ENERGY SOLUTIONS CENTER

Track: Natural Gas Basics
Unit 5: The Benefits of Natural Gas

Eric Burgis, Energy Solutions Center

Presentation Outline

- Gas Production & Consumption
- Projected Reserves of Natural Gas in North America
- Energy Costs
- Efficient Energy
- Resiliency
- Environmentally friendly
- Natural Gas Technologies

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Gas Production & Consumption

Production outweighs consumption in North America

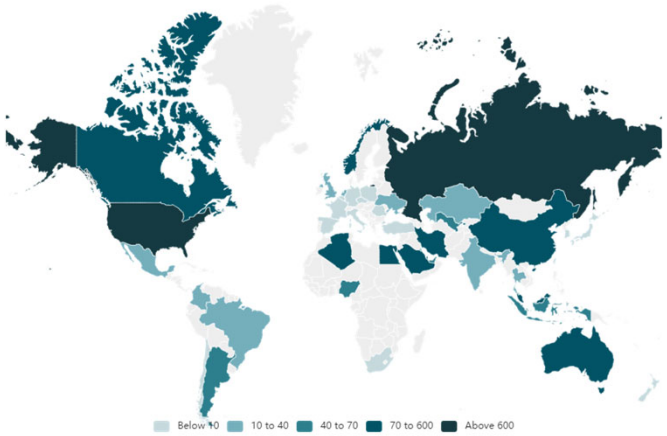
Natural Gas Worldwide

Top 10 Net Producers & Consumers

Production	BCM
United States	**975**
Russia	791
Iran	239
China	209
Canada	**191**
Qatar	169
Australia	143
Norway	119
Saudi Arabia	101
Algeria	90

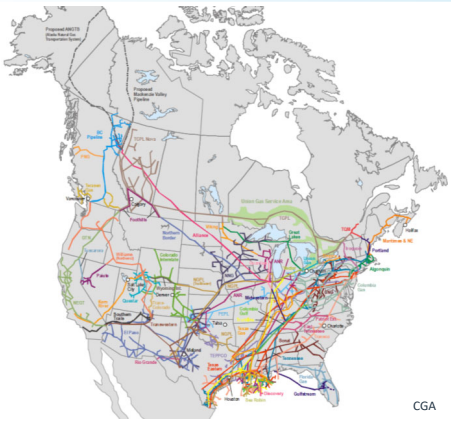
Consumption	BCM
United States	**862**
Russian	565
China	365
Iran	233
Canada	**133**
Saudi Arabia	101
Japan	101
Germany	99
UK	79
Italy	76

Natural Gas Producers



https://yearbook.enerdata.net/natural-gas/world-natural-gas-production-statistics.html for year 2021

Vast Interstate Pipeline Network



CGA

- 2.6 million miles of underground system
- ~2.2 million miles LDC, ~300,000 miles Transmission

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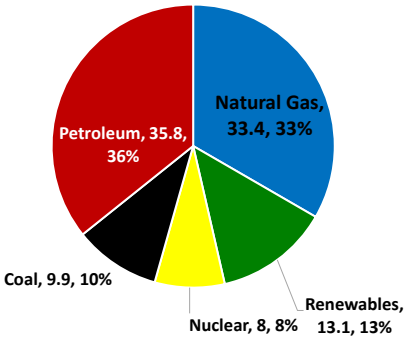
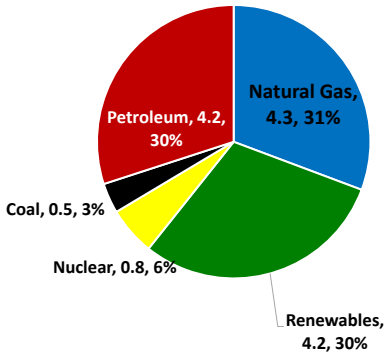
Natural Gas Supports ~1/3 of Primary Energy Consumption

Total Primary U.S. Energy Consumption 2022 (Quadrillion BTUs)



https://www.eia.gov/totalenergy/data/annual/#summary , Table 1.3

Total Primary Canadian Energy Consumption 2021 (exajoules)



https://www.statista.com/statistics/265608/primary-energy-consumption-in-canada-by-fuel/

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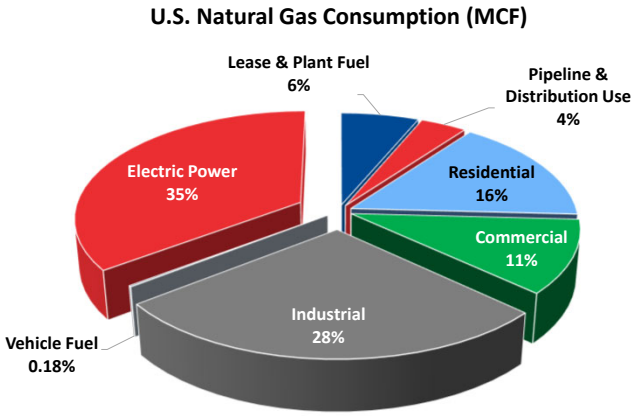
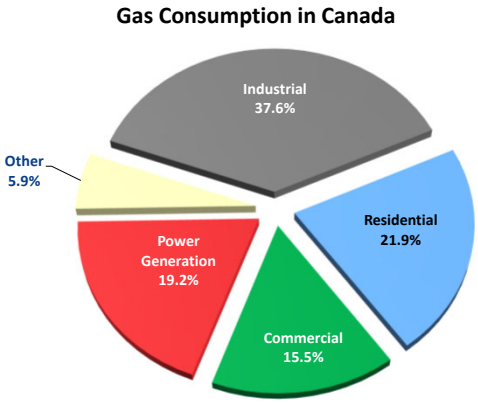
Natural Gas Consumption



http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm



Statistics Canada

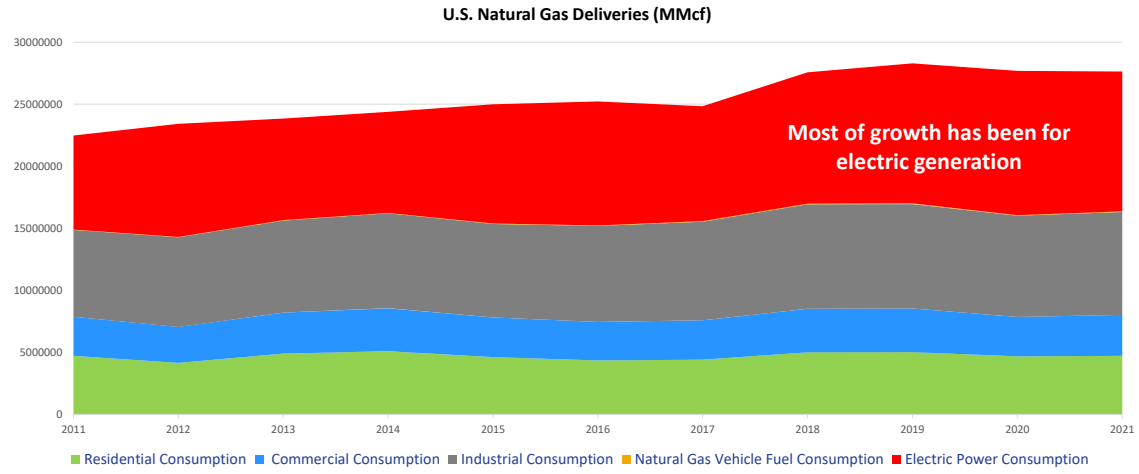
More than 6 in 10 North American Homes Use Natural Gas

- Natural Gas serves:
  - U.S. Homes
    - 75.3 Million of 123.5 U.S. Homes use natural gas (~61%)
  - Canadian Homes
    - Natural gas is used by approximately ⅔ of Canadians in over 7.4 million customer locations across the country

U.S. RECS data

https://www.cga.ca/natural-gas-statistics/natural-gas-facts/

Gas Consumption Remains Consistent for the Residential, Commercial & Industrial Markets



https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

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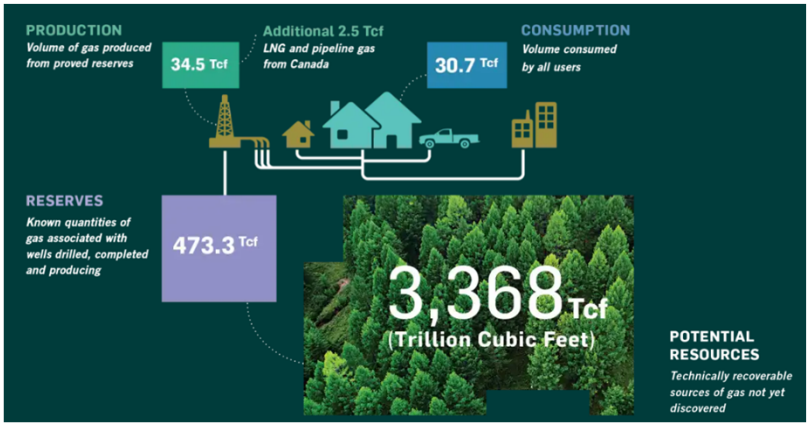
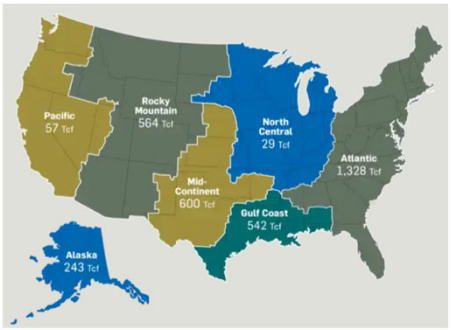
Natural Gas Reserves

> 100 Years of Reserves in the U.S. and > 200 years in Canada

More than 100 Years of Natural Gas Supply in U.S.





2023 AGA Playbook, https://playbook.aga.org/natural-gas-data

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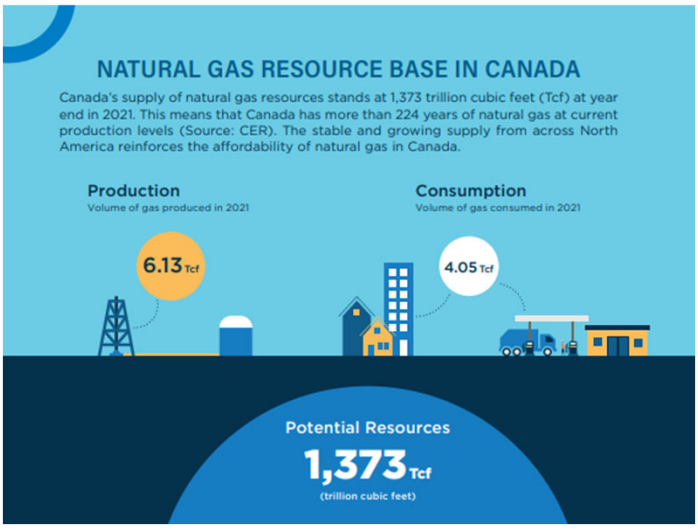
Canada has Over 224 years of Gas Supply



CGA Playbook, 2022

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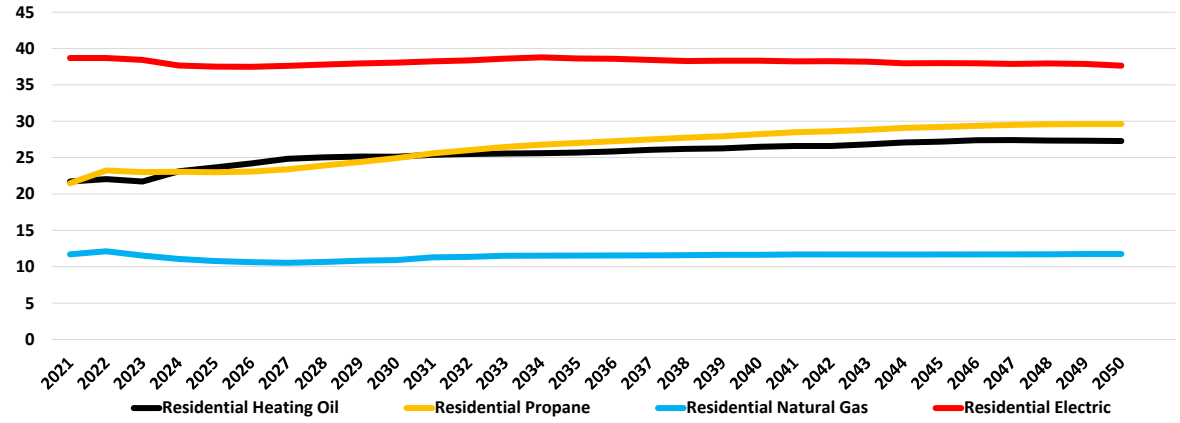
Energy Costs

Natural Gas is Economical

Future Residential Energy Pricing

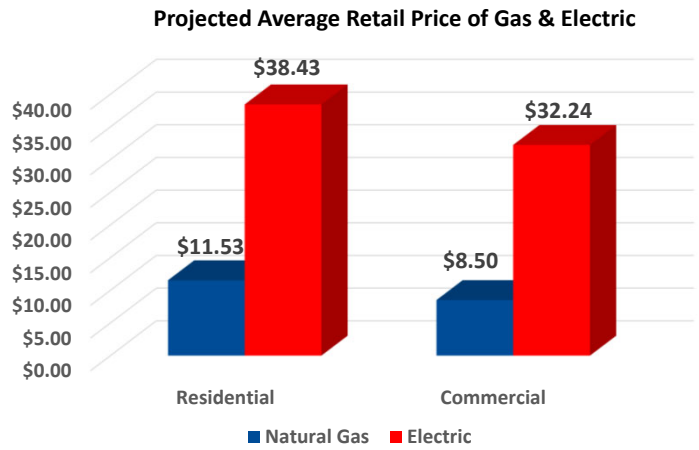
Projected Residential Energy Prices from EIA's Annual Energy Outlook ($/MMBTU)



Natural Gas is projected to continue to be the lowest energy cost for homes on a BTU for BTU basis well into the future.

EIA AEO

Current Average Retail Energy Prices ($/MMBTU)



Electric Retail Rates are more than 3X the cost of delivered natural gas for residential & commercial customers.

Source: EIA AEO 2022, projected 2023 retail pricing, https://www.eia.gov/outlooks/aeo/

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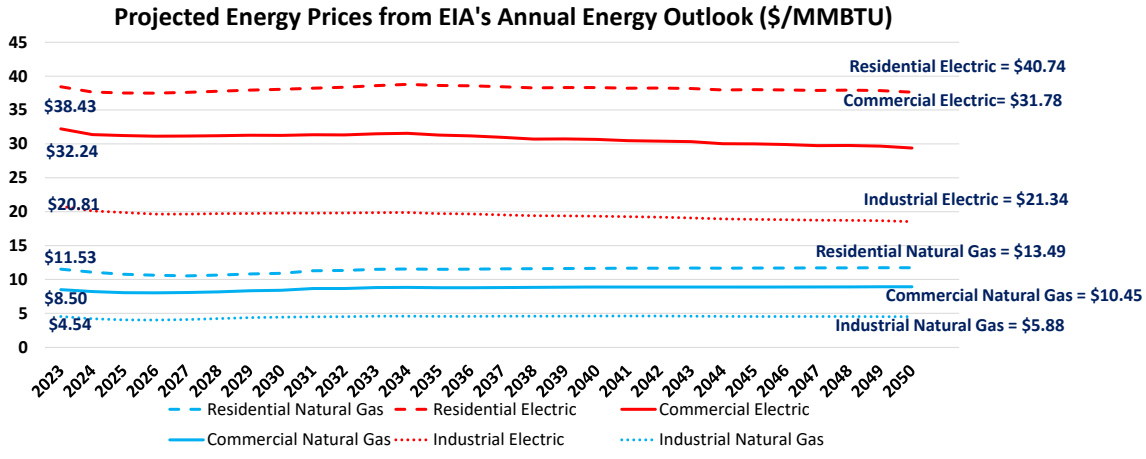
Current Average Retail Energy Prices ($/MMBTU)



Natural Gas is projected to continue to be the lowest energy cost on a BTU for BTU basis for all markets well into the future.

EIA AEO 2022, projected 2023 retail pricing, https://www.eia.gov/outlooks/aeo/

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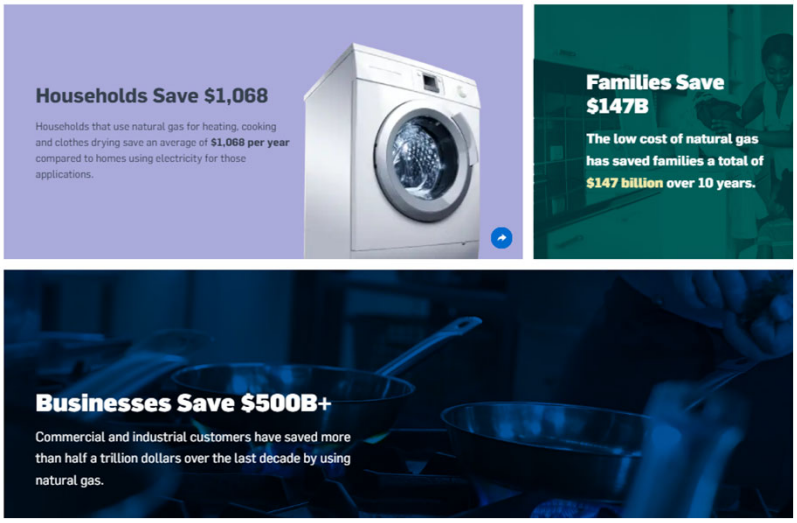
Gas Saves U.S. Homes and Businesses



AGA Playbook, 2023

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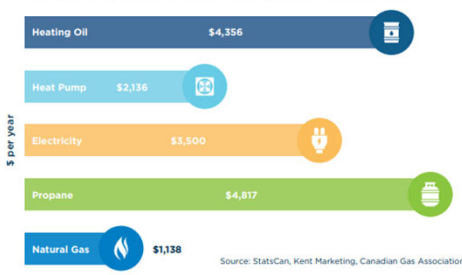
Gas Saves Canadian Home Owners Money

ABUNDANT SAVINGS

At a national level (average), households that use natural gas for space and water heating save $1,000 to $3,000 per year, compared to homes using propane, electricity, and heating oil for the same applications. More recently, natural gas utilities have been looking at new approaches to meeting the evolving energy needs of consumers including hybrid heating — involving the combination of a heat pump and a high efficiency furnace. As we look forward, utilities are supporting the commercialization of gas heat pumps that offer a 40–50 per cent increase in energy efficiency vs. a high efficiency furnace.

Residential Space and Water Heating Costs - Canada 2021



Average savings of up to **$2,000** per year

CGA Playbook, 2019

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Energy Efficiency

Natural Gas is more efficient on a source basis

Typical Efficiencies

- **Efficiency Definition**
  - The related energy output or effect as a result of energy input
- **Heating**
  - With Natural Gas, Oil or Propane the standard efficiency today is around 80-82%
  - Higher efficiency models are also available > 90 %
  - Gas Heat Pumps are approx. 140% efficient
- **Electric Resistance Heating or Gas Infra Red**
  - There is no energy lost in the form of waste heat and is typically 99% efficient, but this efficiency is offset by energy cost
- **Electric Heat pumps** work differently and have efficiencies well over 100%. Electric heat pumps are typically rated in Heating Seasonal Performance Factors (HSPF)

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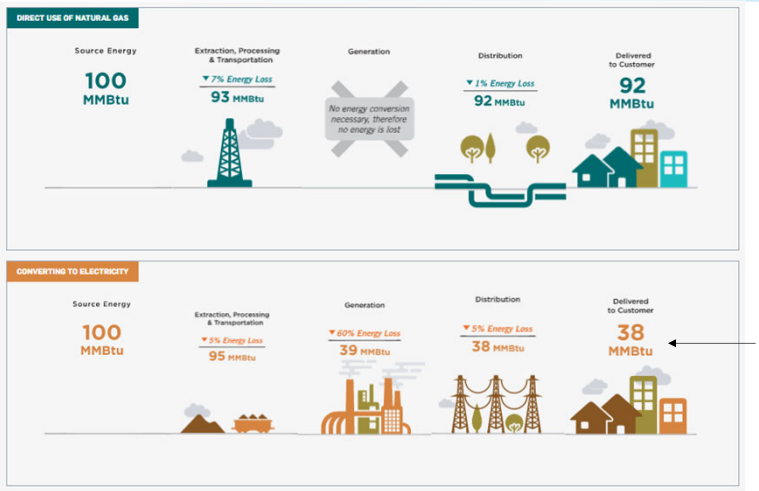
Natural Gas is More Efficient on a Source versus Site Basis



Overall electrical efficiency has increased over past several years as combined cycle gas plants replace old coal plants.

Reduce Generation Losses and T&D Line Losses with CHP

2023 AGA Policy Handbook

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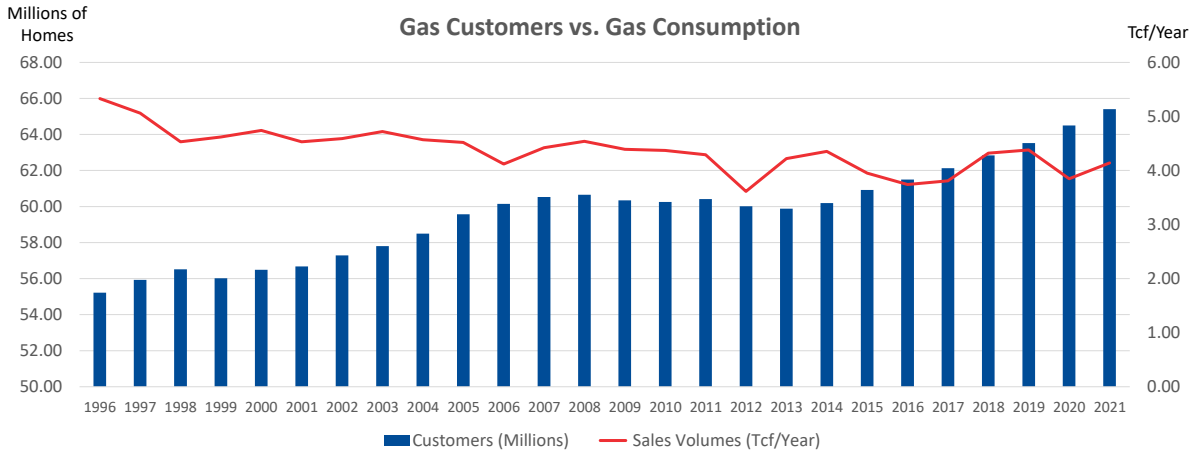
Per Household Gas Use Decreasing While More Customers are Added to the System



Homes and Home Appliances are becoming more efficient which can be seen above as an energy efficiency success story.

AGA Data

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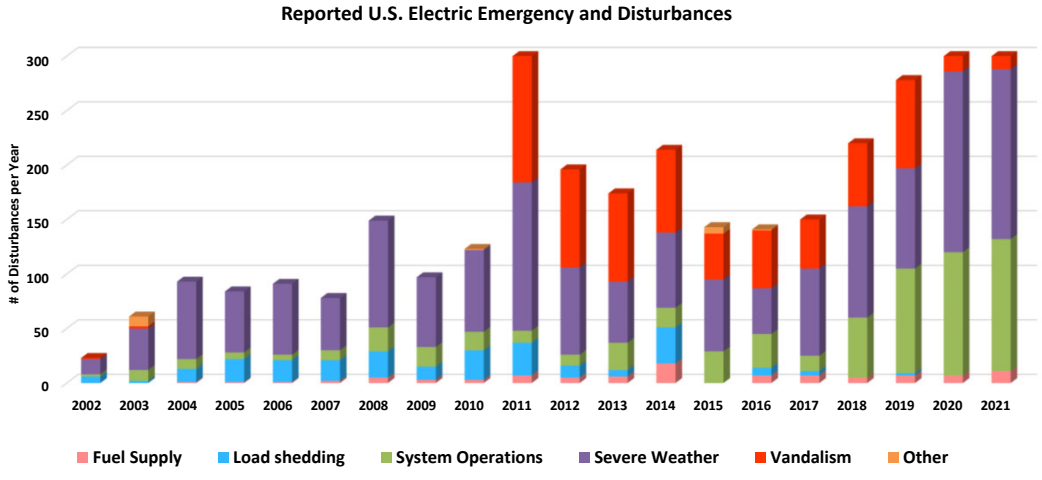
Resiliency

Natural Gas is less prone to disruptions of service

The Electric Grid is Stressed with Congestion and Constraints Leading to More Outages



OE-417 Electric Emergency and Disturbance Reports

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Why the Decline in Electric Grid Reliability?

9,000 MW > 7,000 MW < 8,000 MW

Generation: (Growing)

Transmission & Distribution: (?????)

Load: (Growing)

An aged electric transmission and distribution system cannot handle today's demand for power even if we can generate more power than needed by consumers. T&D Congestion and Constraints continue to increase. Natural Gas use reduces demand for electric helping to stabilize the grid.

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Natural Gas is More Reliable

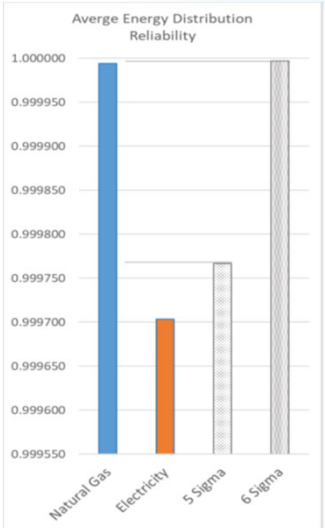

Table 1: Summary Energy Distribution Reliability and Outage Rate Results

Metric	Natural Gas Distribution	Electric Distribution
Average Reliability/Availability (Planned and Unplanned)	0.9999957	0.999703
Average Reliability/Availability (Unplanned)	0.9999991	--
Average Outage Rate – Planned and Unplanned (Event Per Customer Per Year)	0.00895	1.017
Estimated Unplanned Outage Rate (Event Per Customer Per Year)	0.00125	--

Data from GTI Topical Report: Assessment of Natural Gas & Electric Distribution Service Reliability–7/19/18.

Customers that require uninterrupted power want more 9's when it comes power reliability. A rating of 99.9999% reliable is better than just 99% reliable. This study concludes that natural gas is far more reliable than electric.

http://www.gastechnology.org/Solutions/Documents/Assessment-of-Natural-Gas-Electric-Distribution-Service-Reliability-TopicalReport-Jul2018.pdf

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Environmentally Friendly

On a source basis, Natural Gas typically has the lowest carbon footprint compared to other forms of energy

Natural Gas Can be Used to Reduce CO2

NATURAL GAS IS KEY TO A LOW-CARBON ENERGY FUTURE.

Natural gas is a vital part of our energy mix because it produces low CO_2 emissions and provides reliable and efficient energy as we work toward a low carbon energy future.[1]

eia.gov/tools/faqs/faq.php?id=73&t=11

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Natural Gas has Contributed to a Drop CO2 Emissions
(Million Metric Tons)

Sources	Residential	Commercial	Industrial	Transportation	Electric Power	Source Total	
Coal -2011	1	5	151	0	1,718	1,874	
Coal - 2017	0	2	109	0	1,207	1,318	
Coal - 2021	0	1	91	0	908	1,001	Down
Natural Gas - 2011	**256**	**171**	**419**	**39**	**411**	**1,296**	
Natural Gas - 2017	**243**	**174**	**509**	**40**	**506**	**1,472**	
Natural Gas - 2021	**255**	**179**	**530**	**58**	**615**	**1,637**	Up
Petroleum - 2011	78	49	345	1,802	25	2,299	
Petroleum - 2017	60	59	342	1,858	19	2,338	
Petroleum - 2021	63	61	340	1743	17	2,224	
Electricity - 2011	**827**	**767**	**567**	**4**		**2,165**	
Electricity - 2017	**653**	**639**	**448**	**4**		**1,744**	
Electricity - 2021	**604**	**542**	**403**	**3**		**1,552**	Down

Natural Gas and Renewables have replaced coal power, helping to reduce CO2 from electric generation. Overall source emissions have dropped by 16% in the last decade.

Source: https://www.eia.gov/tools/faqs/faq.php?id=75&t=11

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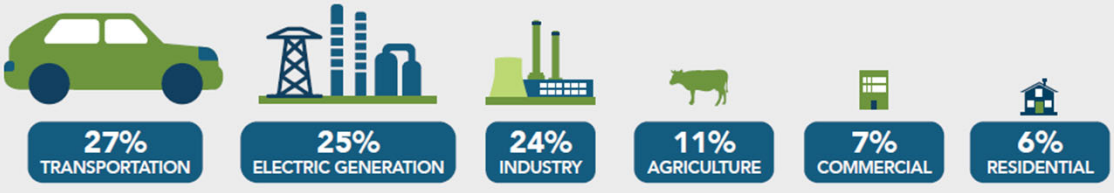
GHG Emissions

GREENHOUSE GAS EMISSIONS BY SECTOR

75% of greenhouse gas emissions in the United States comes from the transportation, electricity generation, and industrial sectors, with the rest coming from agricultural operations and commercial and residential buildings. Plus, over half of energy consumption in U.S. households is used for space heating and cooling.[3]



Total U.S. Greenhouse Gas Emissions by Economic Sector in 2020

3. U.S. EIA, Use of Energy Explained, 2021

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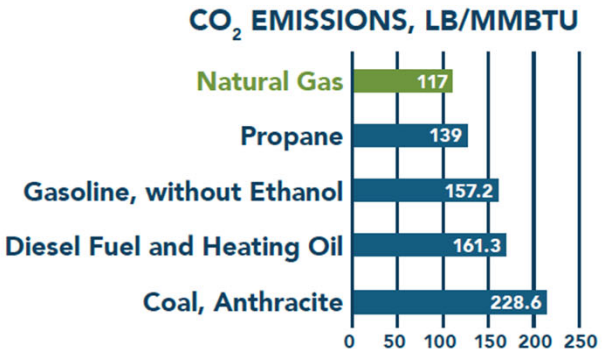
Natural Gas has Lowest Carbon Footprint of any Fossil Fuel

CO_2 CARBON CONTENT OF DIFFERENT FUEL SOURCES

The carbon intensity (i.e., the amount of CO_2 emitted per unit of energy consumed) of natural gas is lower than all other fossil fuels.[1] The fact that natural gas has replaced coal as the top fuel in the U.S. electricity sector is one of the main reasons why this sector has been able to reduce its emissions over the last 10 years.[2] Natural gas vehicles have reduced carbon emissions in the transportation sector.



Source: EIA, Carbon Dioxide Emissions Coefficients

2. U.S. EPA, Sources of Greenhouse Gas Emissions, 2022

Electric eGRID 2023: U.S. Total output = 852,300 LB/MWh.
852,300 LB/MWh / 3,412 MMBTU/MWh = **249.8 LB/MMBTU**

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Natural Gas Lowers Carbon Emissions in Many Ways

UPGRADED NATURAL GAS PIPELINES REDUCE EMISSIONS BY 73%[4]

- Better systems management[3]
- Diligent preventative maintenance
- Enhanced leak detection repair

NATURAL GAS HEAT PUMPS ARE RELIABLE AND EFFICIENT

- Efficiency and savings in moderate climates
- Added performance during very cold weather
- Extract heat from air, ground, or water sources

BIOGAS REFINING CONVERTS METHANE INTO CARBON-NEUTRAL RENEWABLE ENERGY[5]

- The capture of biomethane at wastewater treatment plants, agricultural waste, waste processing facilities and landfills, prevents methane release into the environment.
- Displacing carbon emitting gas with carbon neutral gas significantly lowers greenhouse gas emissions.

DIRECT CONSUMPTION OF NATURAL GAS IS 92% EFFICIENT

- According to the American Gas Association, the direct use of natural gas is more efficient than consuming gas-fired electricity from the grid.
- Direct use of natural gas for heating, cooling, water heating, cooking, and clothes drying cuts carbon emissions by almost 50%.[6]

4 aga.org/news/news-releases/gas-utilities-support-methane-reduction-innovations/ 5 https://gasfoundation.org/wp-content/uploads/2019/12/AGA_3894-RNG-2-Pager_V-11.pdf

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Renewable Natural Gas & Hydrogen Help Reduce Emissions

RENEWABLE

Natural Gas Reduces Carbon Emissions

The capture of biomethane prevents methane from being released into the environment.

Displacing carbon emitting gas with carbon neutral gas significantly lowers total greenhouse gas emissions.[7]

95% OF HYDROGEN

Is Produced From Natural Gas

In the United States, 95% of hydrogen is produced by natural gas reforming in large central plants.[8] The hydrogen production process, delivery and storage, and fuel cell electric vehicles reduce total greenhouse emissions by 50% compared to gasoline vehicles.

More and more waste streams are being identified to produce RNG. New methods to extract H2 from Natural Gas are cleaner and produce Blue or Turquoise Hydrogen.

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

Renewable Natural Gas Could Replace a Significant Portion of Conventional Gas, Reducing the Overall Gas System Carbon Footprint

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 RNG:

1. Anaerobic digestion uses microbes to break down organic matter and converts the resulting organic acids into methane gas.

2. Thermal gasification is a high-temperature process that completely dries biomass, converting it into gas and char.

3. Power-to-gas technologies use electrolysis to convert renewable electricity into hydrogen or methane for natural gas pipeline injection.

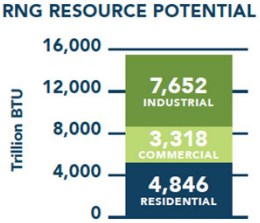
IMPACT OF RENEWABLE NATURAL GAS

RNG is interchangeable with conventional natural gas and can be used in residential, commercial, industrial and transportation applications. Use of RNG can make meaningful progress toward decarbonization.

RNG production could be enough to cover 59% of industrial or 93% of residential natural gas demand.[3]

3. American Gas Foundation, Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment, 2019

RNG RESOURCE POTENTIAL



Up to 30% Hydrogen can be Blended into the Gas System

PRODUCING HYDROGEN

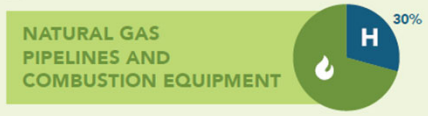
Hydrogen can be produced in several ways. The two most common methods include:

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.[1]

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

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.[2]



1. Florence School of Regulation, Hydrogen in the Energy Transition, 2020
2. U.S. DOE, HyBlend: Opportunities for Hydrogen Blending in Natural Gas Pipelines, 2021

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Carbon Offsets & Carbon Capture Reduce our Carbon Footprint

WHAT ARE CARBON OFFSETS?[2]

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.

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

ADVANCEMENTS IN CARBON CAPTURE AND SEQUESTRATION TECHNOLOGY

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.

- Geologic Sequestration
- Biologic Sequestration
- Commercial Applications
- Flue Gas Conversion

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Benefits of Natural Gas Technologies

Natural gas appliances are preferred by consumers for their comfort, convenience, lifestyle, environmental and cost savings

Lots of Natural Gas Water Heating Options to Choose From

Atmospheric Storage

Boiler

Tankless

Booster Water Heater

Solar/Gas Hybrid

High Efficiency Storage

Direct Contact

Fire-Tube Condensing

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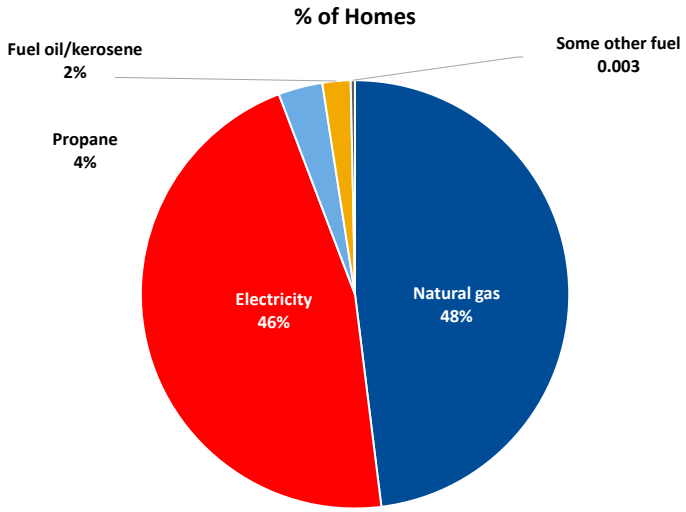
Almost ½ of Homes Use Gas as Their Primary Energy to Make Hot Water



Residential Energy Consumption Survey (RECS)

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Residential Gas Water Heaters have a Low Life Cycle Cost

Life Cycle Cost	Electric Tank	Gas Tank (Power Vent)	Gas Tankless (Standard)	Gas Tankless (Condensing)
Installed Cost – Year 1	$ 750	$ 1,200	$ 1,800	$ 2,500
Tank Replacement – After Yr 12	$ 750	$ 1,200	$ 0	$ 0
Operating Costs – Year 1	$ 574	$ 238	$ 195	$ 166
12 Year Life Cycle Cost	**$ 8,030**	**$ 4,056**	**$ 4,140**	**$ 4,492**
24 Year Life Cycle Cost	**$ 16,983**	**$ 8,112**	**$ 6,480**	**$ 6,484**

Assumes that electric prices increase at 1% per year and that gas prices hold stable for the foreseeable future.

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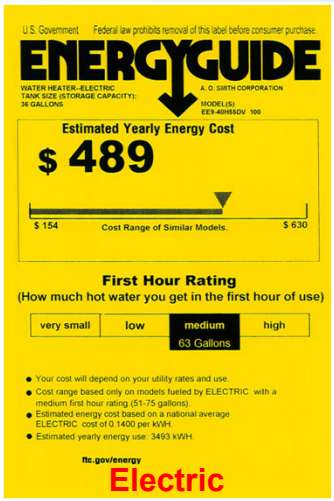
Tank Water Heater Comparison from the Label



- **Gas Benefits:**
- Save Money: $210/Year to operate on gas versus $489 for Electric
- Higher First Hour Rating with 68 gallons of hot water compared to 63 gallons with electric.
- Much faster recovery time from cold shower to recharged. From specifications for each water heater, the gas model recovers at a rate of 42 GPH at 90 Deg F versus just 25 GPH for the electric model.

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Lowes.com, AO Smith Signature 300 Series 40-Gallon Gas & Electric Tank Water Heaters

Improvements & Intelligence for Tank Water Heaters Add Convenience and Save Energy

Microprocessor controls
Tank maintains consistent temperatures

Integrated mixing devices
Allows for storage of hotter water – increasing amount of usable hot water available

Set back controllers
Similar to programmable thermostat

Leak detection devices
Shuts off water if tank leak is detected

Atmospheric flue dampers
Reduces standby losses

Drain water heat recovery

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Residential Gas Water Heating Has Lowest Carbon Emissions

Water Heating Carbon Footprint for family of 3

Water Heater Type	CO_2 #/Year
Electric Tank, .90 EF	4,128
Gas Tank, .62 EF	2,641
Gas Tankless, .82 EF	2,047

Residential Energy Calculator

ESC Energy Solutions Center

Use this calculator to compare natural gas versus other fuels and discover the environmental advantages of using natural gas in your home. Disclaimer

1 Home Information

Home Information

Please provide information about your home. This information is used for all future energy calculations. You will have the ability to return to this page on future steps.

ESC https://esc.energydepot.com/user-information/home

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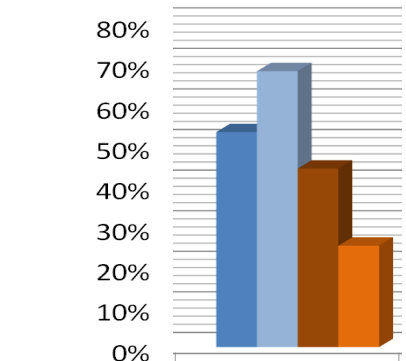
Homeowners Prefer Gas Water Heating

- National Survey of New Home Buyers
- Customers prefer gas water heating:
  - 68% of homebuyers prefer gas water heaters
  - Only 25% want electric



	Water Heating
Current Gas	53%
Preferred Gas	68%
Current Electric	44%
Preferred Electric	25%

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Woodland, O'Brien & Scott

"Customer Preference Study" conducted by Woodland, O'Brien & Scott

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Benefits of Natural Gas Water Heating

- Uses less energy – costing about ½ as much to operate versus electric
- Recovery time is much faster
- First hour rating for tank models is higher with gas
- Style and sizes to fit most installations
- Tankless – Never run out of hot water
- High efficiency options available
- Long life – 20 years or more with tankless

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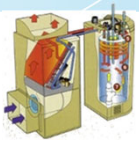
Many Natural Gas Space Heat Options


Warm Air Furnace


PTAC


Wall Hung Boiler


Thru the Wall Furnaces


Combo System Space and Water Heat


Gas Baseboard

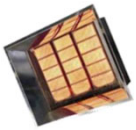

Wall Furnace


Floor Furnace


Heat Pumps


Make Up Air Systems


Boilers


Infrared


Unit Heaters

Rooftop Systems

Combine w/ Hydronic Floor Heating

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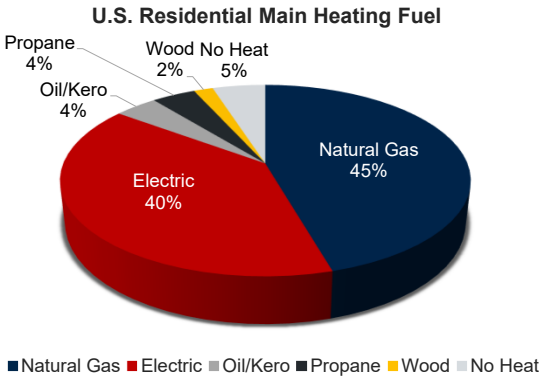
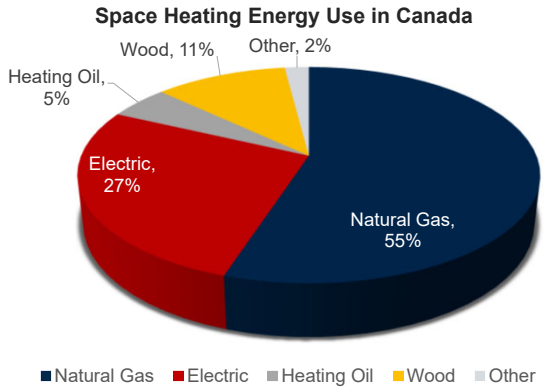
On Average, ~½ of North American Homes Heat with Natural Gas



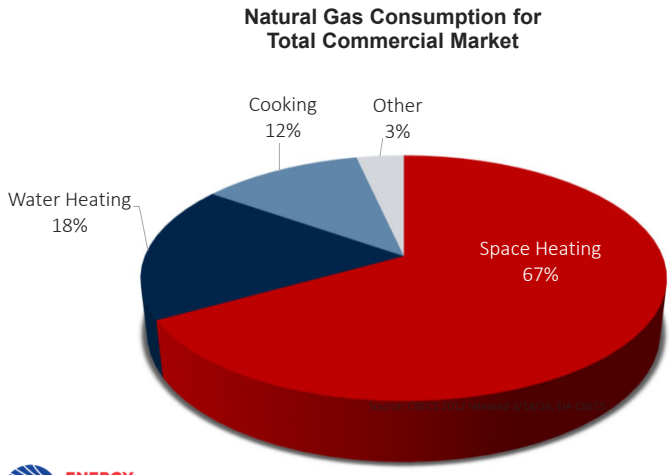
Source: 2020 Residential Energy Consumption Survey, Table Hc6.1
https://www.eia.gov/consumption/residential/data/2020/hc/pdf/HC%206.1.pdf

https://www.eia.gov/totalenergy/data/annual/#summary , Table 1.3 & 2.1f(2.6)



Source: Natural Resources Canada – Energy Fact Book 2022-2023
https://publications.gc.ca/collections/collection_2022/rncan-nrcan/M136-1-2022-eng.pdf

Commercial Market Gas Consumption



The commercial sector typically uses natural gas as its energy source for space heating and hot water heating. Commercial buildings seeking energy savings and reductions in electric demand have also been using natural gas air conditioning systems for many years.

EIA, CBECS

Save CO^2 and $$$ with Gas Heat

- Average U.S. 2,000 Sq Ft home
- EIA average retail energy prices of $9.30/MMBTU and $.13/KWH

	Natural Gas		Electric		
	80% Furnace	92% Furnace	8.7 HSPF Heat Pump	10 HSPF heat Pump	Electric Strip heat
#'s of CO^2/Year (All Generation Sources)	7,260	6,313	15,589	14,106	24,672
#'s of CO^2/Year (Fossil Mix)	7,260	6,313	22,075	19,976	34,938
Energy Cost ($/Year)	$577	$543	$973	$816	$1,781

ESC https://esc.energydepot.com/user-information/home

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Natural Gas Space Heat Benefits

- Save Money over Electric, Oil, Propane Heat
- Faster Warm Up compared to Electric Heat
- Cleaner – Reduced Emissions
- Furnace feels warm and comfortable opposed to cold and drafty
- No Prepayment or waiting for Oil/Propane Deliveries with Gas Heat

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Gas Heat Pumps (GHP) Provide High Efficiency Heat

Absorption Heat Pump

Engine Driven Heat Pump

Thermal Compression Heat Pump

Heat Pump
Water Heater

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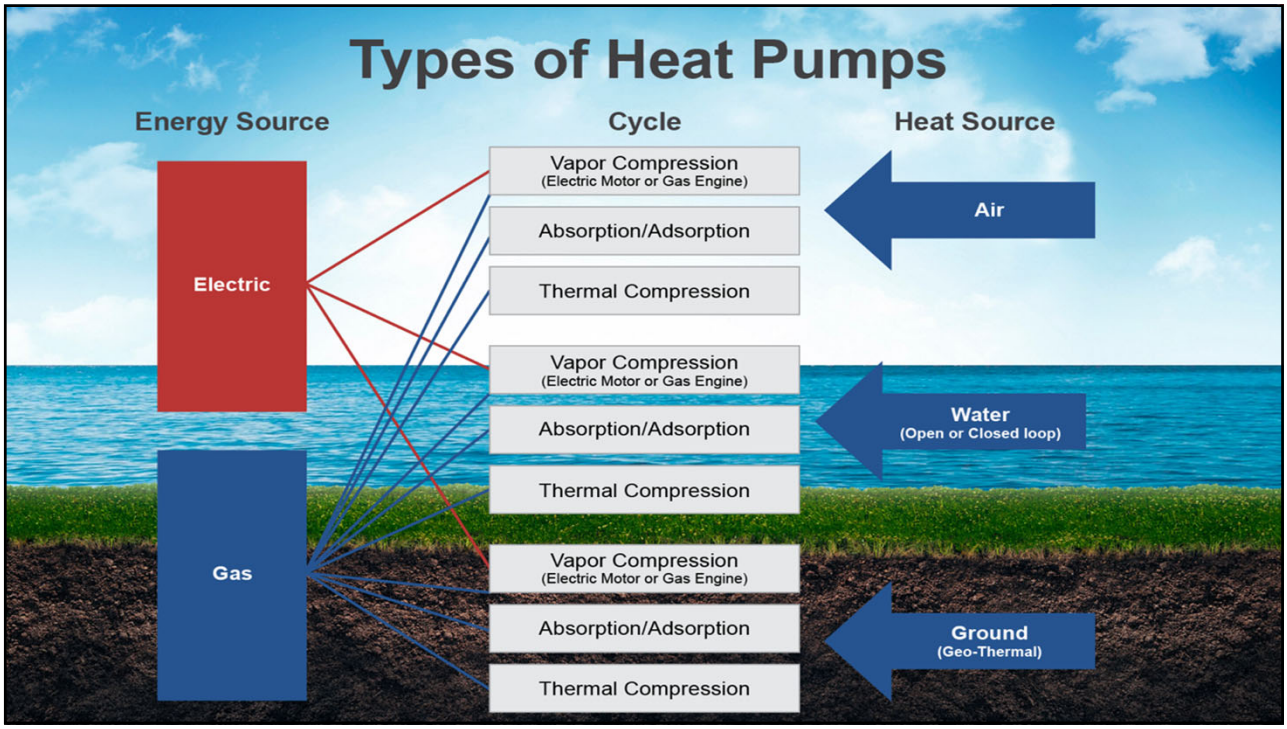
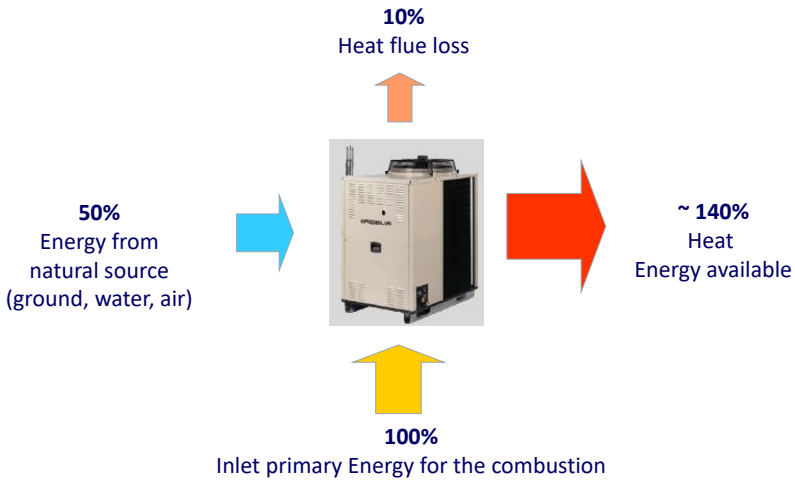


Break the >100% Thermal Efficiency Barrier with a GHP



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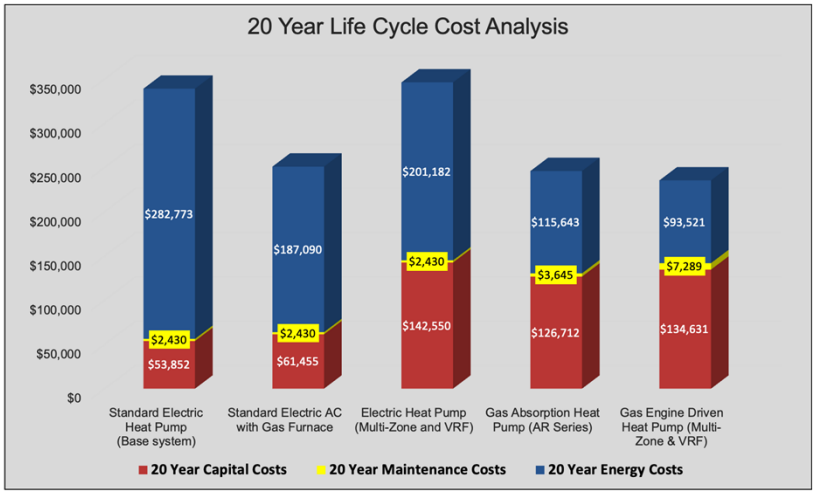
GHP Life Cycle Costs are Lower than Conventional Systems



Note: GHPs can cost 3X that of conventional HVAC systems, but generally have overall lower life cycle costs than conventional systems.

Assumptions: 20-ton system amortized over 20 years at 5% interest with $.17/kWh, $10/kW, and $.65/Therm energy rates, with 2% energy & maintenance inflation rates.

Note that life cycle costs will vary based on energy rates in your region.

https://gasairconditioning.com/general-resources/tools/

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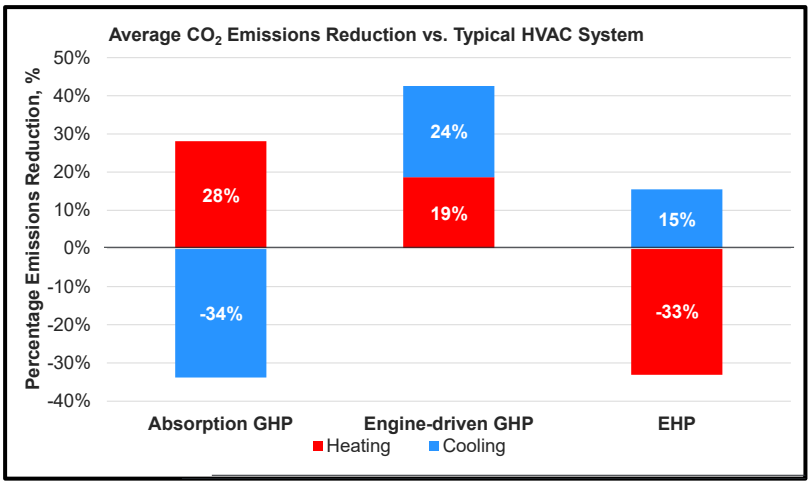
Lifetime Emissions for Gas and Electric Heat Pumps at Commercial Buildings

Baseline is RTU with gas heat & electric cooling.



Source: https://consortia.myescenter.com/GHP/ESC_GHP_Operating_Costs-Emissions-Study-ICF-August2021-Full.pdf

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Gas Heat Pump Benefits

- Save Money
  - ~140% efficient heating
  - Gas cooling
  - Lowest Life Cycle Costs
- Reduced CO2 compared to conventional systems
- Work well in cold climates
- Can obtain much higher efficiencies if simultaneous heating and cooling are needed

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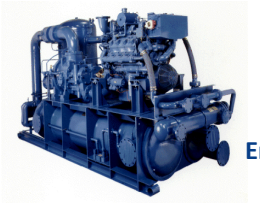
Natural Gas Cooling Options

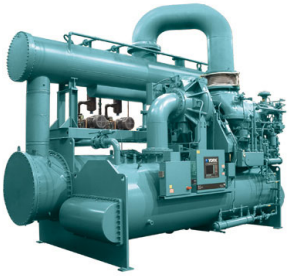
Absorption Chillers

Heat Pumps



Engine Driven Chillers

Steam Turbine Driven Chiller



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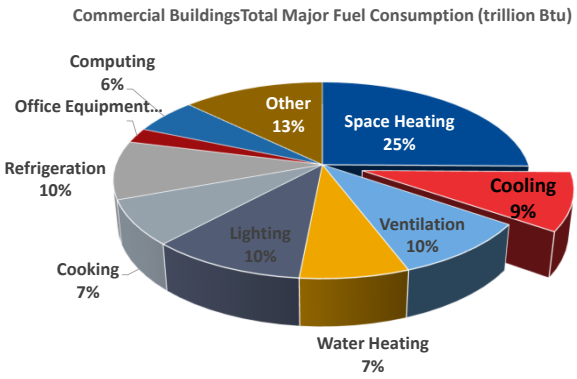
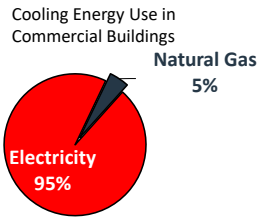
Plenty of Opportunities for Gas Cooling in the Commercial Market





Cooling accounts for 656 Trillion BTU's of energy per year consumed by commercial buildings.

ESC

Source: EIA CBECS Table 5

Natural Gas Cooling Benefits

- Saves Money
- Reduces Electric KW and Demand Charges During Hot Summer Months
- Reduces Emissions
- Lower Cost – Life Cycle Cost Analysis
- Can Reduce Back-Up Generator Size
- Can be coupled to CHP systems

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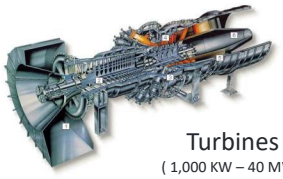
Improve Source Efficiency with Combined Heat & Power

Power Generation Equipment Options

Reciprocating Engines
(5 KW - 8 MW)

Micro – Turbines
(65 – 250 KW)



Turbines
(1,000 KW – 40 MW)

Fuel Cells
(10 – 200 KW)

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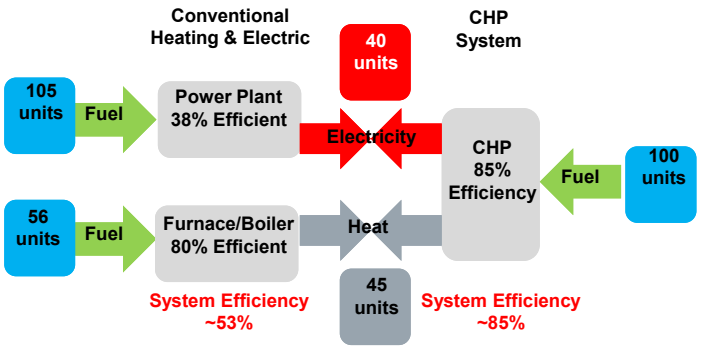
CHP is more Efficient Than Grid Power & Gas Heat



Compared to purchasing electric from the grid and producing heat with a furnace or boiler for the home or business, CHP is much more efficient.

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Life Cycle Cost Tool: Assumptions & Simple Payback

Combined Heat & Power (CHP) Simple Payback Analysis
Use this tool to review various CHP equipment simple payback options. FOR MORE INFORMATION VISIT OUR WEBSITE

Company/Customer Name		Facility/Site Location	

User Inputs:

1. Size CHP Electric Generator (KW)	1,000	8. Ave. Electric Usage Rate ($/KWH)	$	0.14
2. Hours of Cogeneration (/Year)	8,600	9. Electric Demand Charge ($/KW)	$	10.00
3. Number of months generating power	12.00	10. Ave. Natural Gas Rate ($/MMBTU)	$	7.00
4. # Years CHP Plant will be Financed	20	11. Gas Rate for CHP ($/MMBTU)	$	6.00
5. Interest Rate on Loan for Installed Cost	5%	12. Please select Emissions Profile		US Average Fossil
6. Investment Tax Credit	30%	and state/province/region		US Average
7. CHP Incentive ($)	$ -	e-GRID Sub-Region Map		

	Recip. Engine	Micro Turbine	Gas Turbine	Fuel Cell
Simple Payback (Years)	2.2	2.1	2.7	4.3
CHP Size (KW)	1,000	1,000	1,000	1,000
Installed Cost	$2,837,000	$2,500,000	$3,281,000	$4,600,000
Federal CHP Investment Tax Credit	$851,100	$750,000	$984,300	$1,380,000
Cost Less CHP Incentive(s)	$1,985,900	$1,750,000	$2,296,700	$3,220,000
Ave. Annual Maintenance Cost	$180,600	$103,200	$108,360	$344,000
Power Produced (KWH)	8,600,000	8,600,000	8,600,000	8,600,000
Annual Electric Saved on Demand	$120,000	$120,000	$120,000	$120,000
Annual Electric Savings on Usage	$1,204,000	$1,204,000	$1,204,000	$1,204,000
Annual Gas Cost for Cogeneration	$510,294	$660,208	$735,581	$412,800
Recovered Heat (MMBTU/Year)	37,762	40,163	51,184	27,176
Annual Gas savings from waste heat use	$264,332	$281,139	$358,289	$190,232
Annual O&M cost CHP Plant	$690,894	$763,408	$843,941	$756,800
Electric and gas utility savings from CHP	$1,588,332	$1,605,139	$1,682,289	$1,514,232
Total Savings per year from CHP System	**$897,438**	**$841,730**	**$838,348**	**$757,432**

https://understandingchp.com/resources/payback-tool/

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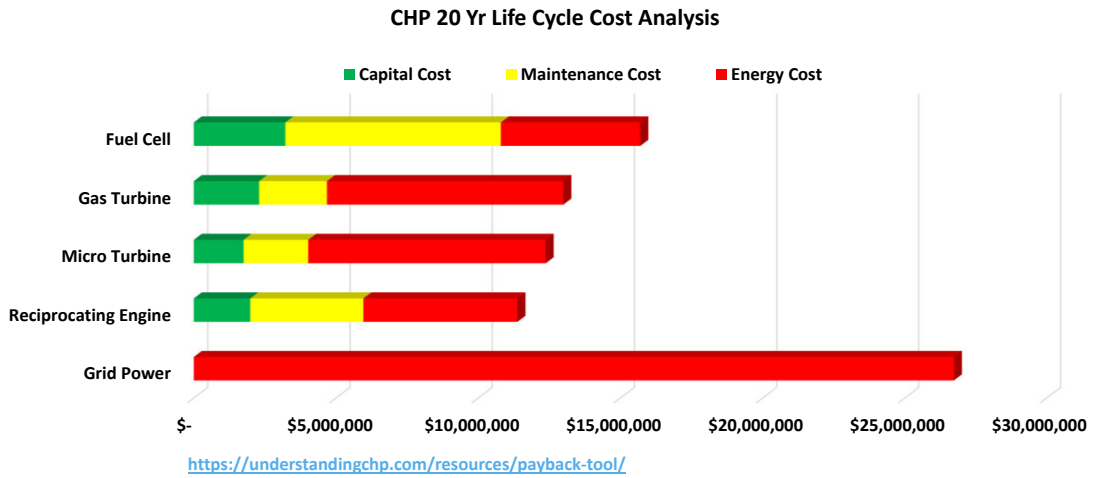
Gas CHP Systems Have Lowest Life Cycle Costs



https://understandingchp.com/resources/payback-tool/

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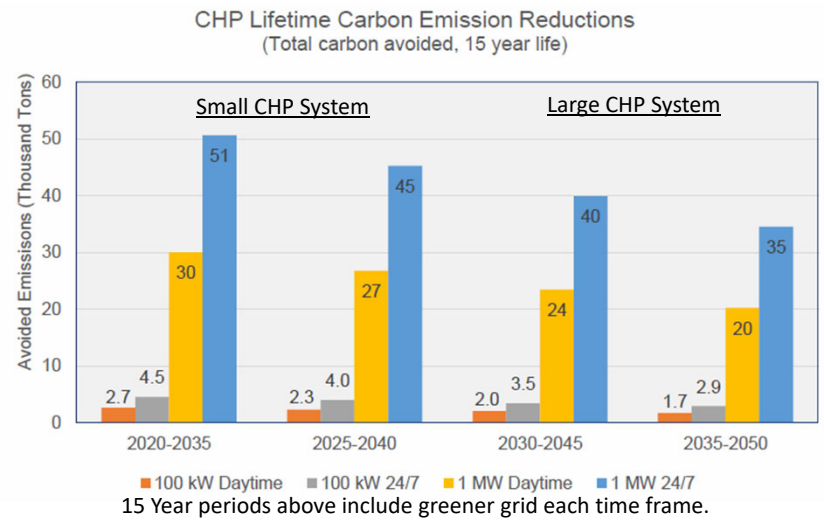
CHP Carbon Emission Reductions (Thousand Tons) Over System Life, Compared to Average U.S. Marginal Grid Emissions



15 Year periods above include greener grid each time frame.

Combined Heat and Power Potential for Carbon Emission Reductions, ICF, July 2020

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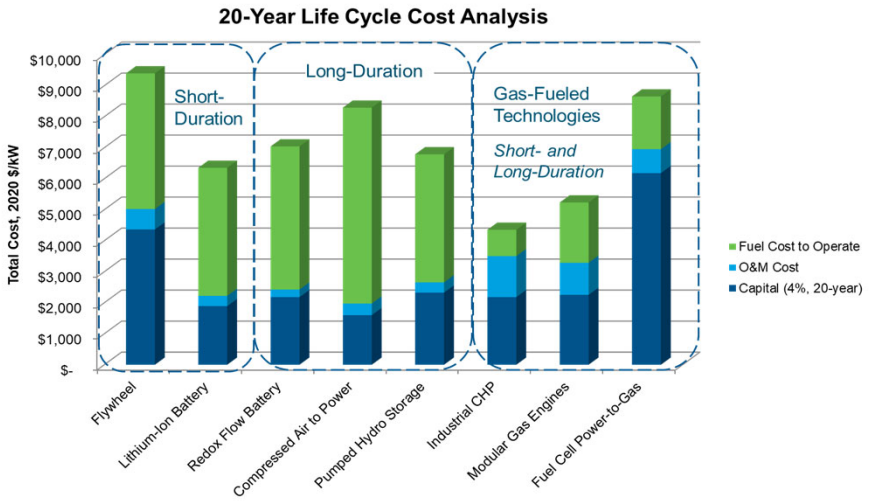
CHP and Gas Power Gen have lowest Life Cycle Cost of any Electric Storage System



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Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF, September 2020

Combined Heat & Power Benefits

- More Efficient Use of Energy
- Reduced Emissions
- Reduced Energy Costs – Lowest Life Cycle Costs
- Improved reliability and resiliency
- Not Reliant on Electric Power Grid

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Natural Gas Humidifiers

- Natural Gas Humidification
  - Natural gas humidifiers add moisture to dry air
  - Natural gas burners boil water to steam and deliver humidity via air handler or blower
  - Minimizes steam pressure
  - Eliminates boiler chemicals
  - Can be used in conjunction with existing boiler

Gas Humidifiers are designed to handle scale build up with daily cleaning and purge cycles

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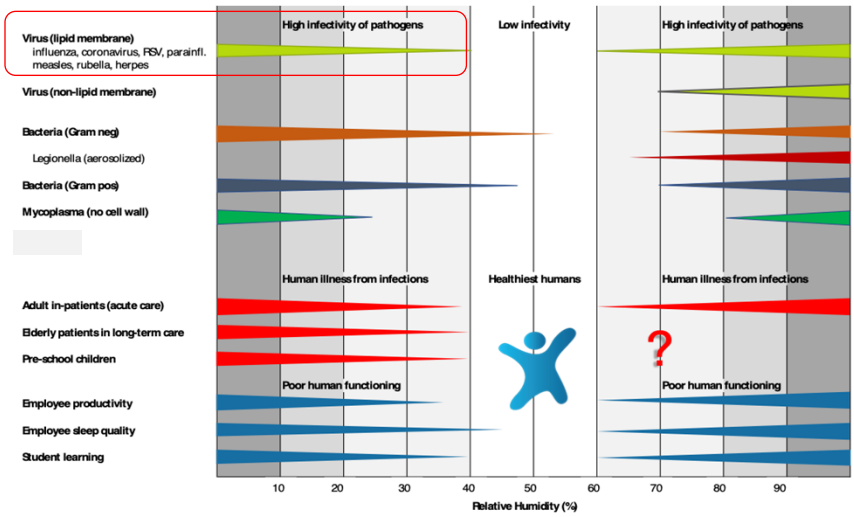
Gas Humidification Helps Reduce the Spread of Viruses, etc.



Taylor Chart 2019, Condair Presentation, Feb 2021 TMAF

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NGVs Produce Much Fewer Emissions

Heavy Trucks

Transit Buses

Taxi & Delivery

Light Duty Personal Vehicles

Garbage Trucks

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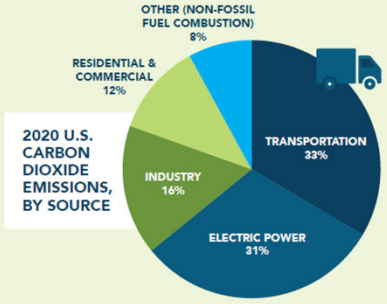
Natural Gas Vehicles

EMISSIONS BENEFITS OF NATURAL GAS VEHICLES (NGV)

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.



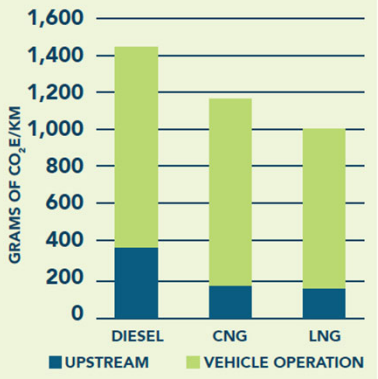
2020 U.S. CARBON DIOXIDE EMISSIONS, BY SOURCE

Source: https://www.epa.gov/ghgemissions/overview-greenhouse-gases

U.S. TRANSPORTATION SECTOR IS THE LARGEST SOURCE OF GREEN HOUSE GAS EMISSIONS IN THE COUNTRY.

NGVS PRODUCE 21% TO 30% LESS CO_2 COMPARED TO DIESEL-FUELED VEHICLES.[3]

RENEWABLE NATURAL GAS (RNG) CAN REDUCE EMISSIONS EVEN FURTHER.



Source: Natural Gas Use in Transportation Roundtable, "Natural Gas Use in the Canadian Transportation Sector"

Summary: Benefits of Gas

- North American production outweighs consumption
- > 100 Years of Reserves in the U.S. and > 200 years in Canada
- Gas is less expensive than alternatives
- On a source basis, natural gas is more efficient than electricity
- Natural Gas is less prone to disruptions of service, and therefore, more resilient
- Gas is environmentally friendly
- Energy efficient natural gas technologies save money and emissions

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Thank you

Please consider taking the on-line test while course material is still fresh in your mind.

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