# The Heat Below Your Feet
# Decarbonizing heat: the role of geothermal and natural gas

## Yellowknife Geoscience Forum

Dr. Catherine Hickson, President, Geothermal Canada;
CEO, Alberta No. 1

November 16, 2022

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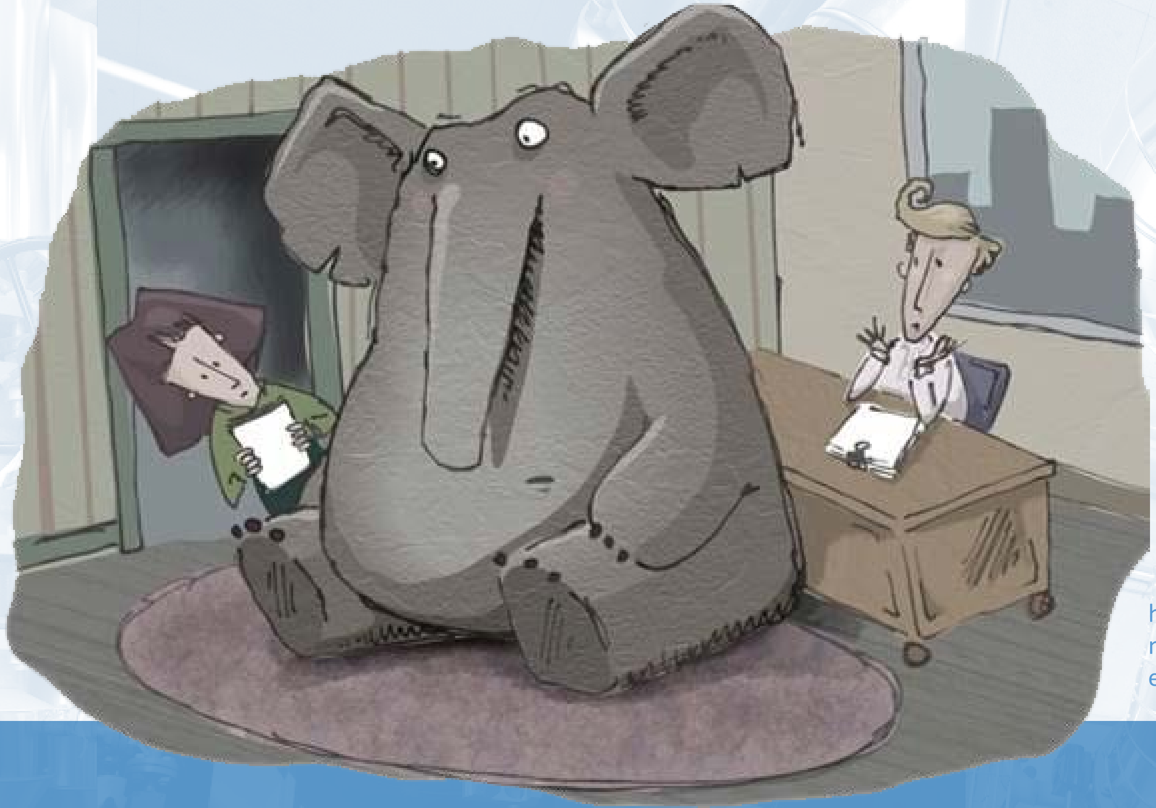
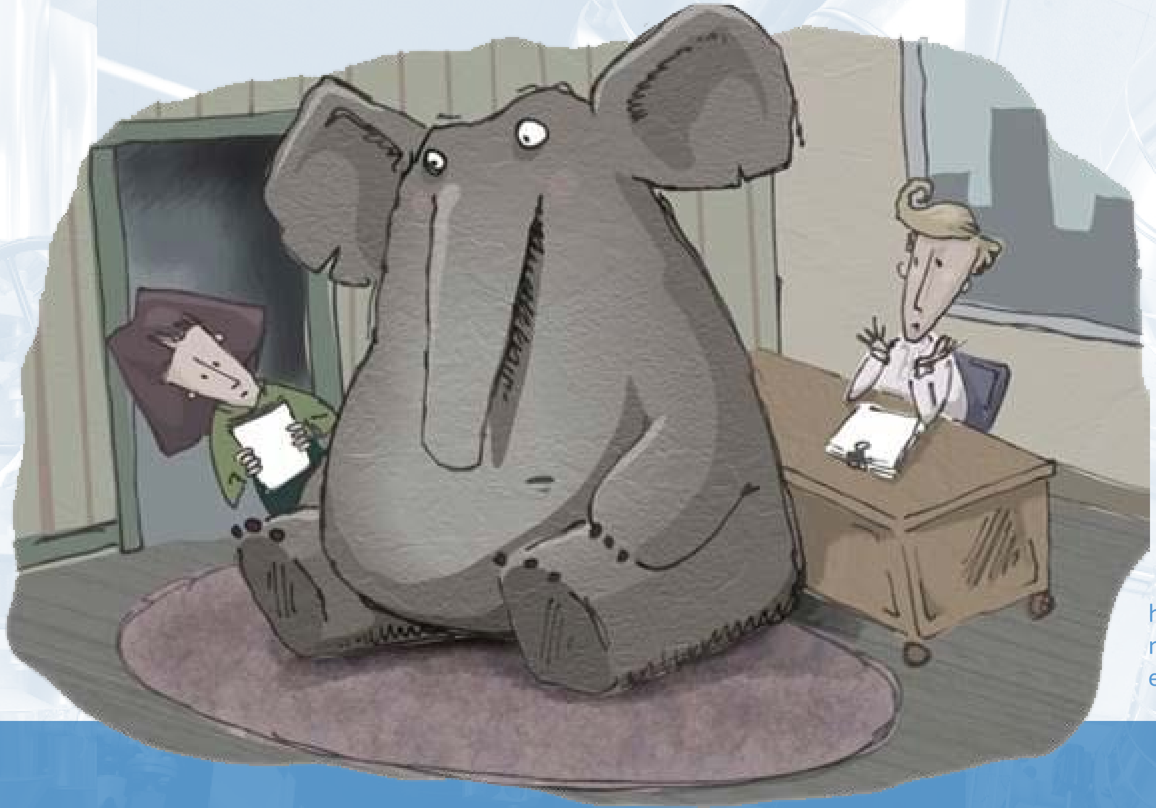
**Villejuif Geothermal District Heating Plant, Paris, France**



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, provide local heating solutions and reduce the worlds GHG emissions?**



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# The world needs a "Plan B"

# October 2010 Chilean rescue of 33 miners.

# Schramm rig – small, mobile, fast drilling

# GeoTec – Chilean drilling company who executed the impossible

Michael Shellenberger – "in our efforts to save the planet are we destroying the environment?" (Jan 4, 2019)

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The path to "electrification of everything" is fraught with both opportunities and misfortune. It is not "one size fits all"

## *Is this what the future looks like?*

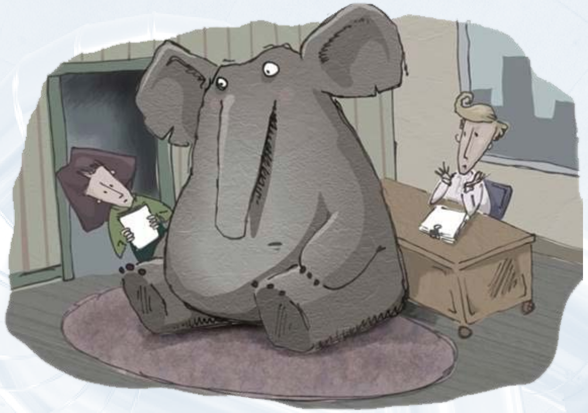
“Plan B” for NWT is a made in NWT solution.

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

The world needs a “Plan B”, AND for the rest of the world, that is decarbonizing heat – but for NWT and other communities in the far north, it is access to baseload, sustainable thermal energy to support a high standard of living, reduce the impact of globally escalating fuel costs, and potential supply chain issues. “Plan B” for the NWT is a made in NWT solution (and it will also decarbonize your heating so you can get grants!).

# THE OPPORTUNITY

## What does PLAN B look like for Canada?



- Providing Natural Gas to markets where reliance remains on coal or wood pellet electrical generation
- Build infrastructure to support energy extraction and transportation to offshore markets (natural gas)
- Build infrastructure to produce thermal and electrical energy by tapping geothermal energy
- For the north, reduce dependance on southern hydrocarbon supplies and unlock local hydrocarbon resources to global markets

# *THE OPPORTUNITY*

**Value chain from geothermal energy production**

- Helping northern communities thrive
  - Reducing reliance on southern markets and supplies – a "built in the NWT solution"
  - Accessible heat built as infrastructure
  - Reducing energy costs
  - Long term price stability
  - Sustainable solution on a multi decadal time frame.
  - Freeing NG and other hydrocarbon resources to be sold into offshore markets where they can offset coal fired electrical generation.
- Helping Canada get to net zero while supporting the Oil and Gas industry and northern development.
- Protecting Canada's sovereignty and influence in the north

# *THE OPPORTUNITY*

**Value chain from geothermal energy production**

- Promoting new industry and self reliance in the north
  - Heat as infrastructure
  - Health and safety
  - Food security (greenhouses and food processing)
  - Eco agricultural clusters (e.g., industrial composting, greenhouses, aquiculture, agricultural drying)
  - Enticing investment to the north (Eco-industrial clusters)

*HOW DO WE GET THERE??*
*DO WE WANT TO GET THERE AND WHY??*

# Do we want to seize the opportunity?

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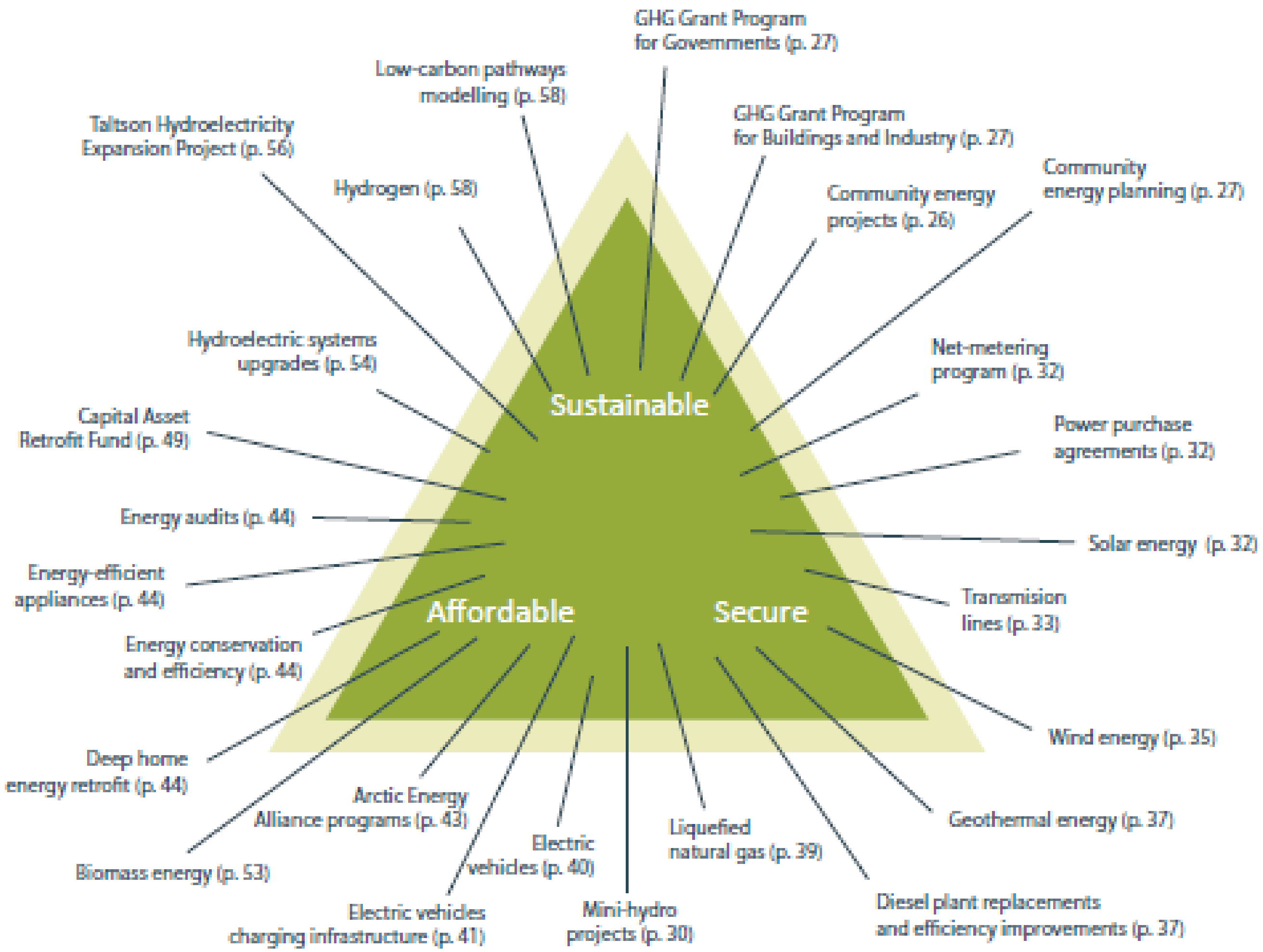
# GNWT Energy Initiatives Report 2021 - 2022

Figure 1. Energy programs, initiatives, and issues advanced in 2021-2022




## Sustainable
## Affordable
## Secure

The NWT is committed to **reducing GHG emissions by 30%** below 2005 levels by 2030. In 2020, the NWT's GHG emissions totaled 1,401 kt CO2e, 19% lower than 2005 levels. The GNWT continues to work with the federal government to refine estimates of the NWT's current GHG trajectory.

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# Electrical and thermal options for the north

1. **Hydro**: Large footprint; low winter flows; low topography in most areas; limited surface drainage in many areas
2. **Wind**: visual impairment, less than 20% efficiency; need to add battery or other storage to system; upgrade grid to handle intermittent power; equipment lifespan is limited.
3. **Solar**: not much in the winter when loads are high; less than 20% efficiencies; need to add battery or other storage to system; upgrade grid; large heating loads can lead to brown outs and power loss; equipment lifespan is limited to 10 to 20 years.
4. **Natural gas**: very high efficiency; power and thermal; needs technically challenging pipelines for long distance transport; compression possible.
5. **Geothermal**: Local thermal solution; small footprint; possible power in many locations; sustainable.
6. **SNR** (Small Nuclear Reactors): Still undergoing R&D; may be difficult to adopt due to lack of public acceptance

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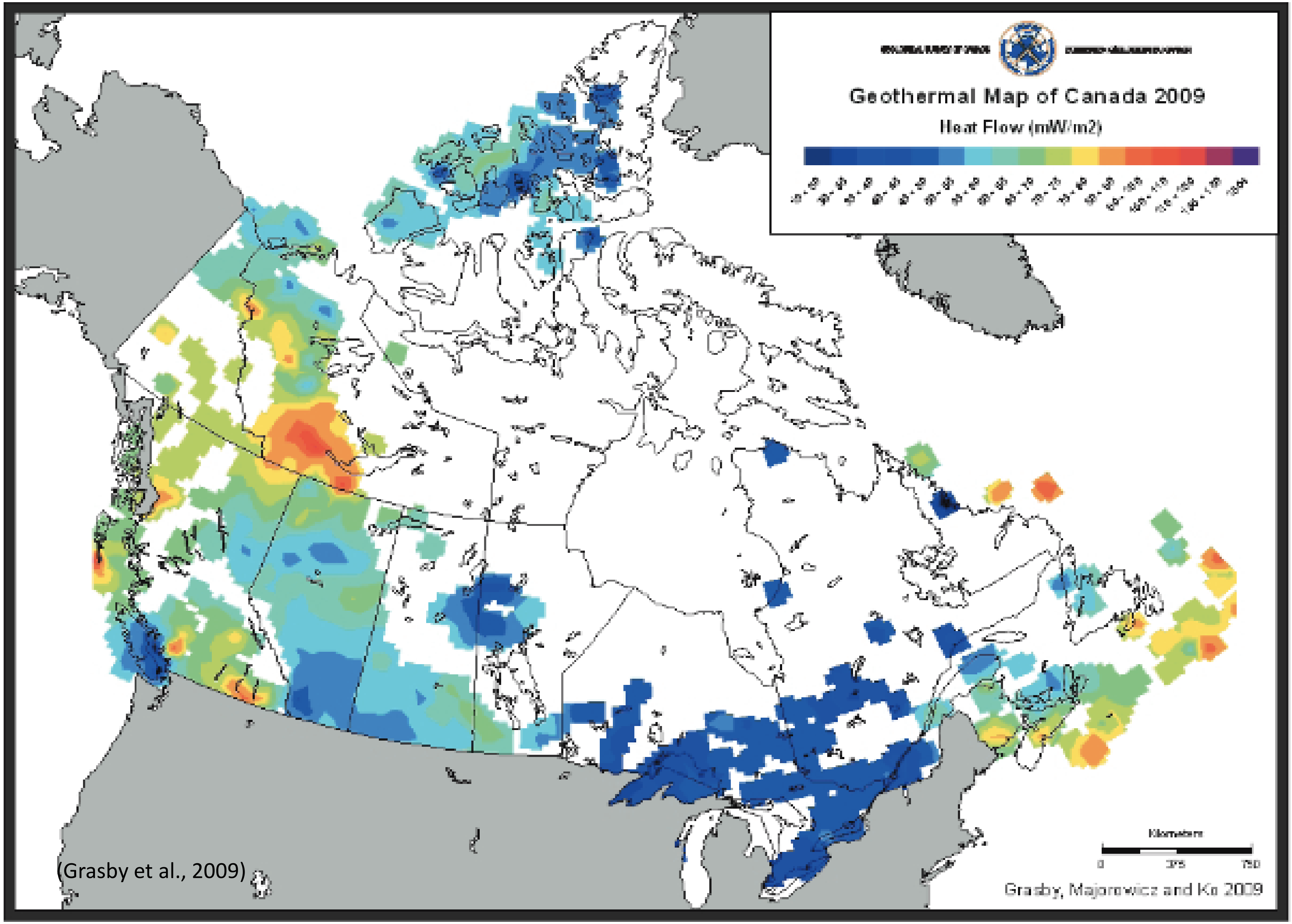
# Northern realities

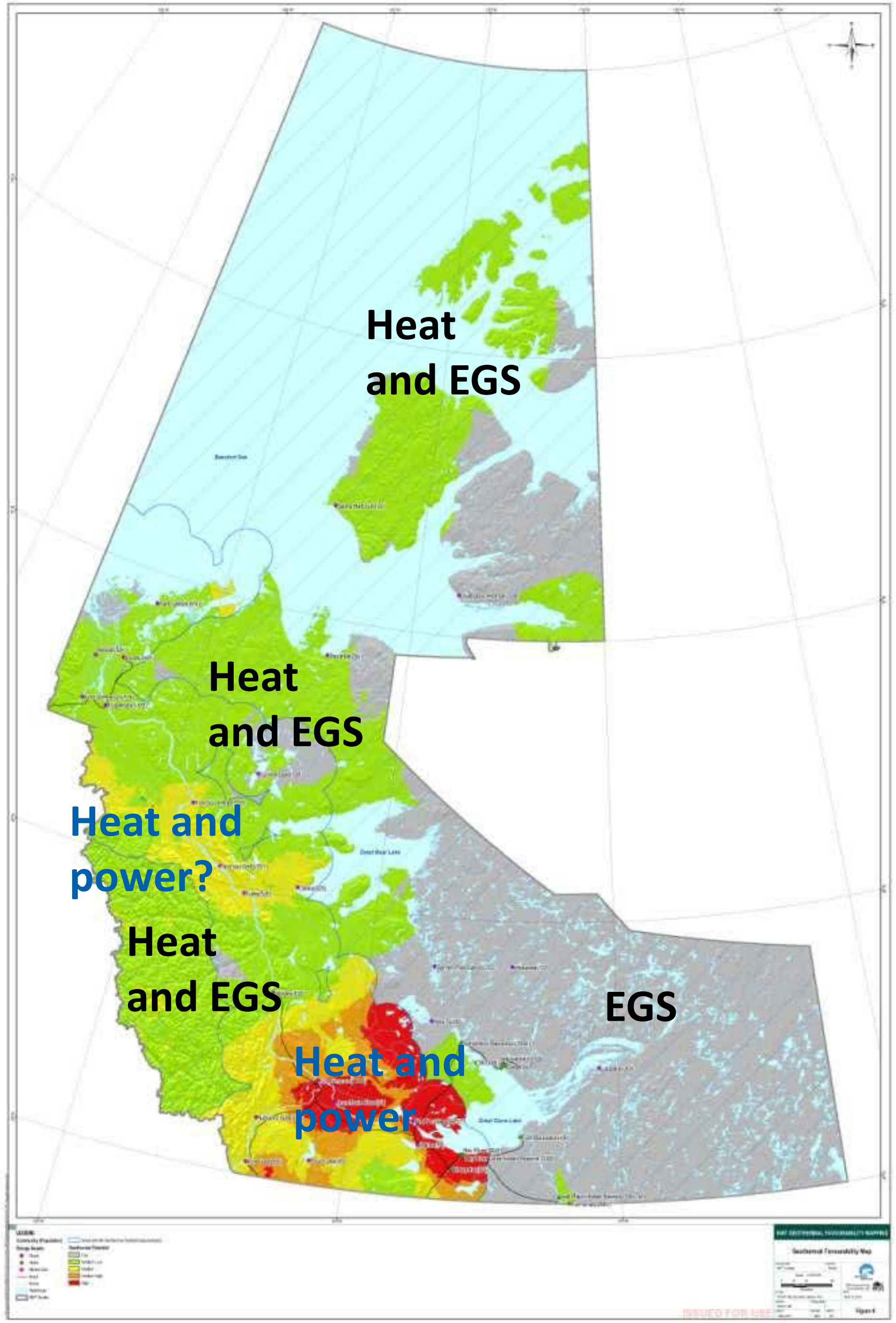
- Inuvik Utilidors and buildings on pilings – great asset for geothermal energy distribution
- Not the same retrofitting issues as in southern Canada.

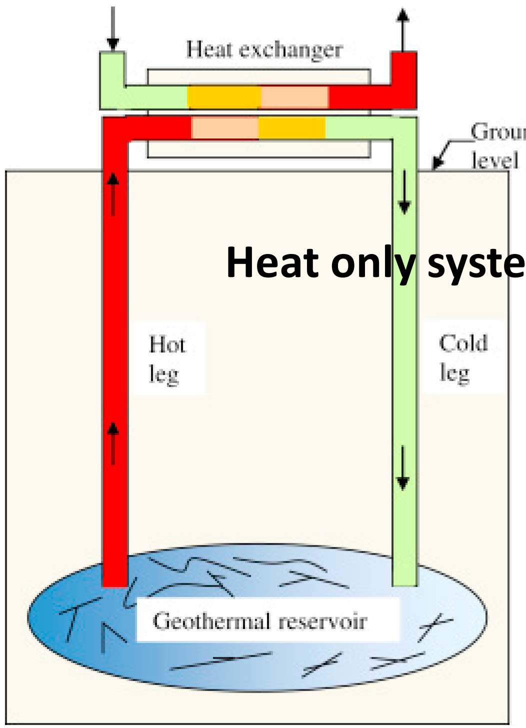
# NWT has a high quality resource



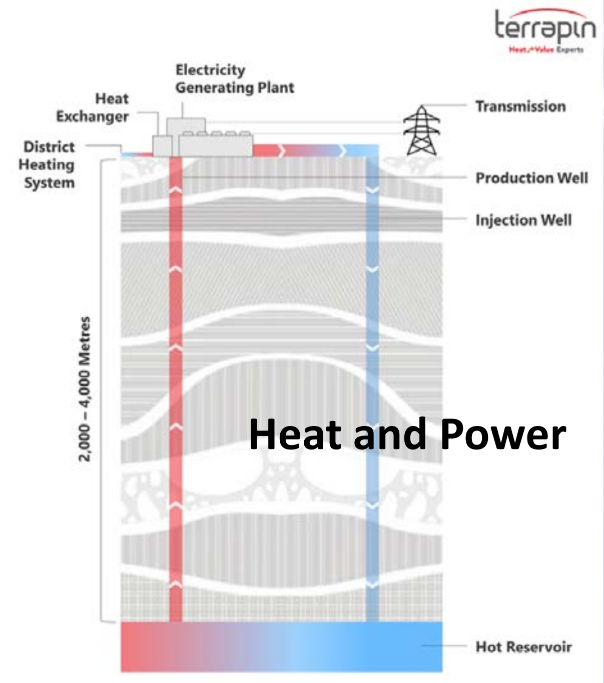

(Grasby et al., 2009)

# Geothermal Potential in the Northwest Territories

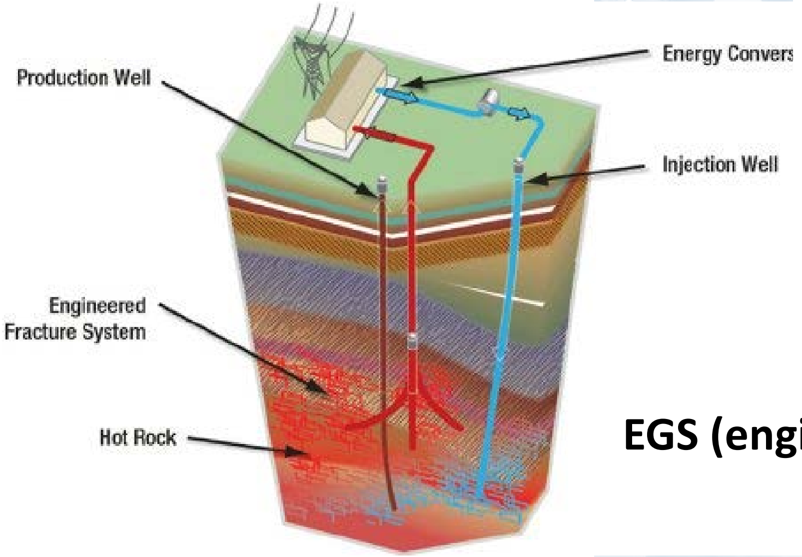



Heat only system




Heat and Power




EGS (engineered) system

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# Why do we want to decarbonize heat and create a “made in NWT” solution?

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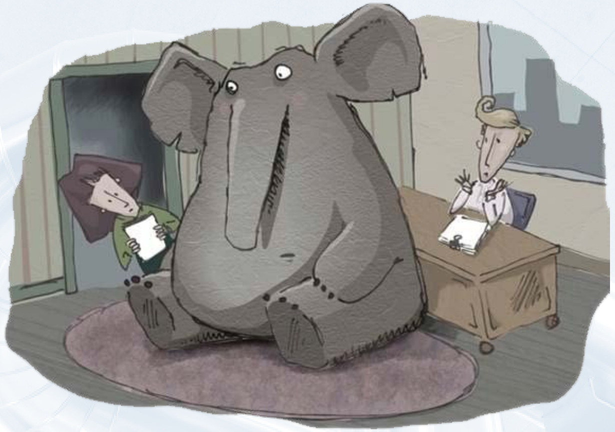
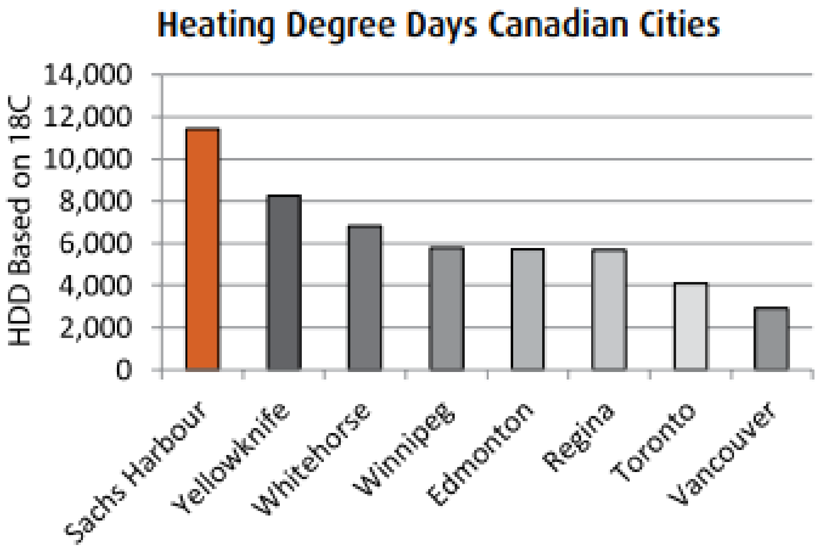
# *IMPACT OF CLIMATE CHANGE*



## Northern regions

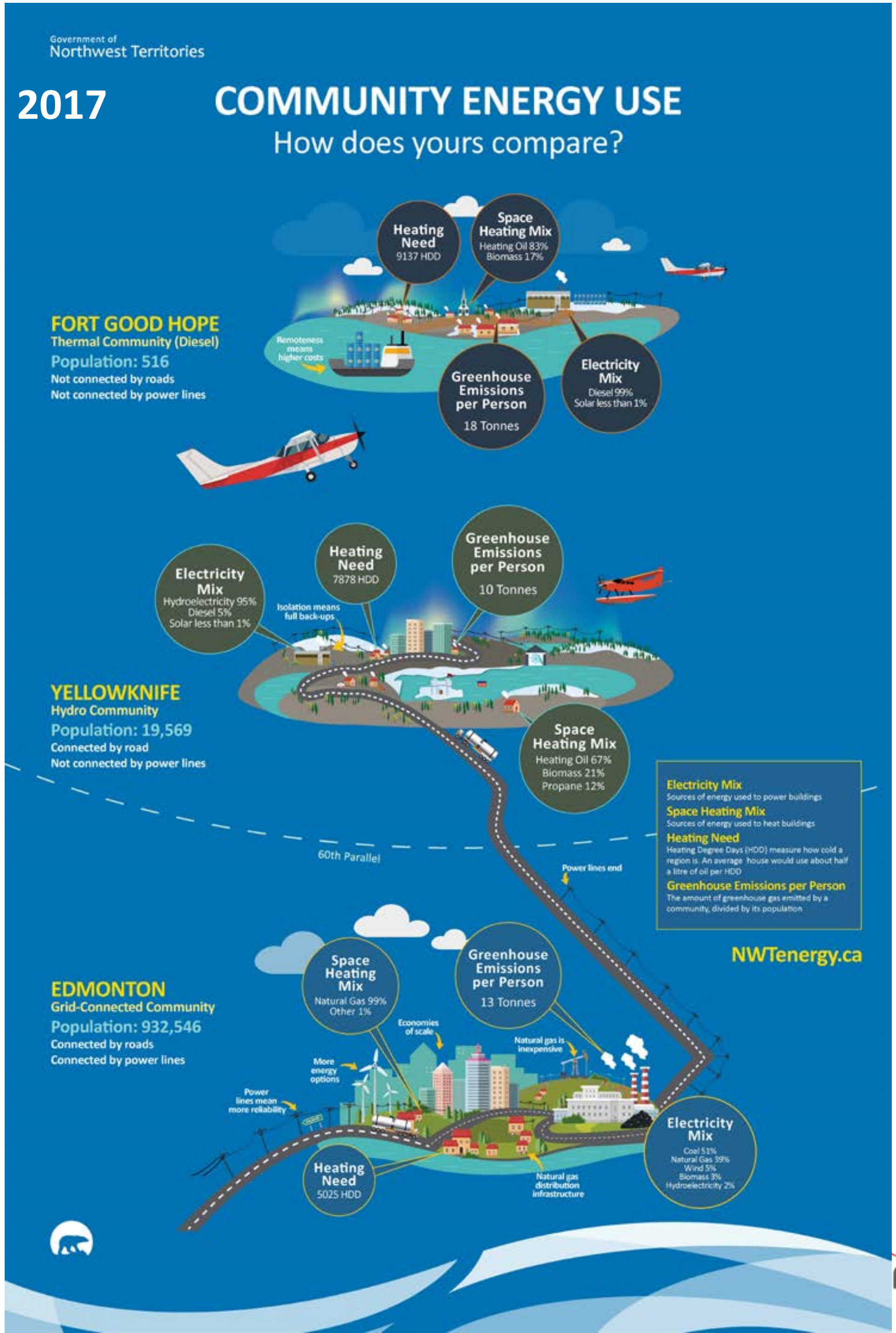
- Reduced sea ice thickness – opens up shipping
- Inability to create/use ice roads consistently – increases costs of transportation of bulk goods.
- Melting of permafrost and impact on built infrastructure
- Coastal erosion from rising sea level – but most of NWT and Nunavut is still rising from the last glacial.
- Food security – altered distribution and migration of wildlife but greater number of heating degrees days.
- Increased vegetation – Boreal forests moving northward
- Release of methane through melting of hydrates.
- Cultural association of the Inuit to the climate and land – hunting and food storage traditions impacted.
- Heritage and special places impacted by land degradation.
- More people moving north – climate refugees.

# Its very cold in the north!




It costs a lot of money to heat homes! Especially when you are reliant on a fuel source that must be shipped in, and the costs continue to escalate.

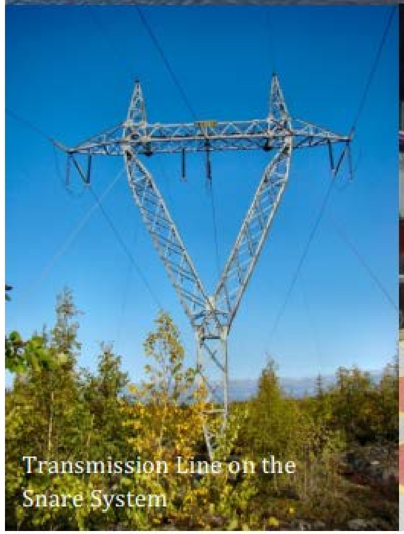
In the north there is limited access to bio-fuels. The Innuit have been able to culturally adapt to this over 1000's of years using local materials and maintaining a small population with a minimal energy demand. Energy consumption is now escalating with development, population growth and a change in cultural practices.



# Electrical generation

Electrical Generation in the NWT

Snare Hydroelectric Plant



Transmission Line on the Snare System

Diesel-fuelled Electricity Generator

Energy consumption is now escalating with development and population growth.

## Powers Plants by Location, Installed Capacity, Owner and Type

### Diesel Electricity

| Location | MW | Owner | Type |
|---|---|---|---|
| **25 communities** | 65 | Northwest Territories Power Corporation (NTPC) | Diesel |
| **5 communities** | 8 | NUL (Northland Utilities Limited) | Diesel |
| **4 mines** | 113 | Various | Diesel |

### Natural Gas Electricity

| Location | MW | Owner | Type |
|---|---|---|---|
| Norman Wells | 15 | Imperial Oil Limited (IOL) | Natural Gas |
| Inuvik | 8 | NTPC | Natural Gas |

### Renewable Electricity

| Location | MW | Owner | Type |
|---|---|---|---|
| Snare Group | 29 | NTPC | Hydroelectric |
| Bluefish (Yellowknife River) | 8 | NTPC | Hydroelectric |
| Taltson | 18 | NTPC | Hydroelectric |
| Diavik | 9 | Mine | Wind |
| Various Locations | 1 | Various | Solar |

MW value have been rounded

2015

# A variety of fuels used for heating

## Which heating fuels are used in the Northwest Territories?

**Heating Oil:** Everywhere in the NWT but to a lesser extent in Norman Wells, Hay River, and Inuvik.

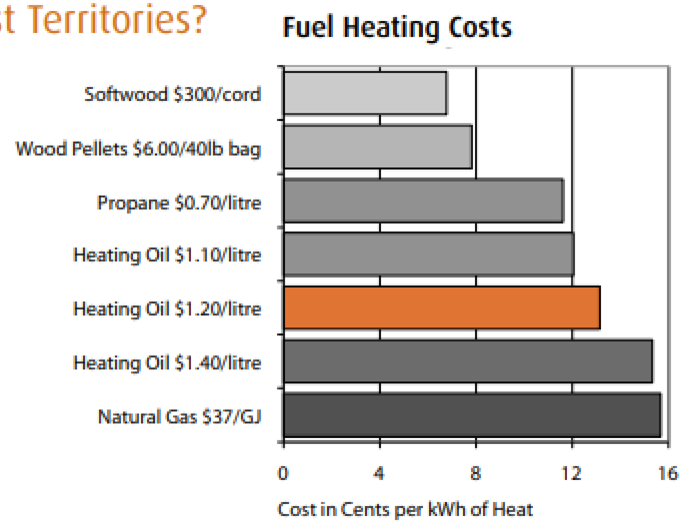
**Natural Gas:** Norman Wells and until recently, Inuvik.

**Propane:** Hay River, Inuvik, and in smaller proportions in other communities on all-season roads.

**Wood Pellets:** South Slave, Fort Simpson, Yellowknife, and Behchoko. Use is increasing.

**Wood:** Throughout the NWT but less in Sachs Harbour, Ulukhaktuk, and Paulatuk where driftwood is sometimes used.

**Electricity:** Fort Smith only for some government buildings (interruptible power).




**Heating Degree Days Canadian Cities**

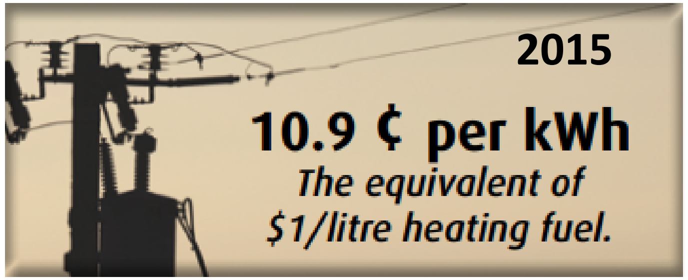
- Hydro low flows are in the winter when demand is the greatest
- Proposed transmission expansion
- Norman Wells C3 pipeline
- Wells drilled in the 1960 – 1970 – very expensive!
- Significant oil and gas reserves "The Northwest Territories (NWT) has vast undeveloped oil and gas reserves. It is estimated that the NWT could hold as much as **37 percent of Canada's marketable light crude oil** resources and **35 percent of its marketable natural gas resources**.

2017 "*I just hope that Canada as a government recognizes the valuable resources that we are sitting on in this region and the potential it provides for the economy of this country as well as to the people of the region.*" Duane Smith

NWTs time may come as oil and gas fields to the south are depleted and the world continues to need NG to meet energy demands.

# Fuel costs are very high


- Norman Wells C3 pipeline
- Wells drilled in the 1960 – 1970 – very expensive!
- Significant oil and gas reserves "The Northwest Territories (NWT) has vast undeveloped oil and gas reserves. It is estimated that the NWT could hold as much as **37 percent of Canada's marketable light crude oil** resources and **35 percent of its marketable natural gas resources**.




The marginal price of producing more electricity is lower than what we pay. Couldn't we use more of our northern resource for heating at this marginal rate?

The GNWT uses electricity to heat a few buildings in Fort Smith. This electricity is interruptible, however, meaning that Northwest Territories Power Corporation can disconnect the buildings if other customers require the power. There are several significant challenges to using electricity for heat:

- The investment in infrastructure to allow electric heating is only used for a portion of the year, which reduces the benefit for ratepayers.
- River flows are lowest in the winter, meaning less capacity when heating requirements are the highest.
- Upgrading power lines, transformers, and service lines is usually necessary for the additional load.
- Separate electric meters are required to sell electricity at a lower rate for heating.
- Space is required in buildings for additional electric boilers to be installed beside the oil boiler(s) or electric duct heaters have to be installed in buildings with forced air heating systems.
- Total electrical and mechanical costs to install electric heating in houses in Lutsel K'e was estimated in a recent study at $26,000 for a duct heater system, and $32,000 for an electric boiler.[3]
- Electricity must cost less than 10.9 cents/kWh to provide a price advantage compared to heating fuel at $1/litre.[4]

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# How do we get there?

# Geothermal Fundamentals

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# Energy Density – hot water vs. other forms of energy

**Matter-dense fuels**

**Energy-dense fuels**

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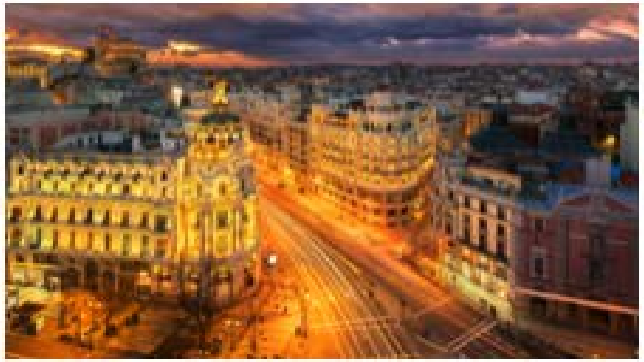
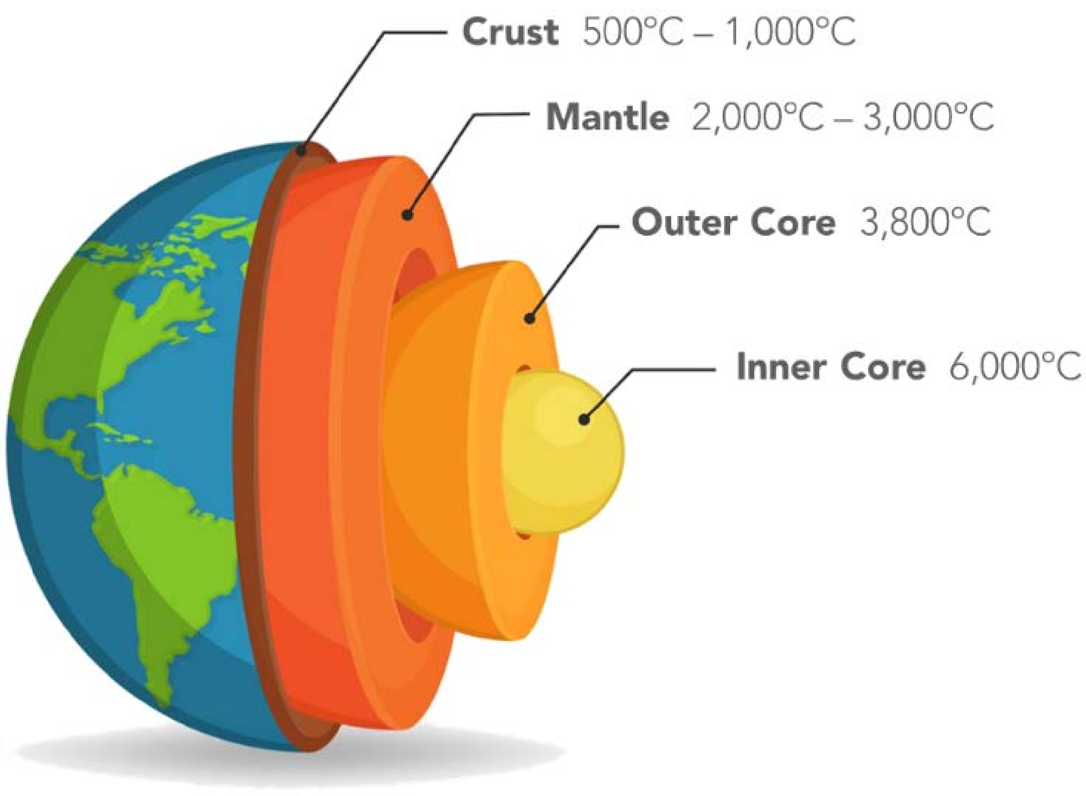
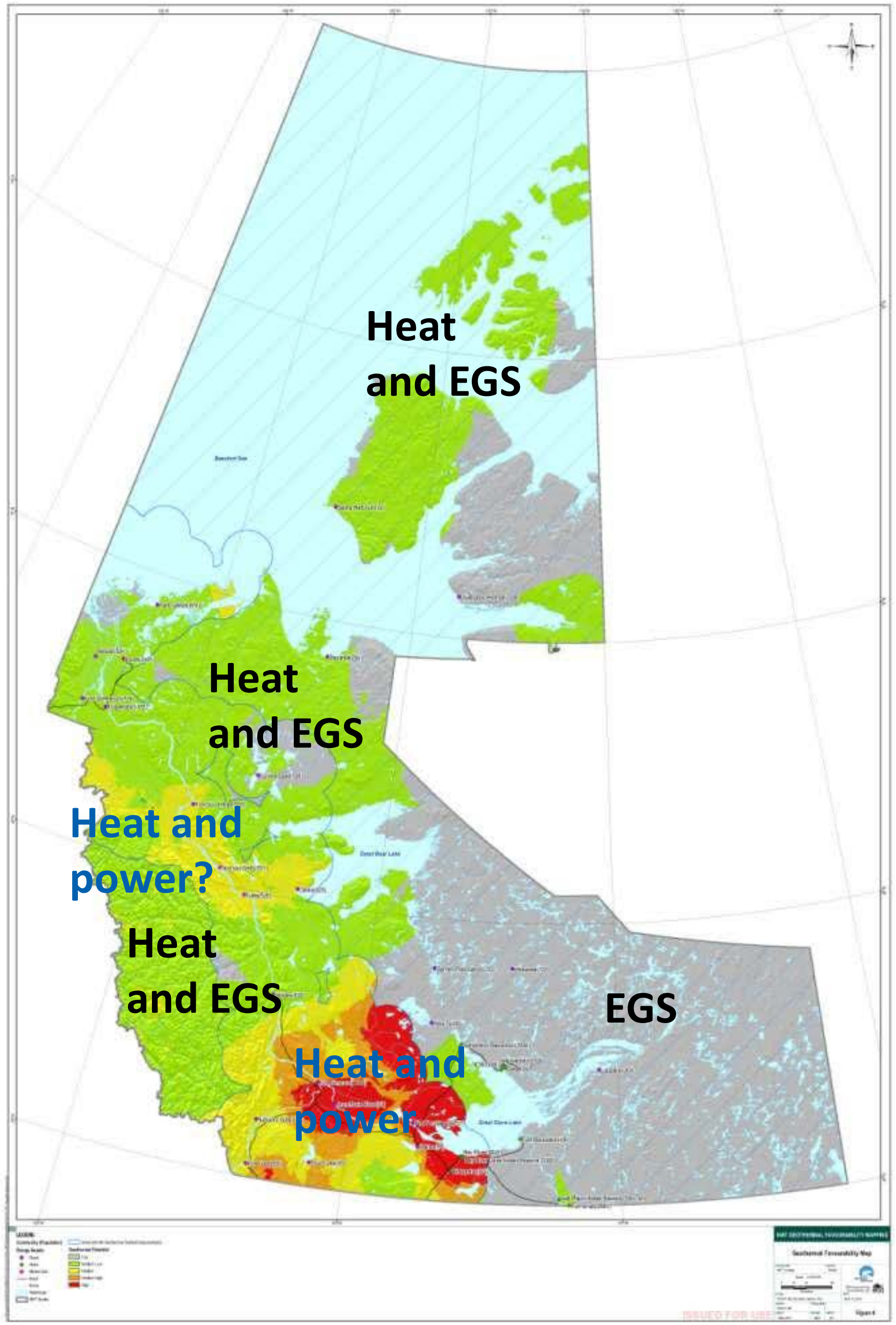
**Renewables (wood, solar, biofuels, wind)** | **Coal** | **Oil** | **Natural Gas** | **Uranium**



# It's Hot Down There!

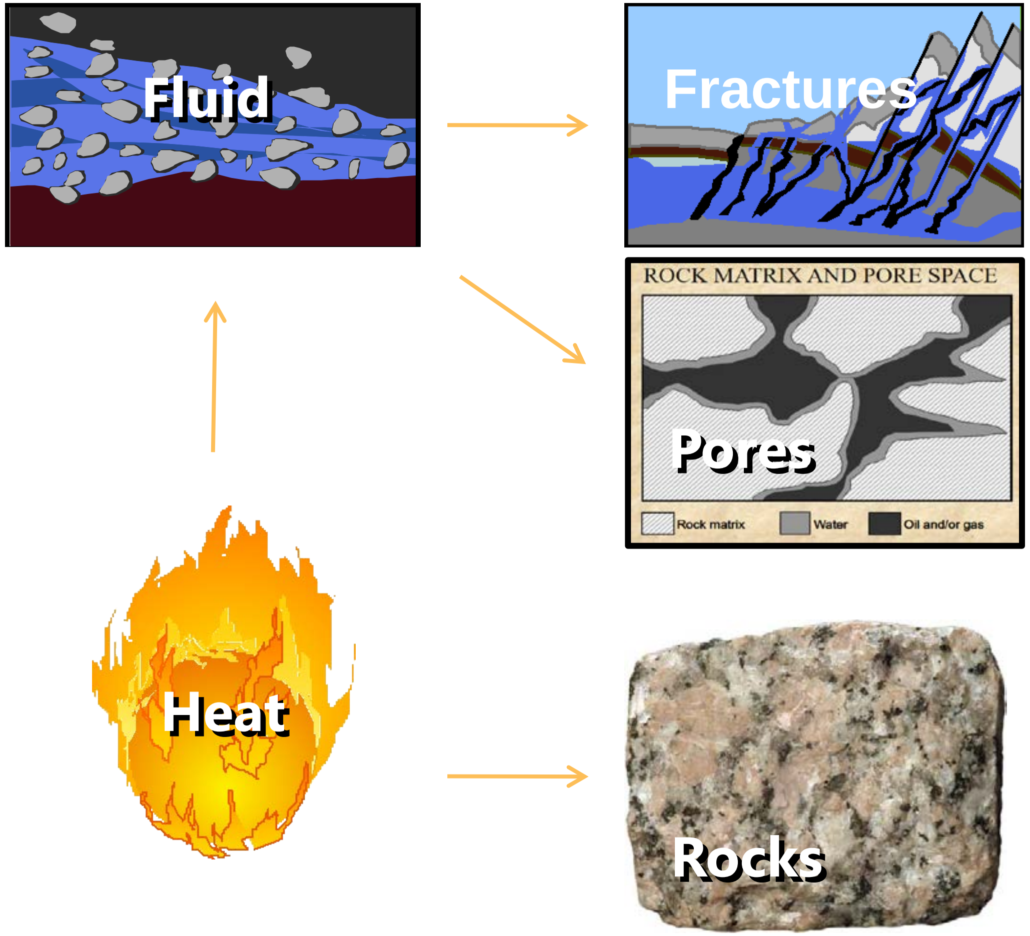


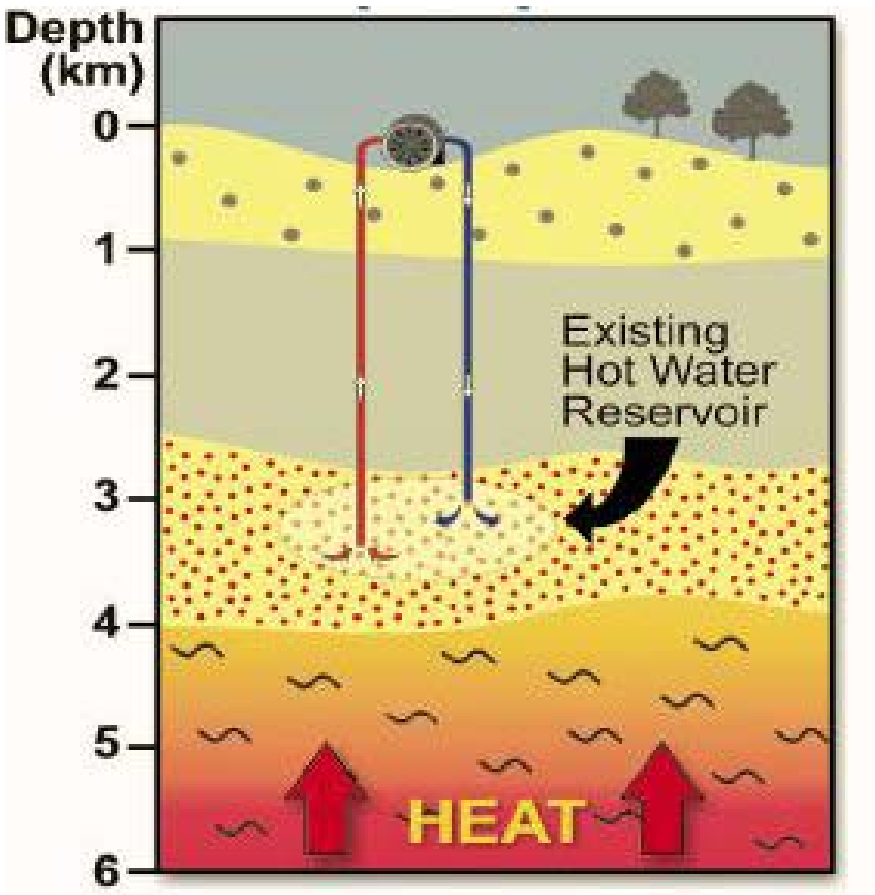

But it doesn't get hot as fast in some areas as in others (geothermal gradient). The Canadian Shield for example is cold – it gains temperature at a rate of about 15 to 18 degrees centigrade per kilometer. This means you have to drill deep to get useful temperatures. Gradients in volcanic areas (for example), might be as much as 100 degrees centigrade per kilometer.



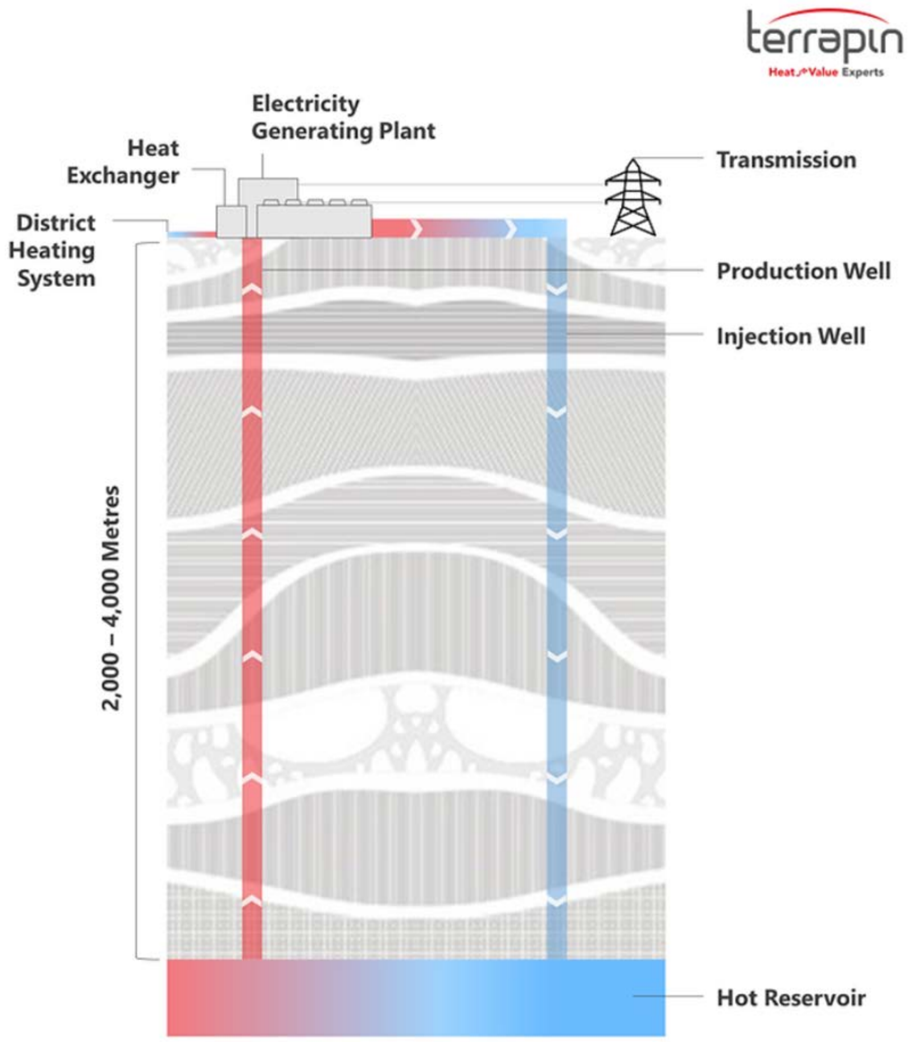
# Geothermal Fundamentals

Conventional geothermal energy can be used for electricity or thermal energy, depending on the temperature.



# Conventional Geothermal – deep drilling

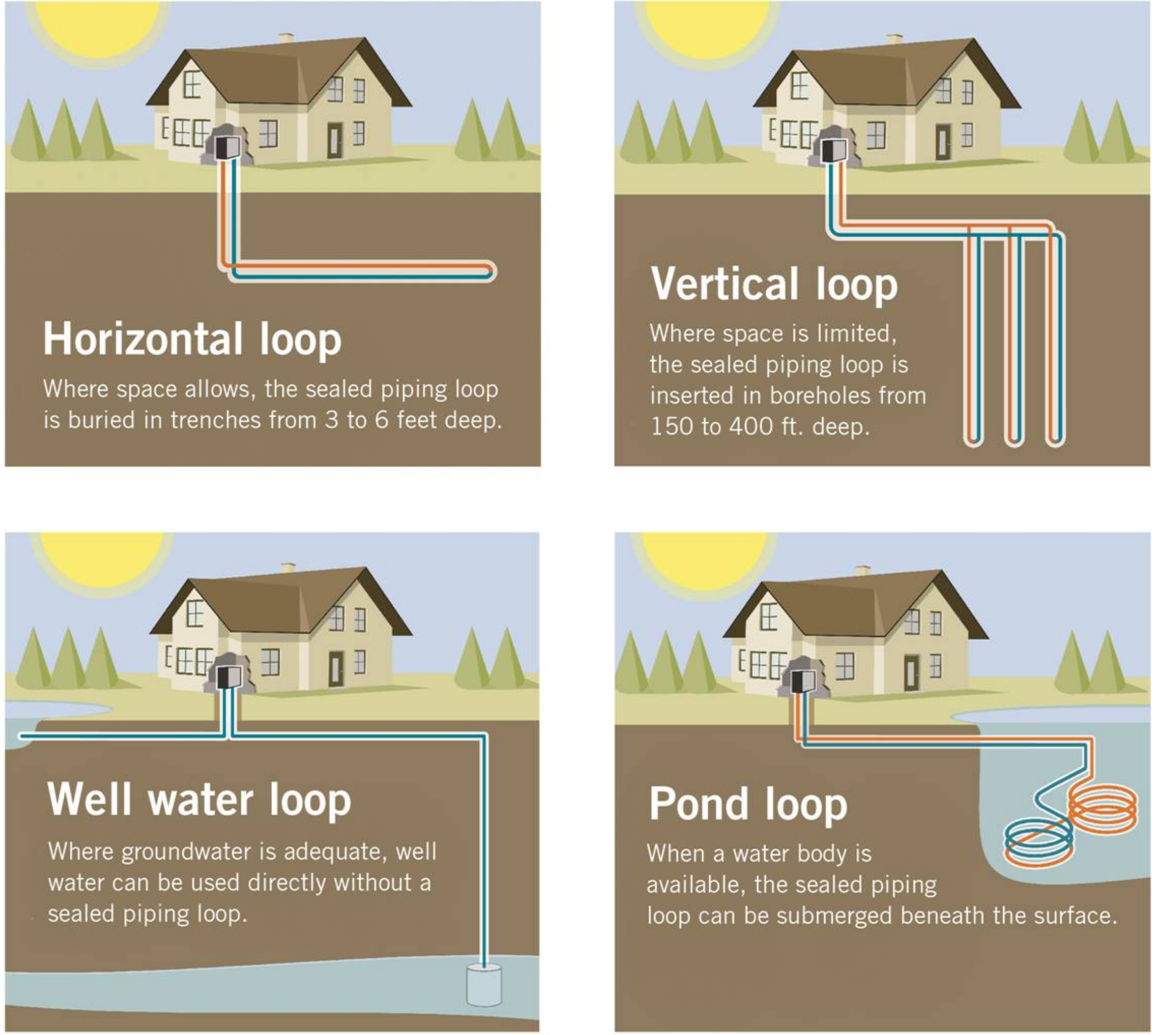



Conventional deep geothermal systems, use brines (or other fluids in the case of a fully closed loop system) to extract earth's naturally occurring heat and bring it to the surface.

The heat is extracted, then the fluid is returned to the deep subsurface, to be reheated and reused.

Geothermal operations preserve mass balance by fully reinjecting the produced brine.

# Geoexchange – use of the shallow subsurface for heat storage and cooling



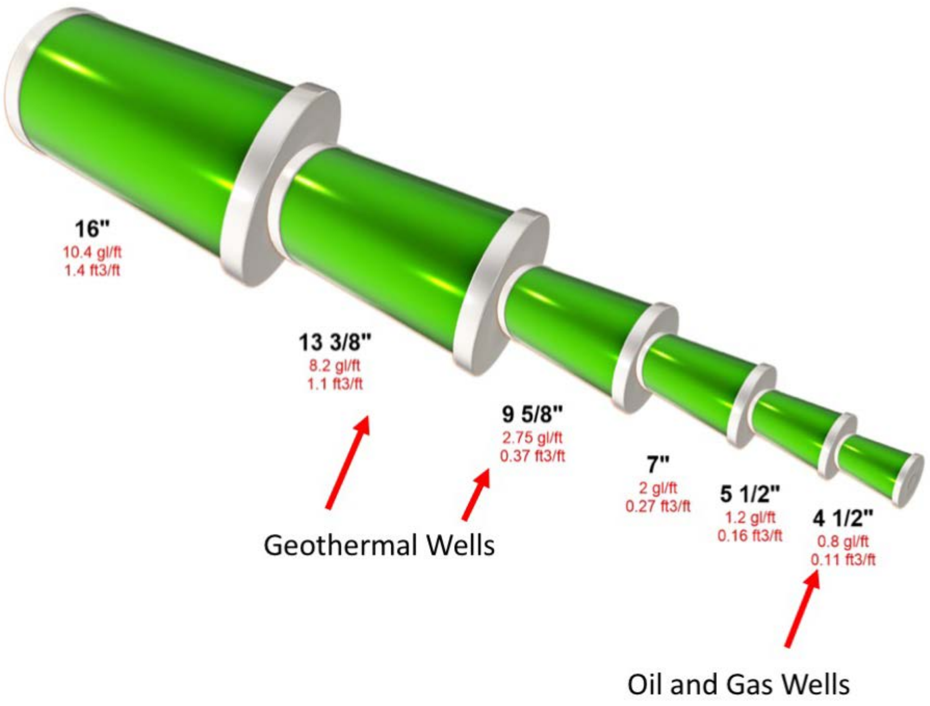

Geoexchange systems use the shallow earth as a storage system for heat energy captured from the sun.

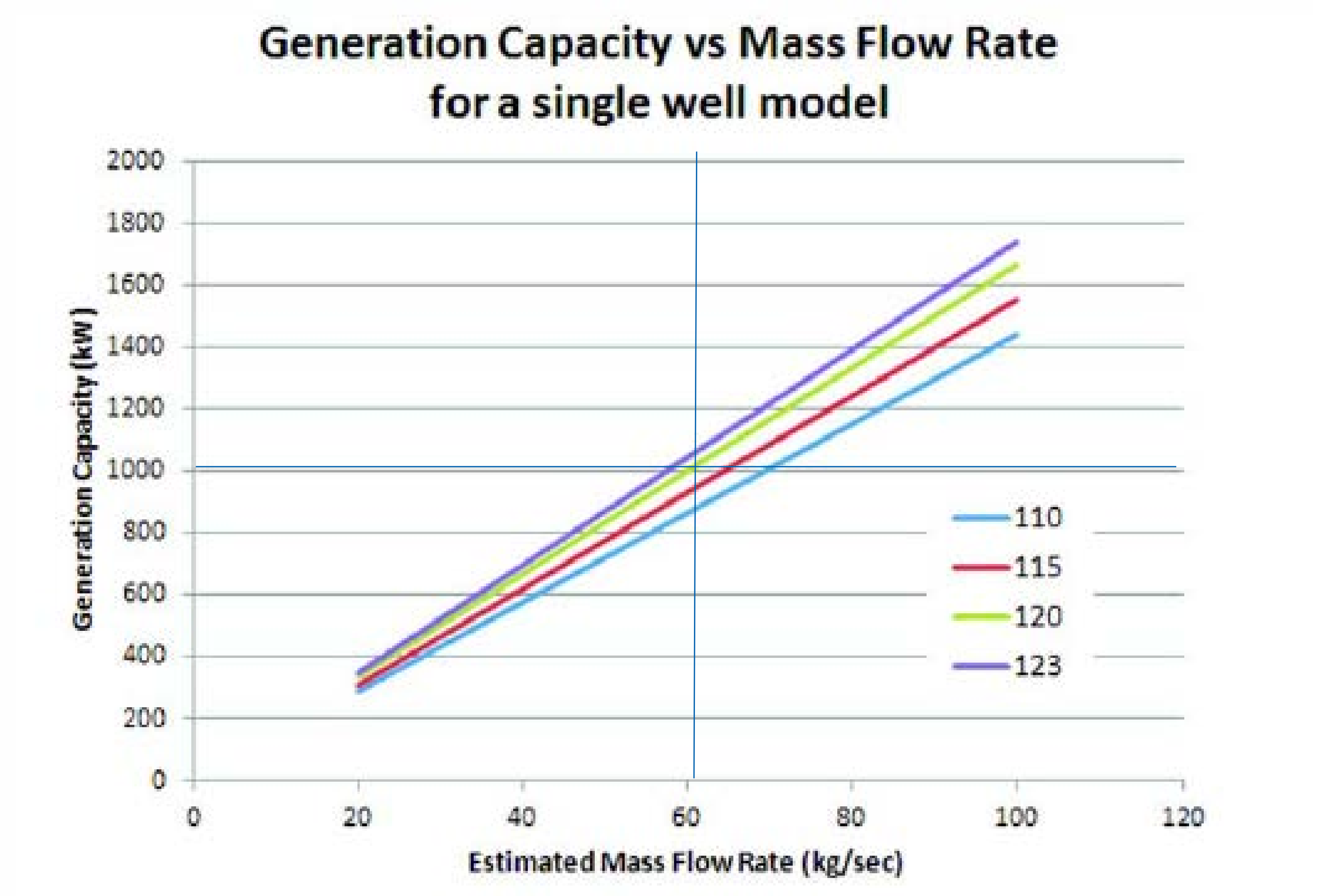
Heat exchangers (or heat pumps) extract atmospheric heat during summer months, storing it for extraction during the winter.

Similarly, systems based on groundwater or surface water use the heat capacity of those systems to do useful work.

A concern with these systems is impact on permafrost.

# Mass flow is the key in low enthalpy systems




To make 1 MWe @115C requires 60 kg/sec of flow

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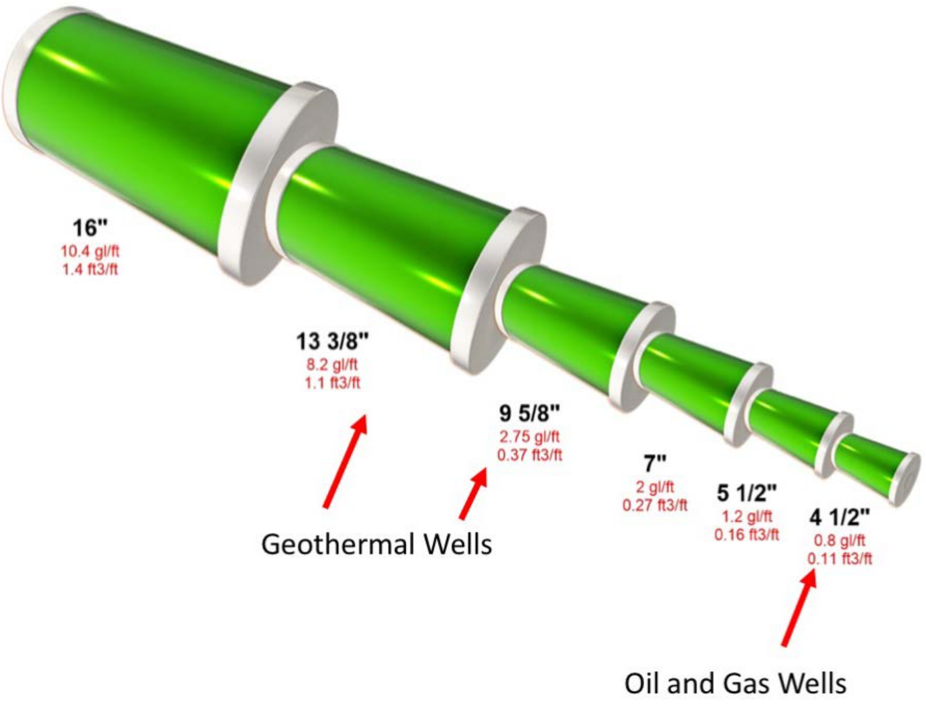
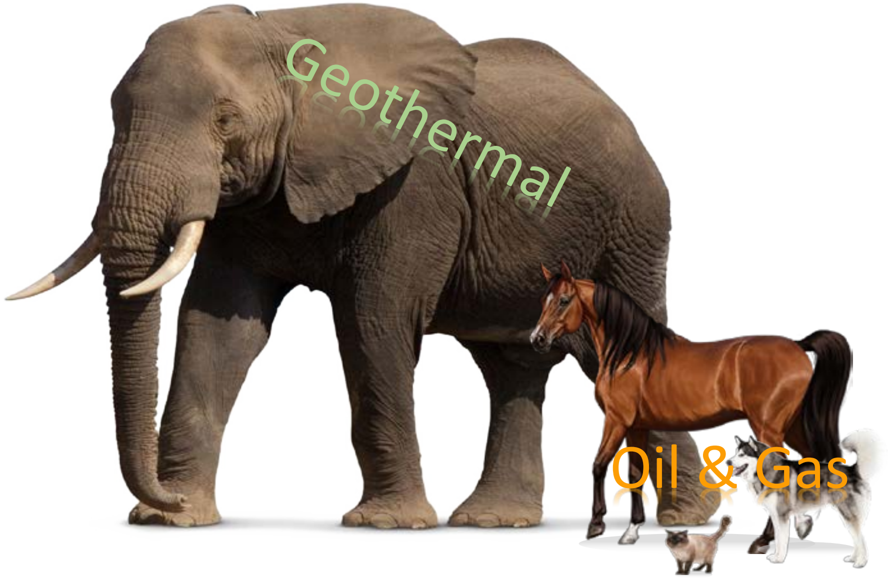
# How to flow all that fluid?

## 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.

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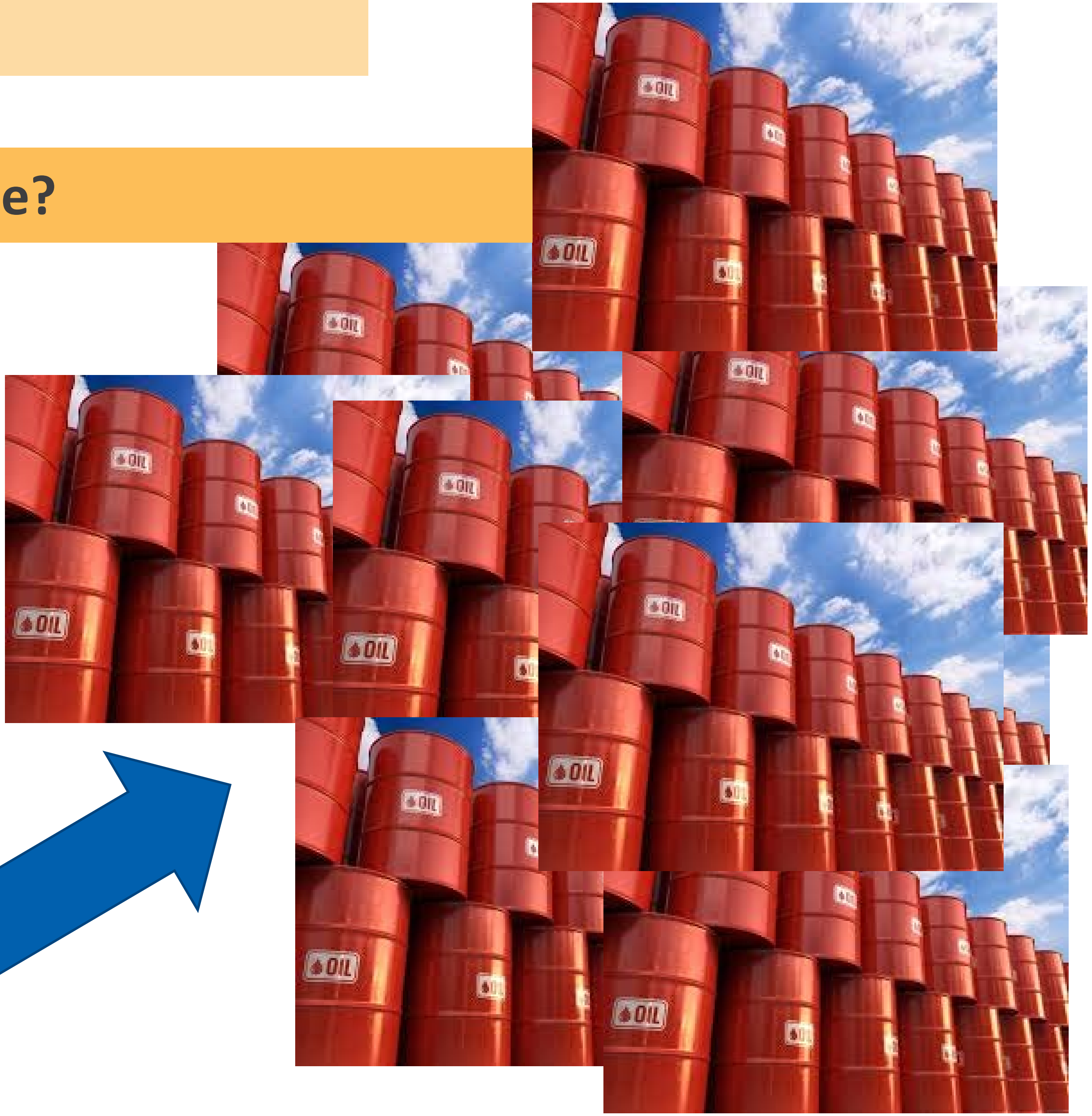
# Heat is Useful Energy

## How much oil does geothermal replace?

A small project (10 MWe and ~60MWth) like 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

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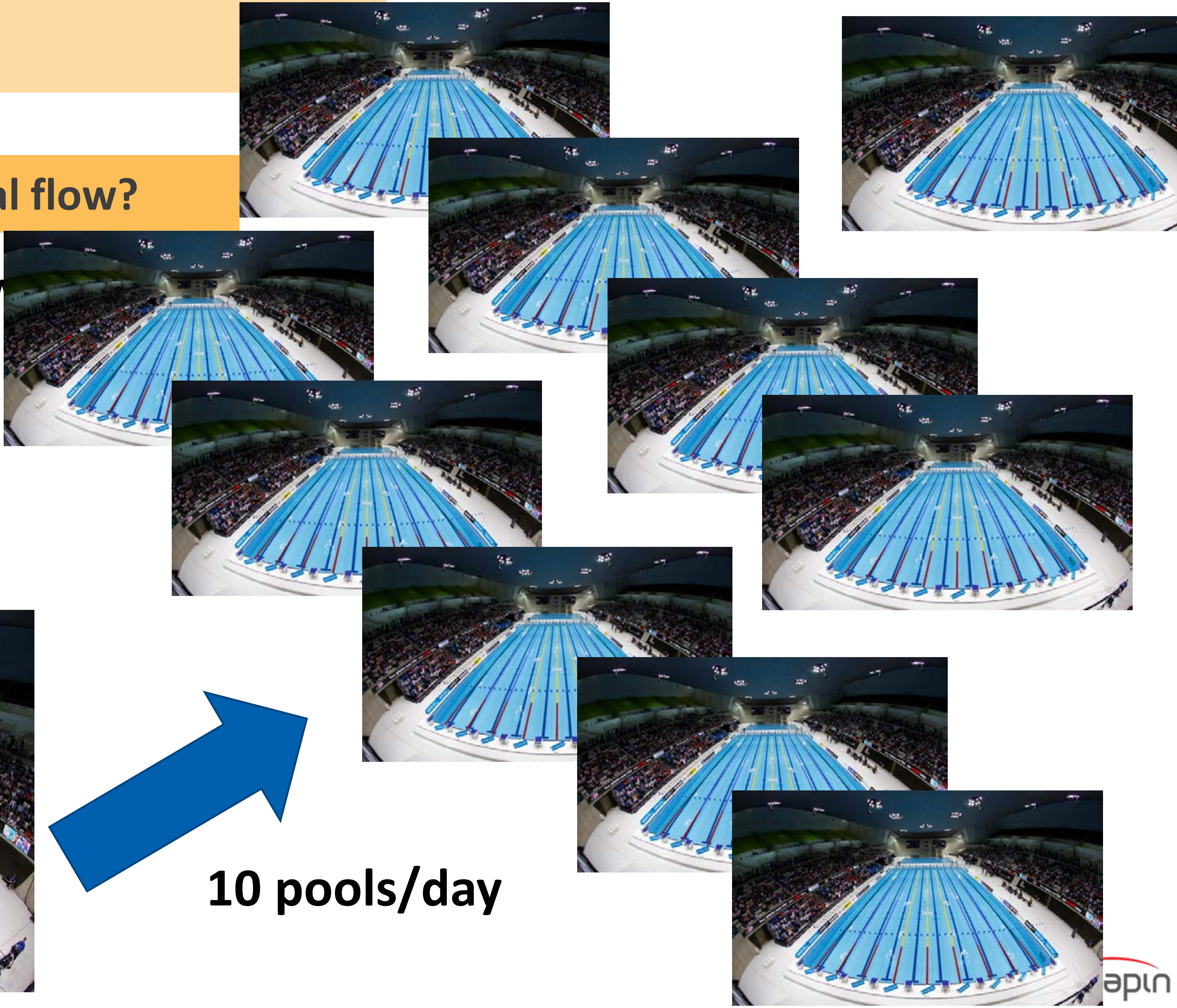
# Heat as Useful Energy

## 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**

# Decarbonizing Energy

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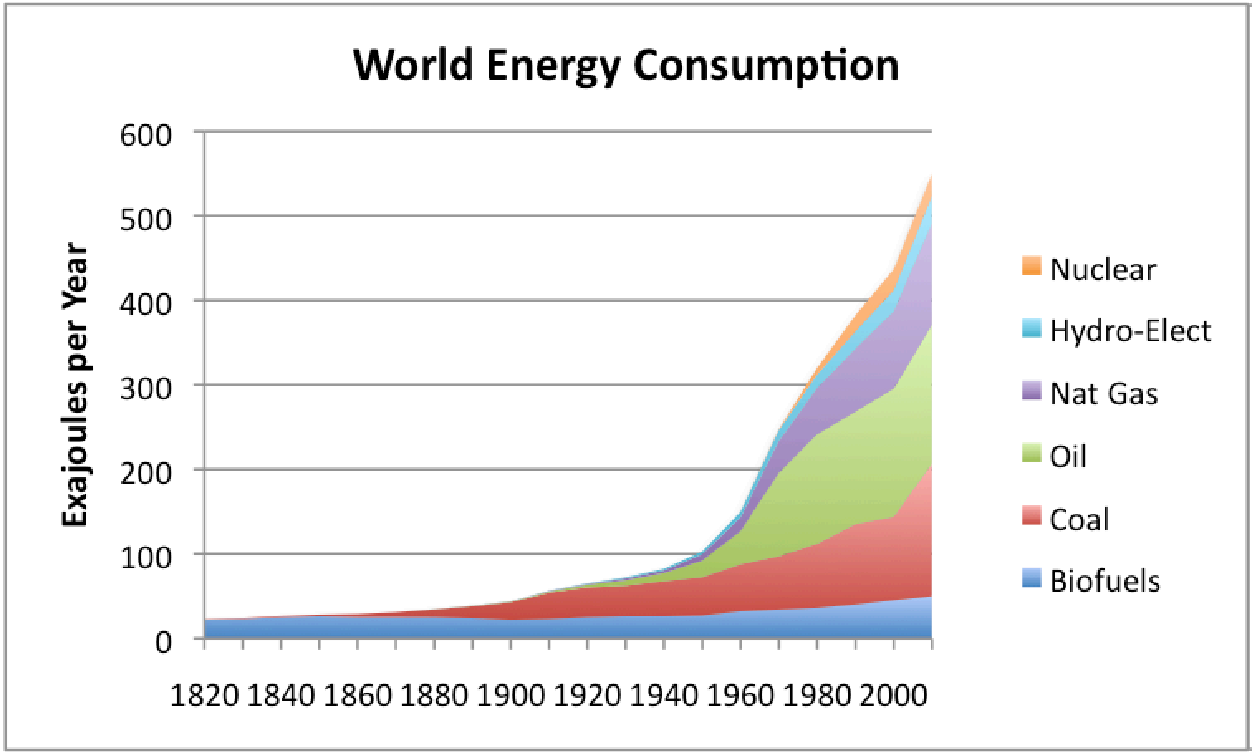
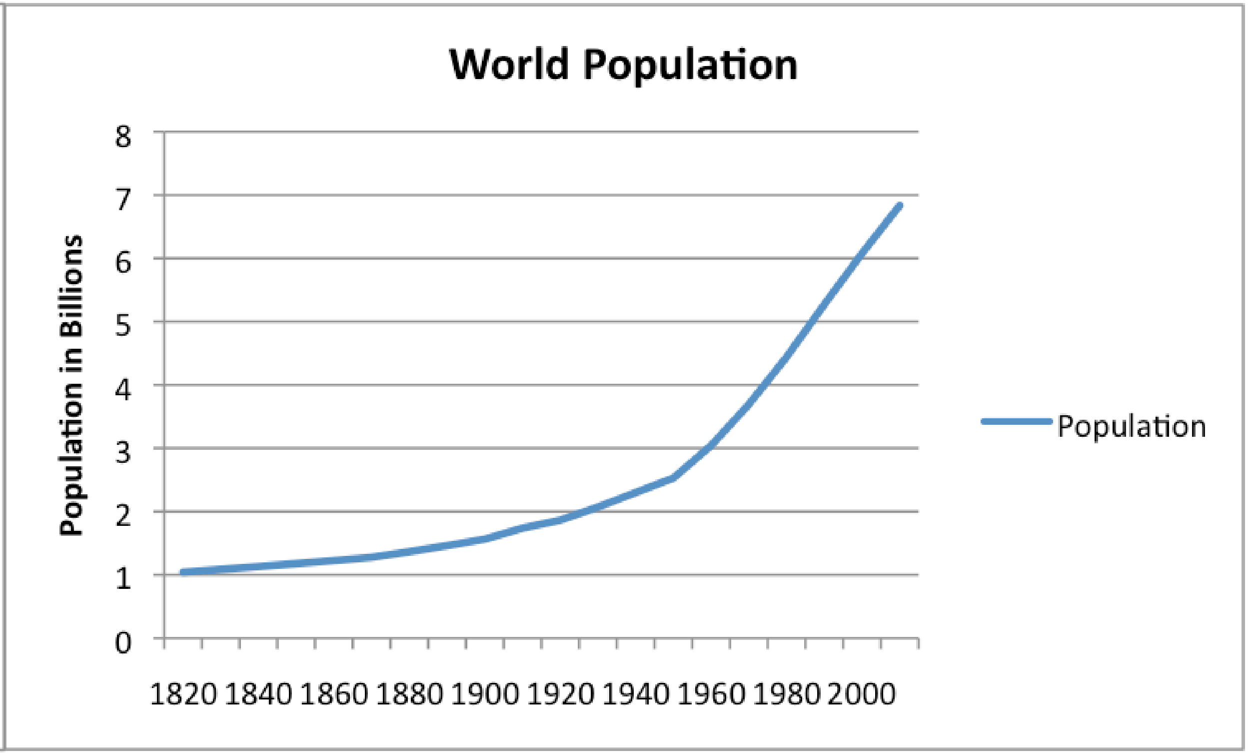
# Massive increase in energy needs with “modernization” and “mechanization”




Increasing world population and increasing energy needs if fueling the surge in energy.

https://www.financialsense.com/contributors/gail-tverberg/world-energy-consumption-since-1820-in-charts

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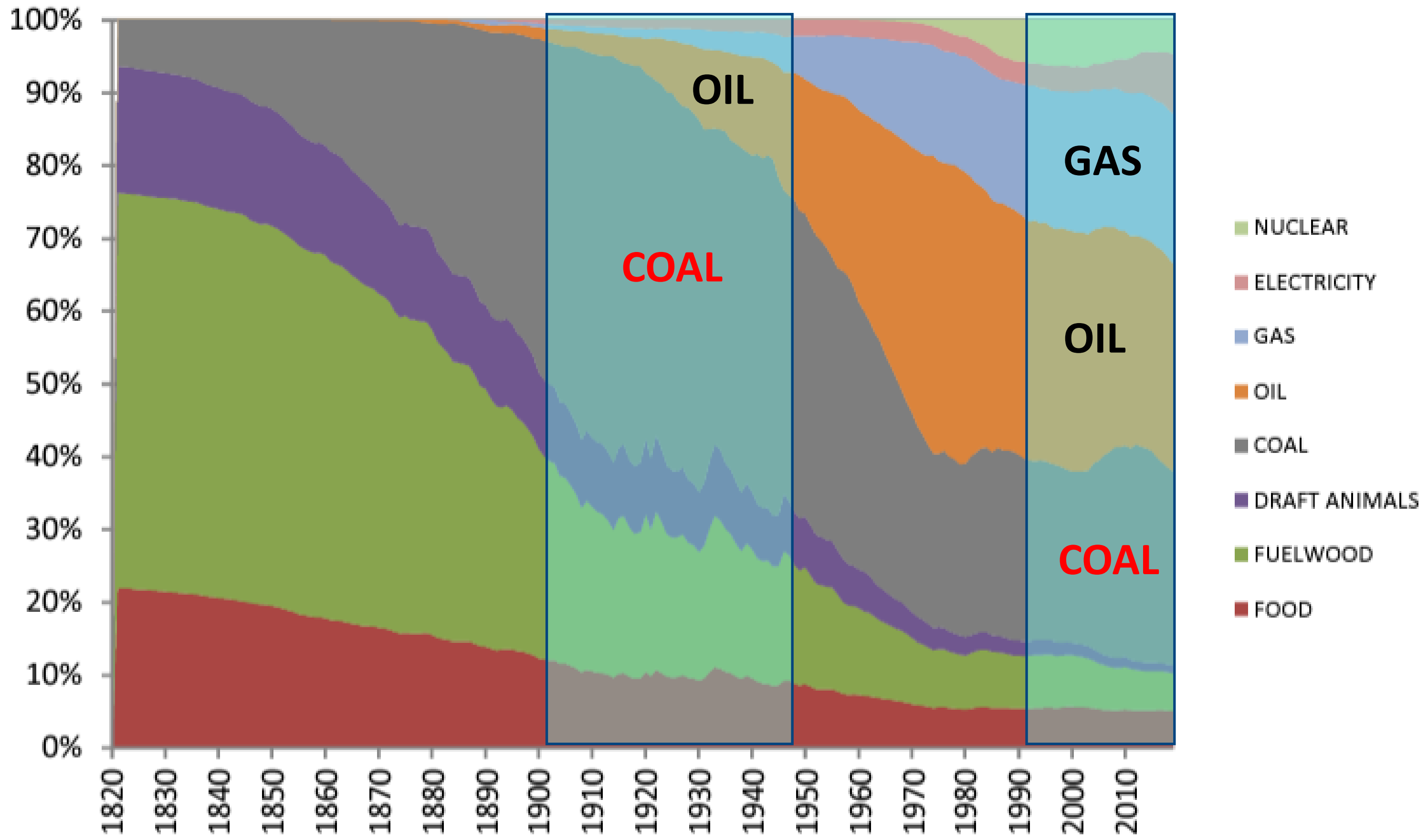
# World continues to massively rely on coal

Much of the worlds heating (and cooling) needs are supplied by Natural Gas, Oil and Coal.

*For the next set of slides, GOOGLE YOUTUBE "World energy1860 – 2019"*

**Figure 11.** Percentage of any source on total World consumption 1820-2018

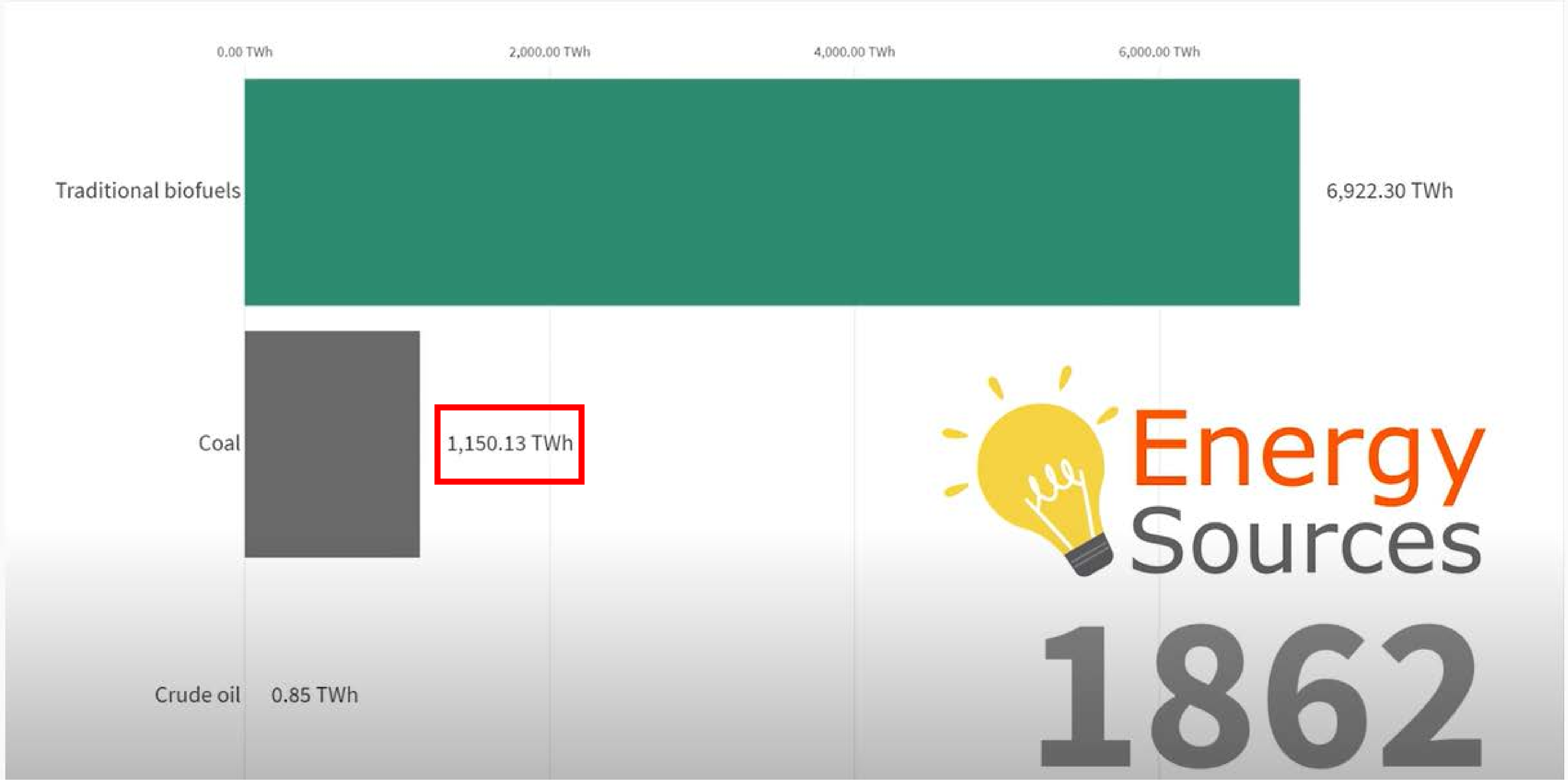



- https://histecon.fas.harvard.edu/energyhistory/DATABASE%20World%20Energy%20Consumption.pdf

# Traditional biofuels and coal were the only option

https://www.youtube.com/watch?v=ELYeTo2HqYY

(DATA FROM BP STATISTICAL REVIEW OF WORLD ENERGY)

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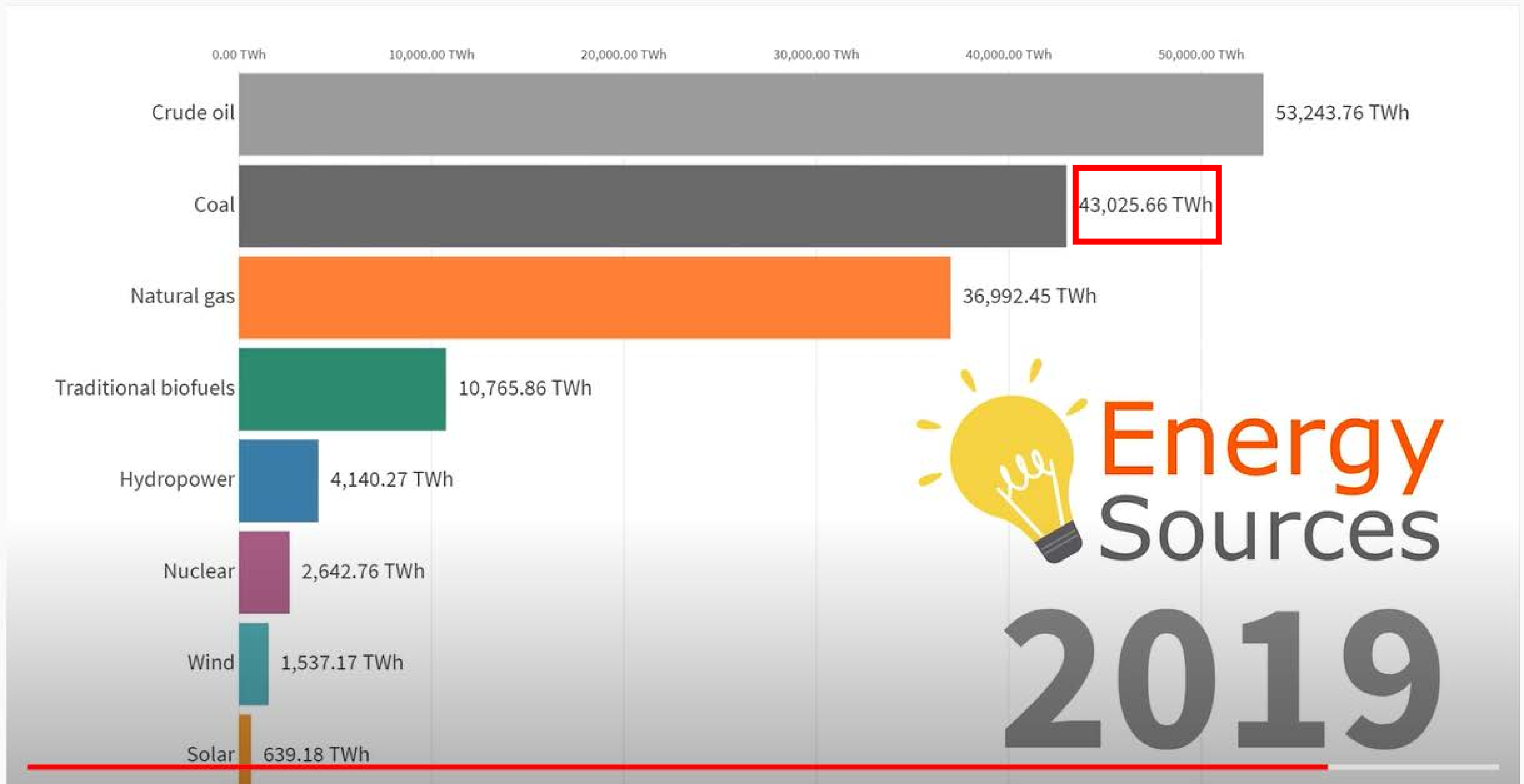
# 2019: Coal energy use up to 43,025 kwh from 5.6 kwh 1900

Total global energy use now up to ~142,000 twh

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# This gets complicated very quickly!

## Specific CO2-emissions of different fuels In relation to one kilowatthour electricity

| Fuel | **Power Plant Efficiency** [%] | **$CO_2$ Emissions** [1] [$g_{CO2}$ / $kWh_{el.}$] |
|---|---|---|
| **Lignite** | **38*** | **1093** |
| ->(Old) | 34 | 1221 |
| ->(Modern) | 43 | 966 |
| ->(Improved) | 51 | 814 |
| **Hard coal** | **39*** | **1001** |
| ->(Old) | 36 | 1084 |
| ->(Modern) | 46 | 849 |
| ->(Improved) | 48 | 765 |
| **Natural gas** | **56.1**** | **433** |
| ->New turbine KW | 39.2 | 619 |
| ->New construction CCGT | 59 | 411 |
| **Natural Gas** Total Greenhouse Effect | **Calc:** Direct [2] + Fugitive Emissions [3] | **$CO_2$ Emissions** [$g_{CO2\text{-}eq.}$ / $kWh_{el.}$] |
| -> 1 % methane leakage | (100+25) % · 204 $g/kWh_{el.}$ = | 503 |
| -> 2 % methane leakage | (100+50) % · 204 $g/kWh_{el.}$ = | 603 |
| -> 3 % methane leakage | (100+75) % · 204 $g/kWh_{el.}$ = | 704 |

**Coal produces about twice the emissions of natural gas.**

Power plant efficiencies play a significant role in total emissions; improving technologies have reduced GHG emissions considerably across hydrocarbon fuel sources. However, Natural Gas emissions are still about ½ of those from coal.

* Mean net electrical efficiency (UBA 2017)

** Mean gross electrical efficiency (UBA 2019)

1) Own calculation from "CO2 emission factor including upstream chain emissions" (UBA 2019, p.43) / "power plant efficiency"

2) Own calculation of direct CO2 emission factor for natural gas: 201 $g_{CO2}/kWh_{PE}$ (excluding upstream chain emissions); assumption for net electrical efficiency = 50%: (201 $g/kWh_{PE}$ ) / 0.5 = 402 $g/kWh_{el.}$

3) Own calculation of fugitive emissions: The release of 1% of the amount of methane needed for 1 kWh of electricity (145 $g/kWh_{el.}$ at 50% efficiency) corresponds to $CO2_{eq.}$ of 36 grams at GWP = 25.

Sources:

- UBA 2021 - Strommarkt und Klimaschutz: Tansformation der Stromerzeugung bis 2050 (p. 66)
- UBA 2019 - Emissionsbilanz erneuerbarer Energieträger 2018 (p. 42f.)
- UBA 2017 - Daten und Fakten zu Braun- und Steinkohlen (p. 31f.)



https://www.volker-quaschning.de/datserv/CO2-spez/index_e.php

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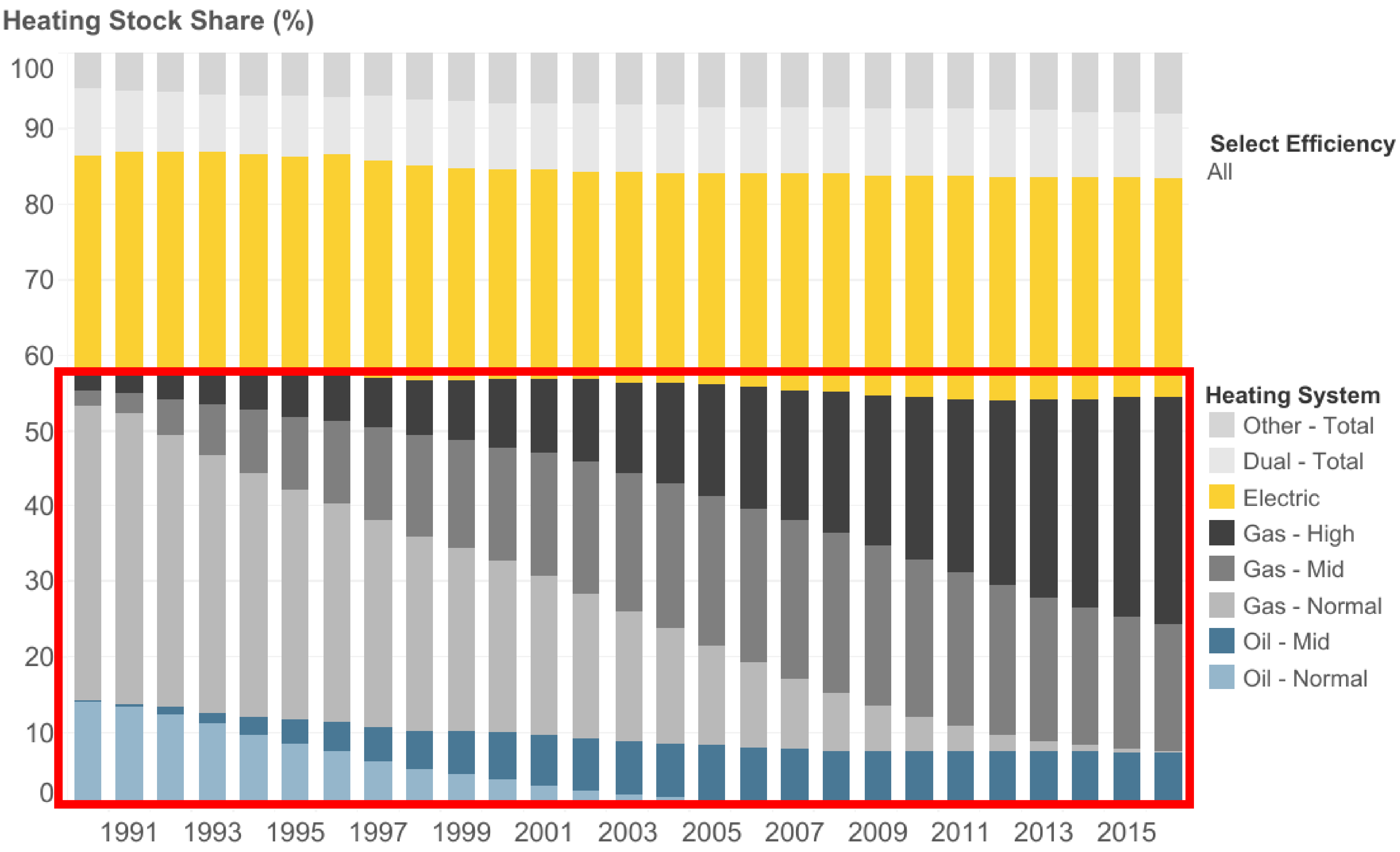
# Mean while - Continuously Improving Efficiencies for Gas




Gas and Oil broken down by Efficiency

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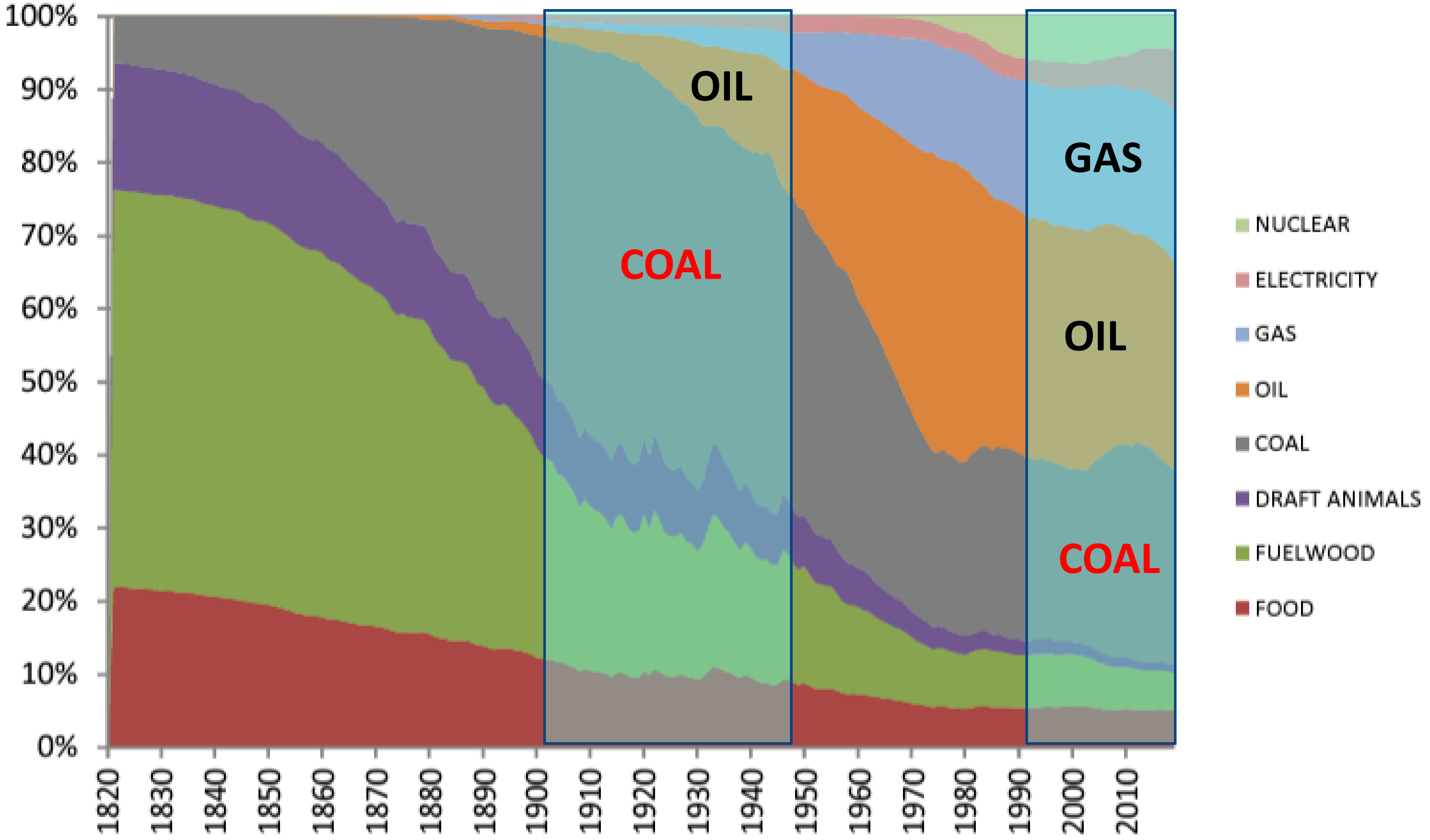
# Take Away: World needs to get off coal as a priority

The world has a long way to go to replace it's heating/cooling needs with other sources of energy and Technologies. Geothermal is there to fill the gap! And so is NG to replace coal fired generation.

**Figure 11.** Percentage of any source on total World consumption 1820-2018




- https://histecon.fas.harvard.edu/energyhistory/DATABASE%20World%20Energy%20Consumption.pdf

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# Let's talk about coal, GHGs and electrification

ALBERTA NO.1 GEOTHERMAL ENERGY PROJECT

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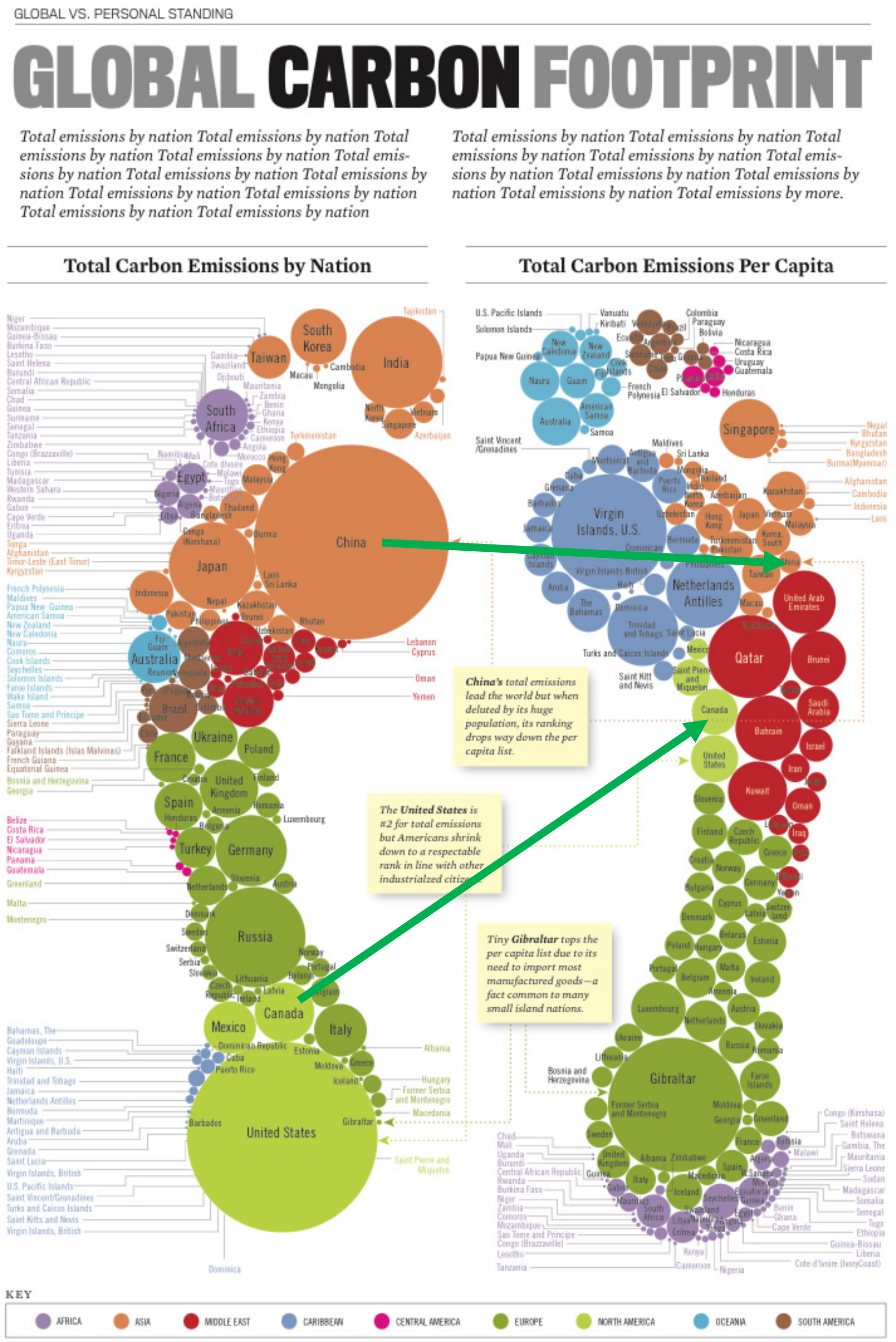
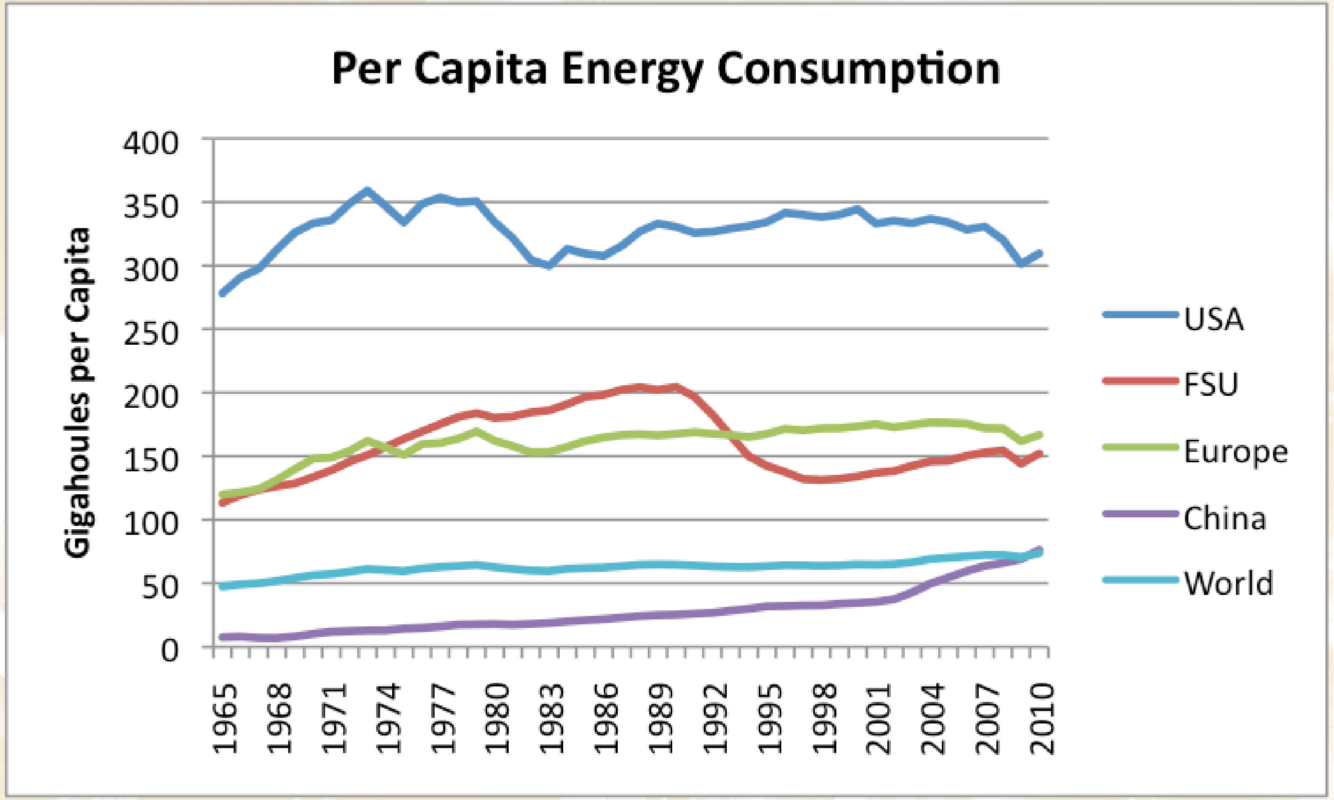
GEOTHERMAL CANADA



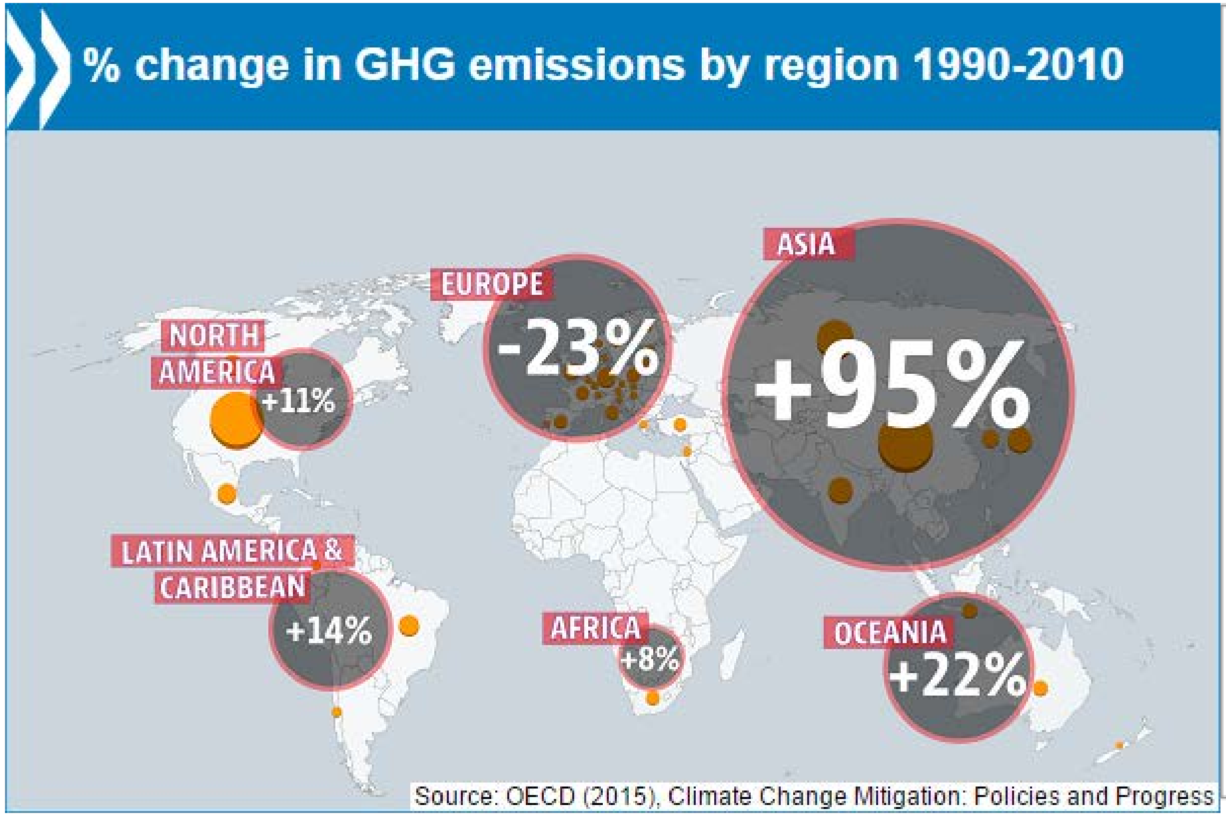

https://complexstories.com/client-projects/global-carbon-footprint/

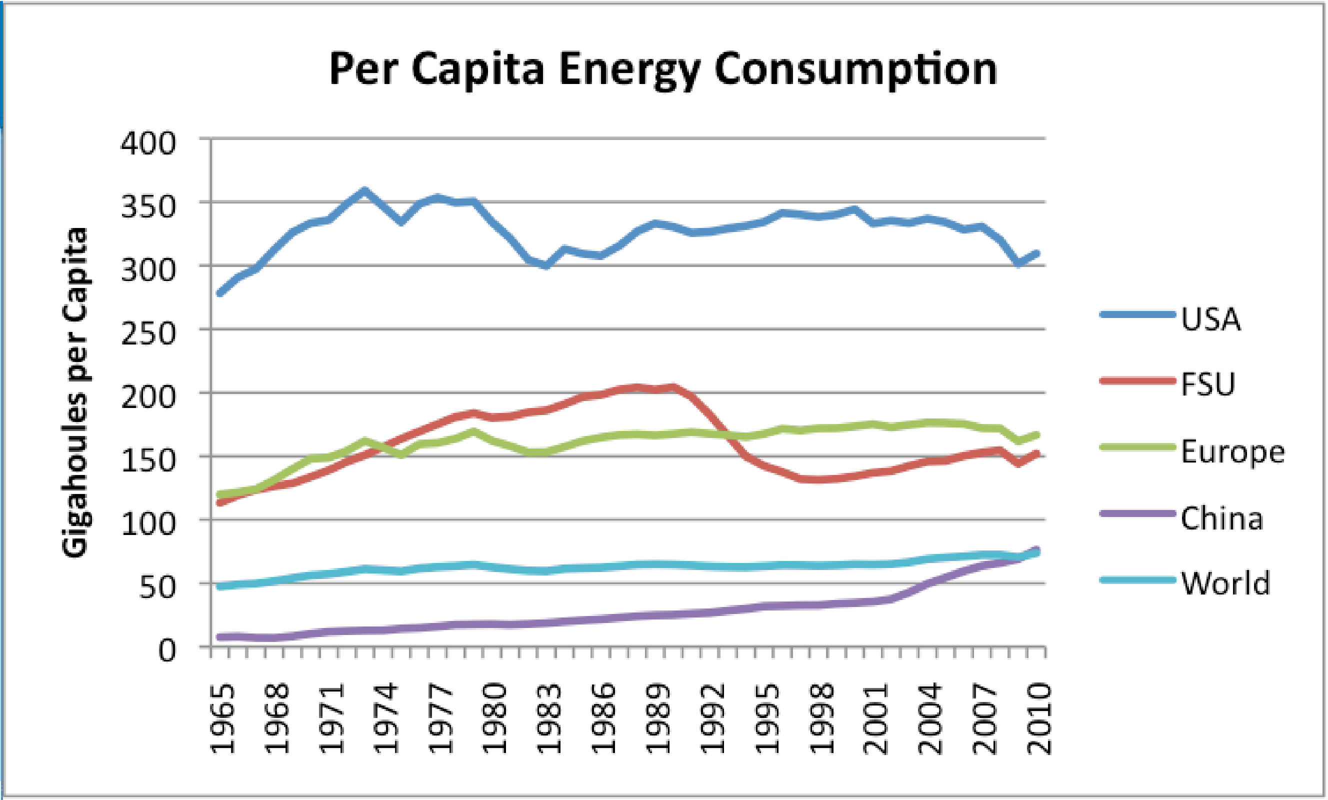



This graph implies that with continued industrialization, China's need for energy on a per capita basis will grow; most of this increased energy use is coming from coal fired electrical generation. Here is the opportunity for Canada and its rich reserves of Natural Gas.

# GHG Emission Increases and Consumption

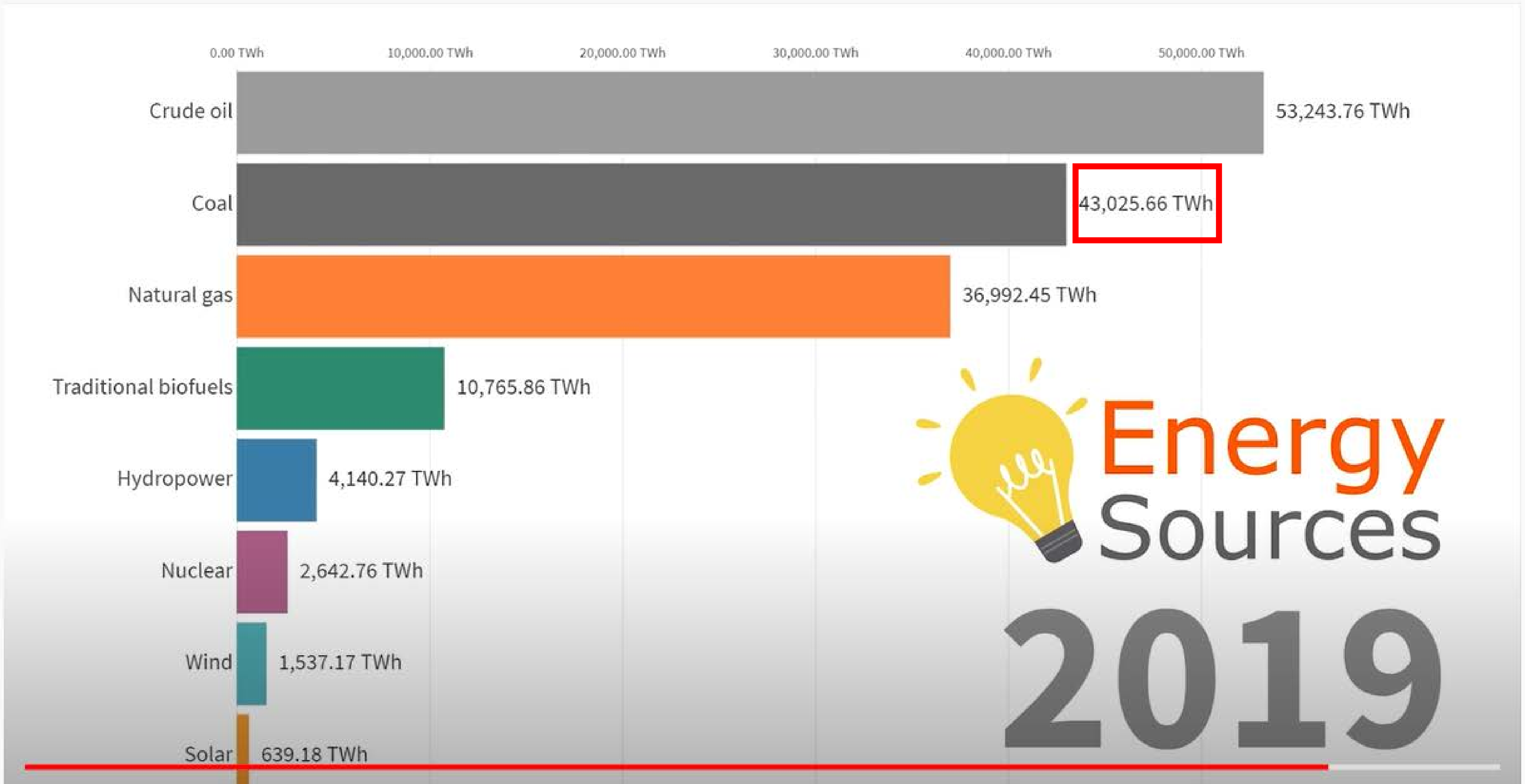
COAL ENERGY USE UP TO 43,025 KWh from 5.6 KWh 1900 – mostly from increased demand for energy by growing and industrialization of populations and societies



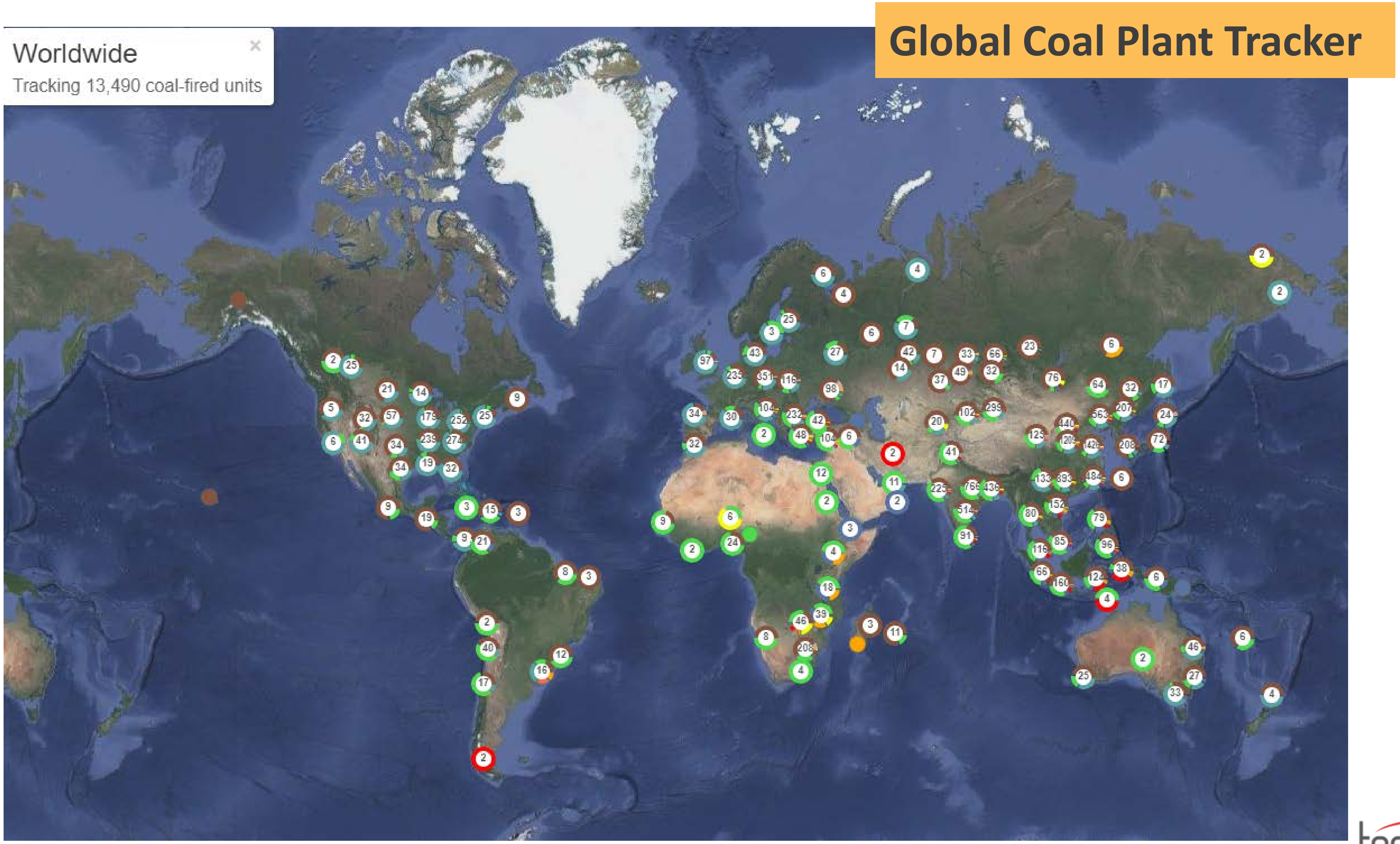



# 2019: Coal 2nd only to crude oil

Total global energy use now up to ~142,000 twh



# 13,490 coal-fired units worldwide

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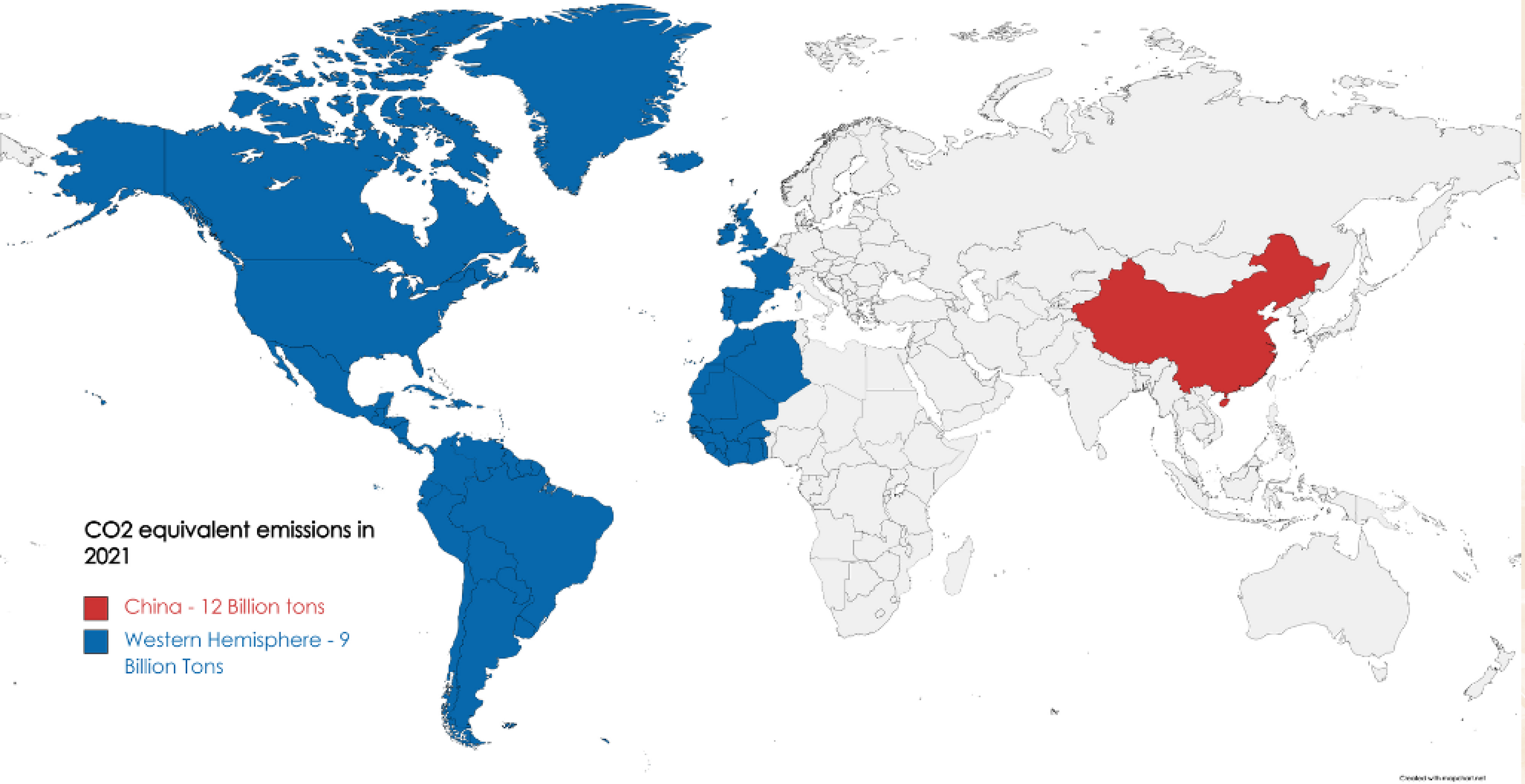
# Permitted and under construction coal plants

## Global Coal Plant Tracker


New, under construction coal plants and permitted plants.

https://globalenergymonitor.org/projects/global-coal-plant-tracker/?gclid=Cj0KCQjwwfiaBhC7ARIsAGvcPe5CWXct-zmD1pu4TWWru4uoPLwv6UVCMXHcy5vcJbMaSPF01BddzVYaAghqEALw_wcB

# China emits more CO2 than the entire Western hemisphere




*Countries spanning both Western and Eastern hemispheres are included*

*China and the Western hemisphere each have a total population of about 1.4 billion*

Here is the opportunity for Canada with its rich reserves of Natural Gas (NG):

We can help reduce GHG emissions in other countries by replacement of their coal fired generation with easily transported NG.

By using geothermal domestically, we "liberate" the NG fuel used for heating to be sold in more lucrative international markets where it will have a much bigger "bang for the buck" in terms of reducing GHGs.

https://www.reddit.com/r/dataisbeautiful/comments/xihnls/oc_china_emits_more_co2_than_the_entire_western/

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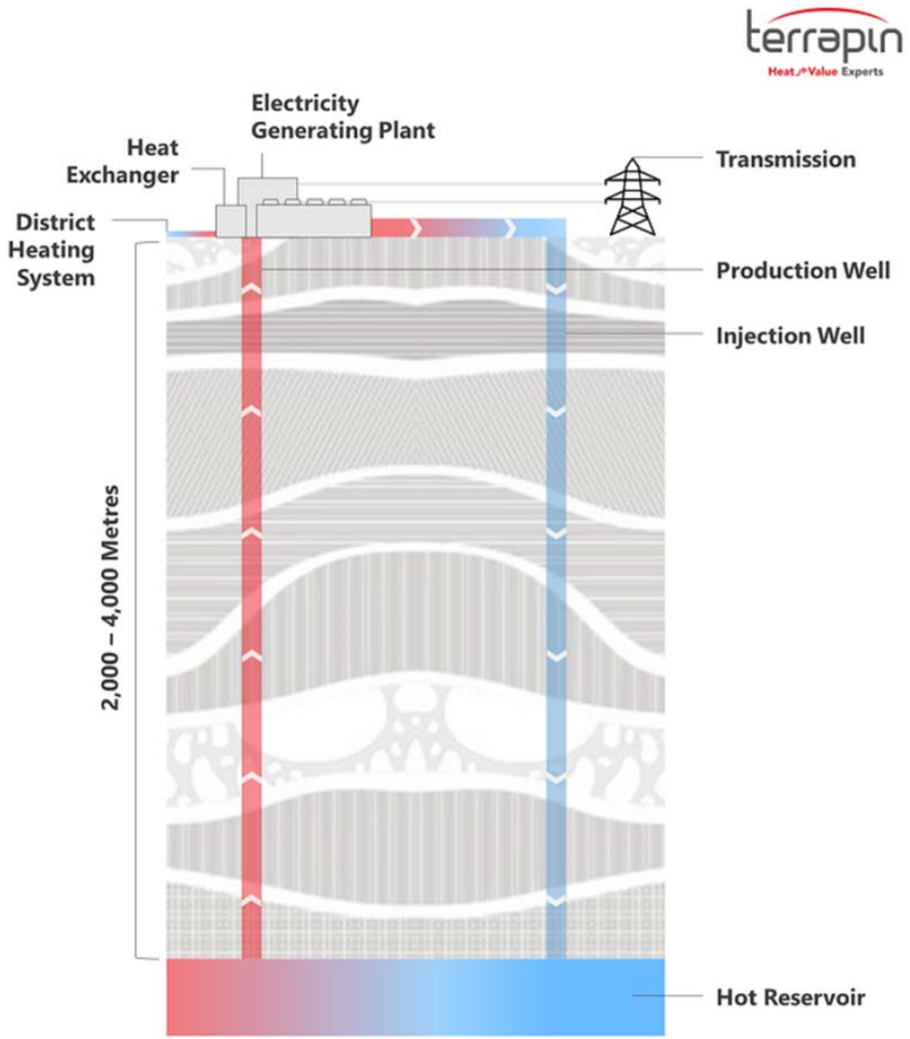
# How can Canada help countries and regions get off burning coal?




- More geothermal to replace natural gas used for heating and more natural gas to replace coal used for power production.
- Natural gas emits ½ the GHGs of coal.
- Get that natural gas to international markets to help our neighbours get off coal!

*Geothermal to replace natural gas; natural gas to replace coal.*

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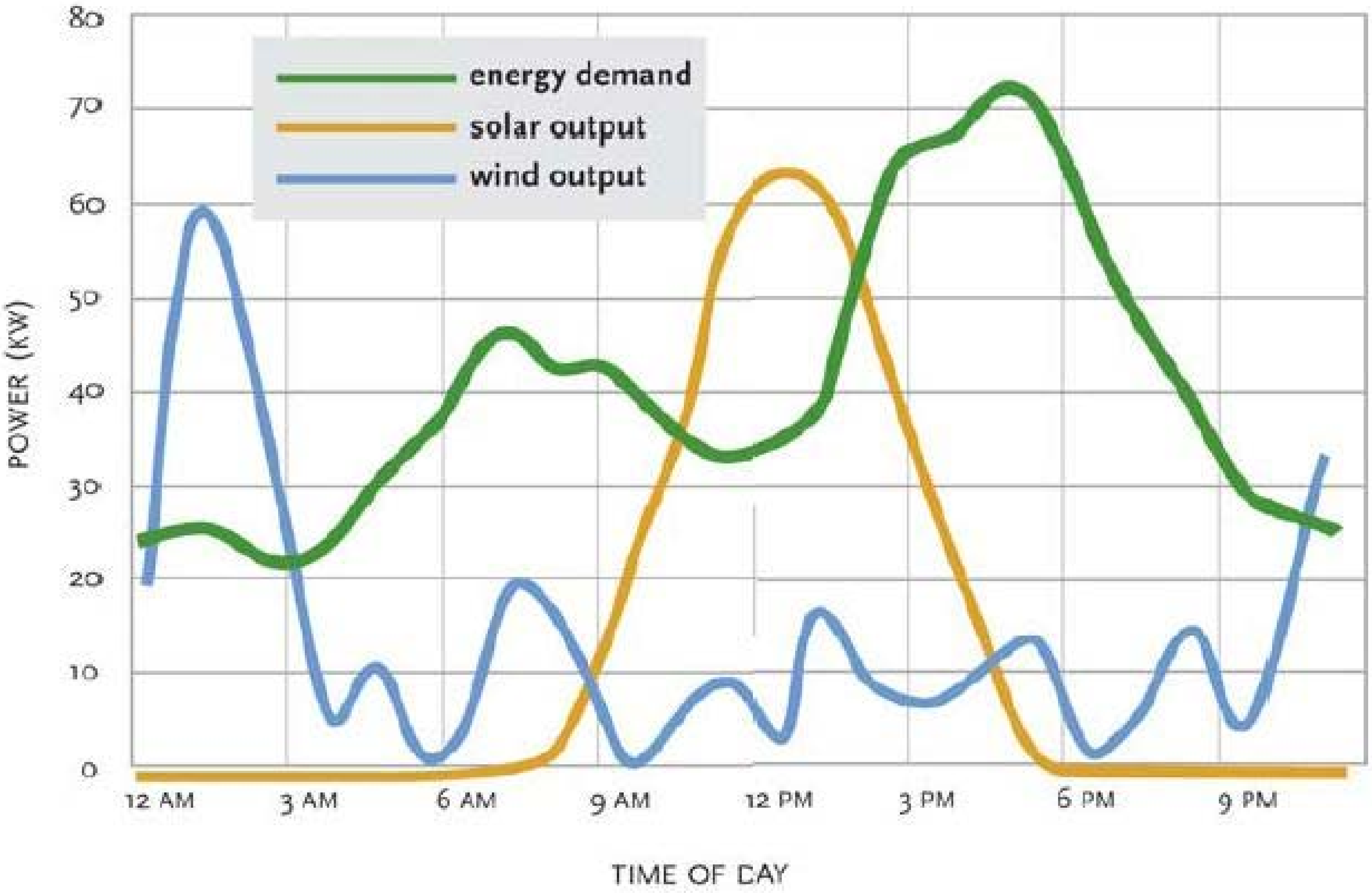
# *And by the way* - need NG to back up solar and wind because of the intermittent power problem needs peaker plants.

This graphic points out the need for energy storage solutions, not just gas peaking plants. Most carbon analysis of solar and wind does not include the need for NG or storage.

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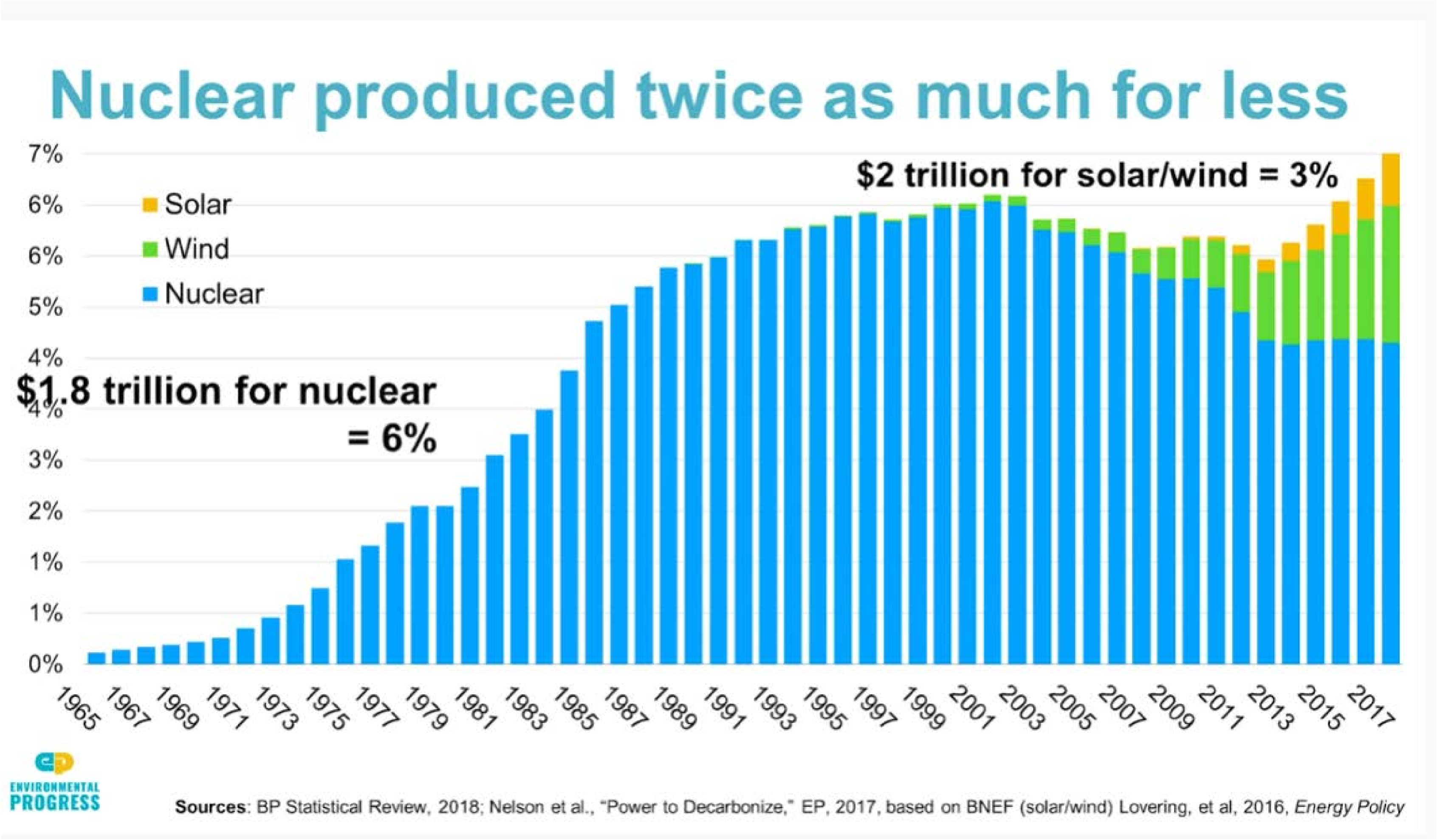
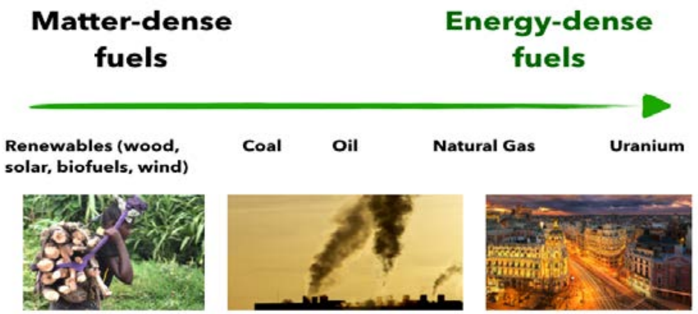
# Michael Shellenberger – "in our efforts to save the planet are we destroying the environment?" (Jan 4, 2019)




Energy density nuclear




Michael Shellenberger – founder of "Environmental Progress" and the "Breakthrough Institute"

Alternative view of solar/wind and nuclear
https://www.youtube.com/watch?v=N-yALPEpV4w

# Canada’s Energy Use

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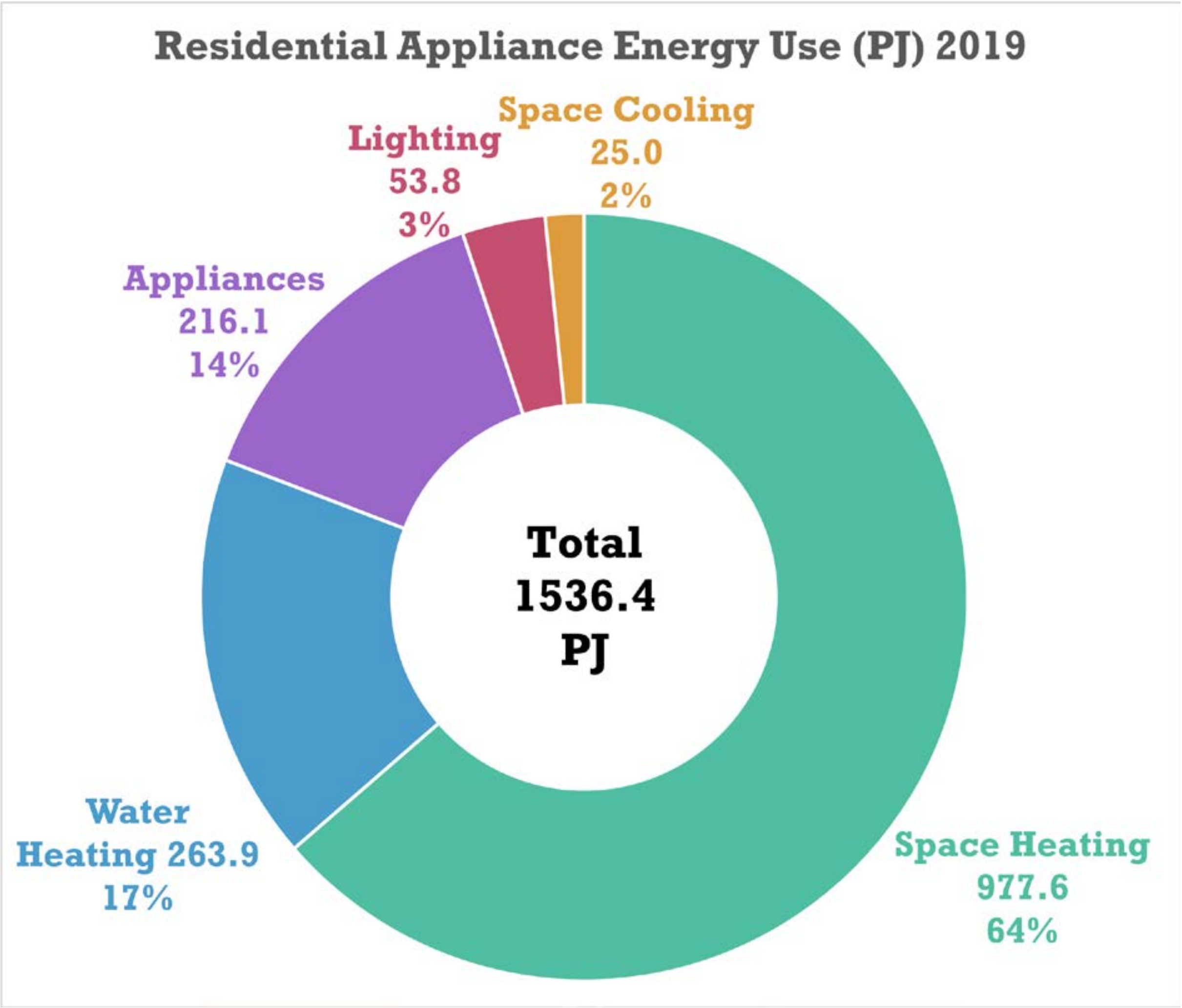
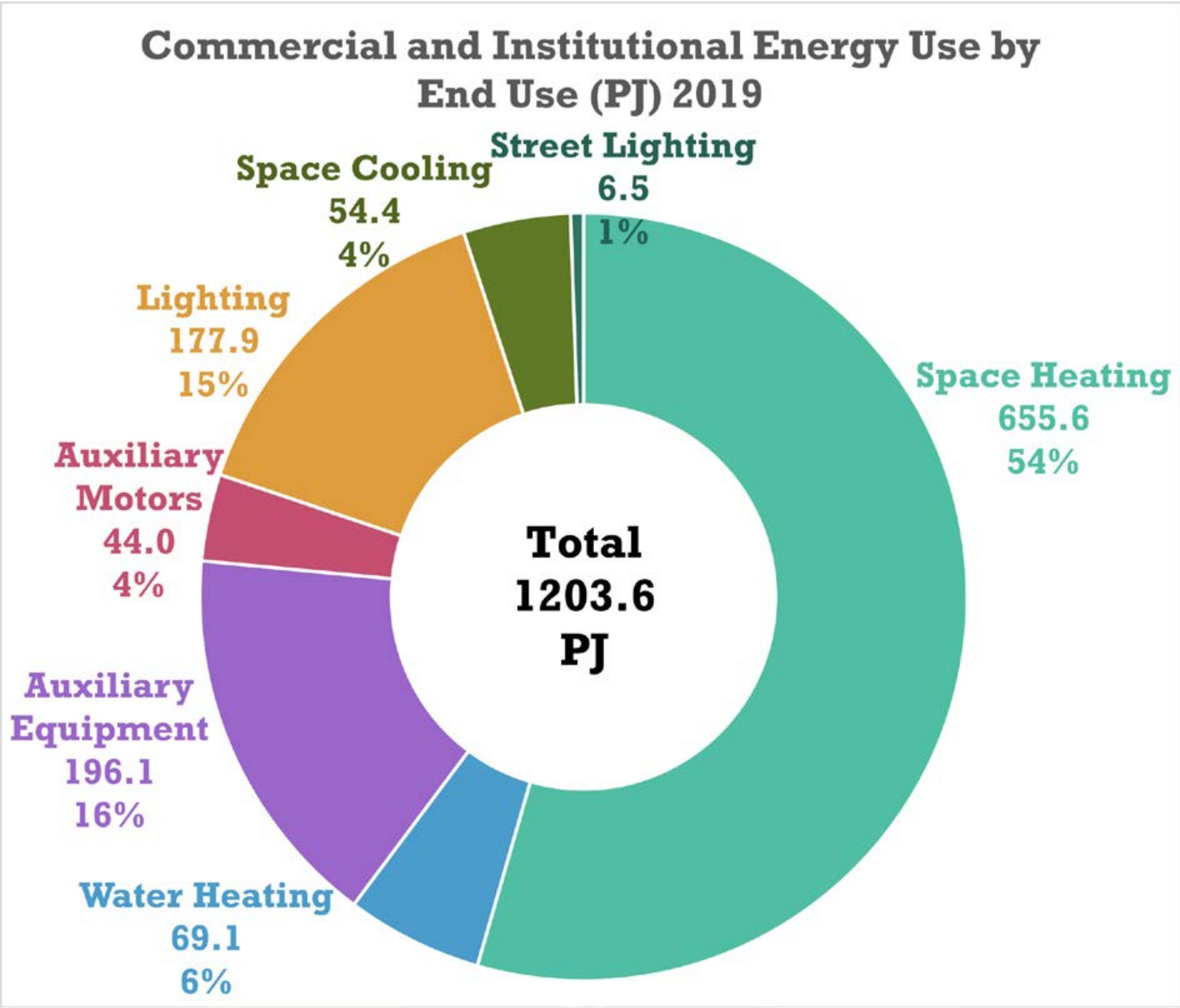
GEOTHERMAL CANADA

# Canada's Residential and Commercial Energy Use

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# Heat is useful energy

## How much would it cost (Canadian dollars) in fuel to heat the same amount of water?

### Cost Comparison of Thermal Energy Output*

**Alberta No. 1**
(Annual Generation)

**985,000 GJ**
clean, constant geothermal heat

→ Offsets **55,160** $tCO_2e$

→ **$3,603,000** heat revenue & **$2,390,000** carbon revenue at $50/tCO_2e$

→ **$3,603,000** heat revenue & **$4,780,000** carbon revenue at $100/tCO_2e$

Equivalent **Hydrocarbon Requirements**

**~161,000 barrels** of oil equivalent

→ Creates **69,230** $tCO_2e$

→ **$10,626,000** fuel cost & **$3,461,500** in carbon taxes at $50/tCO_2e$

→ **$10,626,000** fuel cost & **$6,923,000** in carbon taxes at $100/tCO_2e$

**~26,620,000 m³** of natural gas equivalent

→ Creates **50,580** $tCO_2e$

→ **$2,975,400** fuel cost & **$2,529,000** in carbon taxes at $50/tCO2e

→ **$2,975,400** fuel cost & **$5,058,000** in carbon taxes at $100/tCO_2e$

Using Value of Commodity in CAD: $66/barrel (WCS $51.93USD/barrel); $2.85/GJ

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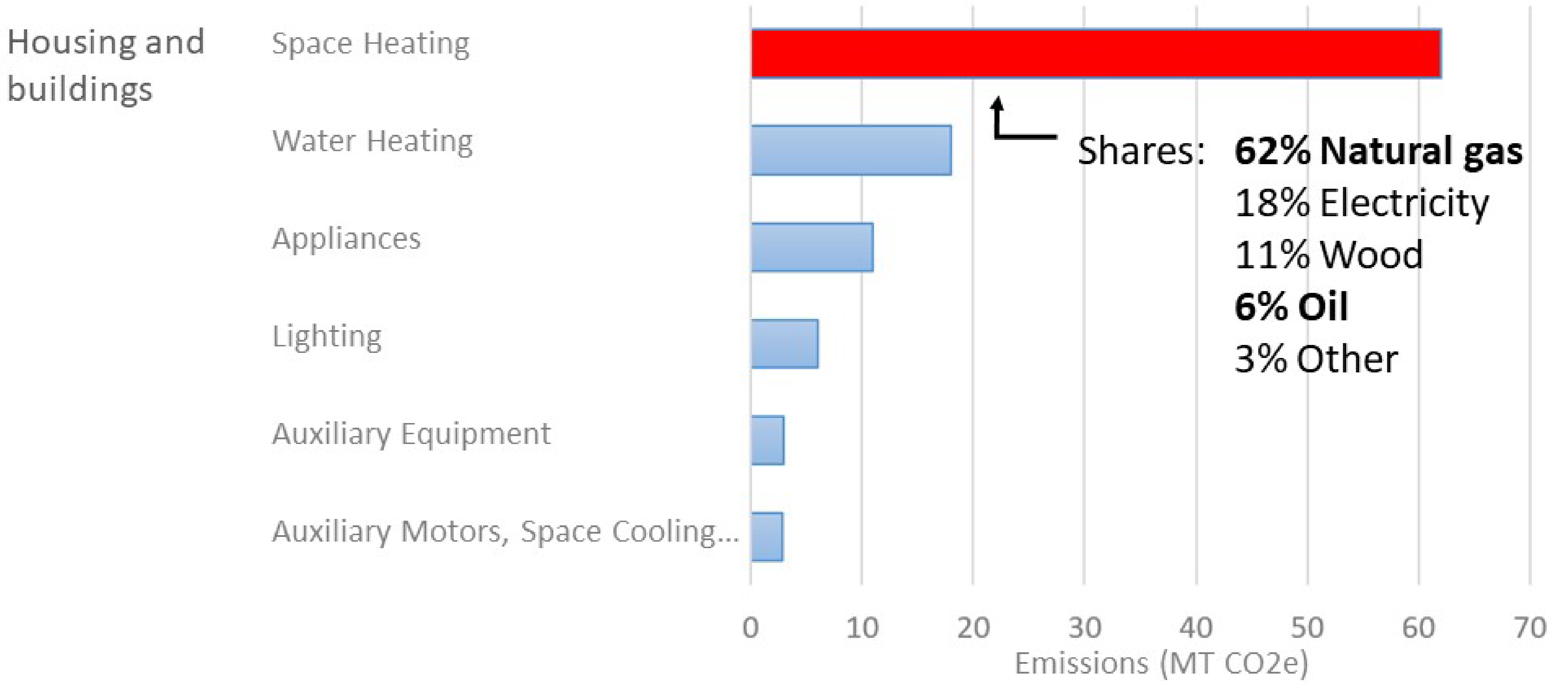
(*assumes only the cost of fuel)

# Canada's Carbon Emissions by Use




Source: NRCan, Energy End Use Data Handbook. 2017.

# Heat is useful energy

**Many companies have not yet grappled with the carbon offsets required for their industrial process**

## Cost Comparison of Thermal Energy Output*

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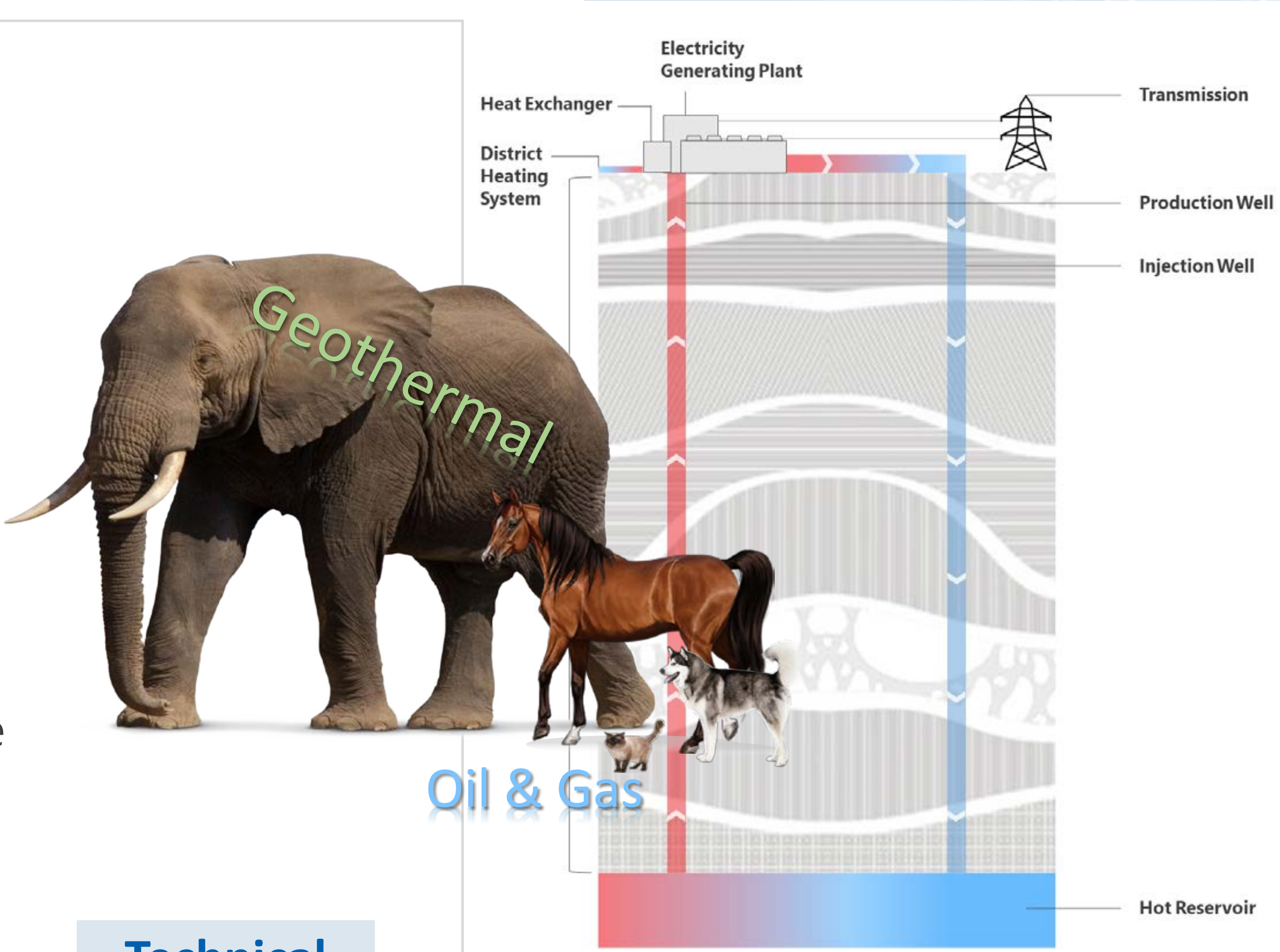
(*assumes only the cost of fuel)

# Conclusions

# Geothermal's technical hurdles

- Very high CAPEX for power projects
- Need to reduce the cost of drilling
- Overcome surface access problems (winter drilling)
- Think small and shallow to provide thermal option
- Consider regional implications for power production
- Review all in costs to electrify a number of communities.
- Long distances to pipeline heat.
- Permafrost concerns for geoexchange
- Minimal loads, sparce population

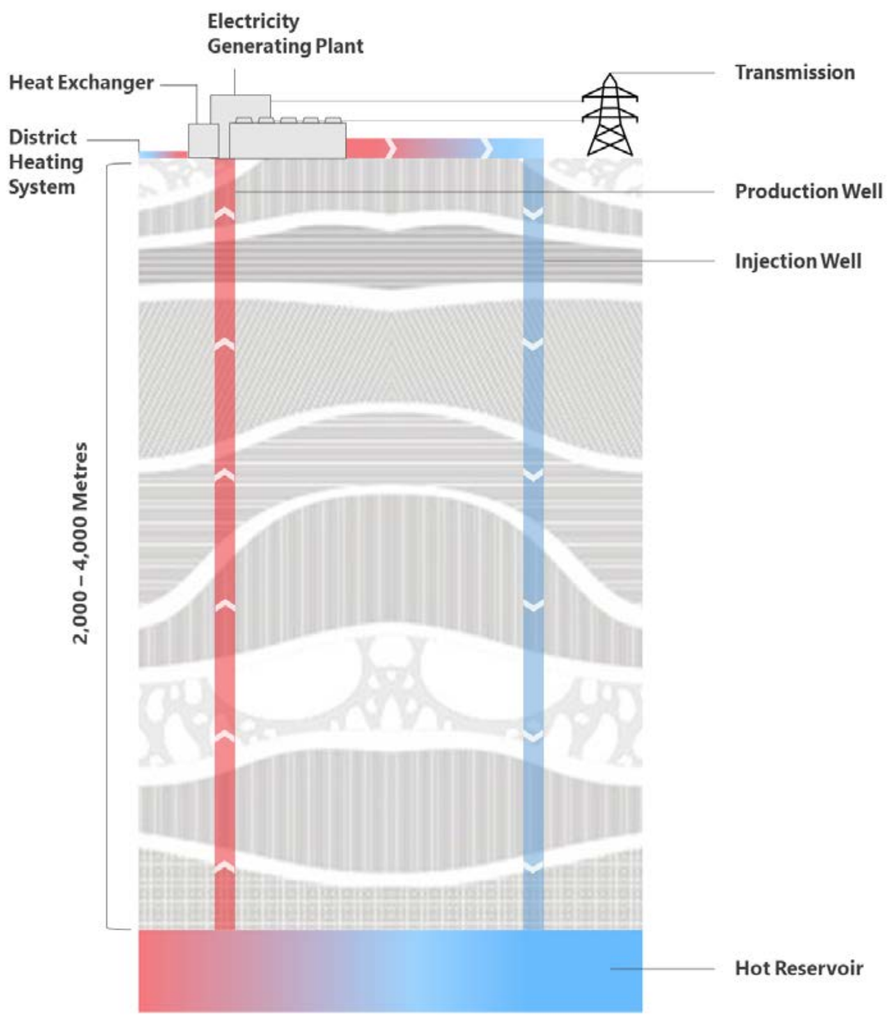



**Financial** **Political** **Technical**

# Geothermal's commercial hurdles

- Carbon emitters have not fully grasped the long-term implications of carbon tax on the economics of their operations.
- Clearing hurdles for the export of Natural Gas.
- "First in kind" seen as too risky for 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**

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# Fiscal Incentives to mobilize capital

The GNWT will not be able to develop these geothermal resources on its own; private sector investment will be required!

Possibilities:

- Grants (Research and Development)
- Loan Guarantees
- Well Failure Insurance
- Low/No Royalties
- Tax Incentives
- Subsidisation
- Guaranteed power purchase agreements
- Guaranteed thermal purchase agreement
- Treating as infrastructure
- Regulatory framework

## What Is Energy Return on Investment (EROI)?

Energy Return on Investment (EROI) is a ratio for describing a measure of energy produced in relation to the energy used to create it. For instance the ratio would illustrate how much energy is used to locate, extract, deliver, and refine crude oil relative to how much useable energy is created.

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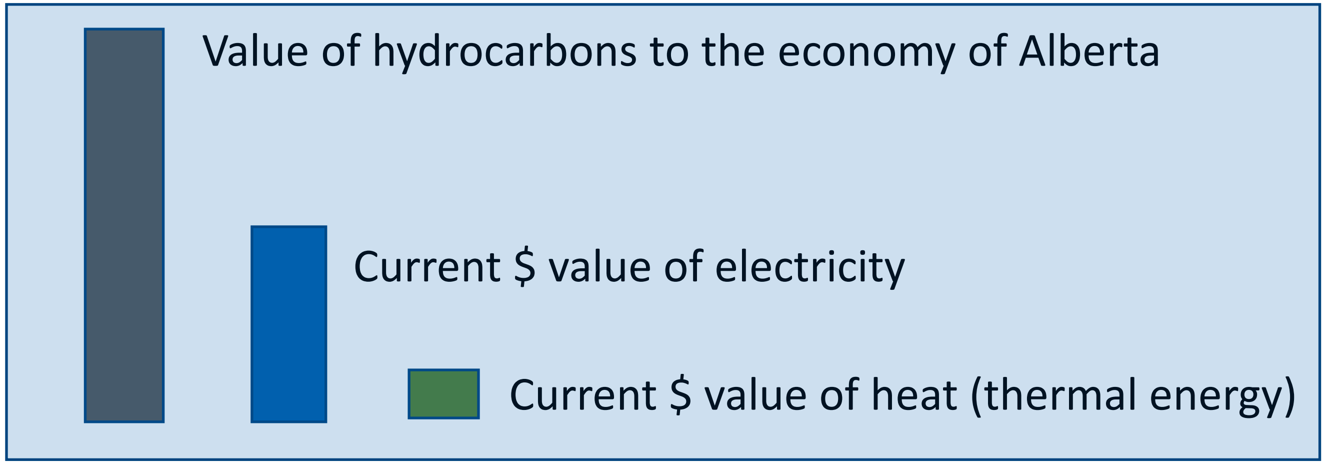
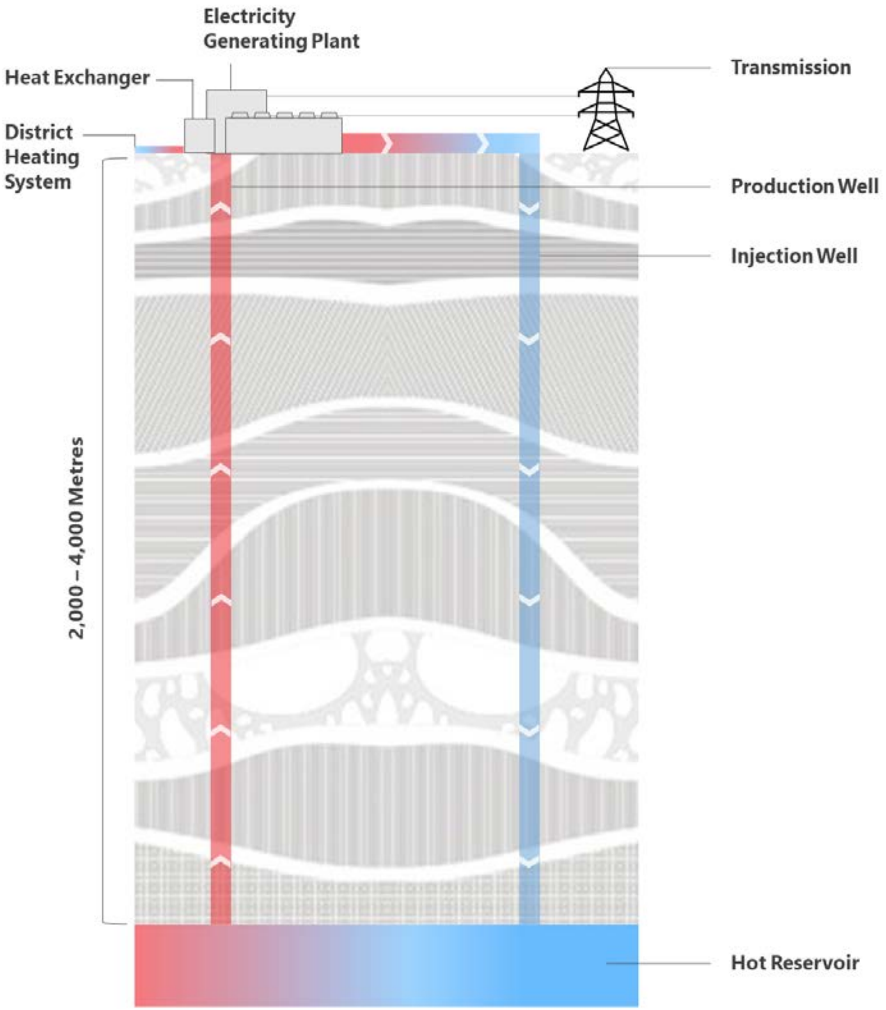
# The keys to the NWT market

- Economics of projects are very different than oil and gas projects for investors willing to take downhole risk.
- Incentivizing investment.
- Think small - geoexchange or low temperature geothermal.
- Help communities make energy decisions.
- Reduce drilling costs/mobilization
- Moving the needle on the value of heat (thermal energy)




**Financial** **Political** **Technical**

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# “Plan B” - NWT’s Next Energy Industry

> **7,000 MW thermal** potential

>**1,000 MW electrical** potential

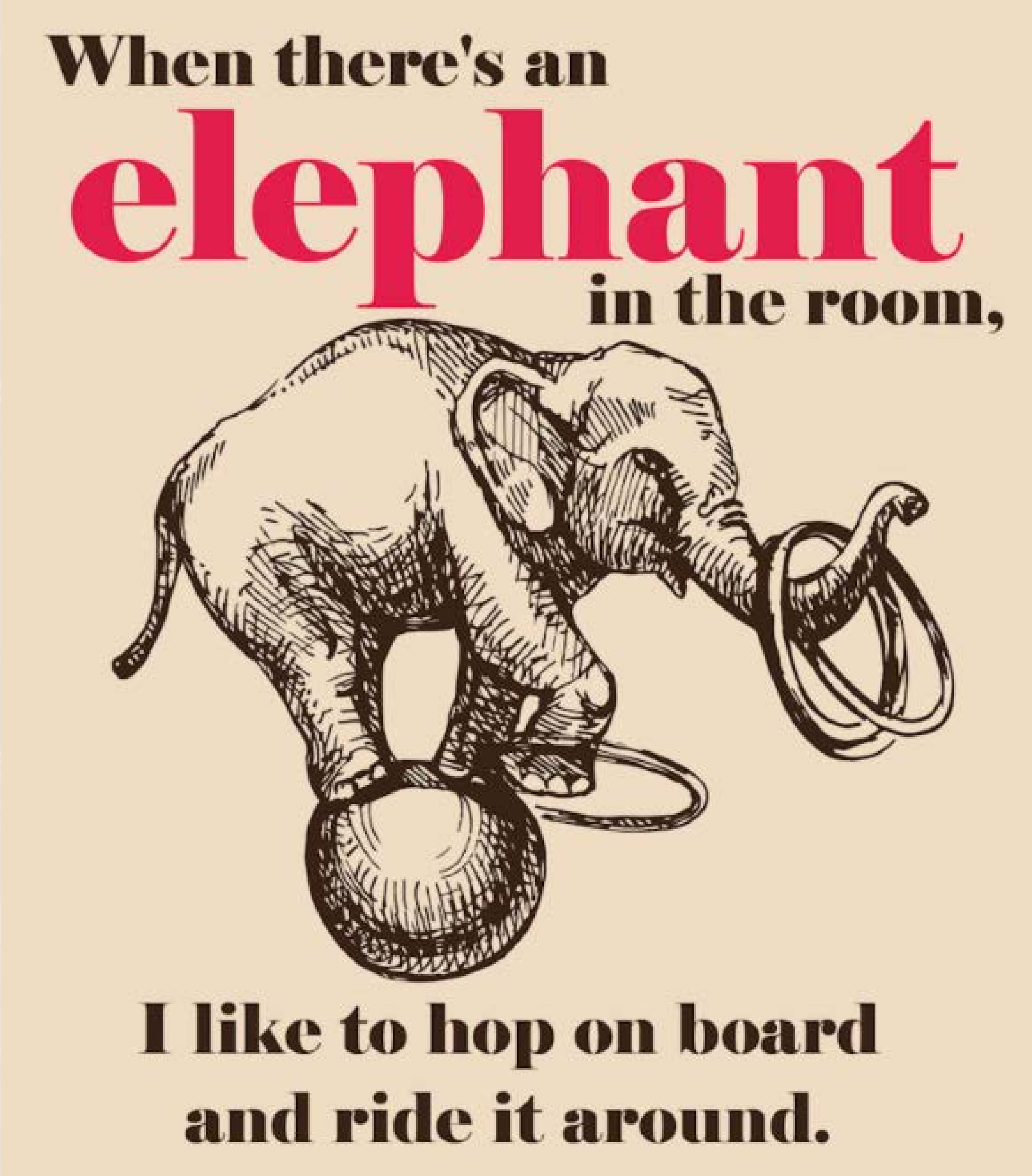
**More community capacity building**

- More small projects – Nahanni Butte
- More local projects – Con Mine, Yellowknife
- More innovation in northern building practices – R2000 building codes
- More waste heat recovery
- More heat storage and geoexchange

***Shout out to Nahanni Butte and Gonezu Energy Inc. (Fort Providence).They are walking the talk and investing in integrated energy solutions for their communities.***

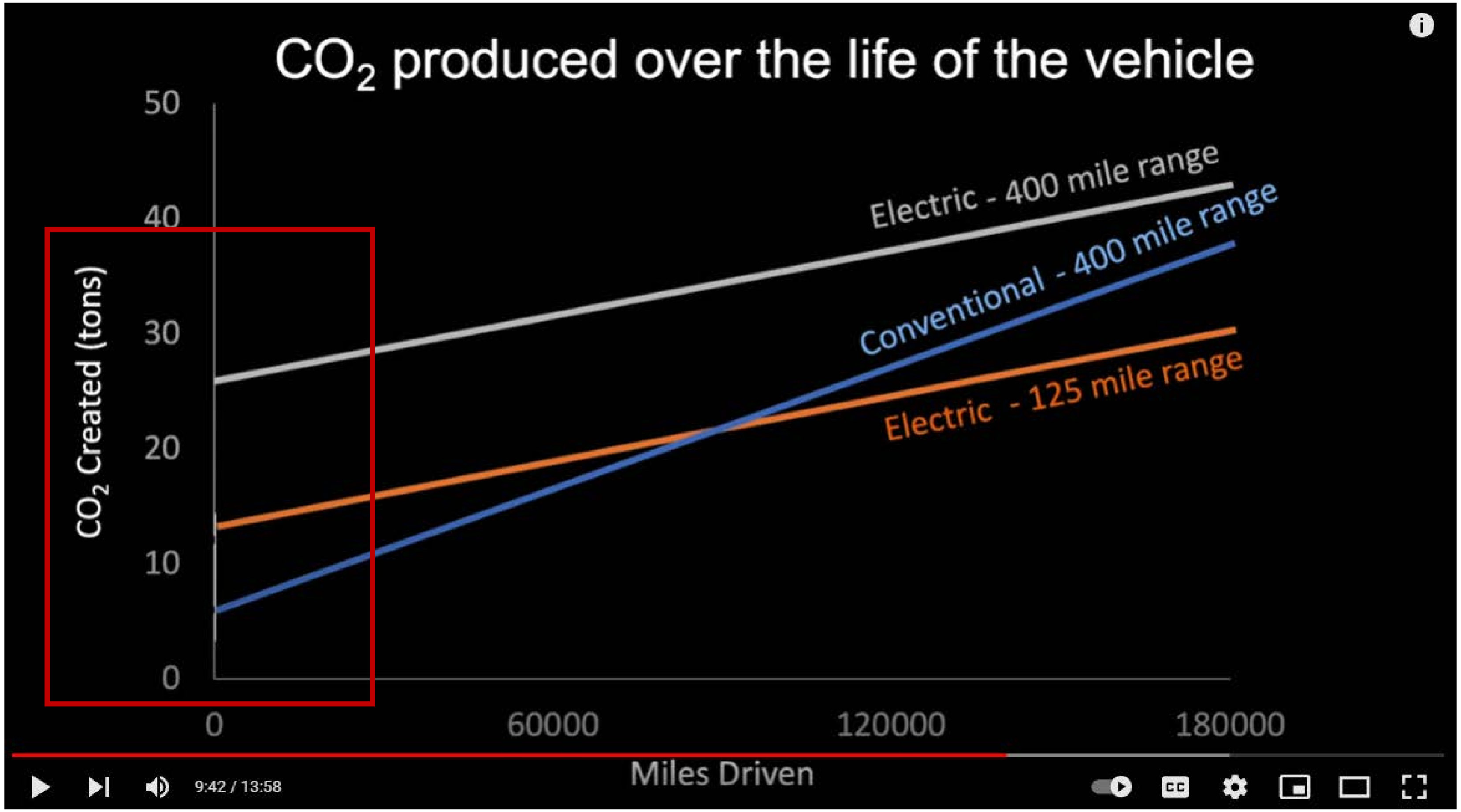
Recognize that geothermal is the "elephant in the room" assisting in decarbonization and increasing the sustainability and livability of northern communities.

Individuals, corporations and governments need to get behind it and give it a push. *Push harder.*



# Driving demand for electricity? Electrification of Vehicles

TEDx talk on electrification of vehicles https://www.youtube.com/watch?v=S1E8SQde5rk
(and the burning of coal)




Electrical vehicles have greater $CO_2$ lifetime emissions than conventional cars; only at high driven mileage do the short-range EV vehicles produce fewer $CO_2$ emissions.

Because of the battery content of the long-range vehicles, the $CO_2$ produced is higher than the conventional vehicle.

**** Assumes grid power that is 67% non-renewable and 33% renewable (does not emit $CO_2$ Hydro/nuclear/solar/wind/geothermal (global average))**

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# Electrification of Vehicles

TEDx talk on electrification of vehicles https://www.youtube.com/watch?v=S1E8SQde5rk
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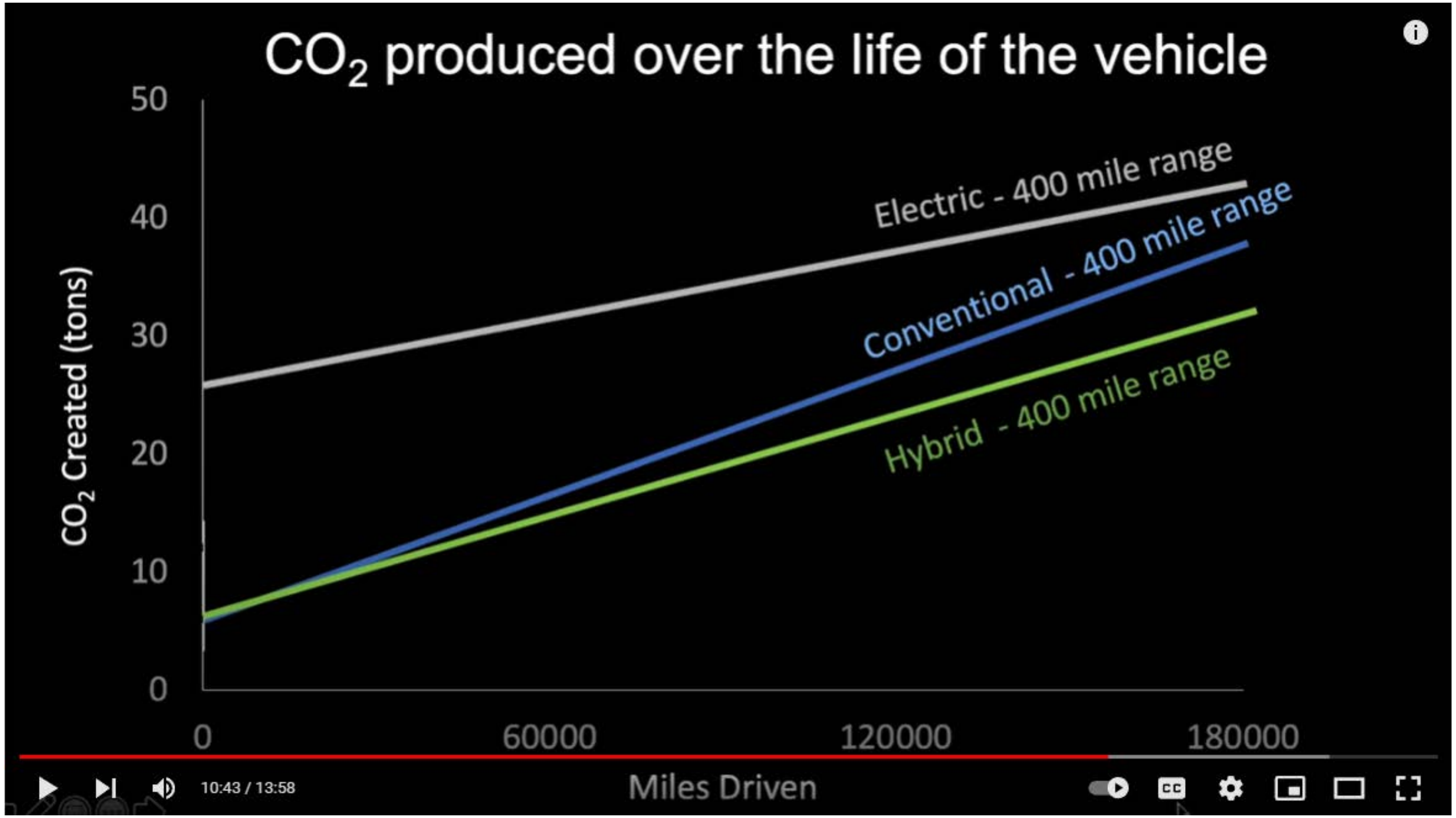


Exception is the hybrid – small battery, and efficient use of bi-fuel energy source.
Also, in jurisdictions that use higher than global average renewable energy in their grids.

**** Assume grid power that is 67% non-renewable and 33% renewable (does not emit $CO_2$ Hydro/nuclear/solar/wind/geothermal (global average))**

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