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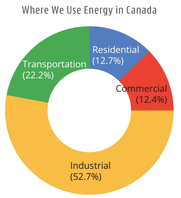
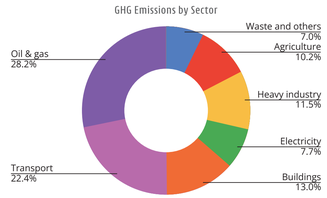
ENERGY INNOVATIONS

Canadians rely on energy. We use a lot of energy for electricity, transportation, heating, cooling and more!



Data source: Canada Energy Regulator (2023)



Data Source: Environment and Climate Change Canada (2021)

Energy comes from natural resources. Natural resources can be **renewable**, meaning we have an unlimited supply or they can be replenished within our lifetime. Other natural resources are **nonrenewable**, meaning we have a limited supply, and once used they cannot be replaced. There are opportunities and challenges with each energy resource - factors such as their location, abundance, efficiency, environmental impact, economic impact, as well as social and cultural considerations. It is important to understand the opportunities and challenges of each natural resource so we make informed decisions about energy into the future.

Renewable Resources	Nonrenewable Resources
wind	coal*
sun/solar	oil*
water/hydro	natural gas*
geothermal	uranium
biomass*	

*Carbon-based fuels

Climate Change

In Alberta we have abundant **fossil fuels** - coal, oil and natural gas - these are **carbon-based fuels**. When we extract and burn these carbon-based fuels to produce energy, carbon dioxide (CO_2) is released into the atmosphere.

Carbon dioxide is an important **greenhouse gas** (GHG), meaning that it traps heat close to the earth's surface. While this '**Greenhouse Effect**' is crucial to maintaining life on Earth, producing too much GHGs causes the Earth's surface to warm, and climate patterns to be altered. It is important to address climate change as it is having consequences for the global environment, economy and society.

What is being done to address climate change?

The Government of Canada and individual provinces and territories have goals to address climate change and reduce **GHG emissions**. You may have heard the term **net zero** - *net zero* means that the total amount of CO_2 released into the atmosphere is the same amount as is removed. The energy landscape is changing to achieve net zero and reduce the overall amount of greenhouse gases emitted by the production and consumption of energy.

Our energy mix is diversifying to reduce our reliance on carbon-based fuels and reduce emissions by incorporating new technology and innovations such as clean fuels, carbon capture, and increasing our use of renewable and alternative energy sources.

Individuals and communities also play a role by reducing personal energy consumption and using energy efficiently. Actions like taking public transit, installing rooftop solar panels and converting to an electric vehicle (EV) have an impact. Look for more examples on the front of the poster!

On the Energy Innovations Poster you will notice sections outlined with different colours. Here is a fun way to follow along:

- Sections in **yellow** focus on **Renewable & Alternative Energy**
- Sections in **blue** focus on **Fossil Fuel Innovations**
- Sections in **orange** focus on **Clean Fuels**

RENEWABLE & ALTERNATIVE ENERGY

Energy Resources For Electricity:

- **Solar** - Solar panels use photovoltaic cells to convert the energy from the sunlight into electrical energy.
- **Wind** - Wind turbines have large blades to capture the kinetic energy in wind and generate electrical energy.
- **Geothermal** - Geothermal is thermal energy (heat) from deep within the earth that can be converted to electrical energy or used for heating.
- **Biomass** - Biomass is organic material such as wood chips, crops, compost and waste. Chemical energy in biomass can be converted to thermal energy when it is burned to create steam, and converted into kinetic and then electrical energy when the steam is used to turn a turbine. Alternatively, biomass can be decomposed by anaerobic bacteria that produce methane to form renewable natural gas, which can then be used to generate electrical energy.
- **Hydro** - Hydroelectricity captures the kinetic energy from moving water in a river or at the bottom of a dam to turn a turbine and generate electrical energy.
- **Nuclear** - A nuclear reactor splits uranium atoms to release thermal energy which is converted to electrical energy. Large nuclear power plants exist in Ontario and New Brunswick; Alberta is considering introducing nuclear energy in the form of microreactors and **Small Modular Nuclear Reactors.**

For decades most of Alberta's electricity was produced by burning coal. In recent years, a phasing out of coal and increased use of natural gas and renewable energy means Alberta's electricity grid is changing. Our lives are becoming more electrified (think electric vehicles!) and demand for energy is steadily increasing. Our use of renewable energy is increasing, allowing us to generate more electricity with less greenhouse gas emissions.

Horseshoe hydroelectric dam

Eavor Technologies geothermal well

Cowley Ridge wind farm

One of the challenges is that some renewable energy has **intermittent** or variable supplies of energy (the sun isn't always shining and the wind isn't always blowing). Energy demand tends to be the highest in the evening (*when most people are at home*) and during the coldest and hottest months of the year (*when we need heating and cooling*). For renewable energy like solar and wind to be most effective it has to be readily available to meet demand. This is where **energy storage** comes in.

Types of Energy Storage:

- **Pumped Hydro** - When there is excess electrical energy water is pumped from a lower reservoir to a higher reservoir. When energy is needed, water in the higher reservoir is released so it flows down to turn a turbine and generate electrical energy.
- **Batteries** - Batteries can store excess electrical energy as chemical potential energy, which can then be converted back into electrical energy when it is needed. In 2020, Alberta's first lithium-ion battery storage facility was built, allowing power from nearby wind turbines to be stored in the batteries and released when it is needed.

Pumped hydro energy storage

Battery storage

Find the renewable and alternative energy and energy storage facilities on the poster!

FOSSIL FUEL INNOVATIONS

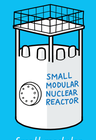
Innovations in the fossil fuel sector are focused on **decarbonization** to reduce emissions from the production of oil and natural gas. Let's explore three emerging technologies - carbon capture utilization & storage, small modular nuclear reactors and bitumen beyond combustion.

- **Carbon Capture Utilization & Storage** are technologies that convert or store carbon dioxide (CO_2) emissions to reduce the amount of CO_2 released into the atmosphere. The CO_2 can be used to extract more oil and gas or turned into something else (such as fuels, concrete or even soap). This is called **carbon capture and utilization**. Alternatively, the carbon (usually in a liquefied form of CO_2) can be injected into deep underground geological formations for permanent storage. This is called **carbon capture and storage.**

Carbon capture & storage pipeline

Soap made from captured carbon (Credit: Clean O2)

- **Small Modular Nuclear Reactors** are nuclear fission reactors that can supply zero-emission energy to industrial sites. Extracting fossil fuels requires heat, which is currently supplied by burning natural gas. Small modular nuclear reactors can produce this heat with zero emissions, and supply electricity as well.



Small modular nuclear reactor

- **Bitumen Beyond Combustion** means using *bitumen* (the 'oil' in oil sands) for non-combustion products. The majority of emissions from fossil fuels come from **combustion,** like when we burn gasoline as we drive our vehicles. Bitumen beyond combustion technologies are ways to use oil sands resources without burning them and releasing CO_2. Bitumen can be turned into products such as asphalt, plastics, and carbon fibre. Look for the *carbon technologies* building on the poster and a unique way to use bitumen that supports a popular winter sport.

Carbon fibre

Innovations in Action:

- Calgary-based companies are integrating CO_2 emissions into the production of soap and concrete.
- 2 active carbon capture and storage operations in Alberta are capturing more than 1 million tons of CO_2 every year from oil sands processing and storing it permanently underground.

CLEAN FUELS

A lot of the greenhouse gas emissions released in Canada come from burning carbon-based fuels (like gasoline, diesel and jet fuel) to power vehicles and methane (natural gas) to operate furnaces to heat our homes. When we burn these fuels using the oxygen (O_2) in air we get water vapour and carbon dioxide (CO_2). Adding excessive carbon dioxide to the atmosphere increases global warming and contributes to climate change.

Burning natural gas (methane)
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + **energy**

Burning gasoline (octane):
$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ + **energy**

There are new technologies focused on changing fuel sources to lower CO_2 emitting fuels - these are the clean (or at least cleaner) fuels.

Clean fuels can be produced several different ways and the primary source for clean fuels is **biomass**. Just like fossil fuels, biomass can be burned or gasified to create thermal energy (heat) and electrical energy. While burning biomass for energy also releases CO_2, unlike the carbon in fossil fuels which was buried underground for millions of years, the carbon in biomass comes from plants which had previously absorbed CO_2 from the atmosphere, making it carbon neutral.

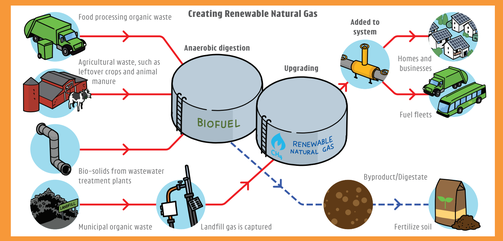
Additionally, the biomass used for clean fuels is typically going to waste (i.e. wood chips, crop residue, compost and waste). By using it for clean fuel production, we are turning a waste product into energy.

Wood chips are a form of biomass

Let's take a closer look at four types of clean fuels.
Biogas/Renewable Natural Gas, Biofuels, Synthetic Fuels & Hydrogen.

BIOGAS & RENEWABLE NATURAL GAS

When **organic materials** decompose, methane and other gases are released - we call this **biogas**. When the biogas is cleaned and the methane is separated it is called **renewable natural gas** and can be used the same way we use natural gas from fossil fuels. It is considered **carbon neutral** because it's from organic material, which is part of the natural carbon cycle.



Renewable natural gas can be used as fuel for vehicles, as a substitute for natural gas in heating systems, and for electricity generation.

Innovation in action:

- Red Deer and other communities such as Calgary and Medicine Hat have added renewable natural gas buses to fuel their transit fleets as an alternative to diesel.
- A facility near Lethbridge captures the methane from agricultural waste and uses it to generate electricity for Alberta's electrical grid.

Lethbridge Biogas

BIOFUELS

A **biofuel** is a liquid fuel that is produced from a renewable resource. Biofuels can be produced from a variety of sources including wood chips, plants, animal fats, food waste, crop residues or even algae! A **biorefinery** is where biomass is turned into biofuels. Types of biofuels include ethanol, biodiesel, methanol and butanol. Biofuels can help reduce our reliance on fossil fuels, which is especially important in the transportation sector where we burn gasoline, diesel and jet fuel.

Plants, like corn, can be fermented into ethanol and methanol. We add ethanol to existing fuels to reduce the amount of fossil fuels needed. The next time you are at a gas station, look for the 'ethanol content' in the gasoline!

Biofuels can also be created from used cooking oil and grease - creating a synthetic **biodiesel** that can be blended with regular diesel to reduce emissions.

In some parts of the world, airplanes are even using biofuels. These **sustainable aviation fuels** are made from residual raw materials like used cooking oil, and they have 80% less greenhouse gas emissions compared to fossil fuel based jet fuels.

Innovation in Action:

- A biofuel facility near Calgary will use non-food grade waste to produce natural gas for heating and electricity.
- Pulp mills use anaerobic digesters to recover organic material from their effluent system. This organic matter is converted into synthesis gas, or syngas, which is then burned to produce both electricity and heat for the pulp mill - this is called '**cogeneration**'.

SYNTHETIC FUELS

All biofuels are synthetic fuels, but not all synthetic fuels are biofuels!

Synthetic fuel is any fuel that is manufactured but functions just like the fuel it replaces. Synthetic fuels can be made from sources like coal, natural gas, peat, biomass (wood, plants, agricultural waste) or landfill waste. All of these sources contain hydrogen and carbon which means they can be turned into products including gasoline, diesel or aviation fuels.

Creating synthetic fuels involves a lot of chemistry! The source material is exposed to high temperatures and controlled amounts of oxygen to create synthesis gas, or **syngas** - a mixture of hydrogen and carbon monoxide. The syngas can then be transformed into liquid fuels by combining the molecules and then refined to make transportation fuels, or generate electricity and heat.

Although there are still emissions when synthetic fuels are burned, a lot of research is going into them because they have the potential to reduce our use of traditional fuel sources and decrease emissions, especially when we use renewable sources to create them. The production of synthetic fuels requires energy to create high temperatures for gasification; new technology is aiming to use renewable energy to help power this reaction. Synthetic fuels represent an innovative way to create additional energy sources and contribute to a cleaner energy future.

Innovation in Action:

- Waste to biofuels facilities divert waste by turning it into synthesis gas (syngas) and then biofuels, or other products like methanol.

HYDROGEN

Hydrogen can be used for electricity, heat and fuel. Even though hydrogen (H_2) is the most abundant element in the universe, it rarely exists naturally in its molecular form.

So, how do we get it? Many things contain hydrogen, including water (H_2O) and fossil fuels that contain hydrocarbons, like natural gas (which is mostly methane - CH_4), and we can separate the hydrogen through **steam reforming** or **electrolysis.**

It takes energy to produce hydrogen, and understanding where hydrogen comes from is important because some processes release emissions and others do not. Hydrogen is sometimes classified into colours depending on how it's produced. The main colours are:

Blue Hydrogen	Produced from natural gas. Resulting CO_2 emissions are captured and stored underground.
Grey Hydrogen	Produced from natural gas. Resulting CO_2 emissions are released into the atmosphere.
Brown Hydrogen	Produced from coal.
Green Hydrogen	Produced by electrolysis powered by a renewable electricity source (i.e. solar, wind, hydro, geothermal).
Pink Hydrogen	Produced by electrolysis powered by nuclear energy.

Hydrogen production in Alberta is mostly blue or grey, meaning it comes from natural gas. Hydrogen from natural gas is considered a clean fuel when it is accompanied by carbon capture.

Blue, grey and brown hydrogen involve **steam reforming,** whereas green and pink hydrogen involve **electrolysis.**

How do these processes actually work?

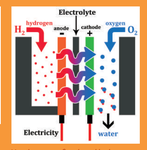
To get hydrogen out of **methane** (CH_4) , we use **steam reforming**. This process uses steam (H_2O) and a catalyst to separate the hydrogen from the carbon. Carbon capture can be used to make this a low emissions solution.

$CH_4 + H_2O$ (+ heat) $\rightarrow CO + 3H_2$

To get hydrogen from **water**, we use **electrolysis** which uses electricity to separate the hydrogen from the oxygen.

How do we transform Hydrogen to electricity, heat and fuel?

Hydrogen fuel cell module (Credit: Ballard Power Systems)



Hydrogen fuel cell diagram

Electricity is produced from hydrogen using a **hydrogen fuel cell**. A hydrogen fuel cell combines hydrogen and oxygen (from the air) without combustion to produce electricity and water vapour.

Like most fuels we produce heat from hydrogen through combustion with oxygen (O_2). Unlike carbon-based fuels this combustion only releases water vapour.

$H_2 + {}^1/_2O_2 \rightarrow H_2O$ + Energy

To use hydrogen as a **fuel**, it can be sent through a hydrogen fuel cell or combusted with oxygen in an engine.

Hydrogen storage

Innovation in Action

- In Fort Saskatchewan, hydrogen is blended into natural gas to reduce the carbon emissions of heating systems.
- Edmonton has hydrogen-powered buses as part of its public transit fleet.

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