UNIVERSITY OF ALBERTA
FUTURE ENERGY SYSTEMS

# Biophysical Impacts And Reclamation Considerations For Solar, Wind and Geothermal Energy Systems

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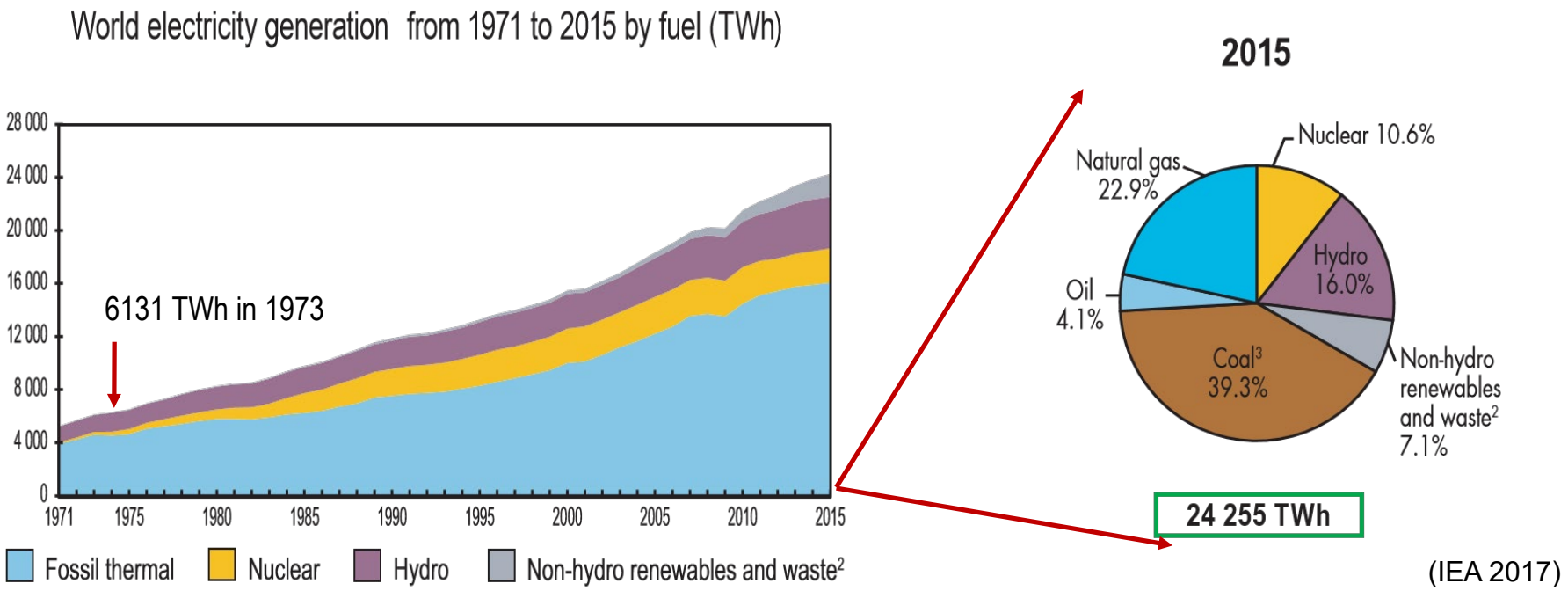
# Global Energy System




(IEA 2017)

- Fossil fuel contributes 66.3 % of world electric energy demand
- Global energy demand expected to increase 35 % by 2030

# Impact Of Conventional Energy System

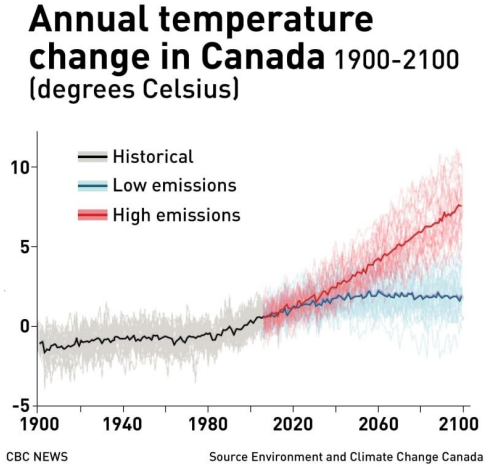
- Fossil fuel based energy is the major source of GHG emission

| Energy type | $CO_2$ [g/KWh] | $SO_2$ [g/KWh] | $NO_x$ [g/KWh] | Particulates [g/KWh] |
|---|---|---|---|---|
| Coal | 994-1130 | ~4.71 | ~2.0 | ~1.0 |
| Oil | ~758 | ~5.44 | ~1.8 | NA |
| Gas | ~550 | ~0.1 | ~1.3 | ~0.06 |

- USA fossil fuels contribute 36 % electricity and emit 41 % $CO_2$
- Alberta fossil fuels contribute 89 % electricity and emit 17 % $CO_2$
- Alberta power sector generated 58 % of total Canadian GHG emissions from power generation

# Impact Of Conventional Energy System

- Emissions lead to increasing climate extreme events




# Importance of Renewable Energy

- Move from carbon intensive to renewable energy can
  - Mitigate climate change
  - Safeguard energy security
  - Increase sustainability of human activities

| Energy Type | $CO_2$ [g/KWh] | $SO_2$ [g/KWh] | $NO_x$ [g/KWh] | Particulates [g/KWh] |
|---|---|---|---|---|
| Geothermal | 0-39 | 0 - 0.16 | 0 | 0 |
| Solar | 14-38 | 0 | 0 | 0 |
| Wind | 12-14 | 0 | 0 | 0 |

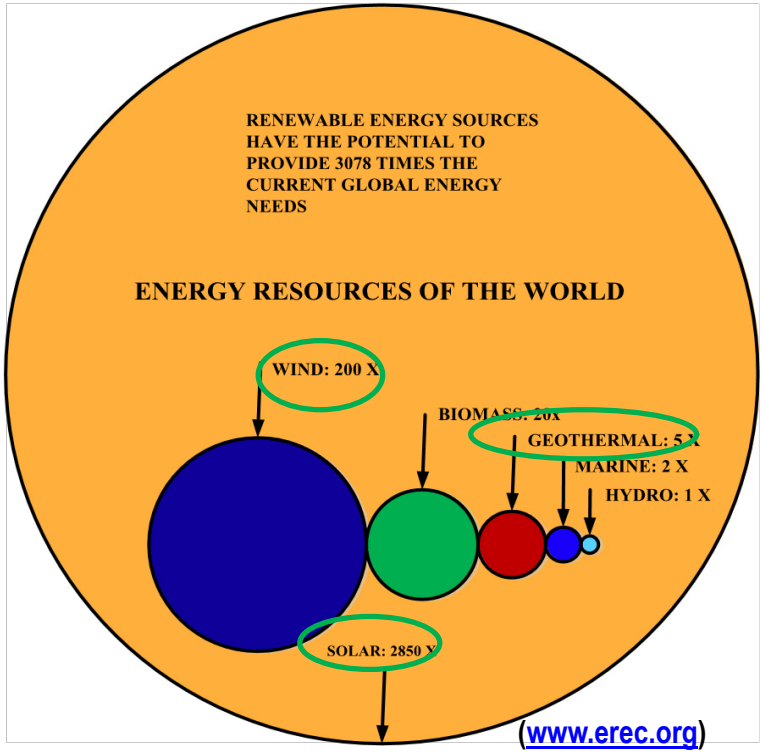
- In USA, if solar energy contributes 10 % of national demand then reduction of $CO_2$ emission would be 6.5 to 18.8 %

# Renewable Energy

- Global production as of 2017
  - Geothermal 14 GW
  - Solar 402 GW
  - Wind 539 GW

- Canada
  - 13th in solar (0.6%) 3.11GW
  - 9th in wind (5.3%) 12.8 GW
  - 167 MWe geothermal for heating

- 1st Geothermal plant Saskatchewan
  - Power 5000 home
  - Offset 27,000 t $CO_2$ $yr^{-1}$

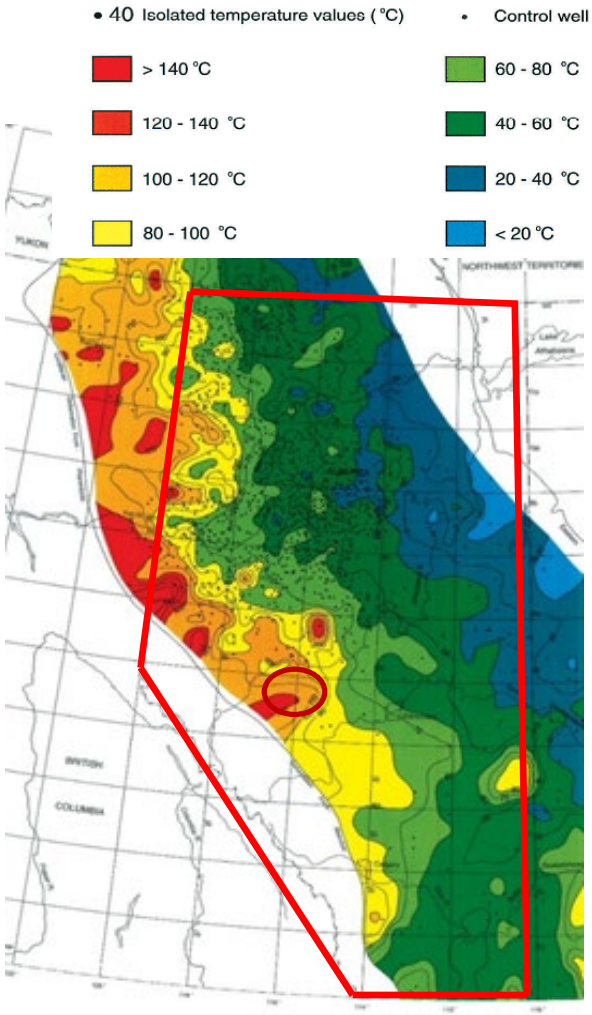



**Global energy resources potential**

- Alberta
  - Solar 63 MW
  - Wind 1.5 GW
  - Geothermal planning

# Alberta Geothermal Energy

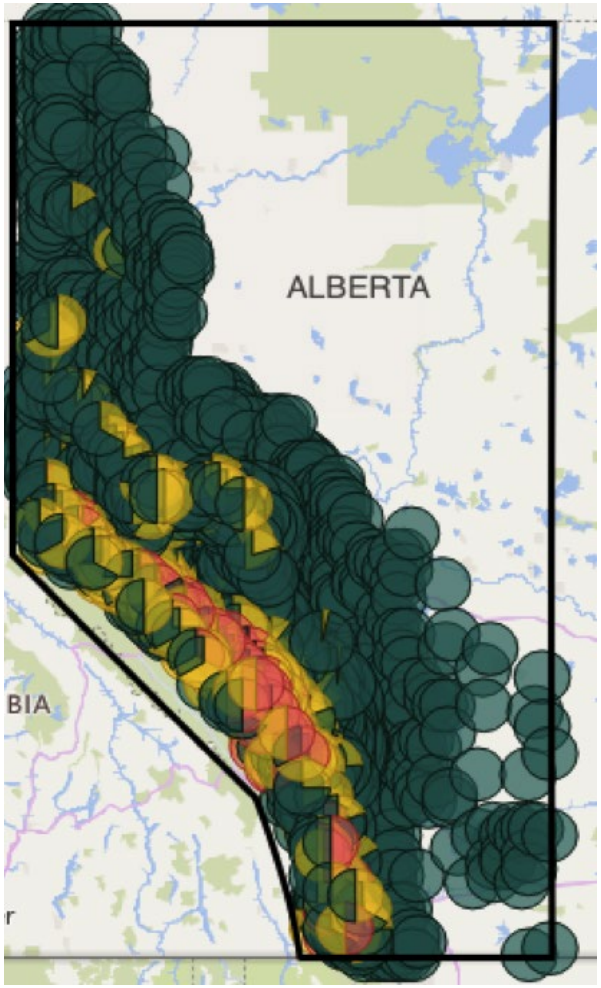
- Can produce 389 GW
  - Plant in Hinton




https://ags.aer.ca/publications/chapter-30-geothermal-regime.htm

60935 oil gas wells

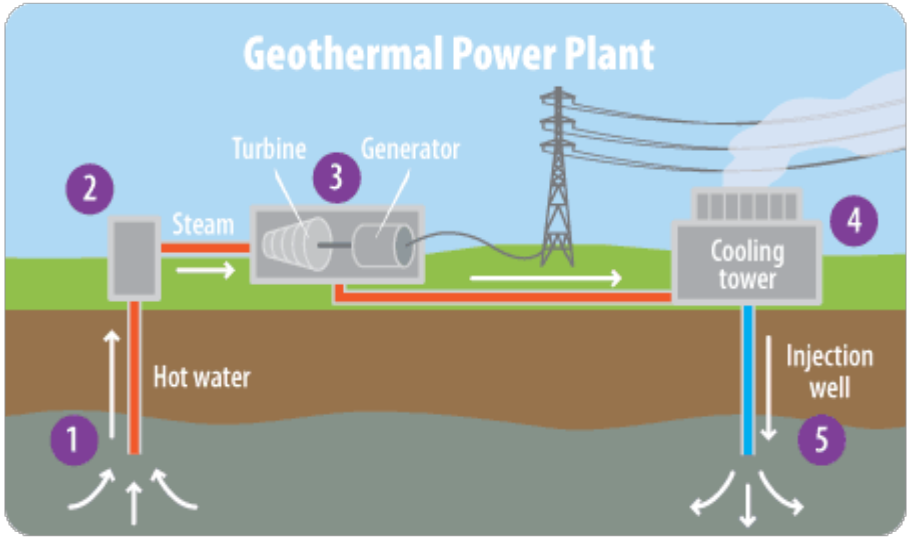
>120°C
>90°C
>60°C




Fuzeium Innovations Inc.

Are solar, wind and geothermal energy sources really as clean as widely believed

# Solar, Wind Geothermal Energy Environmental Impacts



# Environmental Impacts: Solar, Wind, Geothermal

**Soil**

- Compaction and topsoil erosion
- Increase sediment or turbidity in local streams

**Vegetation and wildlife**

- Vegetation and habitat loss
- Wildlife mortality: 37-138K for solar, 20-234K for wind
- Fragmentation and barrier of wildlife movement

**Footprint**

- Wind: ~0.4 haMW$^{-1}$ and temporarily 1.5haMW$^{-1}$
- Solar: 595-6600 m$^2$MW$^{-1}$
- Geothermal: 0.02-3.00 haMW$^{-1}$, conflict with other land uses

# Environmental Impacts: Solar Specific

**Water**

- Cleaning mirrors and panels 860 $LMWh^{-1}$
- 60-90 % water use for dust control

**Hazardous waste**

- Chemical compounds cadmium (Cd), selenium, lead
- 5 g of Cd $m^{-2}$

**Emissions**

- No emission during operation
- Panel manufacturing: 14-38 g $kWh^{-1}$ $CO_2$, ~0.1g$GWh^{-1}$ mercury

# Environmental Impacts: Wind Specific

**Visual**

- Change natural landscapes view, NIMBY syndrome, shadow flickering

**Noise**

- Creates irritating rhythmical swishing tone (<1000 Hz)

# Environmental Impacts: Geothermal Specific

**Air**

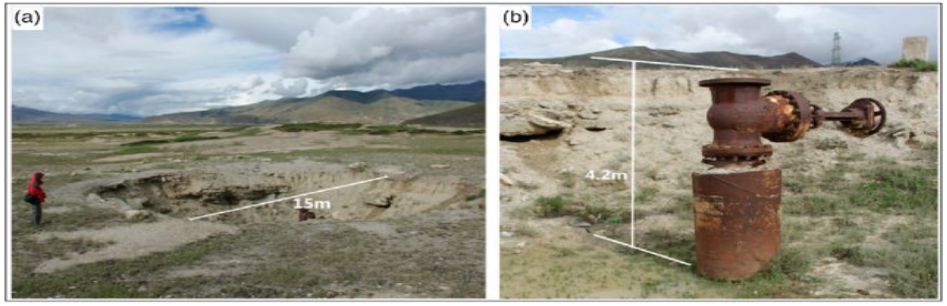
- Greenhouse gas emissions ($CO_2$, $H_2S$, $SO_2$, $NH_3$)

**Water**

- Contamination of aquifers and other water bodies
- 2 km well installation requires 8,000-55,000 $m^3$ of water

**Geophysical and land hazards**

- Subsidence (1-45 cm/yr), landslide and hydrothermal eruptions




**Subsidence:** Geothermal plant in Tibet

(Zhenhong Li 2013)

# Mitigation: Solar, Wind, Geothermal

**Soil**

- Restored surrounding disturbed area for reducing erosion and compactness
- Consider careful landscaping during plant construction

**Vegetation and wildlife**

- Plants should be located in areas of little biodiversity
- Avoid area with important bird habitats or migration routes
- Improving structural design (e.g. enlarging blades, slowing rotational speed of wind turbines)
- Increase visibility or limit operation during the heaviest migration

# Mitigation: Solar, Wind, Geothermal

## Footprint

- Avoid ecologically sensitive areas where possible
- Colocation with other energy systems
- Use landfill or abandoned mine sites (re-powering)
- In USA, >11,000 sites (~6 million ha), can produce 1000 GW

# Mitigation: Solar Specific

**Water**

- Use rain or other recycled water
- Need to develop alternative methods to increase cleaning efficiency
- Plant should be nearby continuous water supply facility
- Avoiding locations that impacts on surface water bodies

**Hazardous waste**

- Recycling solar panels to reduce the hazardous chemical
- Take proper care when disposing of chemicals and cleaning equipment

# Mitigation: Wind Specific

**Visual**

- Proper alignment of wind turbine tower layouts smaller numbers of wind turbines

- Shadow flickering can be reduced by optimizing the rotor blade surface smoothness, coating with less reflecting materials

**Noise**

- Careful design of the blades

- Construct plant close to noisy areas (road traffic)

# Mitigation: Geothermal Specific

**Air**

- Design the plant to avoid steam release to air, use ventilation

**Water**

- Control water spell to soil, and below and above ground aquatic systems

**Geophysical hazards**

- Incorporating reinjection to control subsidence

# Take Home Message: Solar, Wind, Geothermal

- These energy systems are not free of adverse environmental consequences
- Have low GHG emissions and land use, are abundant in nature
- Major environmental drawbacks
  - Bird mortality (solar and wind)
  - Biodiversity and habitat loss
  - Noise (wind)
  - Visual impact (wind)
  - Hazardous chemicals (solar and geothermal)
- Geothermal has small risks of subsidence, induced seismicity and landslides, with potential serious consequences

# Reclamation Consideration

# Reclamation Regulations

- Requires well defined reclamation regulations and reclamation bonds

- Alberta Government amended
  - Conservation and Reclamation Regulation (Government of Alberta, 2018a)
  - Conservation and Reclamation Directive for solar and wind energy operations (Government of Alberta, 2018b)

- No regulations or policies for geothermal energy in Alberta

# Reclamation Process

- An outline of restoration and aftercare statement should be documented at planning phase

- Cover soil should be salvaged and temporarily stockpiled

- Two phases of reclamation
  - Intermediate
  - Final

# Reclamation Process: Intermediate Phase

- Right after plant construction, excluding
  - Wind turbine tower, base of solar panels
  - Geothermal wells heads
  - Facility structures, infrastructure

- Landform should be reconstructed with 10-20cm cover soils replacement depth

- Stockpiled some salvaged cover soils for final reclamation and management

- Cover soils placed roughly or in small piles
  - To reduce compactness
  - To create microtopographic heterogeneity

# Reclamation Process: Intermediate Phase

- Enhance seedbed quality and productivity by
  - Mulching
  - Hydro seeding
  - Targeted fertilization
  - Watering

- Revegetate with desired plant species by planting or seeding

- Revegetated between and under rows of solar panels once they are installed

# Reclamation Process: Final Phase

**Decommissioning**

- Methodical deconstruction process.
- Care taken to reduce disturbance in existing reclaimed areas

**Contaminant remediation**

- Investigation and cleanup of hazardous materials before reclamation

**Reclamation**

- Solar, wind base and geothermal wells should be plugged with previously stockpiled or other soils
- Revegetation with appropriate species by planting or seeding

**Monitoring**

- Until reclamation goals and regulatory requirements are met

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**Theme:** Resilient Reclaimed Land and Water Systems

# Thank You

## Contact

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# Geothermal Energy

Energy that comes from the ground; power extracted from heat stored in the earth