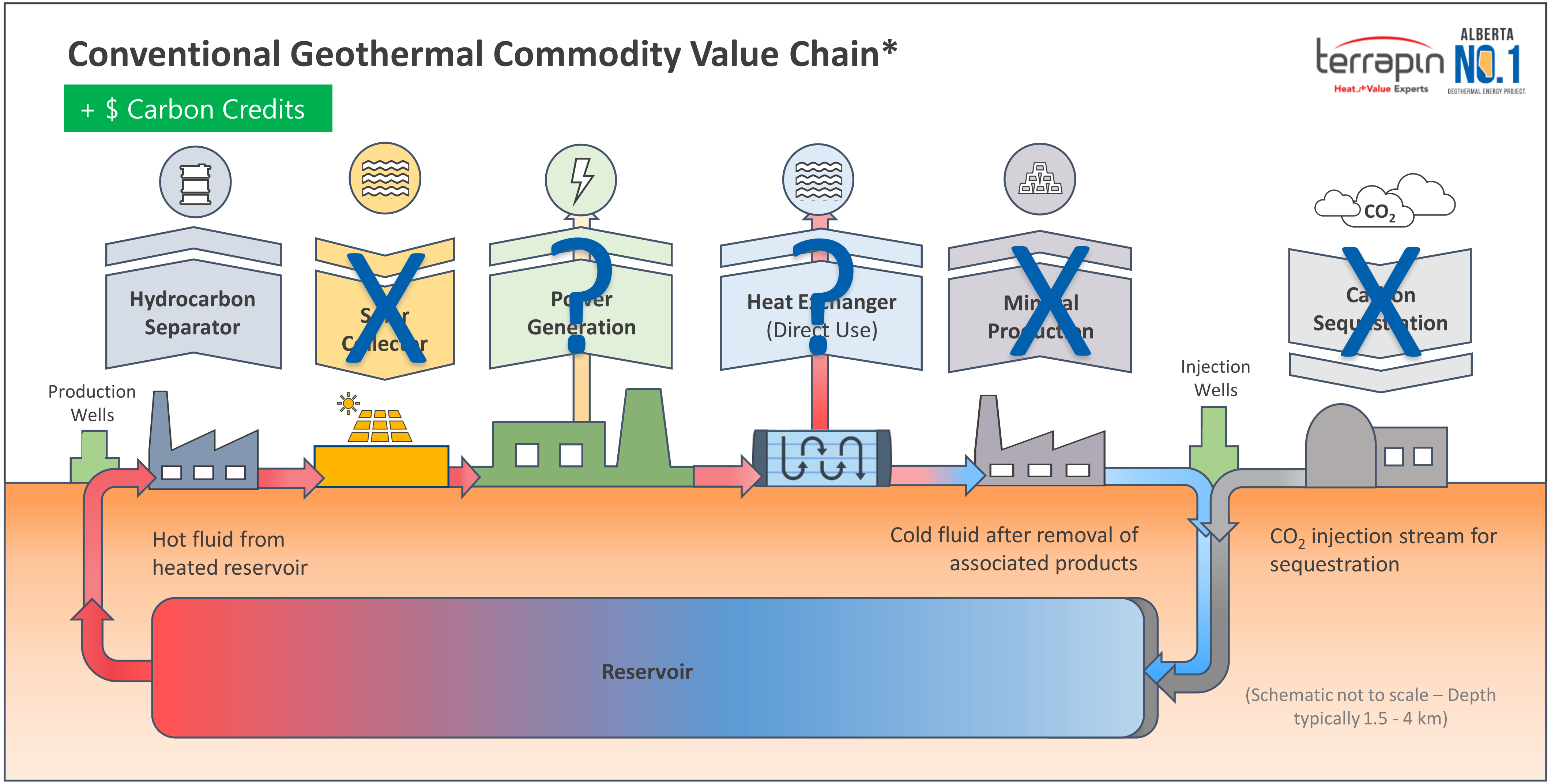
°CELSIUS®
CORNISH GEOTHERMAL DISTILLERY COMPANY

Rum distillation!

Schematic Development Plan B: Heat infrastructure

Scenario B has greater potential to find locations that provide commercial viability for more than one commodity.

B



Addition of solar and other forms of hybrid systems (e.g., thermal storage, co-generation) may help economics in specific jurisdictions as well as support of offset parasitic loads providing more green geothermal power to the grid.

Schematic Development Plan B: Heat infrastructure

+ Carbon & Environmental, Societal and Governance (ESG) Credits

+ Hydro-carbon co-production

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Hydrocarbon-Geothermal Co-Production: Worldwide Scale Status and Evaluation of the Techno-Economic Potential in Serbia

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By E. Jeandel, M. Mecheri and D. Rettenmaier

Publisher: European Association of Geoscientists & Engineers
Source: Conference Proceedings, First EAGE/IGA/DGMK Joint Workshop on Deep Geothermal Energy, Nov 2018, cp-577-00019
ISBN: 978-94-6282-269-6
DOI: https://doi.org/10.3997/2214-4609.201802947

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Abstract | Full-Text | Figures & Tables | References | Cited By | Supplements | Metrics | Related Content

Hydrocarbon-geothermal co-production is an emerging opportunity for a wider development of geothermal energy. In the frame of the french-serbian GOSPEL program (Geothermal Serbian Pilot projects for Heat and Electricity), a state of the art of the synergies and challenges of co-production has been performed. The knowledge of co-production potential at worldwide scale remains limited, but numerous countries have started investigating this topic. On-going projects were mapped, revealing a large diversity of initiatives in regards to the geological settings, possible well configurations and thermal co-production capacities. Besides, the opportunities for hydrocarbon-geothermal co-production in Serbia were studied. Technologies suited to exploit the geothermal fluid and the recovered methane for heat or power production have been identified. Based on the available data of gas contents in geothermal fluids, areas of interest for co-production projects could be selected. Then, different scenarios were considered to assess the techno-economic potential of two sites, based on performance evaluation and a simplified economic model. The preliminary calculations showed that, in all scenarios, methane can be extracted and its combustion can be used for heat and electricity production. The geothermal fluid could also be exploited for heat or power production, depending on the geothermal resource quality and flow volume.

EAGE

DGMK

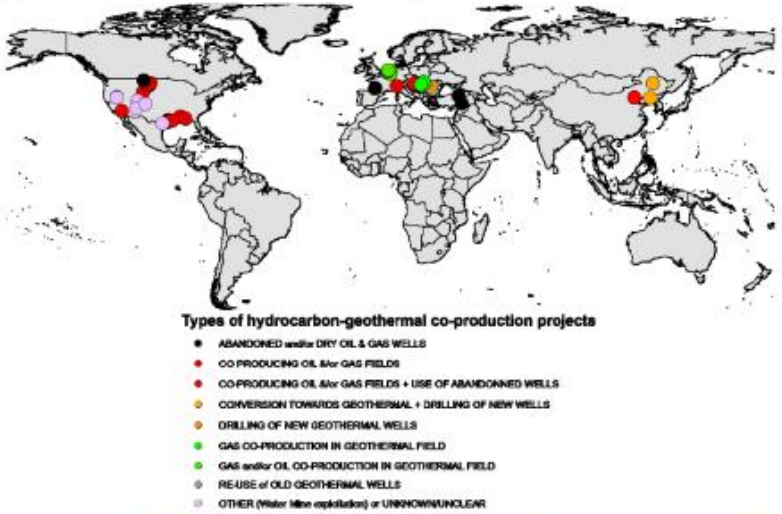
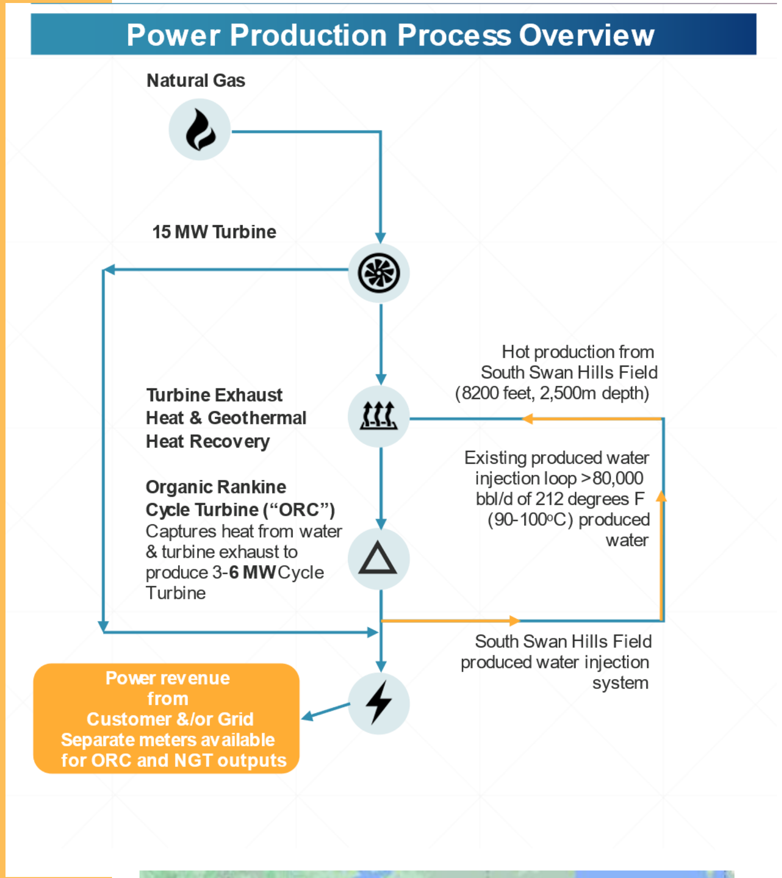


***Figure 1** Mapping of the hydrocarbon-geothermal co-production projects and initiatives at worldwide scale. The projects are classified per types depending on the well configurations.*

Futera Power, Swan Hills, Alberta



FutEra Power is developing the first **co-produced geothermal power plant in Canada,** within legacy oil and gas infrastructure in Swan Hills, AB. The region has been long known for its high well head temperatures (~100°C), high water cuts and very high production rates. These are all attributes that are necessary for successful dual use of existing oil and gas infrastructure. The company plans to commission power generation in Q1, 2022 that includes 3MWe geothermal. FutEra will likely be the next company to produce geothermal power in Canada since the 1984 generation at Mount Meager British Columbia. Check out FutEra's web site https://www.futerapower.com/ for more information.

FUTERA POWER

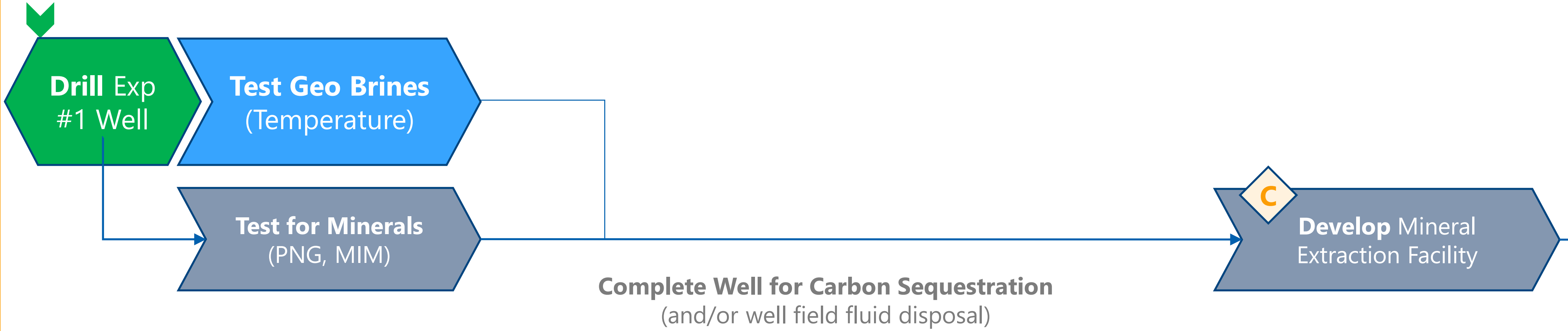
A Subsidiary of Razor Energy Corp.

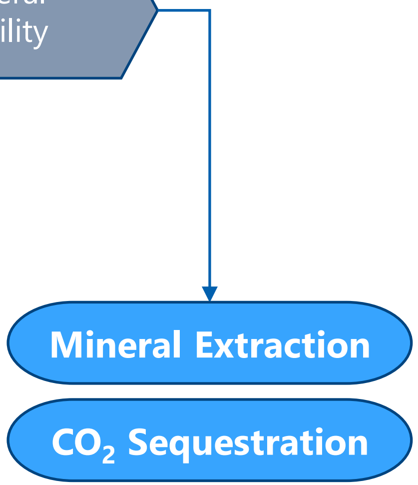
FutEra power plant under construction. Commissioning is expected Q1, 2022

Schematic Development Plan C: Mineral separation

+ Carbon & Environmental, Societal and Governance (ESG) Credits

C





C

Plan C – Mineral separation

If geothermal brines are not commercially viable for geothermal development, revenue will be generated from mineral extraction (petroleum, natural gas (PNG) and/or metallic and industrial minerals (MIM, i.e., Lithium)).

Value additions of:

+ CO_2 sequestration into disposal wells
+ Sale of environmental attributes

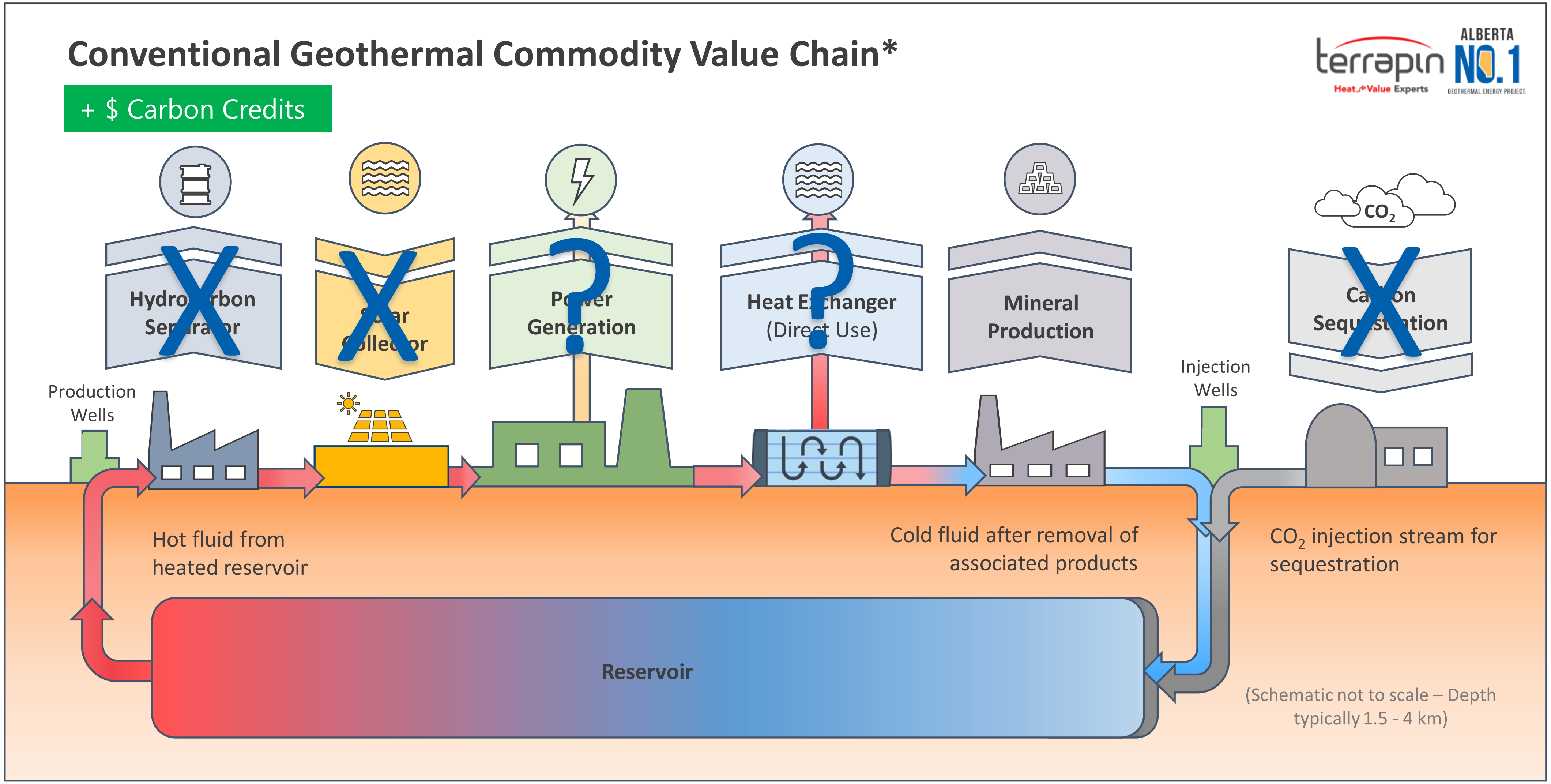
Development Efficiencies

- Agreements necessary to proceed with development of separation and sequestration facilities (JV, earn-in, royalties, etc.).

Schematic Development Plan C: Mineral extraction

Working on Lithium extraction technology from oil field brines

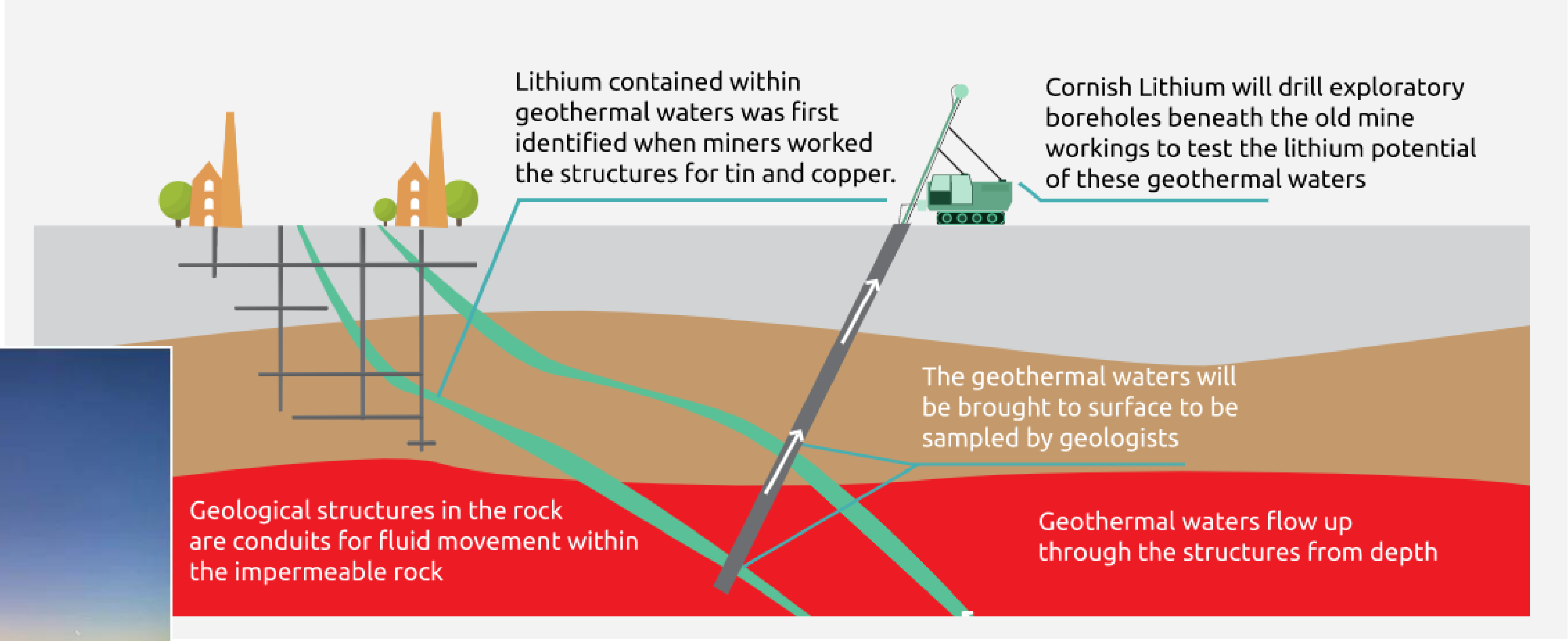
C



Addition of solar and other forms of hybrid systems (e.g., thermal storage, co-generation) may help economics in specific jurisdictions as well as support of offset parasitic loads providing more green geothermal power to the grid.

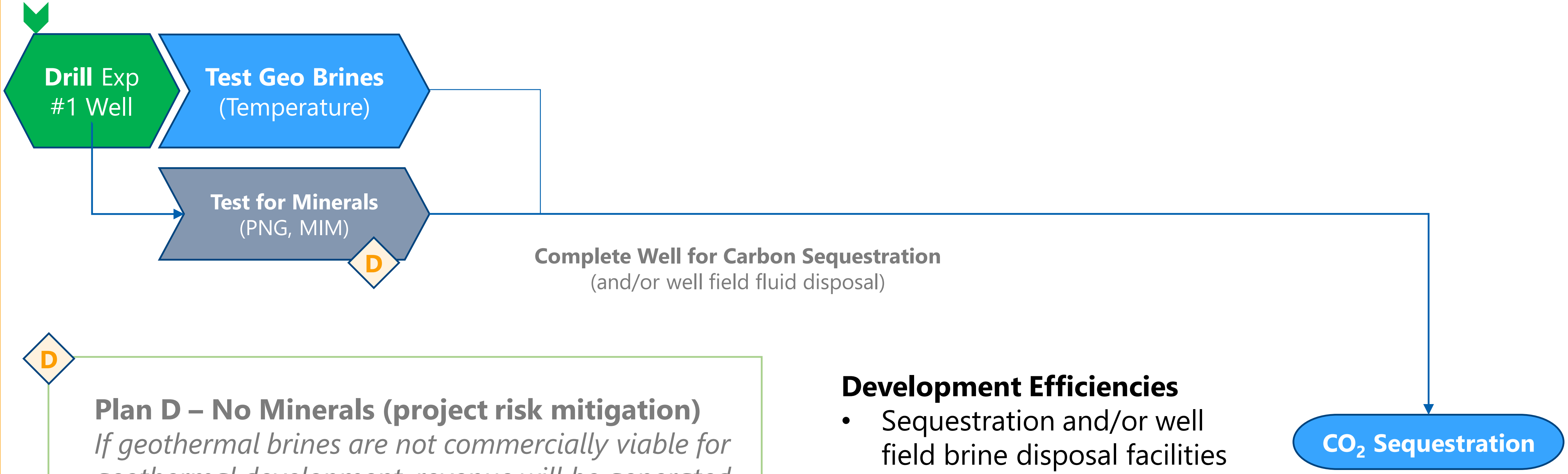
Schematic Development Plan C: Mineral extraction

Cornish Lithium



Schematic Development Plan D: Carbon Sequestration

+ Carbon & Environmental, Societal and Governance (ESG) Credits



D

Plan D – No Minerals (project risk mitigation)
If geothermal brines are not commercially viable for geothermal development, revenue will be generated from:

+ CO_2 sequestration into disposal wells
+ Sale of environmental attributes to companies producing Blue hydrogen, Methanol or other GHG generating commodities.

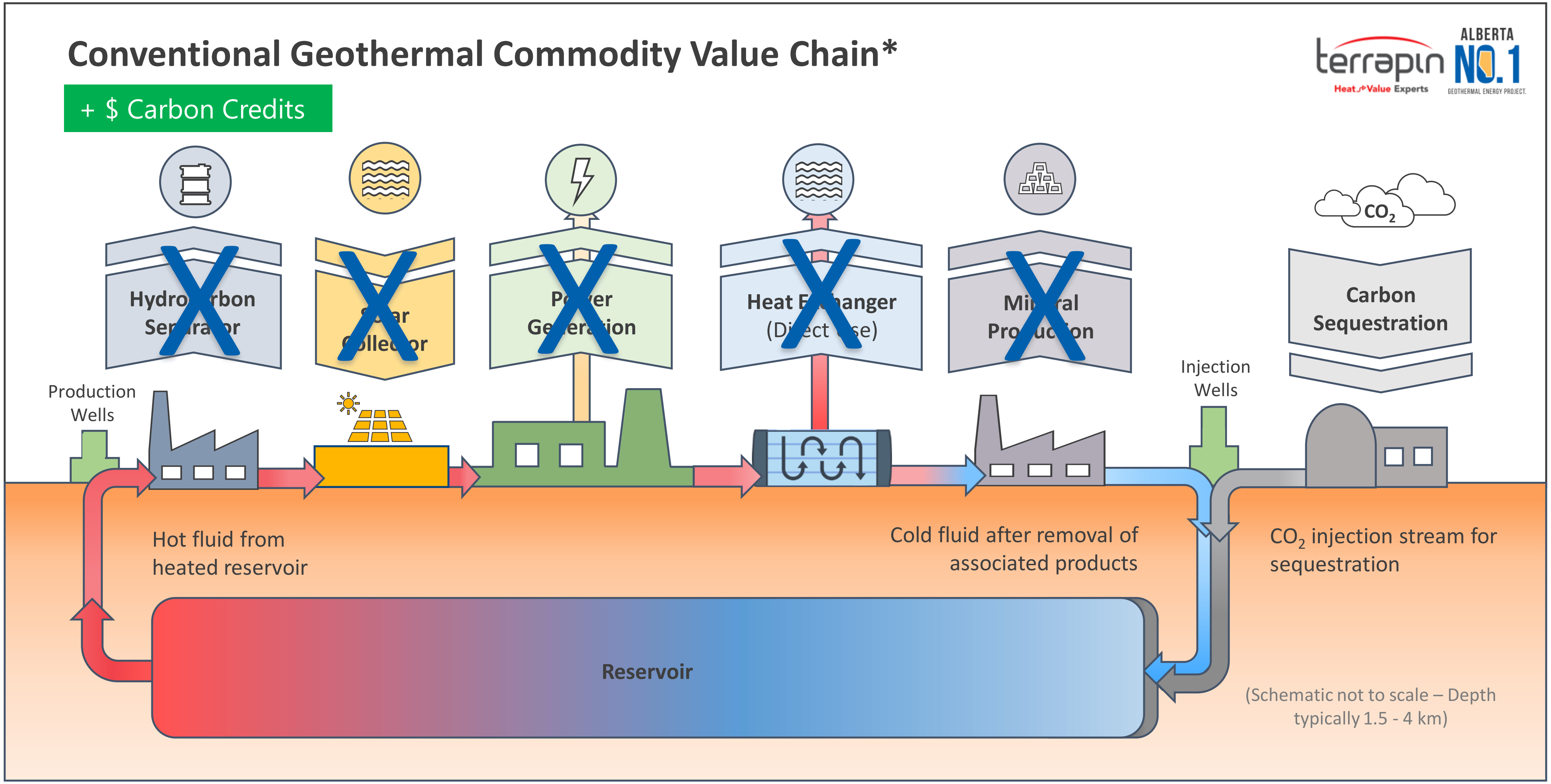
Development Efficiencies

- Sequestration and/or well field brine disposal facilities will require agreements with other companies to develop facilities (JV, earn-in, royalties, etc.).

Carbon sequestration

What if we come up with a cold unproductive well?

D

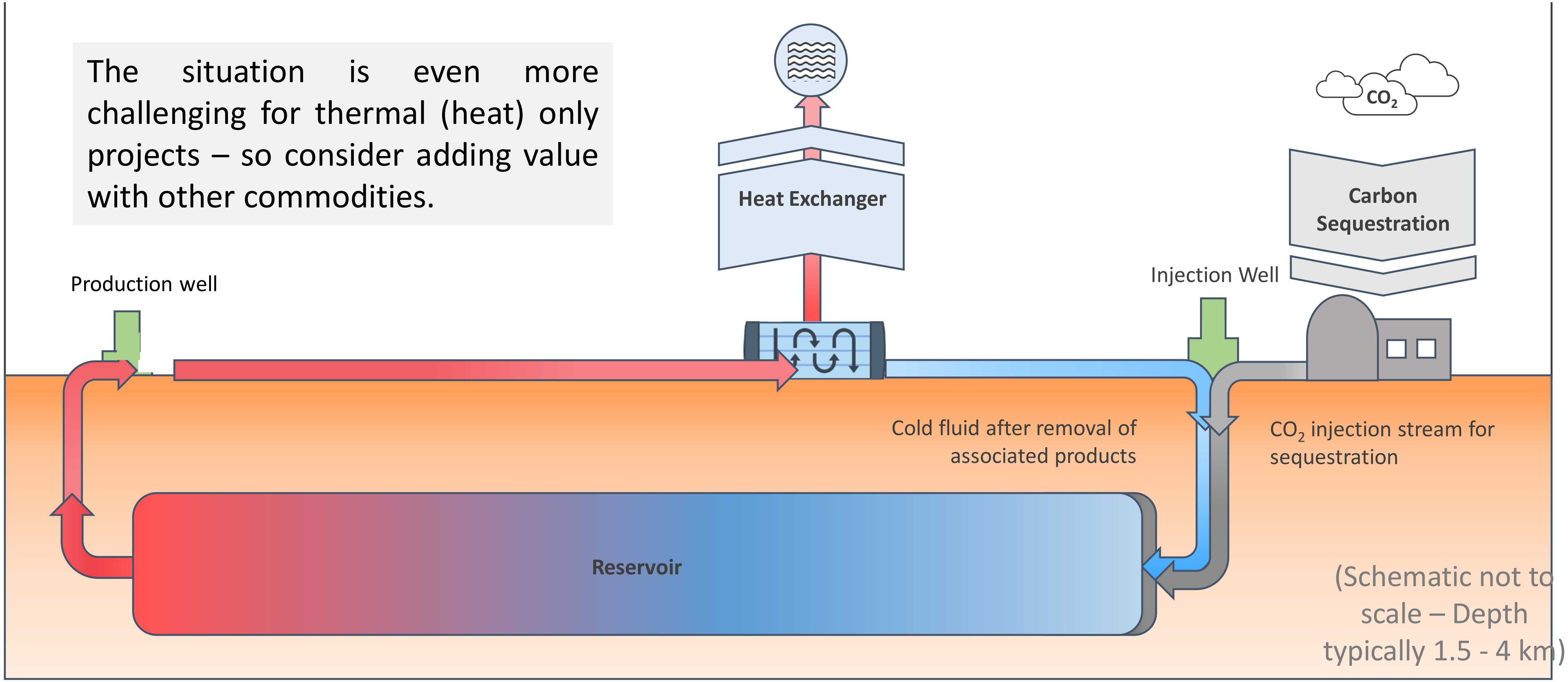


Addition of solar and other forms of hybrid systems (e.g., thermal storage, co-generation) may help economics in specific jurisdictions as well as support of offset parasitic loads providing more green geothermal power to the grid.

Carbon sequestration provides two options

1. *Makes a thermal heating project viable in a sparsely populated region like Canada.*
2. *Provides an economic solution for a well that other values are not achievable - Risk mitigation*

The situation is even more challenging for thermal (heat) only projects – so consider adding value with other commodities.



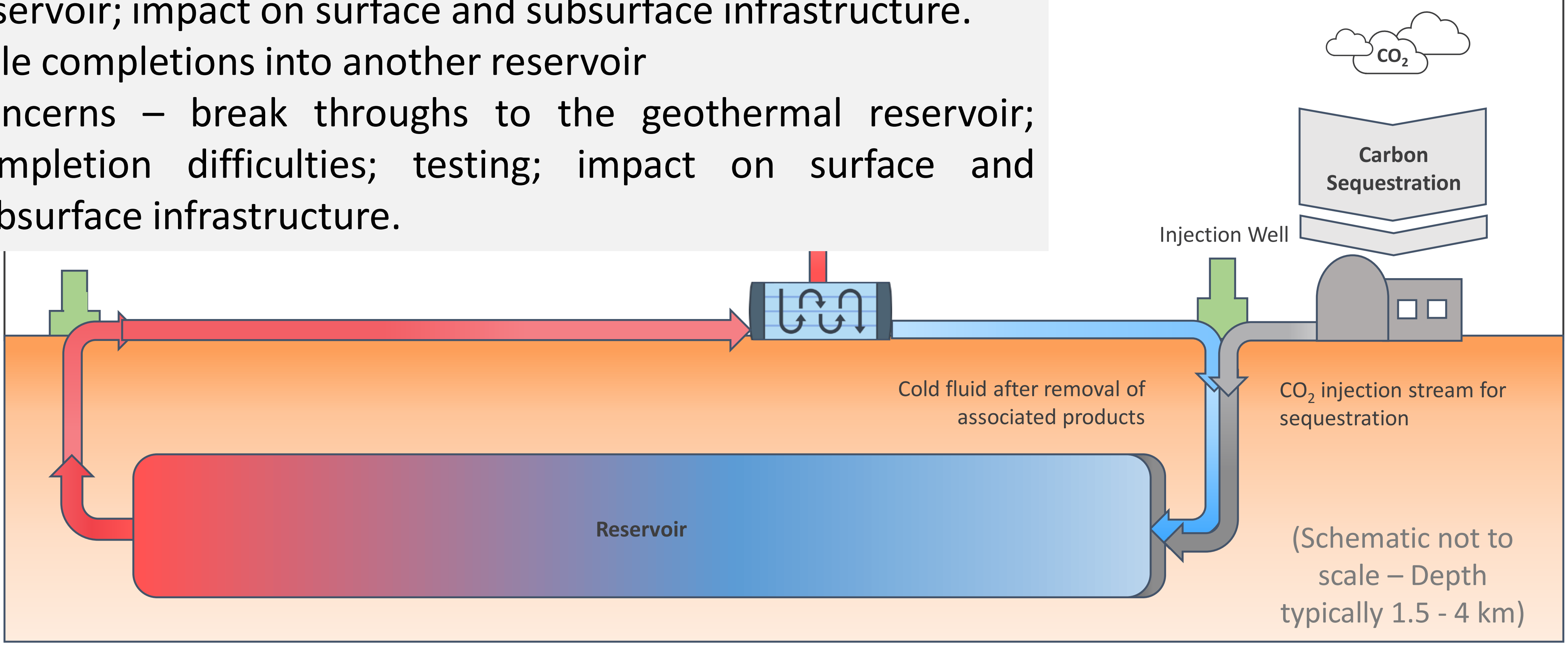
Carbon sequestration – how do we do it?

Co-injection similar to "Water assisted gravity" disposal used for sour gas.

Concerns – long term impact on permeability of the reservoir; impact on surface and subsurface infrastructure.

Multiple completions into another reservoir

Concerns – break throughs to the geothermal reservoir; completion difficulties; testing; impact on surface and subsurface infrastructure.



Carbon sequestration – how do we do it?

Research collaboration project with one of Canada's national laboratories, CanmetENERGY and University of Alberta researchers who have been heavily involved in Alberta's existing carbon sequestration projects, such as Quest.

Rick Chalaturnyk PhD

UNIVERSITY OF ALBERTA

Professor, Civil and Environmental Engineeri
Principal Investigator, GeoREF
Foundation CMG Chair in Reservoir Geomech

Phone: (780) 492-9992
Email: rjchalaturnyk@ualberta.ca
Department: Civil and Environmental Engineering

CanmetENERGY in Ottawa

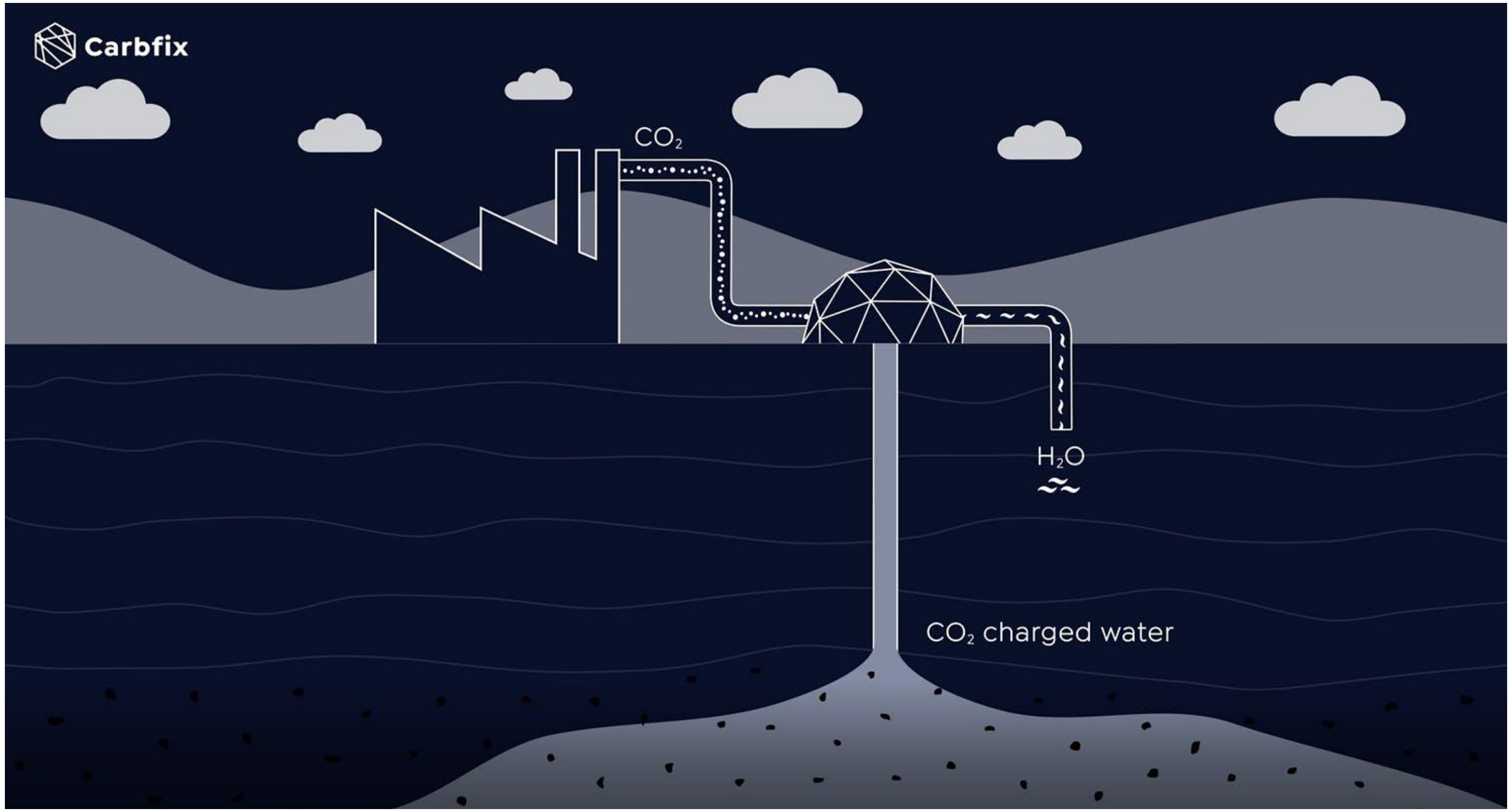
Clean Energy | Research | Innovation | Leadership

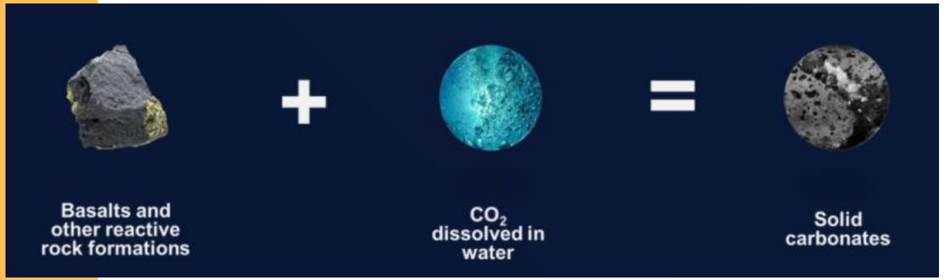
CanmetENERGY Ottawa's mission is to lead the development of energy science and technology (S&T) solutions for the environmental and economic benefit of Canadians. In pursuit of this mission, we:

- apply our scientific expertise and leverage our unique pilot-scale facilities
- accelerate the advancement of clean energy technologies, from the initial research stage through to commercialization
- collaborate with partners, including manufacturers, academia, planners, builders, and all levels of government

Carbon sequestration – CarbFix, Iceland

- Still challenges to be cost effective
- Basalt appears to be highly reactive
- No reports on reservoir impacts
- Scalability unclear
- Need similar geological conditions close to major CO_2 emitters (carbon capture fascilities).





Upside Opportunities

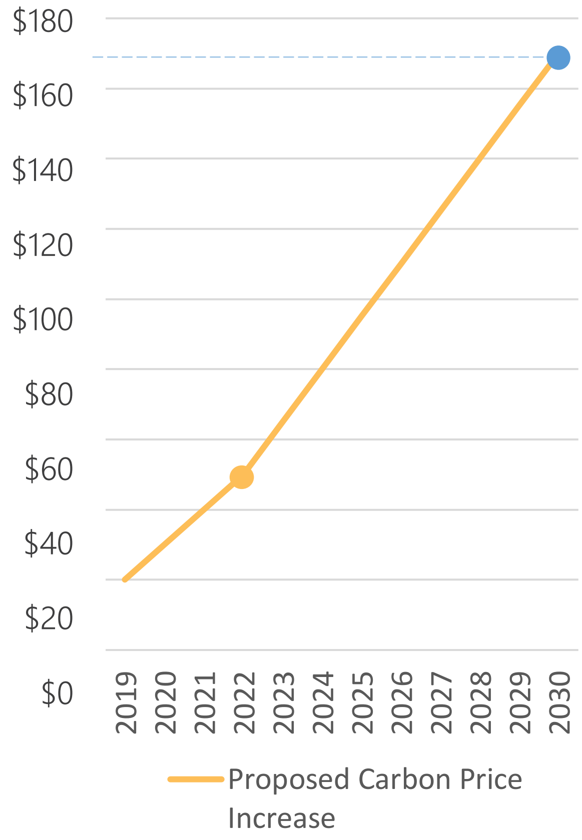
Increase in Carbon Pricing

Financial upside

Canada's carbon price can provide <u>even greater value</u> for investors.

	Upside Case ($170/tCO_2$)	Base Case ($50/tCO_2$)
Project IRR	22.6%	16.0%
Equity IRR (if held in perpetuity)	30.0%	20.0%
Operating EBITDA	$17,223 in 2025	$13,384 in 2025
EV Increase	**$38,390**	

(All monetary values are in $CAD)



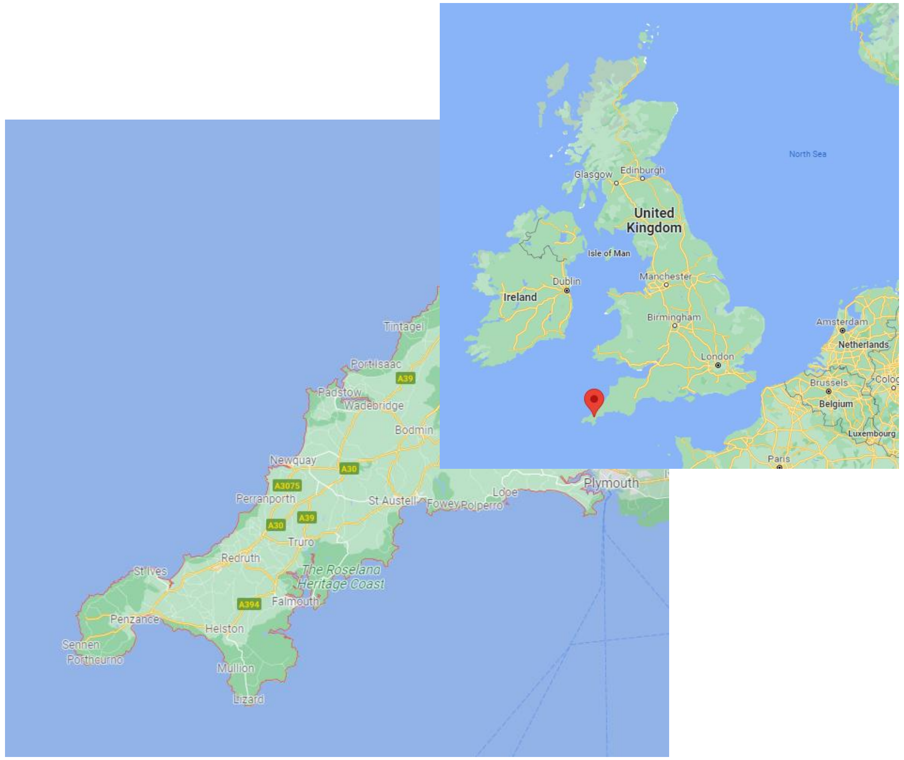
Microgrids of “Firm” energy for industrial clusters

Developing microgrids for power and thermal energy could create scalable opportunities for geothermal power and heat.

This leads us to…

Opinion: Microgrids could prevent need for planned power outages

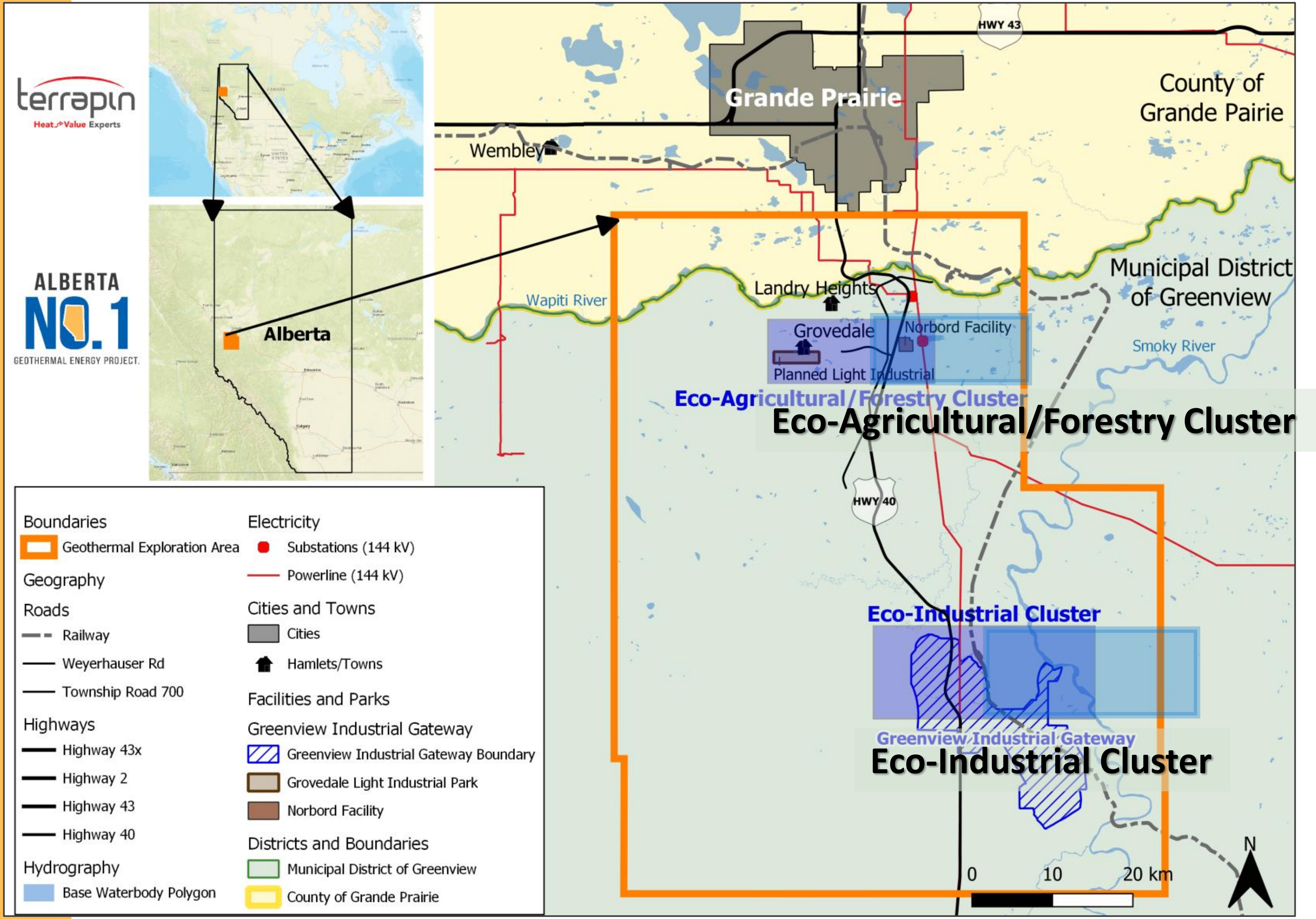
Cornwall and South-West England as an eco-industrial powerhouse.



Micro district and industrial heating grids will be important because of Alberta’s population sparsity and low density.

https://theclimatecenter.org/opinion-microgrids-could-prevent-need-for-planned-power-outages/

Project Location M.D. of Greenview No. 16



Industrial Setting

- Proximity to "CanMex" transportation routes
  - International Railway link
  - Grand Prairie Airport national hub & Class "E" airspace
  - Paved highways 40 & 43 national connections and Waterways F. (minor target)
- Grovedale and Greenview Industrial Gateway industrial parks.
- Existing industry – forestry, agriculture, and hydrocarbon.
- Significant potential for co-location with large CO_2 emitters.

What’s missing?

Getting on with it!

What’s Missing? Why isn’t the world drilling?

Technical

- Investors wary and uncertain of this new form of energy in the Global marketplace.
- Distraction with other “hot” technologies.

Political

- Presenting a compelling case to government for the type of support needed to incentivize a new industry.
- Continued lobbying for government support for direct-use projects and continued support for geothermal projects in general.
- Red tape and bureaucracy around well licensing, subsurface and surface rights.
- In general, geothermal seen as too small to make an impact.
- Distraction with COVID and economic recovery of failing parts of the economy.

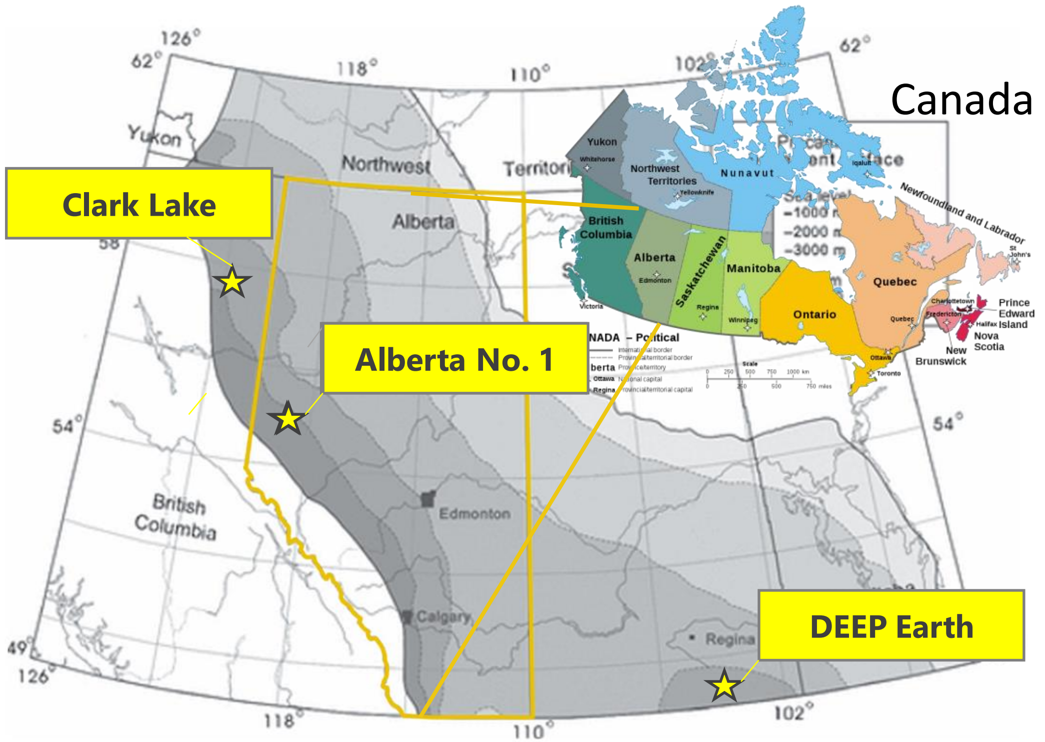
Financial

- Creation of financial instruments to support early entrants and overcome early project phase CAPEX and cash flow uncertainties.

Canada’s Geothermal Development

- Not try to compete with inexpensive natural gas and low-cost electrical generation – emphasize other values.
- Another tool in the toolbox to help reduce GHGs and encourage the energy transition.
- “Green incentives” (carbon tax) need to continue to be supported to make projects viable and disincentive hydrocarbon-based projects.
- Raising capital based on multi commodity model (e.g., carbon sequestration) applicable for conventional geothermal.
- Focus on thermal energy, hybrid systems and microgrids.
- Provincial financial instruments or incentive support to prove conventional geothermal can become an industry and have a significant pipeline of projects.

Western Canada Sedimentary Basin (WCSB)



Based on Bell and Grasby, 2011

WCSB Geothermal Development in the Past

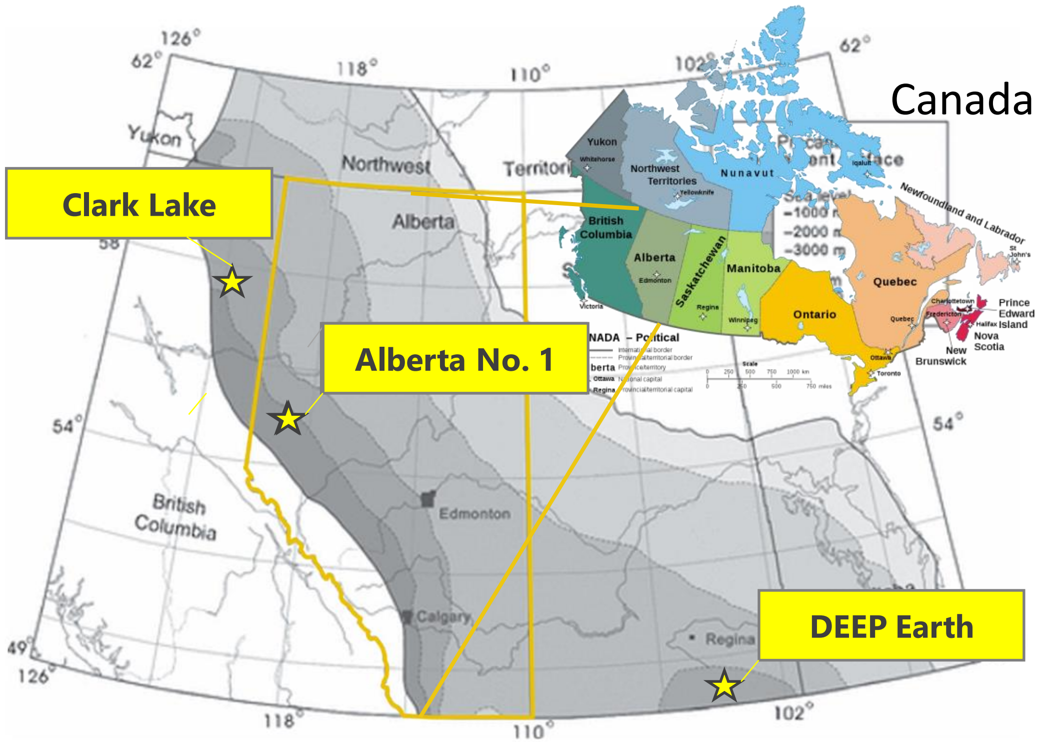
5 years ago, geothermal development in the WCSB was not commercially viable.

- Extremely difficult to raise capital.
- Abundant and cheap fossil fuel alternatives (natu gas, coal).
- No government grants or other low-cost investm funding (or stimulus incentives).

Some developments possible with geoexchange & hybrid systems (solar).

- CAPEX for solar and wind was reduced, and developments incentivized.
- Led to significant buildout.

Western Canada Sedimentary Basin (WCSB)



Based on Bell and Grasby, 2011

Has anything Changed?

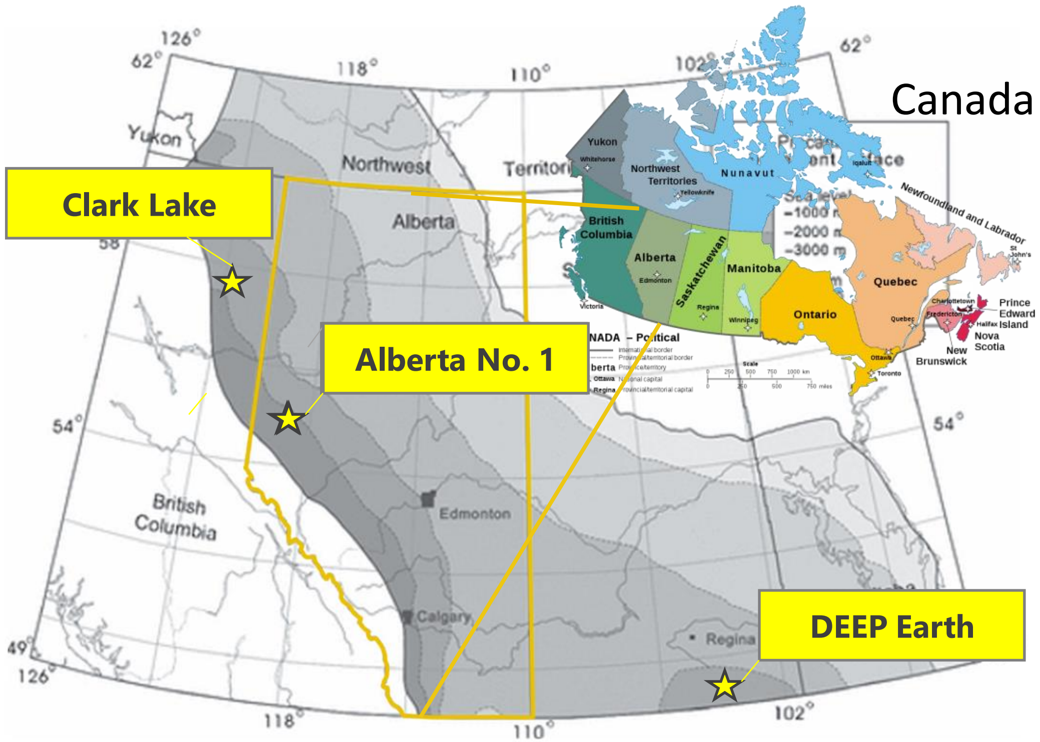
Highlights for the industry in the WCSB:

- "Green incentives" (carbon tax) now a reality.
- Interest in renewables (coal generation being phased out).
- Regulatory framework in Alberta introduced.
- Federal matching dollar grants continues.
- Growing interest in geothermal energy- reduce GHGs and put Alberta's work force back to work.

Challenges That Remain:

- Abundant and inexpensive natural gas.
- Regulatory framework not supportive of geothermal.
- Inexpensive electrical power.
- Limited provincial grant or incentive support.
- Convincing the Alberta Government to support the energy transition to geothermal in a meaningful way.

Western Canada Sedimentary Basin (WCSB)

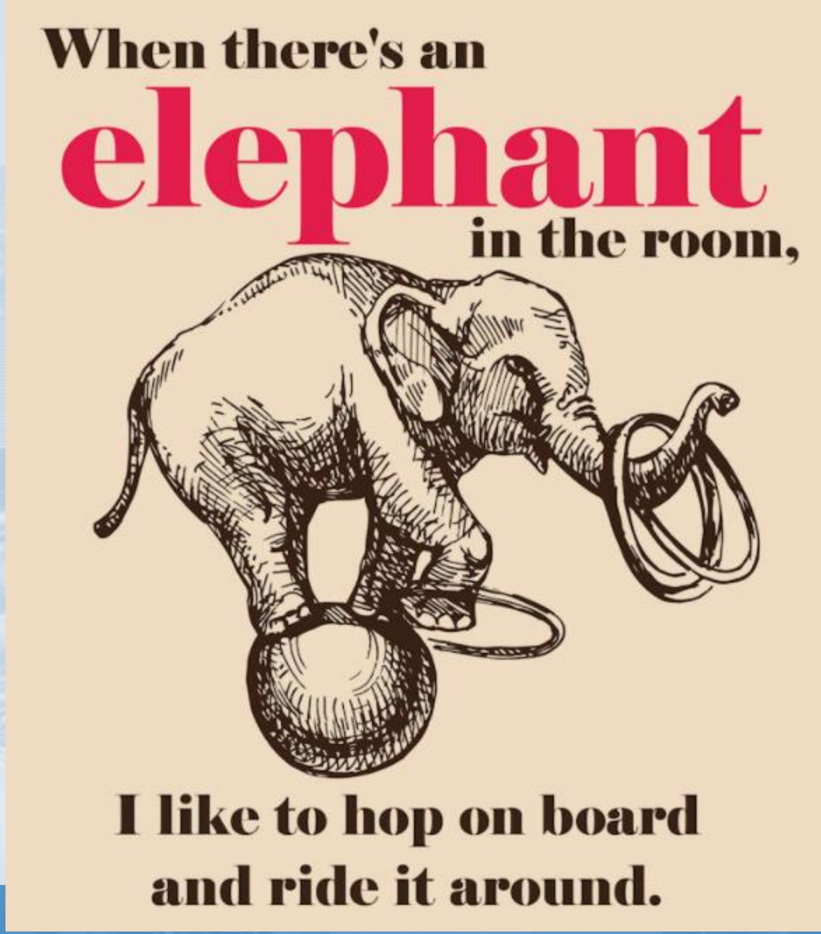


Based on Bell and Grasby, 2011

The Role of Government

What is really needed to create a geothermal industry in Canada

- Government recognition that geothermal resources fill a basic infrastructure needs of a northern climate such as Alberta and Canada in general.
- Understanding that geothermal can support new development of industries (e.g., increase flood security through home grown “green” food).
- **Like bridges, roads, highways, and pipelines, delivery of geothermal thermal energy must be considered “infrastructure” and the costs born across the taxpayer.**
- A regulatory framework that is clear and supportive of development of new industry.
- Financial instruments that help overcome early adopter capex and cash flow challenges.
- Support for municipalities (regulatory, technical and financial) to consider geothermal as part of the toolbox for energy transition and GHG reduction.



Recognize that geothermal is the "elephant in the room" – a perfect fit for many around the globe, assisting in their energy transition – corporations and government need to get behind it and give it a push. Push harder.

Thanks!

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