ESC

ENERGY SOLUTIONS CENTER

Track: Natural Gas Basics
Unit 14: Carbon Reduction Strategies

Eric Burgis, Energy Solutions Center

Topics

- **Lower Carbon Gasses**
  - Renewable Natural Gas
  - Hydrogen
  - Power-to-Gas
  - Transitioning to a Low Carbon Future
- **Strategies to reduce our carbon footprint**
  - Responsibly Sourced Gas
  - Carbon Offsets and Renewable Gas Certificates
  - Gas Power Generation to Balance Renewable Electric
- **Energy Efficiency**
  - EE and Weatherization Programs
  - Technologies that save energy
  - Natural Gas Vehicles
  - Zero Net Energy

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Lower Carbon Gasses

Renewable Natural Gas

Renewable Natural Gas (RNG)

- Renewable natural gas (RNG) from biomass helps to meet America's growing demand for a low-carbon, affordable, and reliable fuel. RNG is fully compatible with conventional natural gas and the existing pipeline infrastructure.
- RNG is made by capturing and refining biogases released from decomposing organic waste material.
- RNG is considered a carbon neutral fuel, with even greater benefits when it is produced from organic waste that would otherwise decay and create methane emissions.[1]
- Since RNG is ready to use in existing natural gas infrastructure, it can be injected into pipelines to immediately begin reducing natural gas carbon content.[2]

1 SoCalGas, What is Renewable Natural Gas?
2 U.S. EPA, Renewable Natural Gas, 2022

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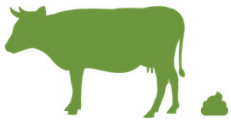
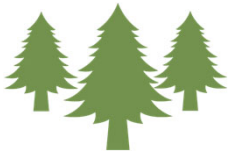
Feedstocks and Processes

RNG is derived from various biogenic feedstocks including wastewater sludge, animal manure, food waste, agricultural residues, forest product residues, municipal waste, and energy crops.

Three processing systems can produce renewable gas:



1. Anaerobic Digestion



2. Thermal Gasification

3. Power-to-Gas

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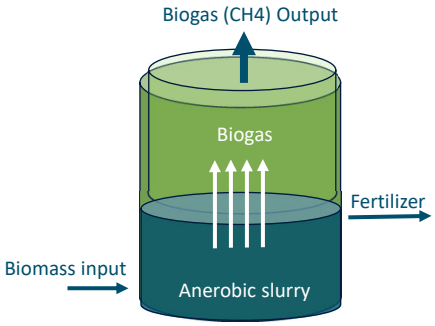
1. Anaerobic Digestion

Anaerobic digestion uses microbes to break down organic matter and converts the resulting organic acids into methane gas. This process is well-suited to "wet" biomass such as food waste, animal manure, and wastewater sludge.



https://gasfoundation.org/wp-content/uploads/2019/12/AGA_3894-RNG-2-Pager_V-11.pdf

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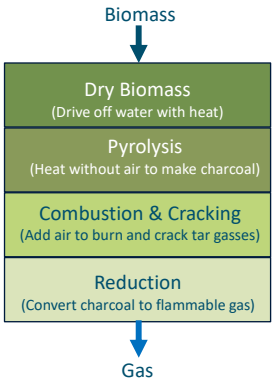
2. Thermal Gasification

Thermal gasification is a high-temperature process that completely dries biomass, converting it into gas and char. Energy crops are a "dry" feedstock that are expected to be utilized more frequently over the next two decades.



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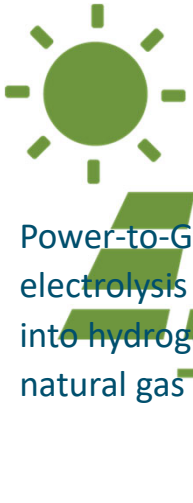
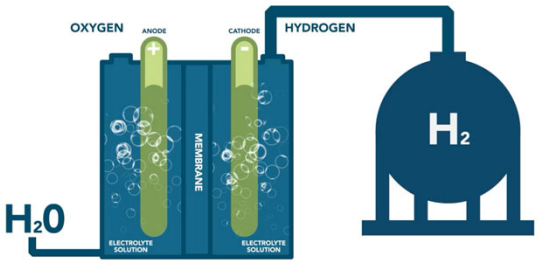
3. Power-to-Gas



Power-to-Gas technologies use electrolysis to convert electricity into hydrogen and methane for natural gas pipeline injection.



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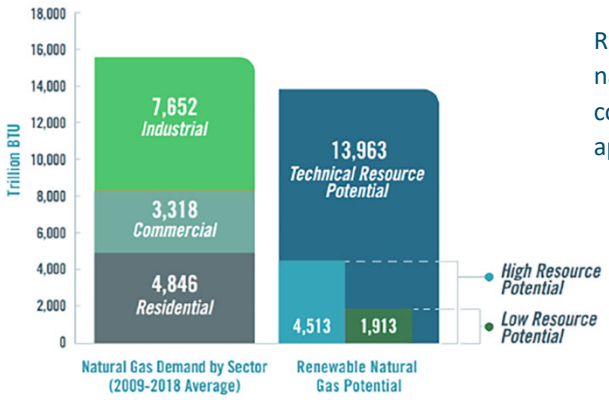
RNG Resource Potential



RNG is interchangeable with conventional natural gas and can be used in residential, commercial, industrial, and transportation applications.

Source: American Gas Foundation, "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment", 2019

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Next Steps for RNG

Demand for RNG is growing as industries can use this fuel to reduce emissions across their entire supply chain. In cases where methane from biogas would have been released into the atmosphere, RNG can go beyond carbon-neutral to being carbon negative*. The carbon reduction impact of RNG can be even greater when carbon-capture technologies are installed at points of use.

Hydrogen and power-to-gas options will offer additional fuel-based pathways to carbon neutrality for these sectors.

*Advanced Clean Tech News, Is RNG a California-Only Fuel?, 2020

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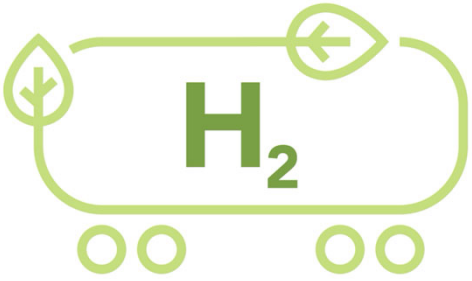


Hydrogen's Role in the Low-Carbon Economy

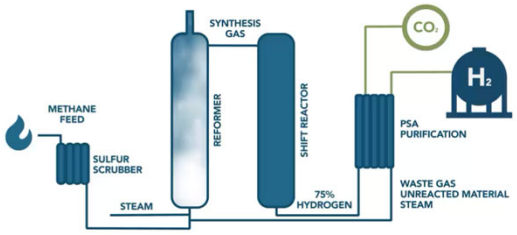
Hydrogen will play a key role in the transition to a clean energy economy across many sectors. Hydrogen does not release greenhouse gas emissions during combustion and can generate electricity, fuel vehicles, and provide heat for homes, businesses, and industry.

Producing Hydrogen

Hydrogen can be produced in several ways. The two most common methods include:

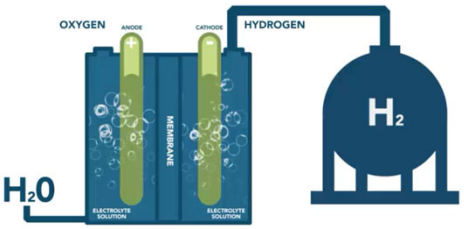
STEAM-METHANE REFORMING (SMR)

SMR uses high-temperature steam to heat methane from natural gas, producing hydrogen and carbon dioxide. More than 90% of hydrogen produced today is through SMR.*



ELECTROLYSIS

Electrolysis uses an electrical current to split water molecules into oxygen and hydrogen.



*Florence School of Regulation, Hydrogen in the Energy Transition, 2020

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Carbon Neutral Hydrogen

Hydrogen produced from the reformation of biomass/waste, including renewable natural gas (RNG), can be considered carbon neutral. Hydrogen produced with fossil fuels can also be considered carbon neutral when paired with carbon capture, utilization, and storage (CCUS) technology.*

* 2G Energy, Hydrogen for CHP Systems

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Colors of Hydrogen

	Terminology	Technology	Feedstock/ Electricity Source	GHG footprint
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind | Solar | Hydro Geothermal | Tidal	Minimal
	Purple/Pink Hydrogen		Nuclear	
	Yellow Hydrogen		Mixed-origin grid energy	Medium
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen (SMR + Carbon Capture)	Natural gas reforming + CCUS Gasification + CCUS	Natural gas | coal	Low
	Turquoise Hydrogen	Pyrolysis	Natural gas	Solid carbon (by-product)
	Grey Hydrogen (SMR)	Natural gas reforming		Medium
	Brown Hydrogen	Gasification	Brown coal (lignite)	High
	Black Hydrogen		Black coal	

* The GHG footprint is given as a general rule, but can be higher for each category

https://globalenergyinfrastructure.com/articles/2021/03-march/hydrogen-data-telling-a-story/

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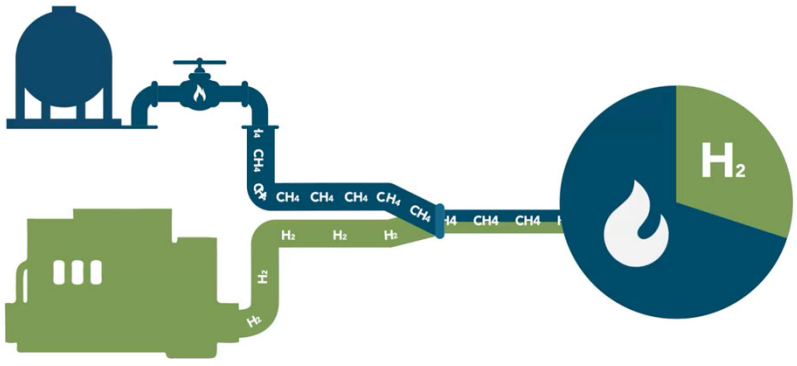
Blending Hydrogen with Natural Gas

Natural gas pipelines and combustion equipment can incorporate hydrogen in blends up to 30%, depending on equipment design and application.*



*U.S. DOE, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines, 2021

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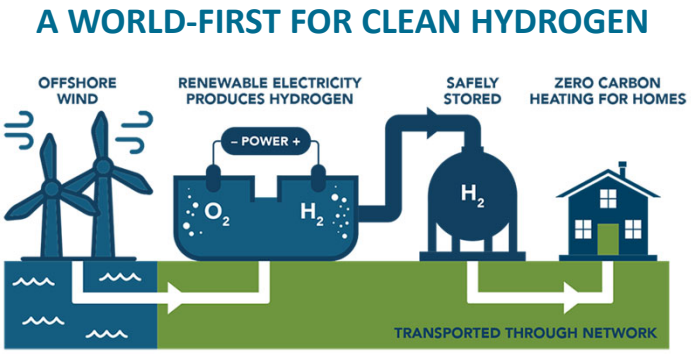
Hydrogen Production from Excess Renewables

Excess renewable energy can be used to power electrolyzers and produce hydrogen. Existing natural gas infrastructure can be used to provide long-duration storage of hydrogen, complementing shorter-duration battery storage systems.



Source: DOE, "How Wind Energy Can Help Hydrogen Contribute to a Zero-Carbon Future"

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Hydrogen's Applications

Hydrogen can be blended with natural gas, using existing infrastructure, to reduce emissions from residential, commercial, and industrial facilities. Existing natural gas infrastructure can provide long term storage of hydrogen, complementing shorter duration battery storage systems as well as improving the economics of hydrogen usage.

Hydrogen can also enable decarbonization of the transportation sector by using zero emissions fuel cell electric vehicles.

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Hydrogen Programs and Policies

The U.S. Department of Energy (DOE) has dedicated programs and initiatives focused on making clean hydrogen more abundant, affordable, and reliable. DOE's Hydrogen Shot initiative is focused on reducing the cost of clean hydrogen by 80% by 2030.[1]

The Canadian government has developed a plan to increase investment and deployment of hydrogen in order to reach their mid-century emission targets.[2]

[1] U.S. DOE, Hydrogen Shot [2] Natural Resources Canada, Hydrogen Strategy for Canada, 2020

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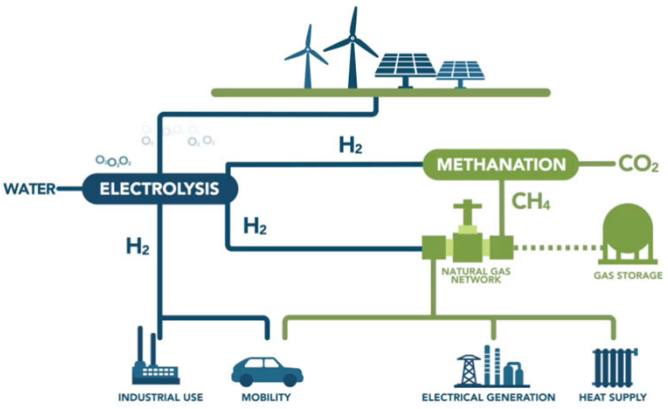
Power-to-Gas

Power-to-Gas is an important feature of a low-carbon economy and can help improve the economics of zero-carbon fuels, enhance the resilience of the power grid, and increase the deployment of renewable energy technologies.

What is Power-to-Gas?

Power-to-Gas (P2G) converts surplus renewable energy into gaseous hydrogen that can be delivered through existing natural gas infrastructure.

P2G can be stored taking advantage of existing natural gas infrastructure and used during times of peak energy demand.



Source: MDPI, "A Critical Study of Stationary Energy Storage Policies in Australia in an International Context: The Role of Hydrogen and Battery Technologies"

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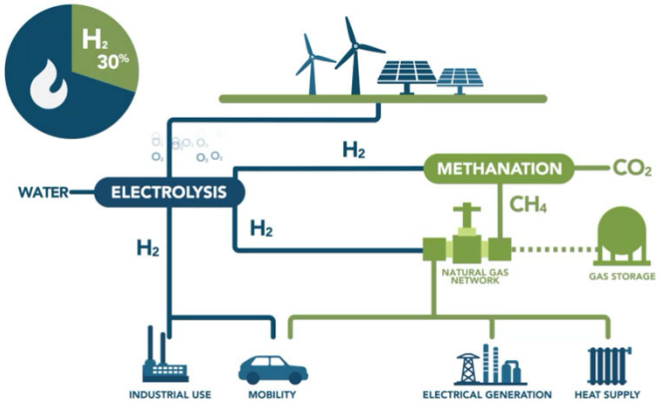
Natural Gas Compatibility

Hydrogen can be blended with natural gas up to 30% in pipeline equipment designed for natural gas.*



*U.S. DOE, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines, 2021

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Synthetic Methane

Hydrogen can also be further processed into synthetic methane, able to fully displace geologic natural gas making use of existing infrastructure and equipment. Synthetic methane is 100% compatible with natural gas pipelines and combustion processes.

U.S. DOE, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines, 2021

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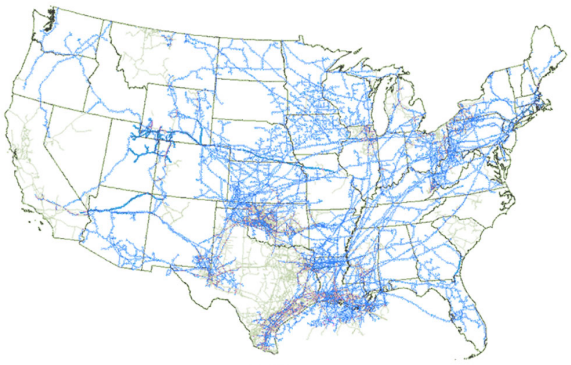
Transitioning to a Low Carbon Future

Using Existing Gas Infrastructure

Vast Natural Gas Transmission & Distribution System

North America's natural gas infrastructure is a highly integrated network that can transport and distribute resources throughout the country.

This existing pipeline network has approximately 3 million miles of pipe that can be used to distribute low-to-zero carbon fuels to reduce greenhouse gas emissions



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Blending Hydrogen and Renewable Gas with Existing Natural Gas

RENEWABLE GAS BENEFITS:

- RNG IS FULLY COMPATIBLE WITH CURRENT NATURAL GAS INFRASTRUCTURE.
- CAN BE INJECTED IMMEDIATELY INTO PIPELINES TO BEGIN REDUCING GREENHOUSE GAS EMISSIONS.
- CAN REPLACE A SIGNIFICANT PORTION OF EXISTING NATURAL GAS DEMAND

HYDROGEN BENEFITS:

- SURPLUS RENEWABLE ENERGY CAN BE USED TO PRODUCE ZERO-CARBON HYDROGEN
- HYDROGEN CAN CURRENTLY BE BLENDED UP TO 30%*

* https://www.energy.gov/sites/default/files/2022-12/hyblend-tech-summary-120722.pdf

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Modernizing Gas Distribution Infrastructure

Existing distribution infrastructure can be upgraded and modernized in a way that minimizes methane emissions. Methane emissions can be minimized further by:

- ELIMINATING FLARING AND VENTING
- PLUGGING NATURAL GAS WELL HEADS
- IMPLEMENTING MODERN PRACTICES THAT CAN BETTER DETECT AND ELIMINATE METHANE LEAKS ON THE DISTRIBUTION SYSTEM
- CERTIFICATIONS (RESPONSIBLY SOURCED GAS) ENSURING ORGANIZATION'S GAS IS SOURCED WITH MINIMAL ENVIRONMENTAL AND SOCIETAL IMPACTS

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Strategies to Reduce Our Carbon Footprint

Responsibly Sourced Gas

Responsibly sourced gas is a key strategy to minimize methane emissions that might occur across the natural gas supply chain.

RSG Limits Methane Leaks Across the Supply Chain

- Responsibly sourced gas **(RSG)** is conventional natural gas that has been certified by a third party to verify that its procurement, i.e., the collection and delivery of the gas, meets a set of environmental criteria.
- RSG is also referred to as certified natural gas, differentiated gas, green gas, independently certified gas, and reduced-carbon natural gas.
- To be certified as RSG, natural gas must comply with stringent greenhouse gas emissions standards compared to current regulations.
- Natural gas may be considered responsibly sourced if it is delivered with <1% residual methane emissions.

*U.S. EPA, Global Methane Initiative, 2022

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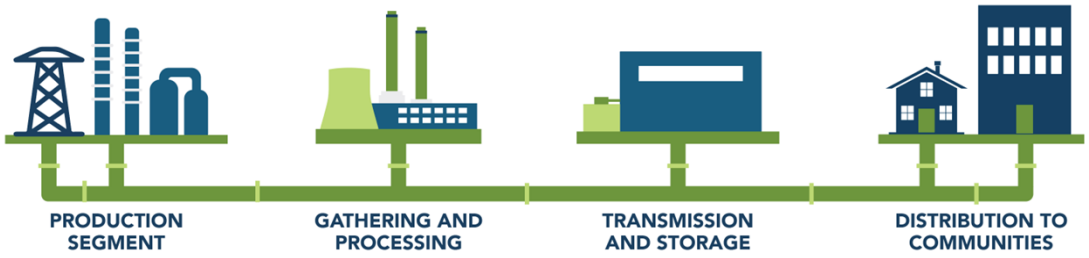
RSG Limits Methane Leaks Across the Supply Chain

Preventing methane leaks reduces heat-trapping greenhouse gases up to 25 times more than removing the same amount of carbon dioxide*



* U.S. EPA, Global Methane Initiative, 2022

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Certification Program: MiQ

MiQ is a methane emissions certification standard that currently certifies over 4% of the global gas supply. MiQ grades different producers of natural gas based on their methane emissions. This is done by assessing a producer's natural gas supply chain and giving each phase of the supply chain a methane intensity grade on a quarterly basis.

https://miq.org/

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Certification Program: EO100

EO100: The Equitable Origin also certifies natural gas producers by assessing their methane emissions across their respective supply chains. It also has an additional set of criteria that assesses fair labor and working conditions and that ensures the rights of indigenous people are respected.*

EQUITABLE ORIGIN

*Equitable Origin

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Certification Program: TrustWell

TrustWell 2.0 (through Project Canary) offers similar certificates, but they differ from E0100 and MiQ in that they require continuous monitoring of emissions data.

PROJECT CANARY

* https://www.projectcanary.com/next-gen-energy/responsibly-sourced-gas/

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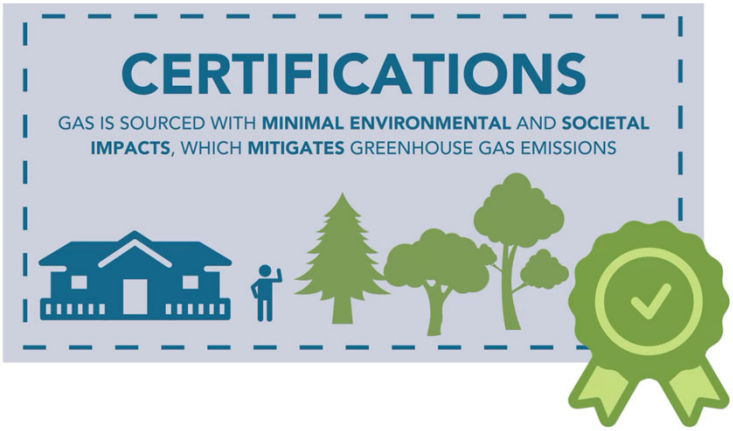
RSG Certification

Certifications help organizations ensure their gas is sourced with minimal environmental and societal impacts.



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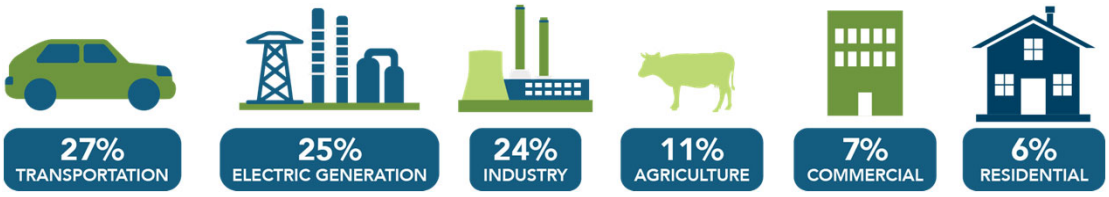
Carbon Offsets

The natural gas industry is committed to reducing carbon emissions. By leveraging carbon capture, carbon offsets, and Renewable Natural Gas (RNG) certificates, natural gas can help achieve our low carbon energy goals affordably while maintaining reliability.

Where does Carbon Dioxide Originate?

Carbon Dioxide (CO2) and other greenhouse gas emissions are produced by a number of sources.



Total U.S. Greenhouse Gas Emissions by Economic Sector

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

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What Are Carbon Offsets

Carbon offset projects are specific activities intended to reduce greenhouse gas emissions. Offsets work by eliminating emissions elsewhere to balance out carbon produced in another location.*

* https://www.epa.gov/sites/default/files/2018-03/documents/gpp_guide_recs_offsets.pdf

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How do Offsets Reduce Carbon Emissions?

Carbon offsets are measured in metric tons of CO2 or CO2 equivalent and can be purchased to offset not just carbon but other common greenhouse gases. Offsets serve as credits that balance carbon-generating activities of residents and businesses from the three scopes of emissions recognized by the EPA.

Scope 1-Direct Emissions
Scope 1 emissions are any direct emissions from the activities of an organization. This includes burning fossil fuels for heat or burning gasoline to power a vehicle

Scope 2-Indirect Emissions
Scope 2 emissions are indirect emissions associated with the production of electricity, heat, and steam purchased by an organization. These emissions are indirectly released as a result of the organization's operations.

Scope 3-Other Indirect Emissions
Scope 3 emissions refer to any other indirect emissions throughout the value chain. This includes emissions released when purchasing, transporting, and disposing of materials, goods, and services.

*U.S. EPA, Scope 1 and Scope 2 Inventory Guidance, 2021

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What are Renewable Natural Gas (RNG) Certificates?

- Natural gas consumers can purchase RNG certificates as an alternative way to balance out emissions from gas consumption.
- An RNG certificate is an instrument that gives the holder ownership of the greenhouse gas emission reduction that was generated by the capture of biomethane that is processed into renewable natural gas.
- Also called buying "virtual RNG", purchasing an RNG certificate mitigates emissions from natural gas consumption.

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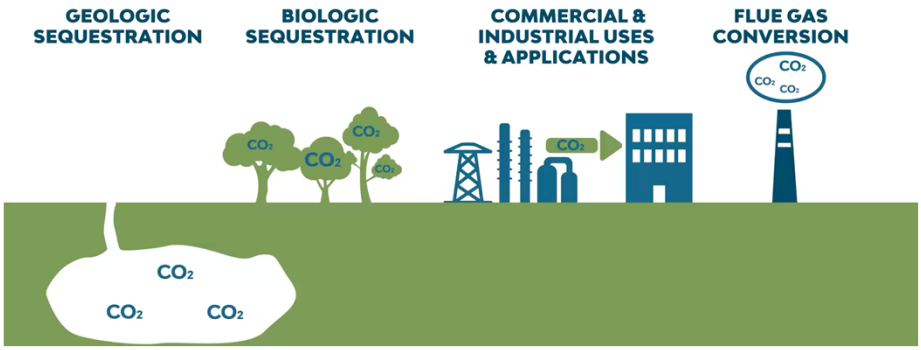
Carbon Capture and Sequestration

Carbon capture and sequestration refers to technologies that remove carbon from exhaust emissions and store it safely where it causes little to no environmental impact. Several techniques already exist that significantly reduce greenhouse gases when consuming natural gas.



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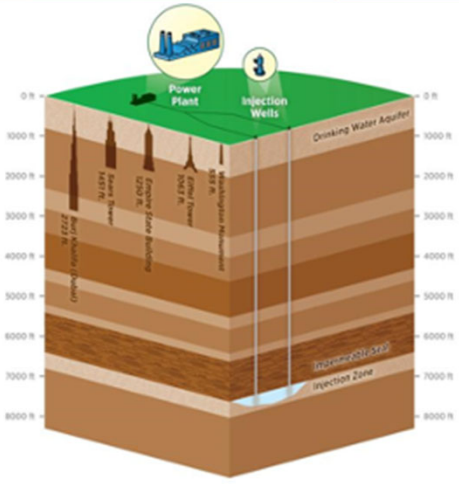
Carbon Utilization & Sequestration

- Geologic Sequestration: CO2 is stored deep below the surface of the Earth by injecting it into porous rock formations where it cannot escape.
- Biologic Sequestration: By feeding CO2 to plants, their natural growth process converts carbon into plant matter.
- Commercial Applications: Captured carbon can be repurposed by industry across a range of commercial applications, including enhanced oil recovery in wells, food and beverages, and fire-fighting equipment.
- Flue Gas Conversion: Carbon captured from flue gas can be converted into carbonate (pearl ash) for the manufacturing of soaps and detergents.



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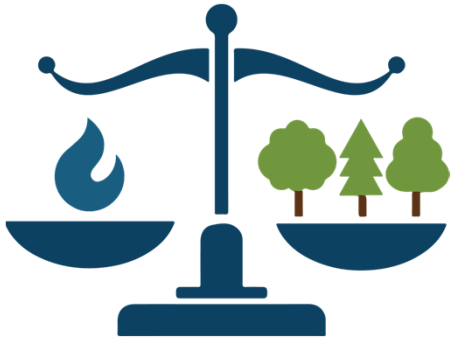


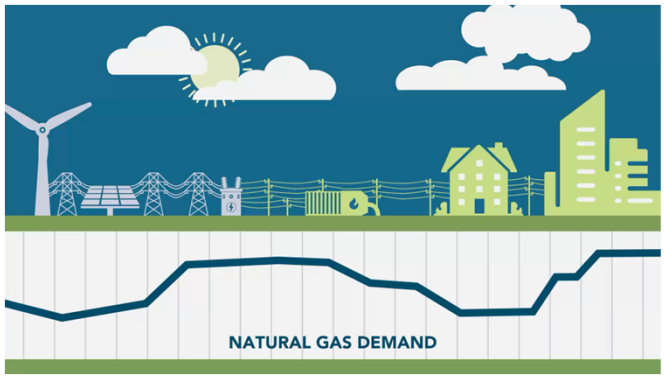
Balancing Power and Variable Renewables with Gas

Flexible grid resources, such as natural gas and energy storage, can help manage the intermittency and variability of renewable energy resources, and minimize costs associated with a low-carbon power grid.

Planning for a High Renewable Energy Future

In order to ensure system flexibility, utilities will need to balance the intermittent and variable energy output of solar & wind power with other, more reliable, energy generation technologies whose power output can quickly ramp up or down.

Gas and storage resources can quickly adjust their output to compensate for changes in renewable power output and ensure a reliable and continual balance between supply and demand.



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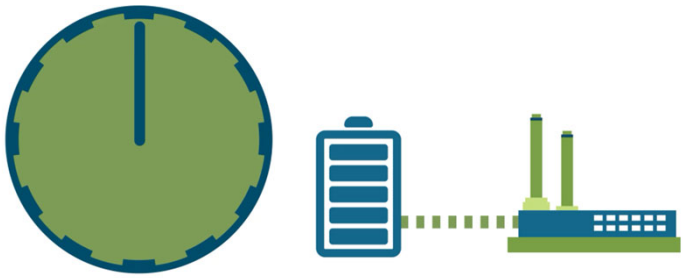
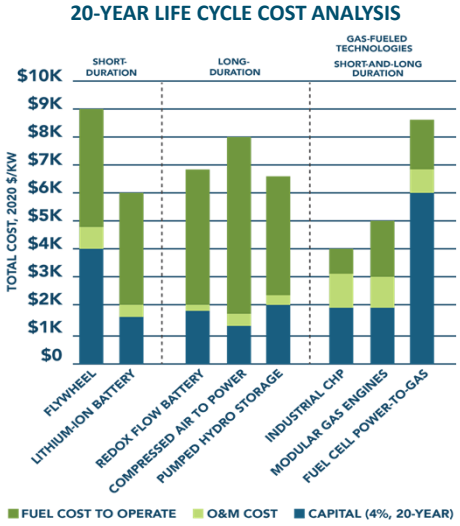
Types of Flexible Grid Resources

Energy storage technology options are generally divided into two categories: short duration (< 4 hours) and long duration (> 4 hours). Gas-fueled technologies, can be more commercially viable than other energy storage options.





Source: ICF, Energy Storage Comparison Analysis with Gas-Fueled Technology

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Natural Gas as an Option for Flexibility

While grid-scale energy storage systems develop and become more cost-effective, utilities can use gas-fueled technologies to balance variable renewable energy output.

- Start-up times of about 3-5 minutes
- Combined heat & power and gas engine generators have the lowest lifecycle costs compared to electric storage technologies
- Fueling with renewable natural gas provides flexibility and greenhouse gas (ghg) reductions
- Potentially can be retrofitted to use hydrogen*
- Supports long-term storage of hydrogen
- Maximum utilization, cost-effective, reliable and resilient

*https://www.2g-energy.com/products/hydrogen

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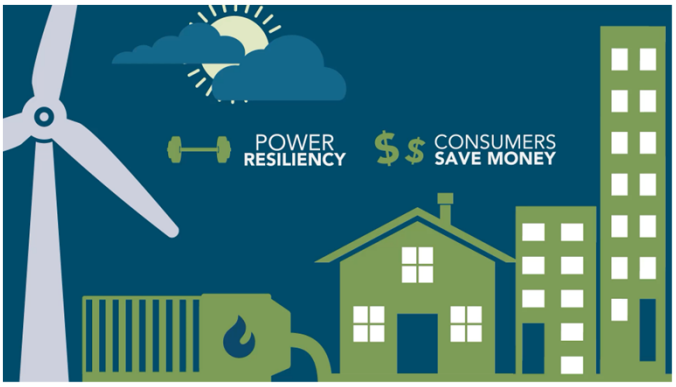
Flexible Grid Resources Minimize Cost of Decarbonization and Enhance Resiliency

Variable renewable energy resources will likely play a large role in decarbonized electricity system, pairing these resources with flexible natural gas power generation resources will minimize the cost of the low-carbon transition. Incorporating flexible natural gas generation resources that can provide power resiliency during periods of low renewable energy output and will help reduce future electricity prices and save consumers significant amounts of money.[1,2]



[1] Progress in Energy, Role and Value of Flexibility in Facilitating Cost-Effective Energy System Decarbonization, 2020
[2] Joule, The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation, 2018

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Natural Gas Emissions Will Drop in the Future as Lower Carbon Gases are Blended into the Natural Gas Distribution System

Renewable Natural Gas Reduces Carbon Emissions

Renewable natural gas (RNG) from biomass helps to meet America's growing demand for a low-carbon, affordable, and reliable fuel. RNG is fully compatible with conventional natural gas and the existing pipeline infrastructure.

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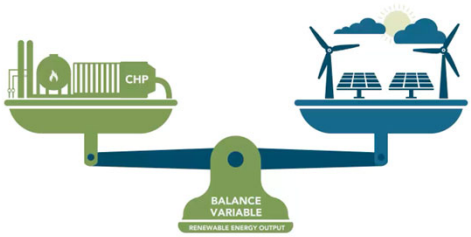
Flexible Combined Heat and Power Systems

One way utilities can cost-effectively balance the intermittency of variable renewable energy is by leveraging Combined Heat & Power (CHP) systems at commercial & industrial sites.

- Flexible CHP systems provide electricity and thermal energy for heating, processes or other plant operations.
- Flexible CHP systems provide additional generation capacity that can be used when the grid demand increases and/or renewable resources are not available.



FLEXIBILITY **REDUCE GREENHOUSE GAS**

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Energy Efficiency

Utility Energy Efficiency and Weatherization Programs

Energy Efficiency and weatherization programs work together to cut household energy expenditures, reduce greenhouse gas emissions, and increase the resiliency of our buildings.

Weatherization Programs

- Weatherization Programs (WPs) are partnerships between federal/state governments and utilities to provide low-income households with technical and financial assistance to lower household energy bills.
- These programs help protect structures, such as a home or business, from outdoor elements, such as precipitation, sunlight, wind, etc.
- Weatherization Programs can help decrease the energy expenditures of low-income families and reduce their carbon footprint.

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Weatherization Measures

MECHANICAL IMPROVEMENTS
- REPLACING AGING HEATING/COOLING SYSTEMS
- INSTALLING HEATING PIPE INSULATIONS

BUILDING SHELL IMPROVEMENTS
- REPLACING LEAKY WINDOWS AND DOORS
- REPAIRING ROOF AND WALL LEAKS

ELECTRIC AND WATER IMPROVEMENTS
- INSTALLING EFFICIENT LIGHT SOURCES
- LOW-FLOW SHOWER HEADS

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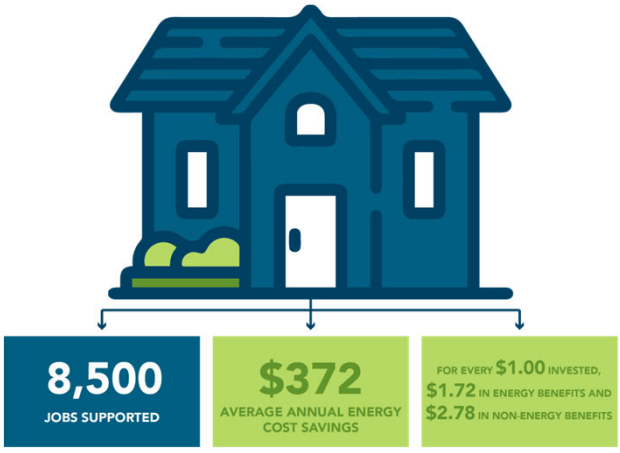
U.S. Department of Energy Weatherization Assistance Program

The U.S. Department of Energy Weatherization Assistance Program (WAP) has helped 7 million low-income families reduce their energy costs and improve their environmental footprint.



Source: U.S. DOE, "Weatherization Works"

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Environmental Benefits of Weatherization

- Weatherization is an impactful strategy to reduce greenhouse gas emissions and other pollutants.
- Weatherization Programs can help reduce sector emissions by making homes and businesses more energy efficient.
- With less energy required for space heating and cooling, carbon emissions can be significantly reduced through targeted state/province and utility programs.

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Many Gas Utilities Offer Energy Efficiency Programs

Energy Efficiency programs often provide rebates or incentives when high efficient equipment is installed.

High Efficiency Furnace

High Efficiency Water Heater

Smart Thermostat

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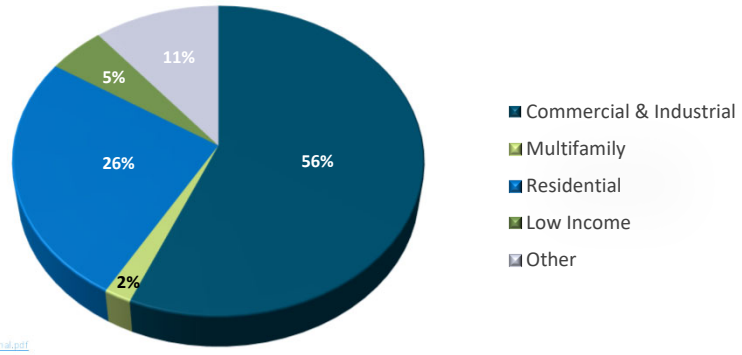
Gas Utilities & Energy Efficiency

Natural gas utilities have had long-standing efficiency programs that have yielded multiple benefits for their customers including improved energy affordability and resilience

The value of natural gas energy efficiency savings across the United States and Canada totaled approximately $383 million in 2019.

US and Canadian Gross Incremental Natural Gas Savings by Customer Class



https://cee1.org/sites/default/files/2021-09/2020_AIR_Final.pdf

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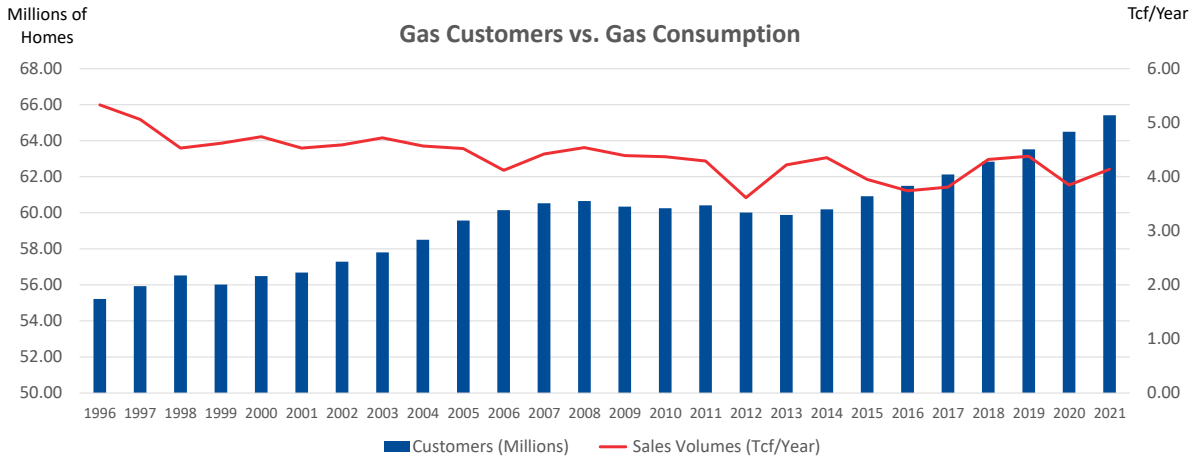
Per Household Gas Use Decreasing
(Energy Efficiency Success Story)



AGA Data

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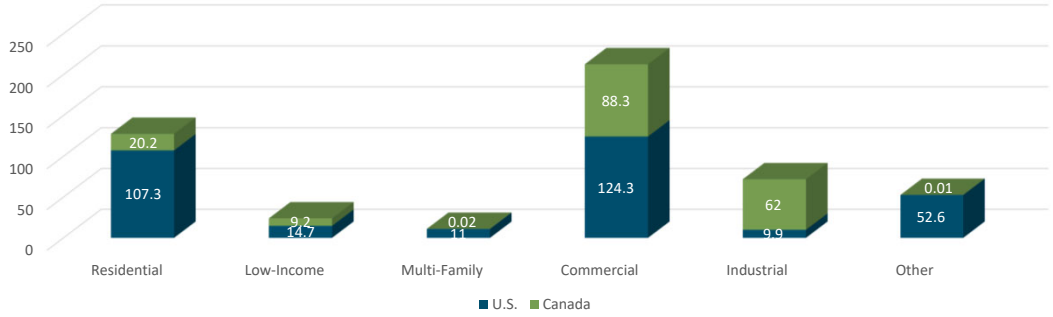
Emission Reductions from Energy Efficiency Improvements

Natural Gas Efficiency Program Estimated Savings Impacts by Customer Segment for 114 programs (Million Therms)



U.S. participating utilities saved 319 million therms through natural gas efficiency programs, thus avoiding 1.7 million metric tons of CO2. Canadians saved 178 million therms, avoiding .95 million metric tons of CO2 in 2019.
Total North American CO2 savings is equivalent to removing 560,254 cars off the roads for 1 year.

Chart data: https://www.aga.org/wp-content/uploads/2022/04/eereport-part-2-final.pdf
Car equivalent assumption: https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references

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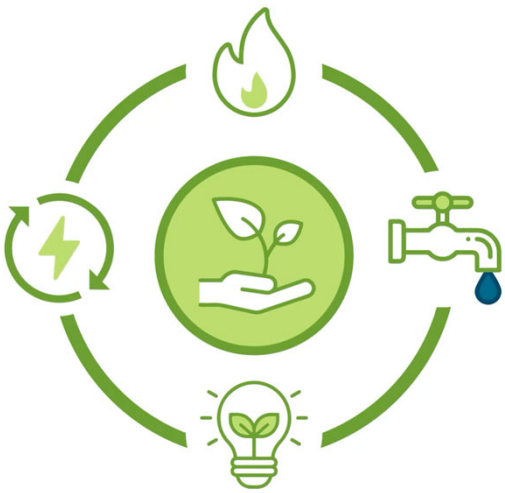


Energy Efficient Technologies

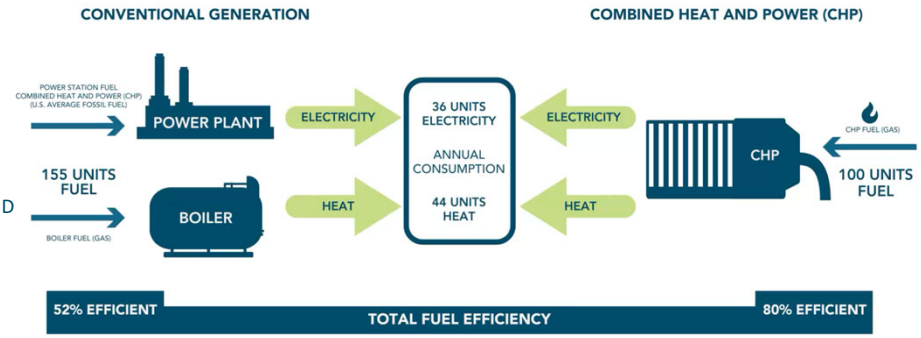
Energy Efficient technologies can play a pivotal role in a low-carbon future. Gas-powered technologies can offer efficient and cost-effective methods to reduce energy requirements, fuel consumption, and greenhouse gas emissions.

Combined Heat and Power Systems

Combined heat and power (CHP) systems are onsite generators that provide both power and thermal energy from a single fuel source.[1] CHP, also referred to as cogeneration, captures heat that would otherwise be wasted and applies it to various end-uses, such as space heating, cooling, hot water, and process heat.

CHP BENEFITS[2]

- INCREASES ENERGY EFFICIENCY
- REDUCES ELECTRICITY COSTS
- IMPROVES RESILIENCY
- REDUCES EMISSIONS WHEN COMPARED TO SEPARATE HEAT AND POWER SYSTEMS



[1] U.S. DOE, Combined Heat and Power Deployment Program, 2021 [2] CHP Alliance, CHP is a Low-Carbon Reliable Alternative to New Central Gas Plant, 2020

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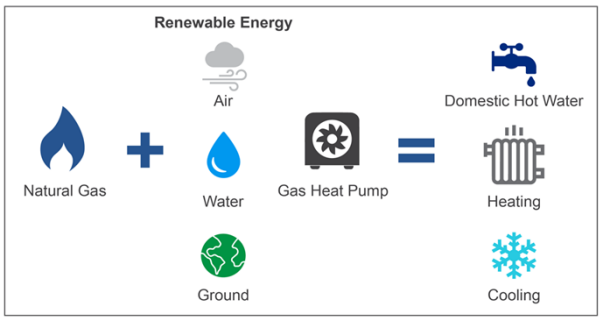
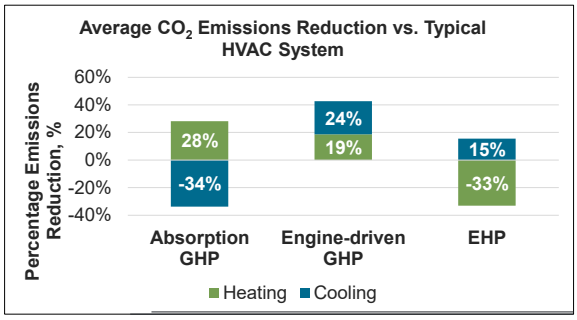
Gas Heat Pumps

Gas heat pumps offer an all-in-one high efficiency heating and air conditioning solution. They work by using thermal energy such as natural gas and an outdoor heat source to achieve the desired indoor heating effect. In many circumstances, gas heat pumps use less fuel and produce fewer greenhouse gas emissions than electric heat pumps.[1]





[1] ICF, Comparison of Operational Costs and Carbon Emissions for Gas and Electric Heat Pumps at Commercial Buildings, 2021

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High-Efficiency Gas Water Heaters

High-efficiency gas water heaters include condensing tank-style, tankless, and gas heat pump water heaters. These systems offer efficiency increases between 20% and 75% compared to standard tank water heaters.

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High Efficiency Residential HVAC

With heating and cooling accounting for half of a typical home's energy use, high-efficiency HVAC systems can play a critical role in reducing energy costs and emissions for homeowners. HVAC system efficiencies can be improved by upgrading to high efficiency furnace or boiler, or by installing a gas heat pump.

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Fuel Cells

Unlike reciprocating engines that combust fuel, fuel cells work by using an electrochemical process to produce electricity and heat. Fuel cells can be used in a wide variety of sectors and applications including transportation, power, industrial, residential, and commercial settings. Depending on the fuel sources, fuel cells can produce little to no greenhouse gas emissions. Additionally, fuel cells operate at higher efficiencies than conventional combustion-based technologies, with efficiencies capable of exceeding 60%. *

*U.S. DOE, Fuel Cells

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Integrated Energy-Hybrid Heating Systems

Integrated energy systems combine energy efficient heat pump technology with high-performing boilers or furnaces. While heat pumps are typically highly efficient, they operate best in warm temperate climates and may not perform as well in very cold environments. Adding a natural gas-fired boiler or furnace can improve the cost and environmental benefits of electric heat pumps and significantly reduce the cost of the decarbonization by avoiding the costly overbuild of electric transmission and distribution needed only on the coldest days of the year.

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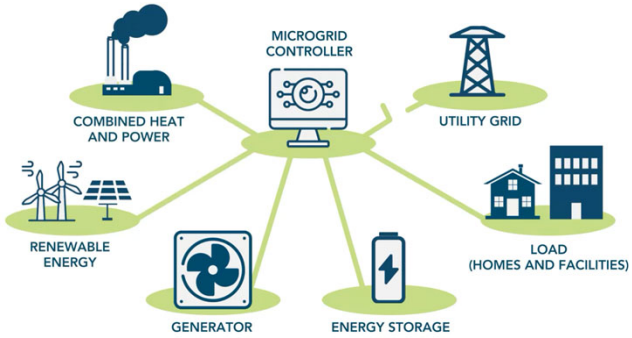
Microgrids

- Microgrids are decentralized networks of electricity users, transmission infrastructure, and local distributed energy resources.
- These systems are capable of incorporating a variety of generation technologies, including natural gas generators, solar arrays, wind farms, and energy storage systems.
- While still connected to the utility grid, microgrids are capable of operating autonomously in the event of a grid outage, which increases local energy resilience.
- Since microgrids generate electricity locally, they are also able improve efficiency by reducing energy lost during the transmission and distribution of electricity.



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Natural Gas Vehicles

Natural gas vehicles can reduce emissions from the transportation sector, currently the largest source of emissions in the United States and second largest in Canada.

Compressed Natural Gas (CNG)

- Natural Gas in Gaseous Form
- Can be transported to fueling stations or stored in pressurized tanks[1]
- Takes up less space compared to conventional natural gas
- Used in a range of on-road vehicles

[1]Energy Education, Compressed Natural Gas, 2018

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Liquefied Natural Gas (LNG)

- Cooled Into A Liquid
- Kept At Very Low Temperatures For Storage And Shipping
- Takes Up Less Volume Than CNG[2]
- Used In A Range Of On-Road Vehicles

[1]Energy Education, Compressed Natural Gas, 2018. [2]U.S. DOE, Liquified Natural Ga

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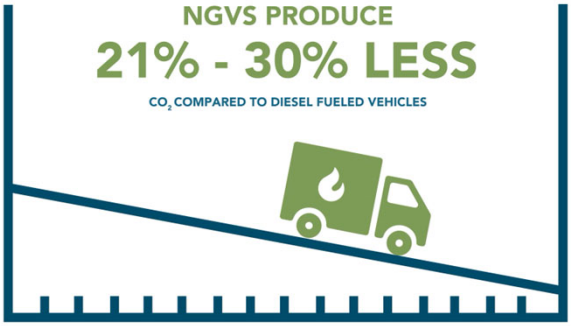
Emissions Benefits of Natural Gas Vehicles

One of the primary advantages of NGVs is that they produce significantly less tail pipe emissions than diesel vehicles. The adoption of NGVs can be an effective strategy to reduce transportation-related emissions and comply with stricter clean air regulations.



https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/alternative-fuels/resources/pdf/roadmap.pdf

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Additional Benefits of Natural Gas Vehicles

- CNG is estimated to cost 40% to 45% less than gasoline and diesel.
- Natural gas vehicles can also incorporate renewable natural gas (RNG), reducing emissions further.
- More than half the fuel used in NGV's is RNG.

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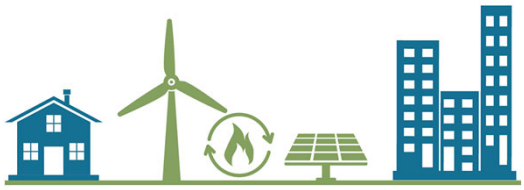
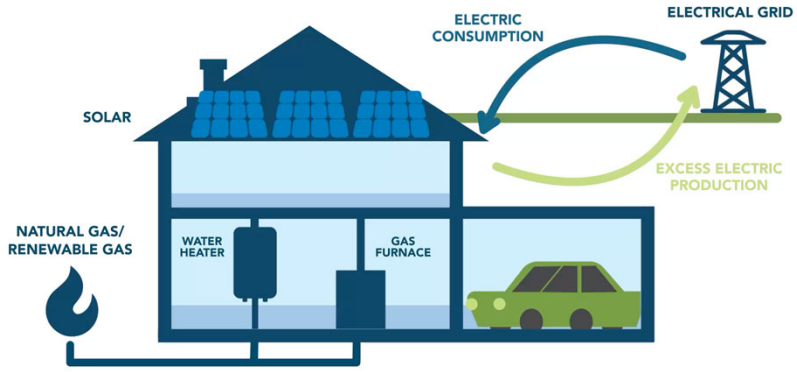


Zero Net Energy Buildings

Zero net energy buildings combine renewable energy technologies and energy efficiency measures to reduce greenhouse gas emissions and improve the resiliency of our built environment.

Zero Net Energy Homes

For a building to be classified as ZNE, it should produce enough renewable energy to offset the amount of energy that it consumes over the course of a year.



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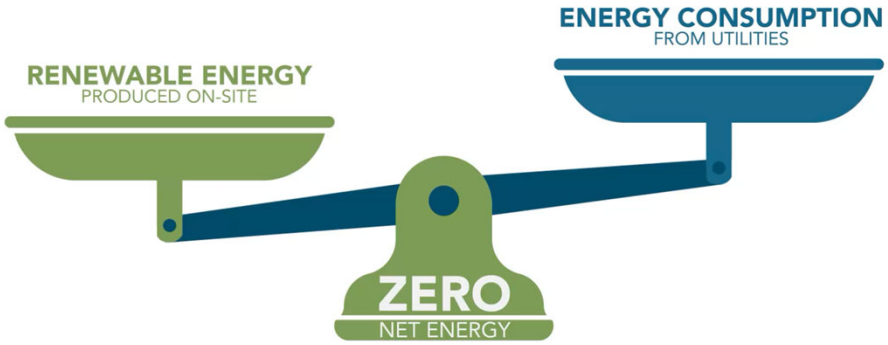
Zero Net Energy Building Certification

Third party certifications are used to verify that buildings meet ZNE criteria under normal use conditions. Certification requires that a home or building offsets its source energy using on-site renewable or through carbon offsets.



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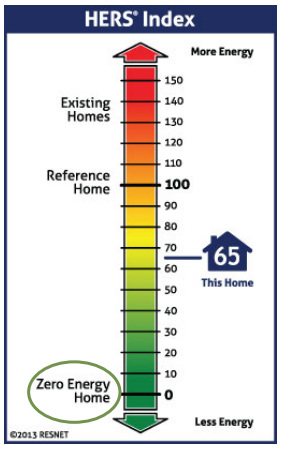
Home Energy Rating System

ZNE certifications for residential buildings often factor in a Home Energy Rating System (HERS) score, which is determined by a nationally recognized system that assesses features like its building envelope and HVAC system to evaluate the home's energy performance. Lower scores mean that the home is more energy efficient compared to a reference home. A score of 0 indicates a zero net energy home.



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How to Achieve Zero Net Energy in Buildings

ZNE buildings often consume electricity from the utility grid, produce their own electricity via on-site renewable energy, and return any surplus renewable energy to the grid to be used by other buildings. Highly efficient technologies and systems can reduce the amount of energy required for routine building use and operations, making it easier to reach ZNE status. Incorporating highly efficient technologies also serves to lower the cost of serving the building's energy needs with renewable energy.

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Features of ZNE buildings include:

- Exterior wall insulation and air sealing to protect against moisture problems and reduce air leaks
- Rooftop solar photovoltaic (PV) and renewable thermal energy such as biomass to meet the energy needs of the building
- Daylighting to control the admission of natural, direct light to reduce electricity use
- Monitoring plug loads with meters
- Ground-source heat pumps that use the earth's constant temperature to cool and heat the building

Whole Building Design Guide, Net Zero Energy Buildings, 2016

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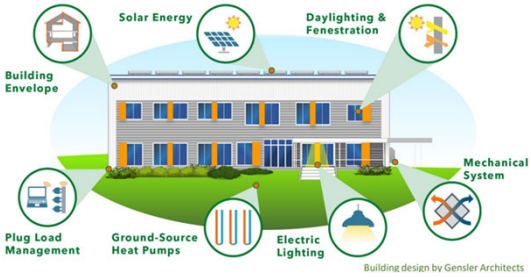
Natural Gas Can Play a Role in Zero Net Energy Buildings

Many ZNE buildings source electricity from renewables like solar PV but require natural gas for heating and cooking functions. Efficient natural gas systems can be used in ZNE buildings, but the emissions associated with their combustion must be offset by onsite renewable energy production.



*Whole Building Design Guide, Net Zero Energy Buildings, 2016
https://www.energy.gov/sites/default/files/2022-05/bto-zeb-houston-052522.pdf

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