ENERGY SOLUTIONS CENTER

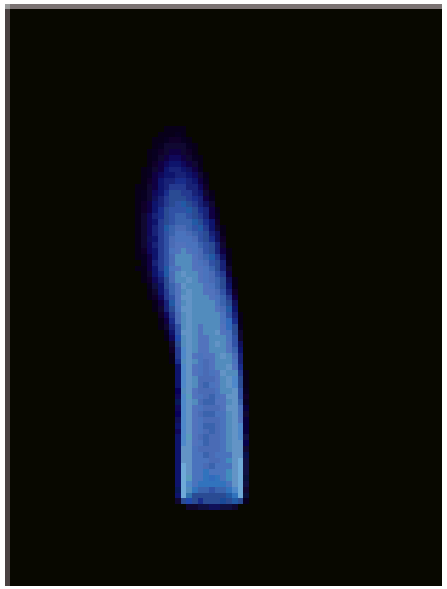
Energy Industry Fundamentals

Understanding Carbon Footprint

Eric Burgis, Energy Solutions Center

Presentation Outline

- What is a carbon Footprint and why should we be concerned?
- Electric Generation
- Measuring Carbon Footprint
- Reducing Carbon Footprint
- Direct Use of Natural Gas



Presentation note:
There are many differing views of how our carbon footprint may impact climate change, and varying views of what we need to do to reduce our carbon footprint.

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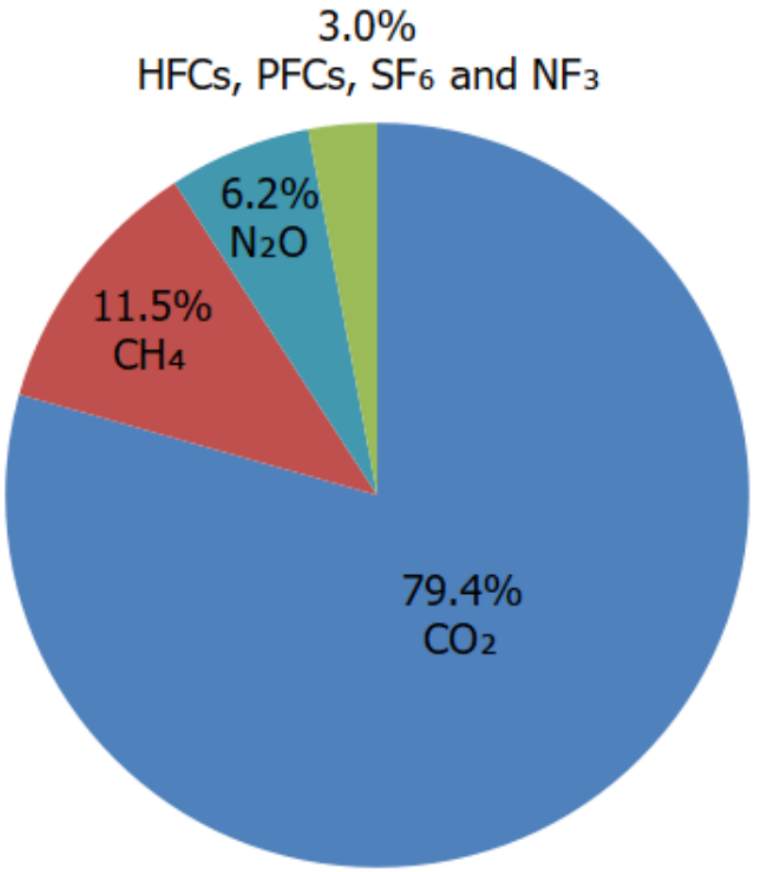
Carbon Footprint

What is a Carbon Footprint?

- A carbon footprint is a measure of the amount of greenhouse gases produced from human activities, usually measured in units of carbon dioxide (CO2).
- A carbon footprint quantifies the amount of emissions released by routine activities, such as generating electricity, driving, farming, and manufacturing.
- Calculating carbon footprints for individuals and businesses is critical to making informed decisions on how to reduce carbon emissions.

Greenhouse Gas Emissions by Gas



Total U.S. Emissions in 2021 = 6,340 Million Metric Tons of CO_2 equivalent

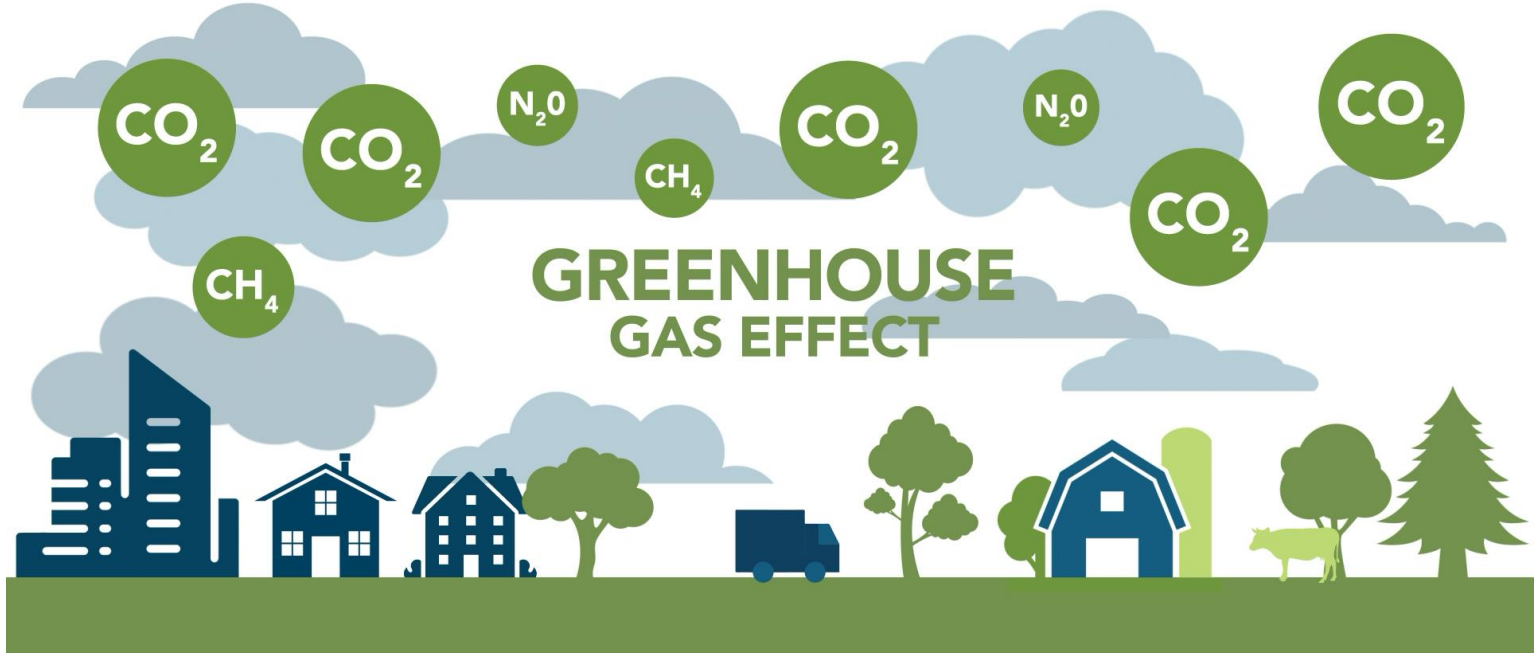
https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Global ~35 GTons CO2 per year

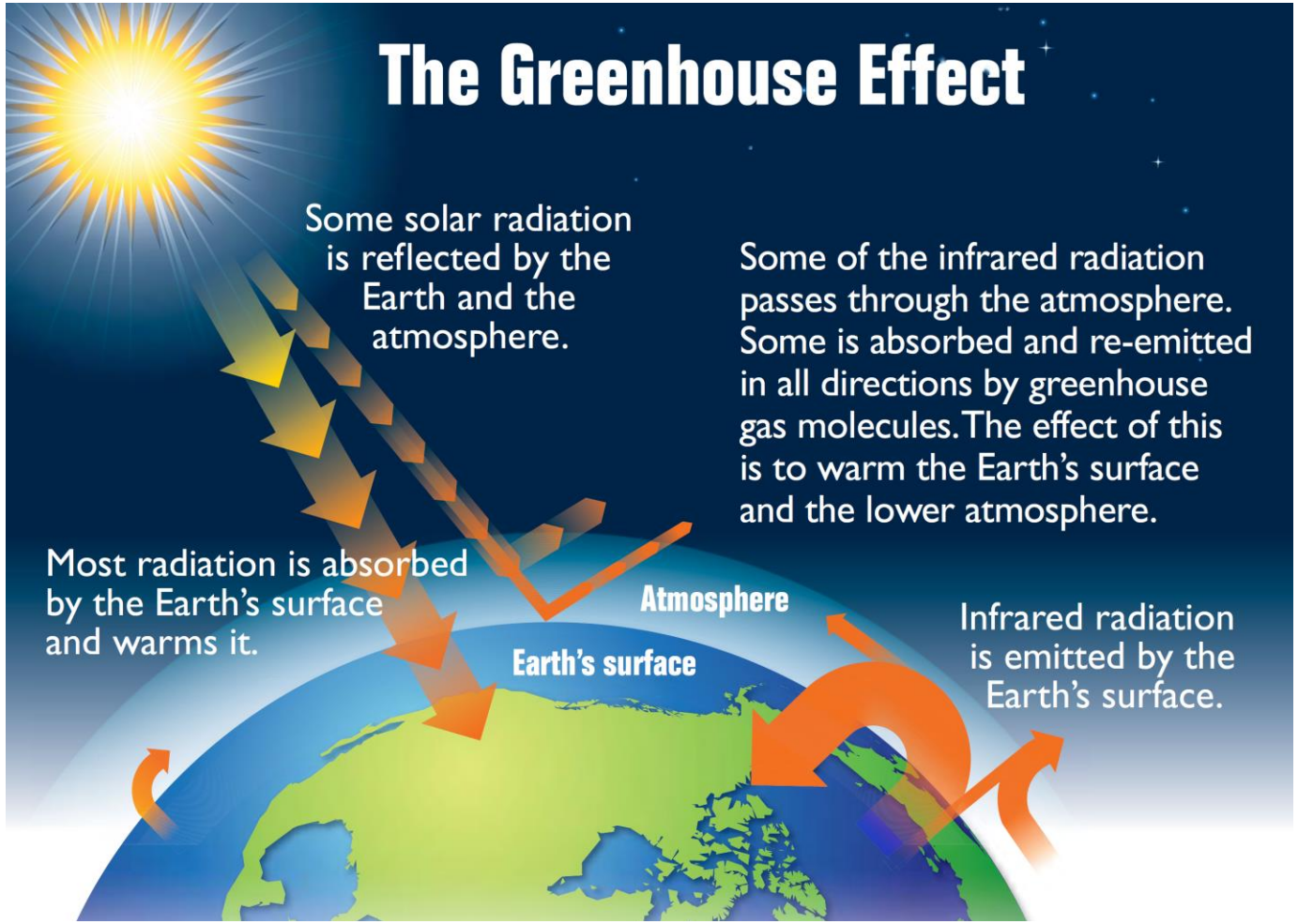
https://www.co2.earth/global-co2-emissions

The Greenhouse Effect

The greenhouse gas effect results from the presence of carbon dioxide, methane, nitrous oxide, and other greenhouse gases in our atmosphere.



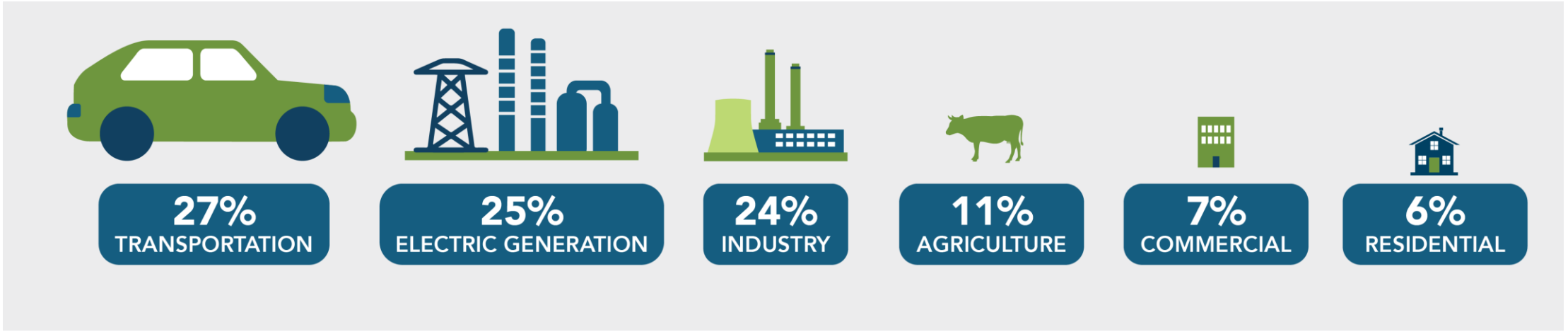
The Greenhouse Effect



- Greenhouse gases trap reflected solar radiation from the sun to insulate the earth and stabilize atmospheric temperatures.
- Increasing concentration of greenhouse gases from human activities has intensified the effect, resulting in more heat being trapped, higher average global temperatures, and climate destabilization.
- Two times more CO2 is being emitted than can be naturally sequestered.

Greenhouse Gas Emissions by Sector

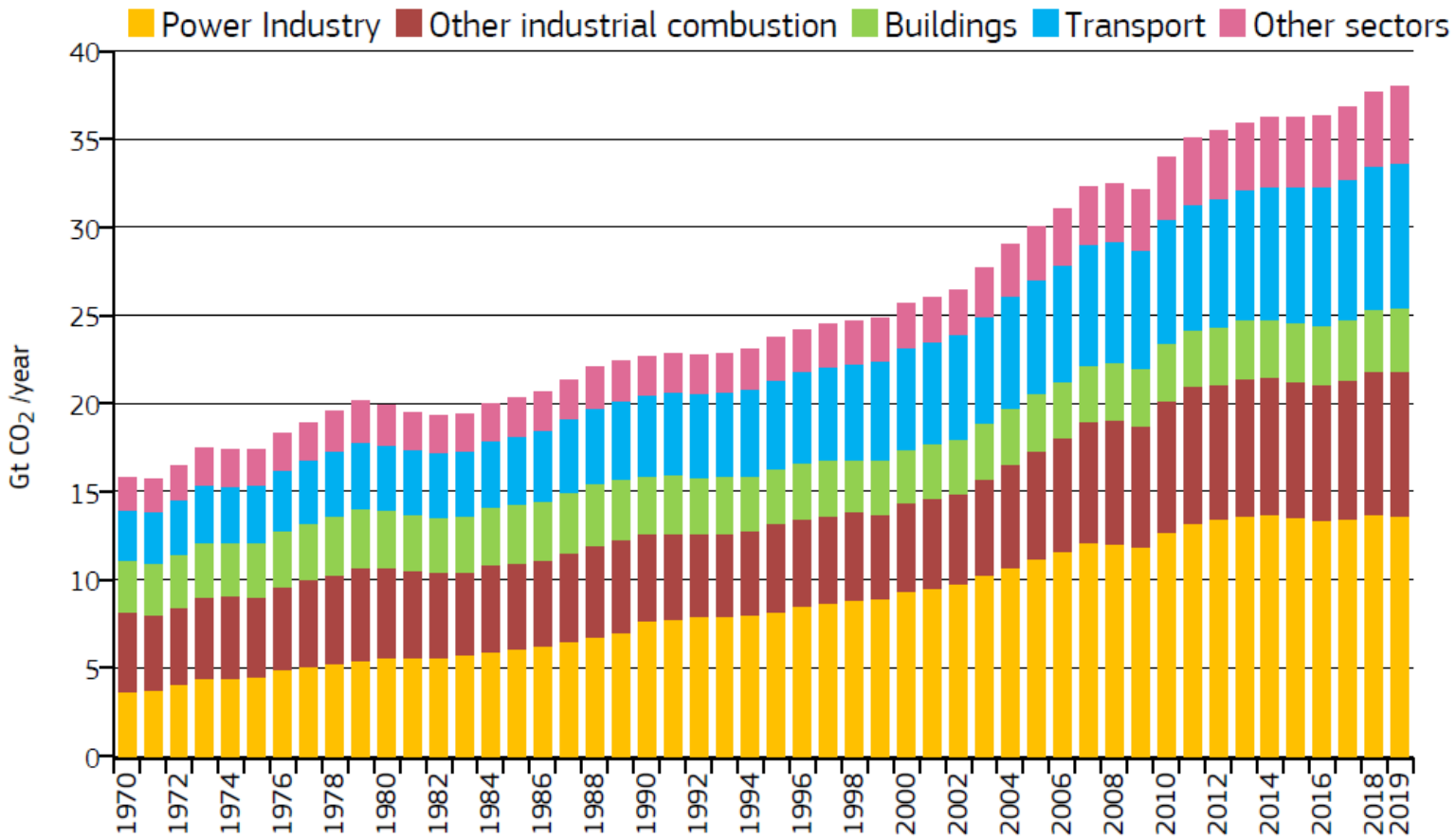
75% of greenhouse gas emissions in the United States comes from the transportation, electricity generation, and industrial sectors, with the rest coming from agricultural operations and commercial and residential buildings. Plus, over half of energy consumption in U.S. households is used for space heating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



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

Historic Global Fossil CO2 Emissions

Figure 2. Total global annual emissions of fossil CO_2 in Gt CO_2/yr by sector. Fossil CO_2 emissions include sources from fossil fuel use, industrial processes and product use (combustion, flaring, cement, steel, chemicals and urea).



Source: JRC, 2020.
Fossil CO2 and GHG emissions of all world countries - 2020 Report, https://edgar.jrc.ec.europa.eu/report_2020

The increase in CO2 has occurred over decades…

- Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities the past couple centuries and now far exceed pre-industrial values determined from ice cores spanning many thousands of years
- The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use changes
- Methane and nitrous oxides are primarily due to agricultural uses

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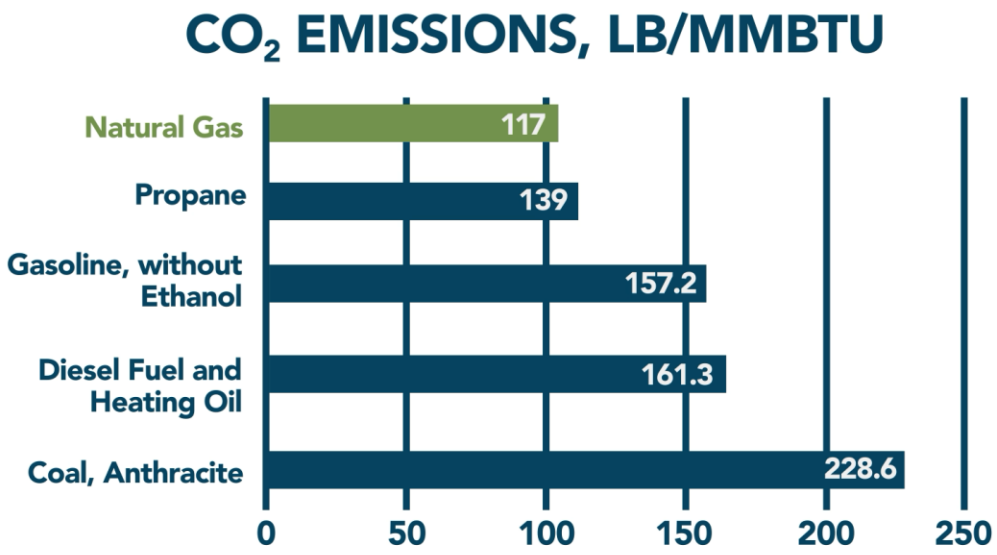
Carbon Content of Different Fuel Sources

- The carbon intensity (i.e., the amount of CO2 emitted per unit of energy consumed) of natural gas is lower than all other fossil fuels.
- 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.*



Source: EIA, Carbon Dioxide Emissions Coefficients

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

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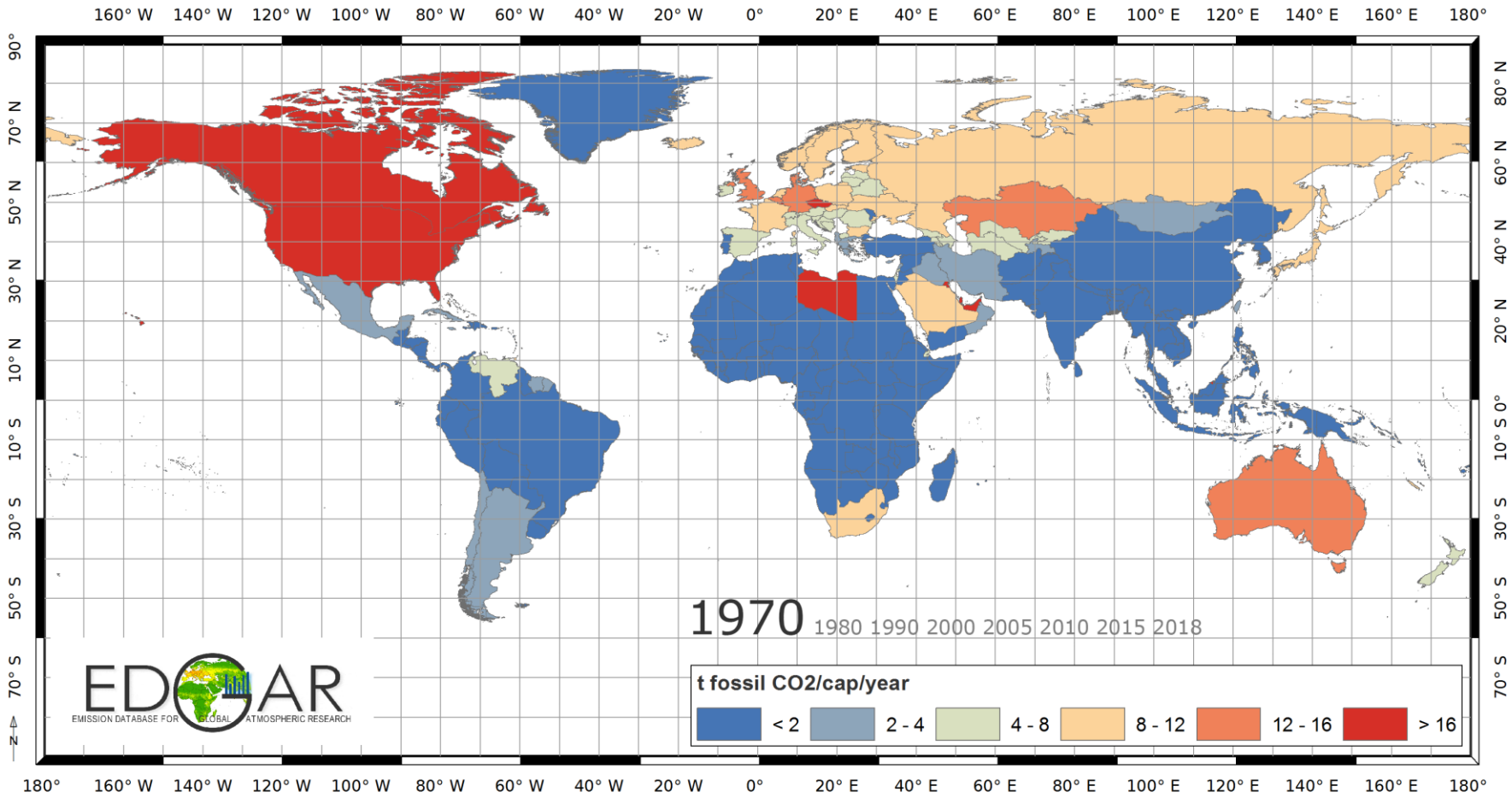
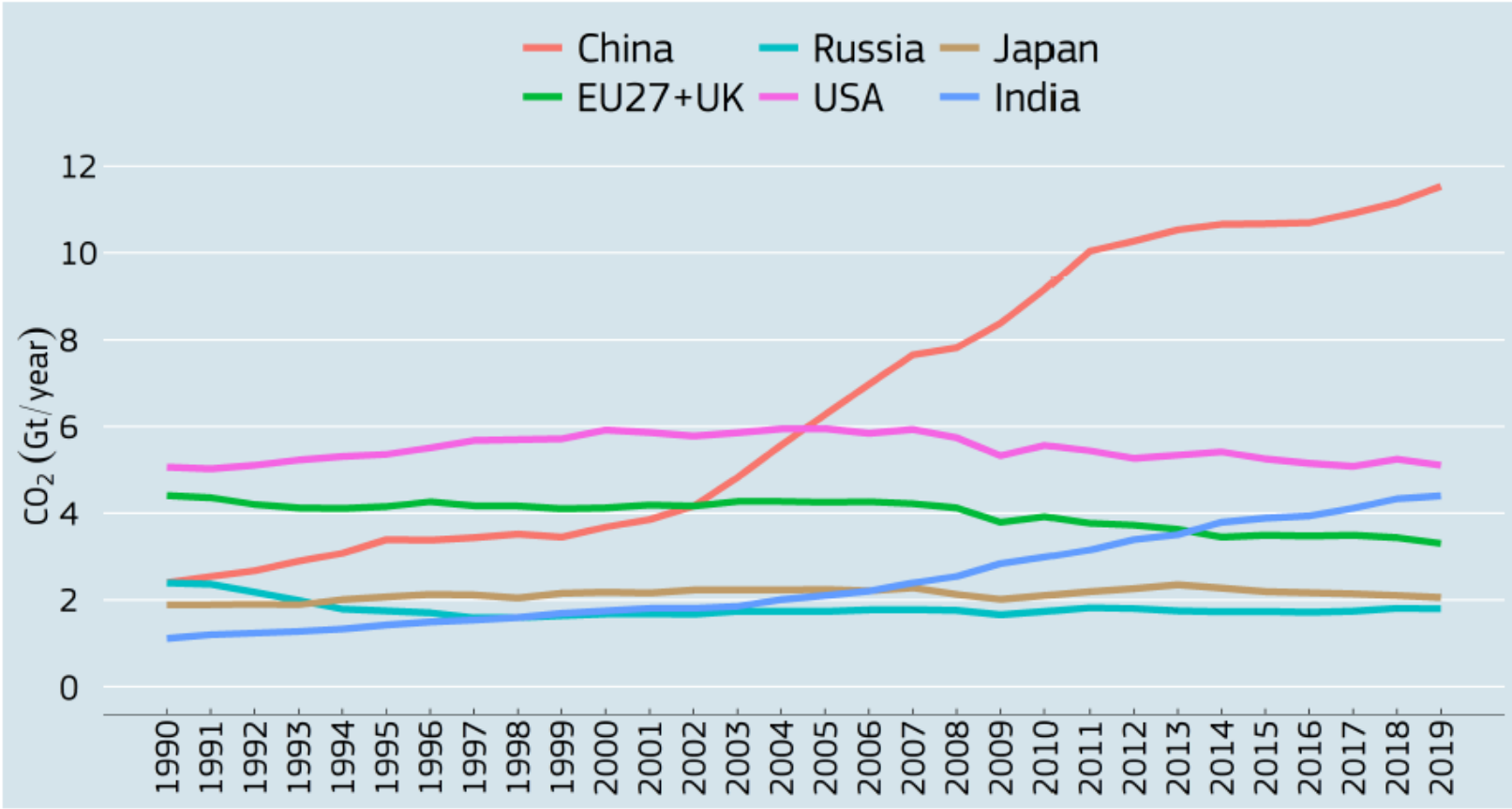
Historical Fossil CO2 Emissions by Country



https://edgar.jrc.ec.europa.eu/report_2020#data_download

Major CO2 Emitting Economies

Figure 1. Fossil CO_2 emissions of the major emitting economies.

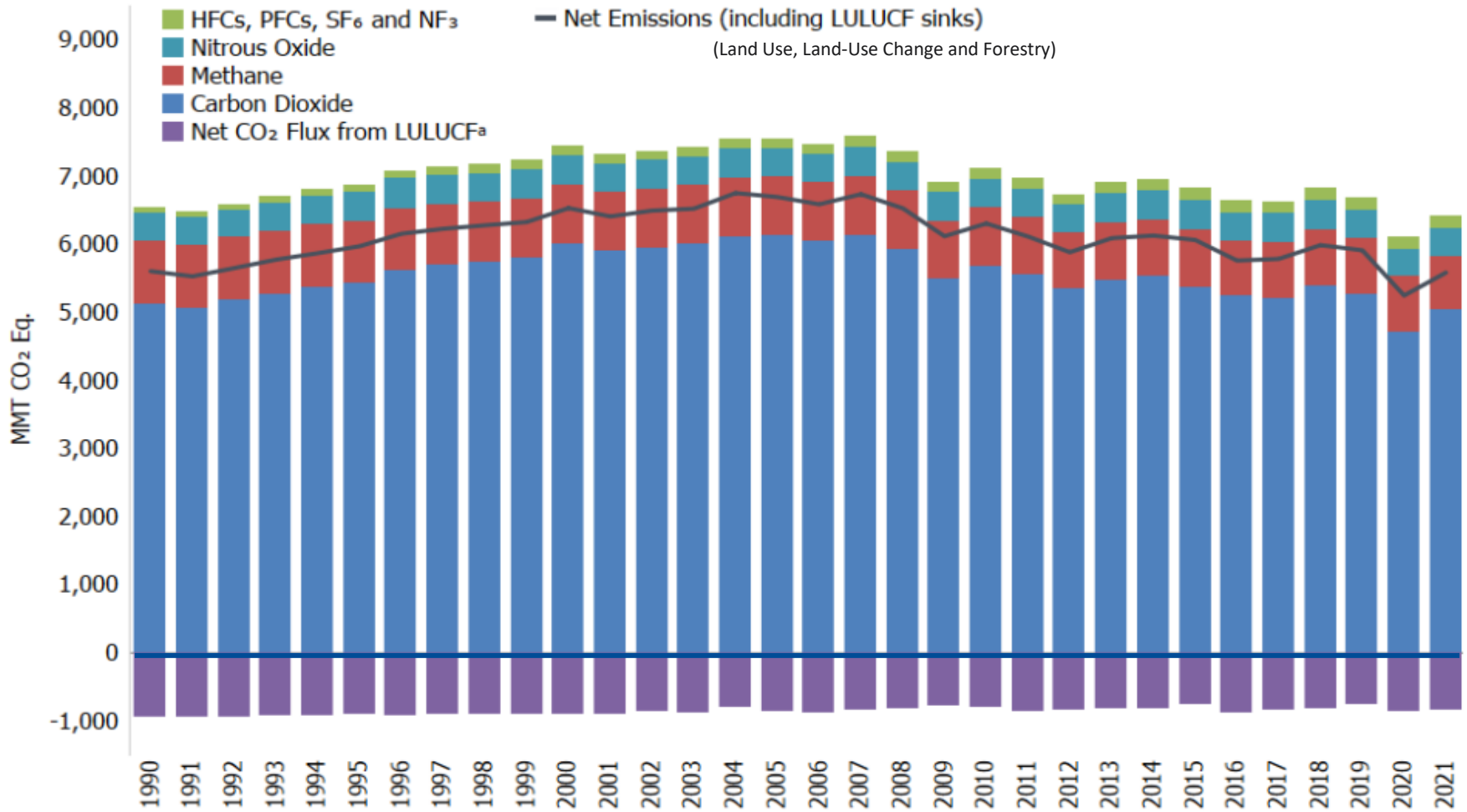


Source: JRC, 2020.

Fossil CO2 and GHG emissions of all world countries - 2020 Report, https://edgar.jrc.ec.europa.eu/report_2020

Greenhouse Gas Emissions & Sinks

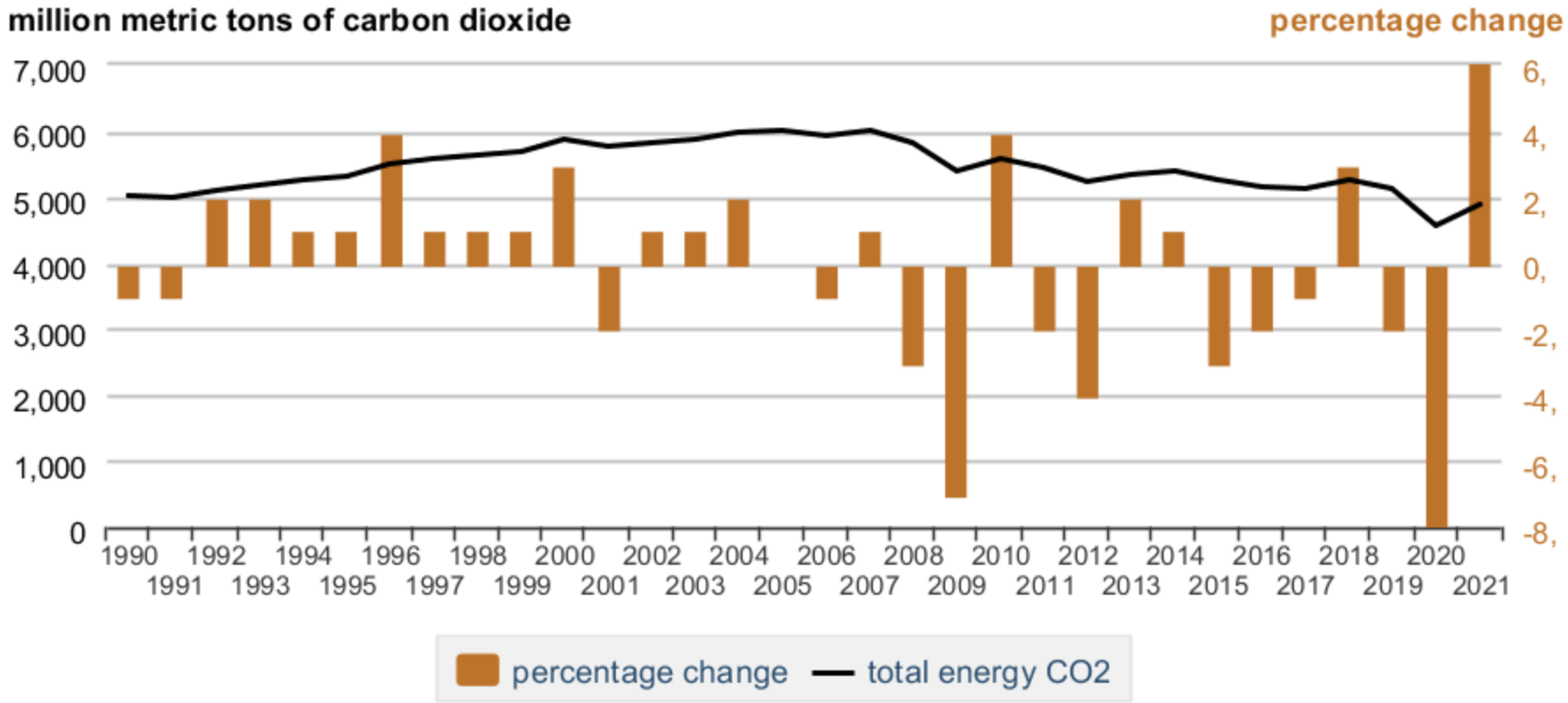
Figure ES-1: U.S. Greenhouse Gas Emissions and Sinks by Gas



Source: Page 39 of: https://www.epa.gov/system/files/documents/2023-04/US-GHG-Inventory-2023-Main-Text.pdf

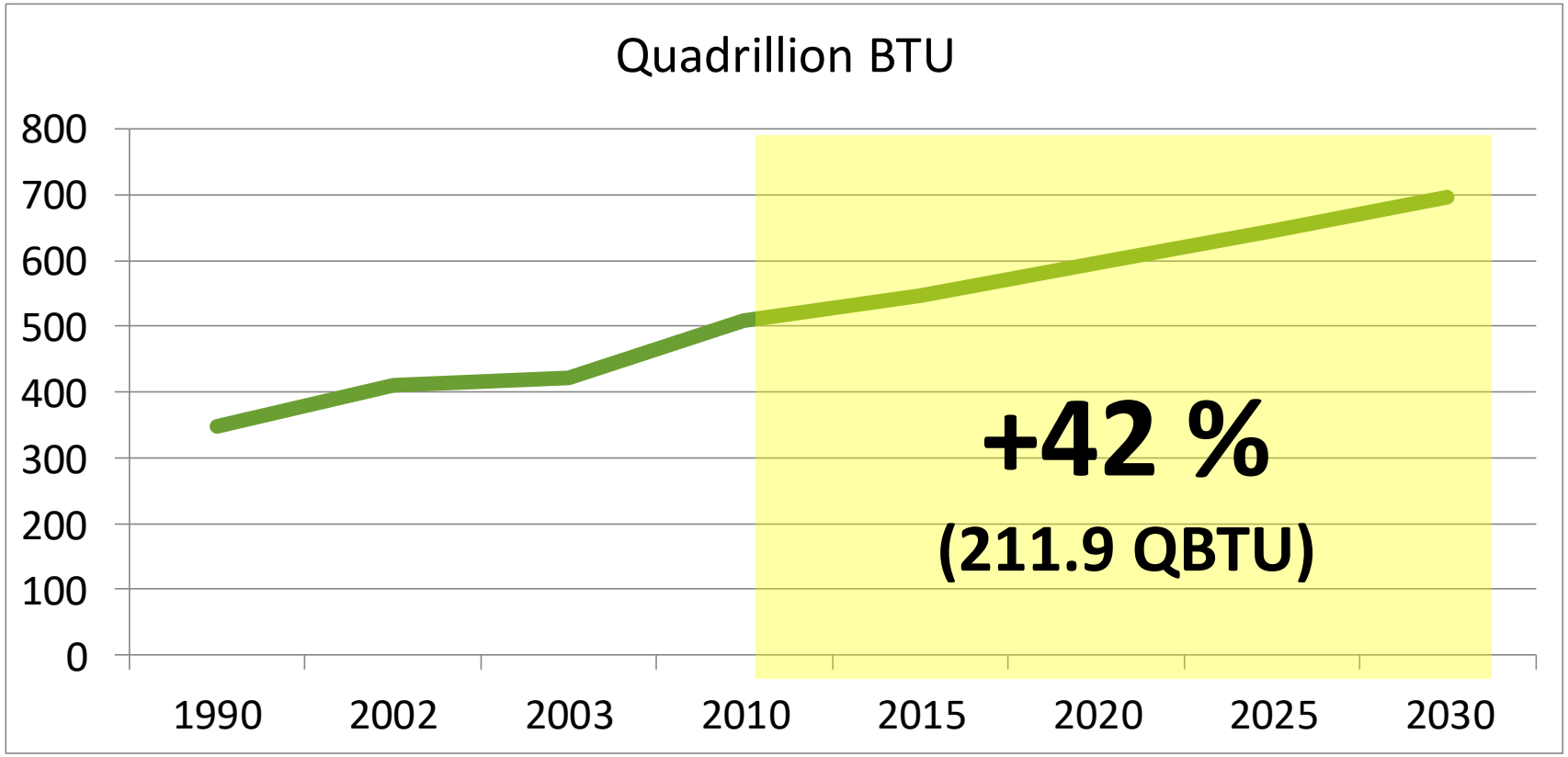
U.S. CO2 Emissions Declining

Figure 1. Annual emissions of and percentage change in energy-related carbon dioxide



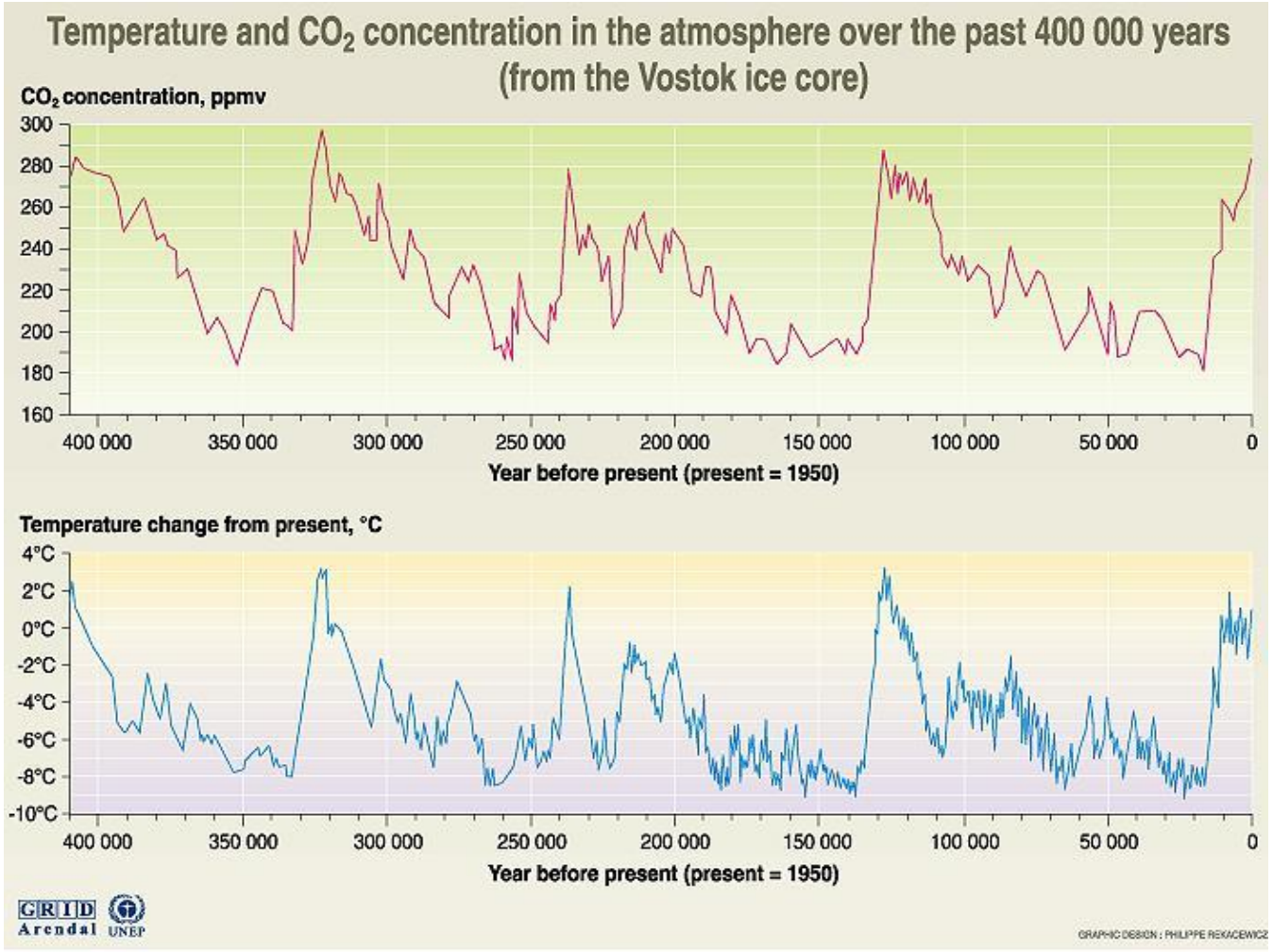
Data source: U.S. Energy Information Administration (EIA), *Monthly Energy Review*, October 2022, Table 11.1, Carbon Dioxide Emissions from Energy Consumption by Source

World Energy Consumption Projections



Source: Energy Information Administration - World Total Energy Consumption by Region, Reference Case, 1990-2030

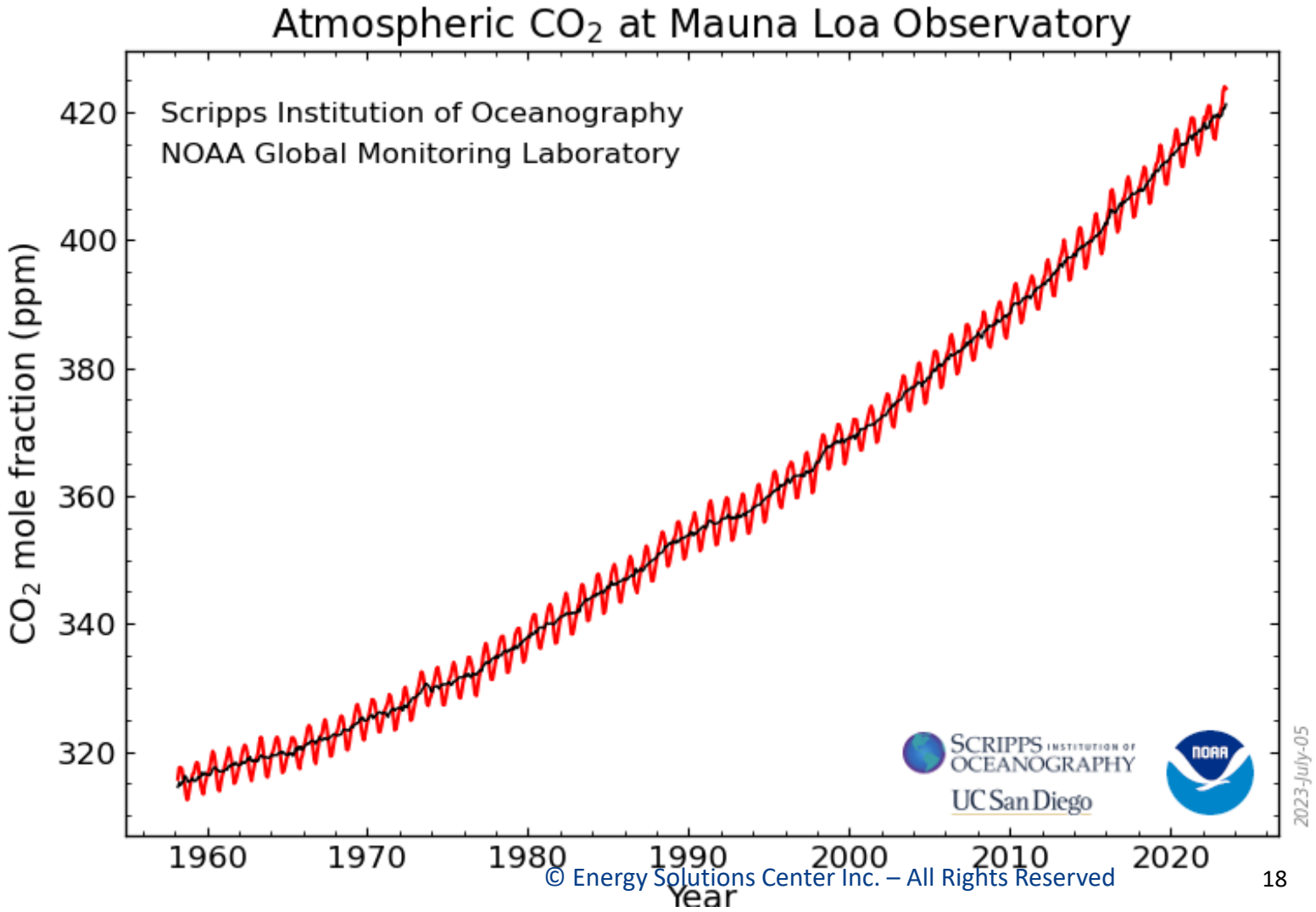
CO_2 and Temperature Trends



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

Recent Trends in CO2

- Beyond Cyclical
- Unprecedented CO2 Levels
- June 2023 Global concentration was 424 PPM



Recent Climate Changes

- Weather extremes – drought, floods, intense storms, heat waves
- Coral reefs disappearing
- Agricultural productivity decreases
- Species extinction
- Loss of global coastal wetlands
- Dislocation, malnutrition and disease

Photo Credit: NASA Hurricane Ike – September 9, 2008

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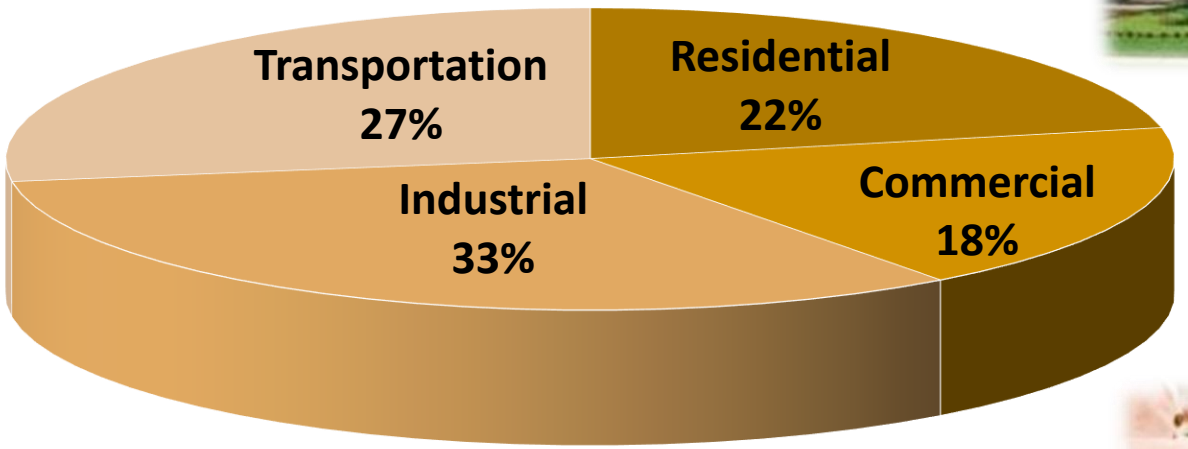
How BIG is Our Footprint?

2022 Energy Consumption by End-Use Sector

100,414 Trillion BTU's

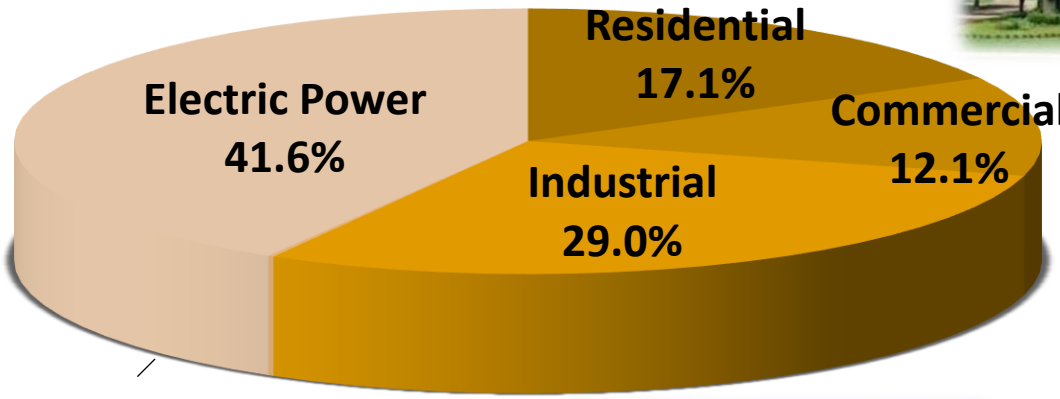


Source: Energy Information Administration, https://www.eia.gov/totalenergy/data/monthly/#consumption

Natural Gas Consumption

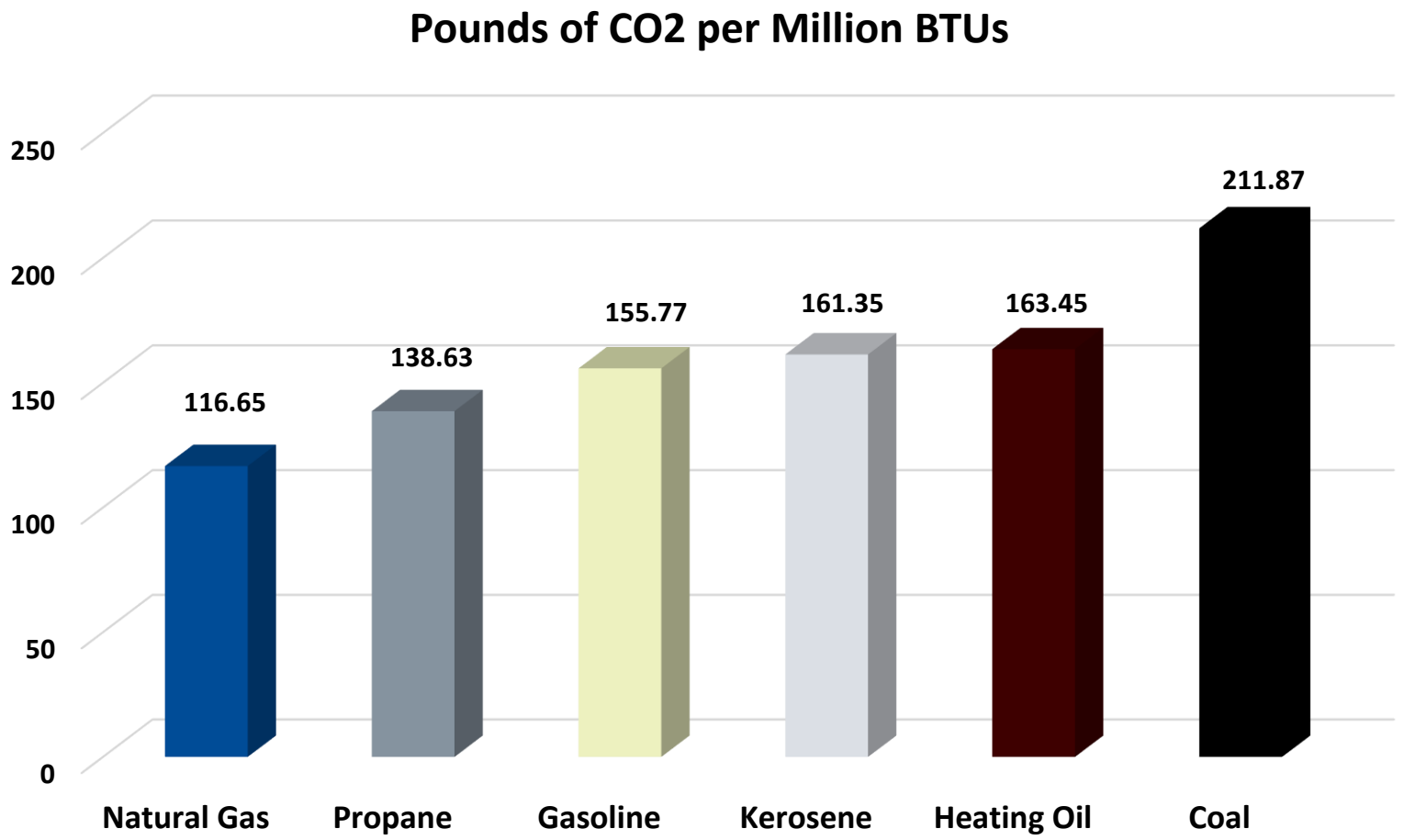
2022 Natural Gas Consumption by Sector

29,140,426 Million Cubic Feet



Source: Energy Information Administration, www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm

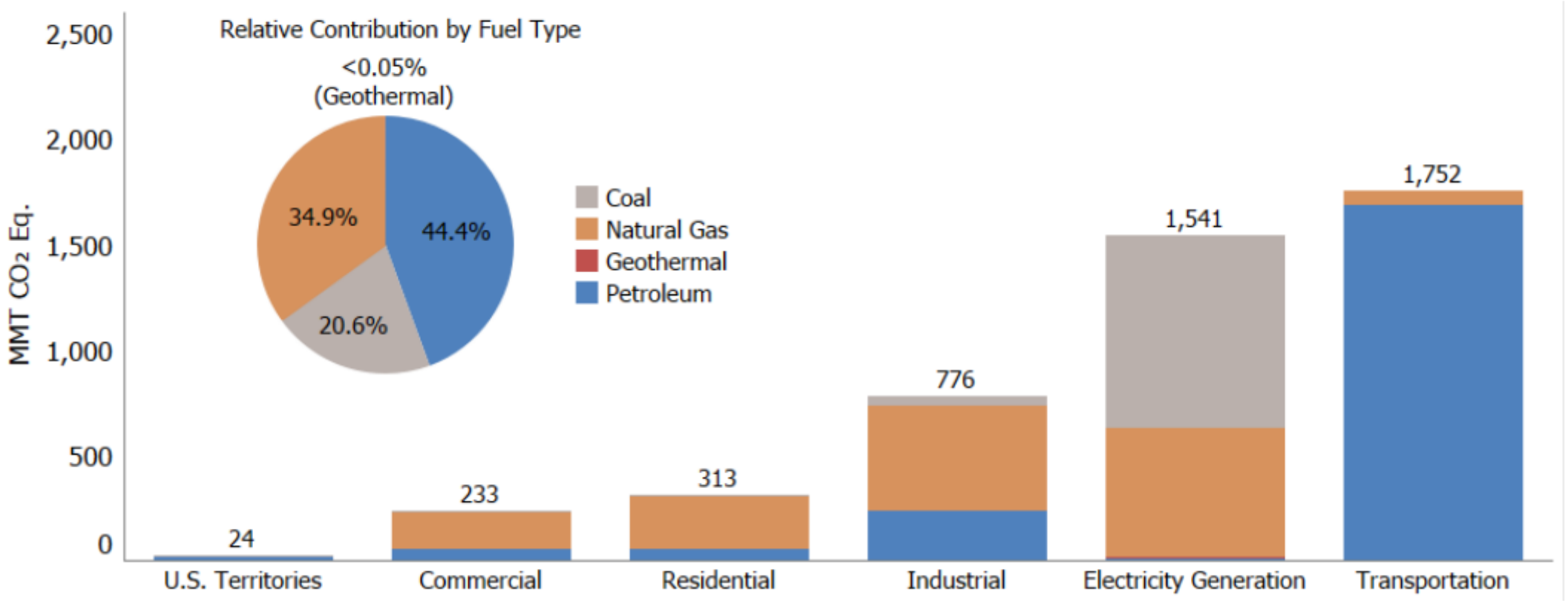
Environmental Benefits



Data release 10/5/22, https://www.eia.gov/environment/emissions/co2_vol_mass.php

CO2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

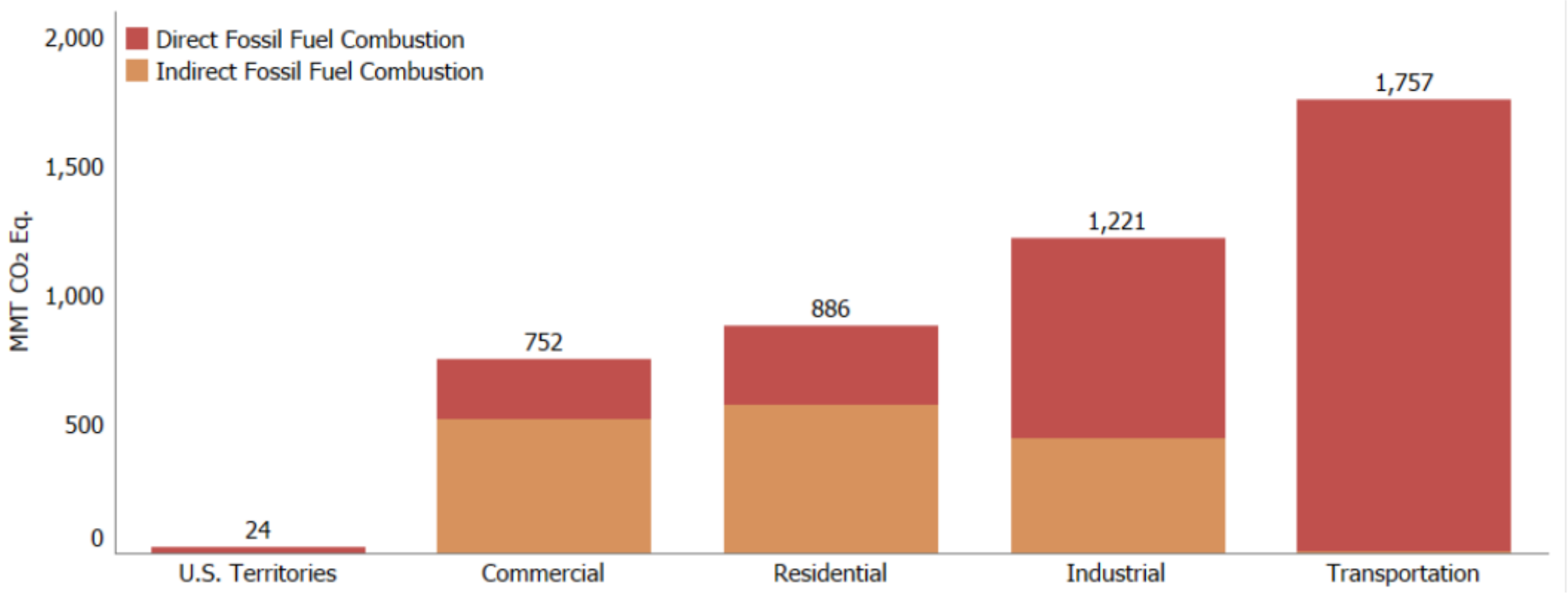
Figure ES-5: 2021 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type



Page 44: https://www.epa.gov/system/files/documents/2023-04/US-GHG-Inventory-2023-Main-Text.pdf

End-Use Sector Emissions of CO2 from Fossil Fuel Combustion

Figure ES-6: 2021 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion



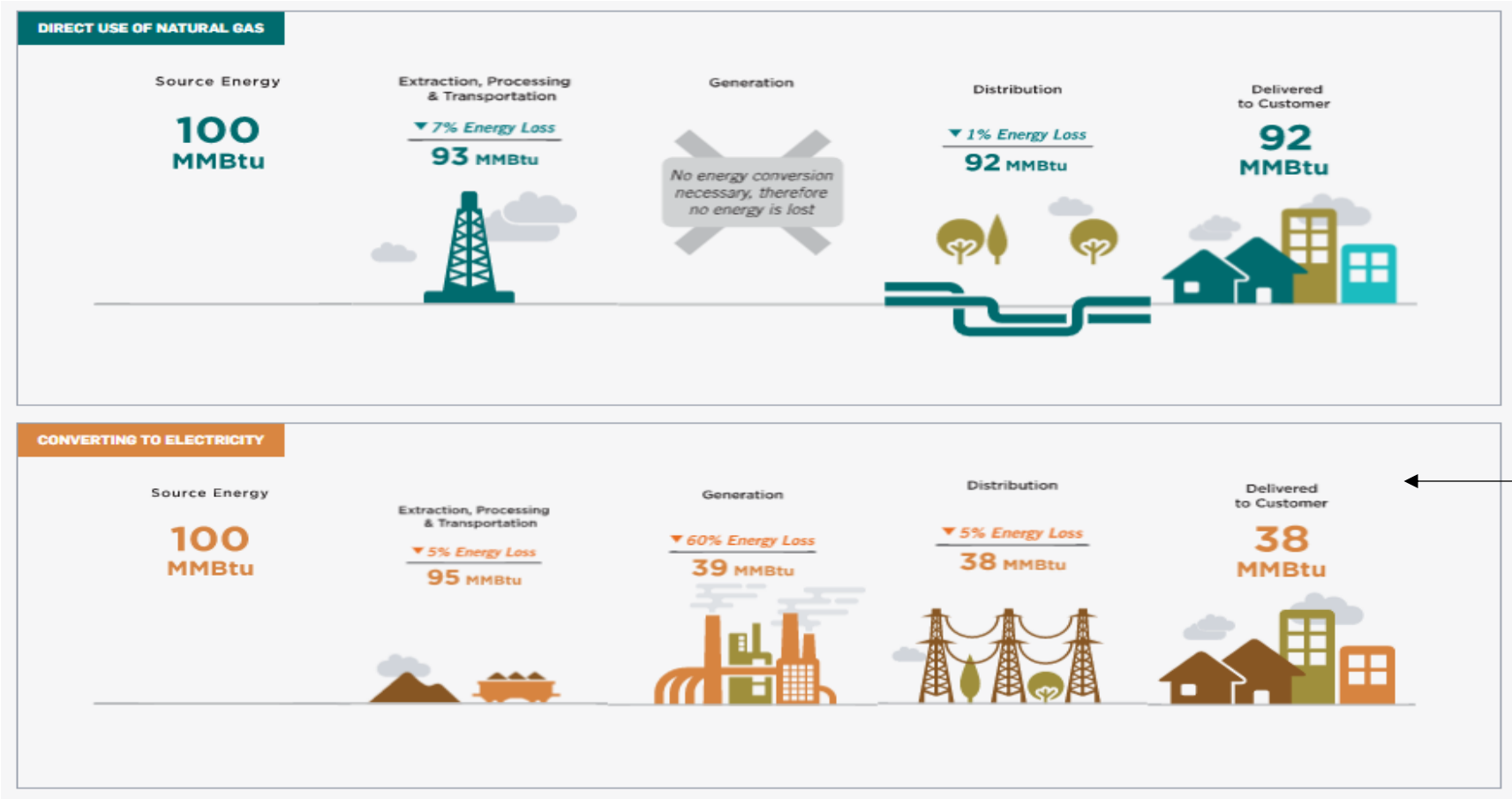
Electric power emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity use (i.e., indirect fossil fuel combustion)

Footprint Factors

- Energy usage
  - Appliance efficiency
  - Energy supply efficiency
    - Natural gas supply
    - Electric supply
      - —Emissions vary based on the generation mixture

Electricity

Source to Site Efficiency



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

Electric Generation Options

- Coal
- Simple Cycle Gas Turbines
- Combined Cycle Gas Turbines
- Hydro
- Nuclear
- Renewable – Solar & Wind

Electric Generation Mix

How does the mix impact the CO_2 produced annually?

Coal

Nuclear

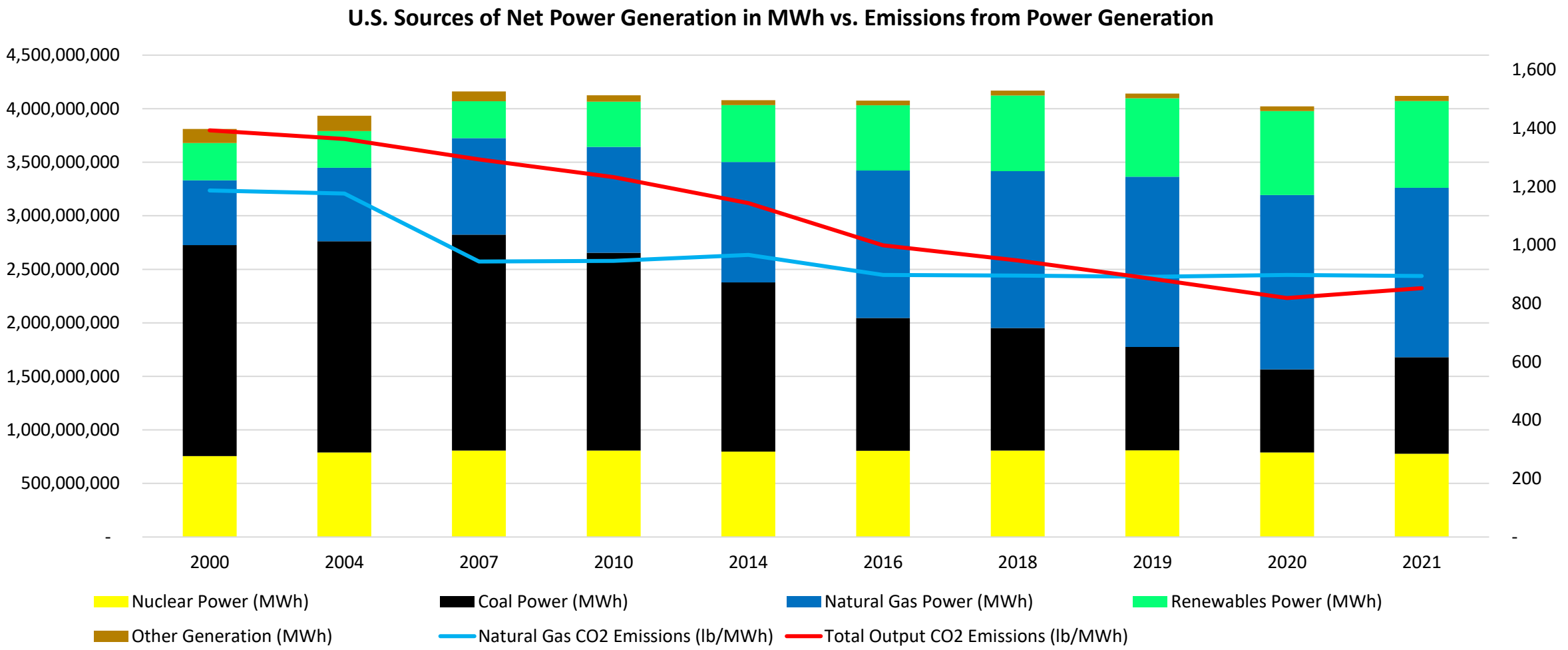
Natural Gas

Power Plant

Transmission

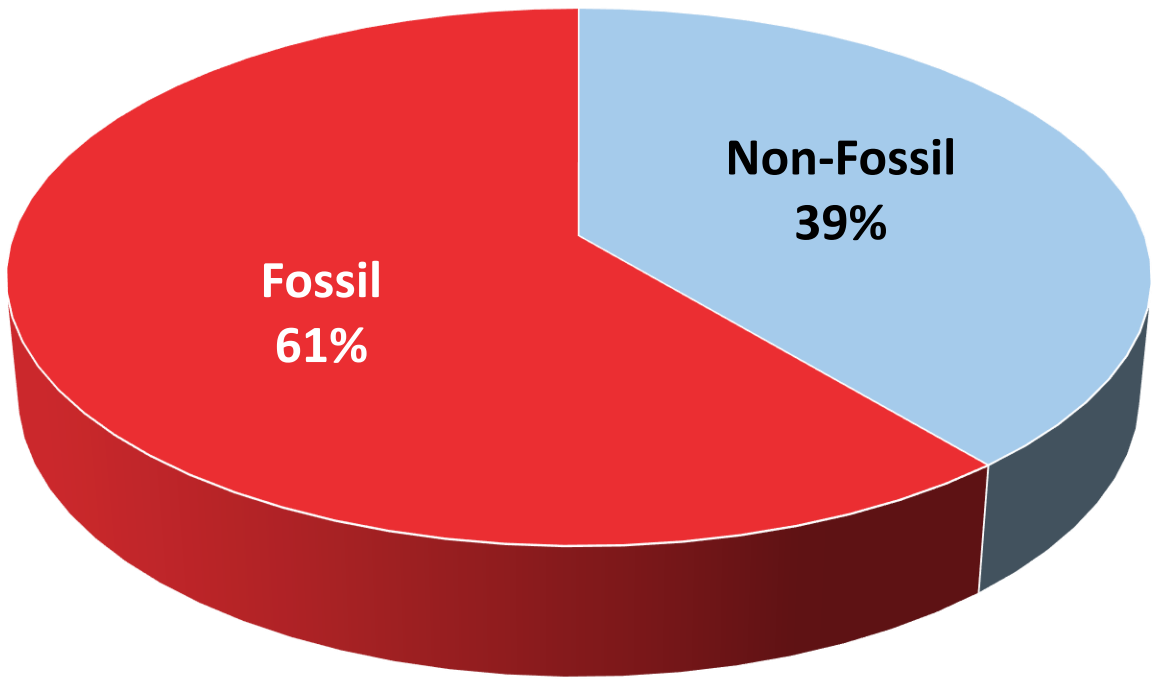
End Users

Electric Generation Mix



Fossil versus Non-Fossil Power Generation

U.S. Fossil vs. Non-Fossil Power Generation



E-Grid data

Fossil

- Natural Gas
- Oil
- Coal
- Other

Non-Fossil and Renewable

- Nuclear
- Wind
- Solar
- Hydro
- Biomass
- Geothermal

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General Rule of Thumb

- Generally speaking, the non-fossil fuel and renewable power plants operate when they are going to operate – these plants do not get turned off
  - Solar operates when the sun is shining
  - Wind generates power when the wind is blowing
  - Hydro power production is scheduled for specific times of the day provide enough water has built up to produce the power
  - Nuclear operates 24/7
- Fossil Fueled Power plants are the last on and the first off to balance load requirements

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Measuring Carbon Footprint

Making the Case to use Fossil Fuel Mix

Because renewables and non-fossil power plants do not cycle on and off to meet electric load, it can be assumed that only fossil fueled power plants cycle on and off to meet load requirements

This means any analysis of CO_2 emissions from electric usage should be performed using the Fossil fuel mix

Water Heater Comparison

All Power Generation Mix

	Tank Electric	Tank Natural Gas	Tankless Natural Gas
Appliance UEF	0.91	0.58	0.81
Source Energy MMBtu/Year	33.5	22.6	17.5
CO_2 Pounds/Year	6,010	2,641	2,047

Using ESC's Residential CO_2 tool
National Average for Family of 3

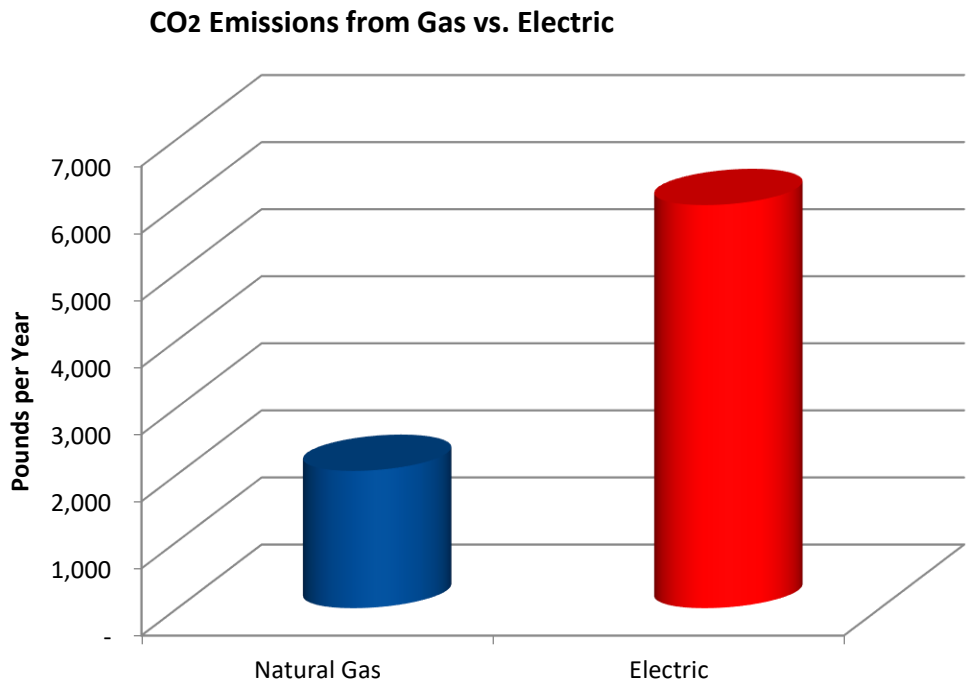
Water Heater Comparison

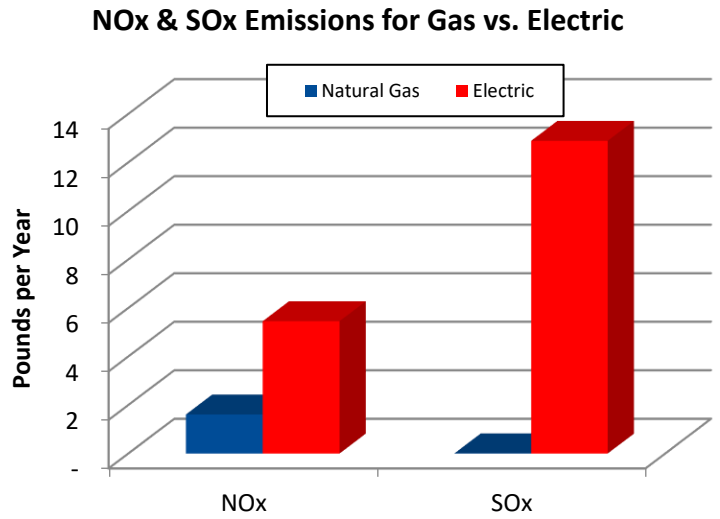
Fossil Fuel Power Only

	Tank Electric	Tank Natural Gas	Tankless Natural Gas
Appliance Efficiency	0.91	0.58	0.81
Source Energy MMBtu/Year	46.8 **Higher**	22.6 **Same**	17.5
CO_2 Pounds/Year	8,511	2,641	2,047

Using ESC's Residential CO_2 tool
National Average for Family of 3

Electric Tank vs. Gas Tank Water Heater Fossil Fuel Mix





Using ESC's Residential CO_2 tool
National Average for Family of 3

Electric Water Heater Comparison

Based on Power Mix

	Tank Electric Fossil only Mix	Tank Electric All Power Mix
CO_2 Pounds/Year	8,511	6,010

Using ESC's Residential CO_2 tool
National Average for Family of 3,
.9 EF factor electric tank water heater

Residential Energy Efficiency Ratings

Space Heating

	Electric Heat Pump	Natural Gas Furnace	H.E. Natural Gas Furnace
			
Efficiency Ratings:	**8.5 HSPF**	**80% AFUE**	**92%+ AFUE**

Space Heater Comparison

Fossil Fuel Power Only

	Standard Electric Heat Pump	Standard Gas Furnace	H.E. Gas Furnace
Appliance Efficiency	8.5 HSPF	80%	92%
Source Energy MMBtu/Year	76.4	62	54
CO_2 Pounds/Year	13,894	7,260	6,311

Using ESC's Residential CO2 tool
National Average for 2000 sq ft home

Residential Energy Efficiency Ratings
Clothes Drying

DOE site-specific energy ratings are misleading.
While DOE rates an electric appliance with a more efficient energy rating than a similar gas appliance, in reality that electric appliance consumes more source energy, pollutes more, and costs the consumer more to operate.

	Electric	Natural Gas
		
Efficiency Rating:	**3.01 EF**	**2.67 EF**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**8.7**	**3.3**
Energy Cost /yr:	**$102.60**	**$32.75**
CO_2 Emissions (Pounds/yr):	**1581**	**381**

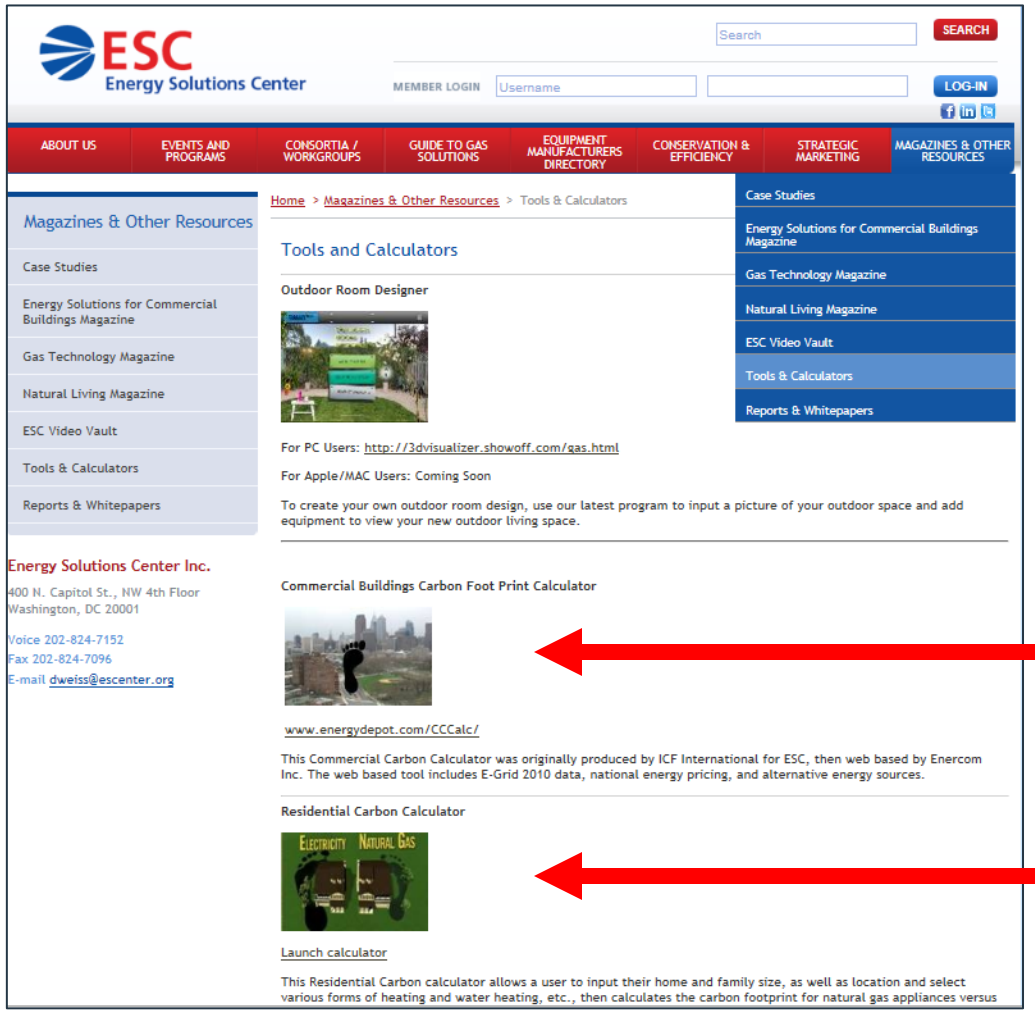
Using ESC's Residential CO_2 tool
National fossil power mix, and 7 loads laundry per week

Residential Energy Efficiency Ratings
Cooking Equipment

	Electric	Natural Gas
		
Energy Factor	**10.9 EF**	**5.8 EF**
Full-Fuel-Cycle Energy Consumption (MMBtu/yr):	**8.1**	**5**
Energy Cost[1]/yr:	**$96**	**$50.29**
CO_2 Emissions (Pounds/yr):	**1479**	**585**

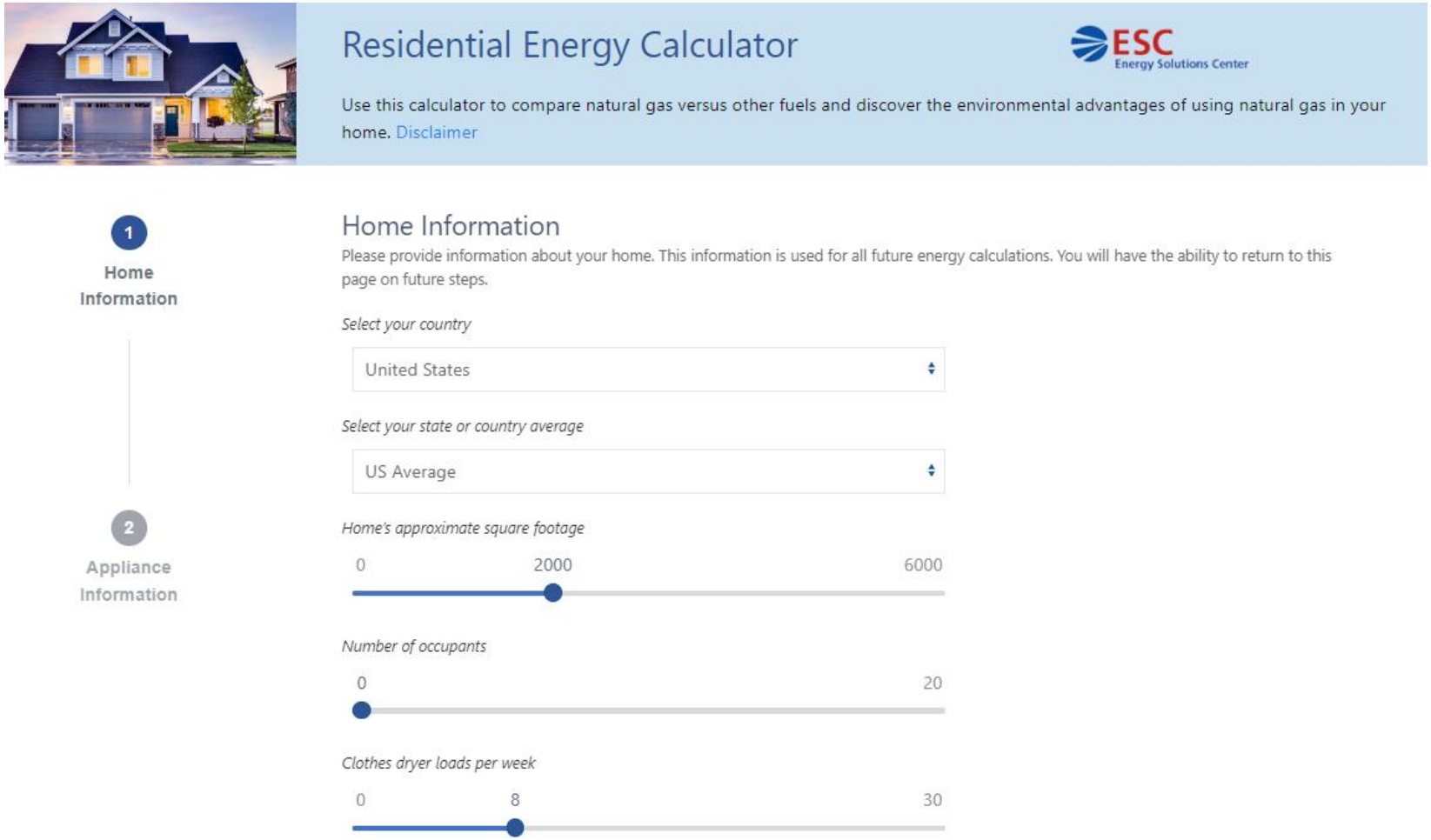
Using ESC's Residential CO_2 tool. National fossil power mix.

ESC's Carbon Calculators



Accessible from ESC Website under 'Magazines & Other Resources' navigation tab

ESC's Residential Carbon Calculator



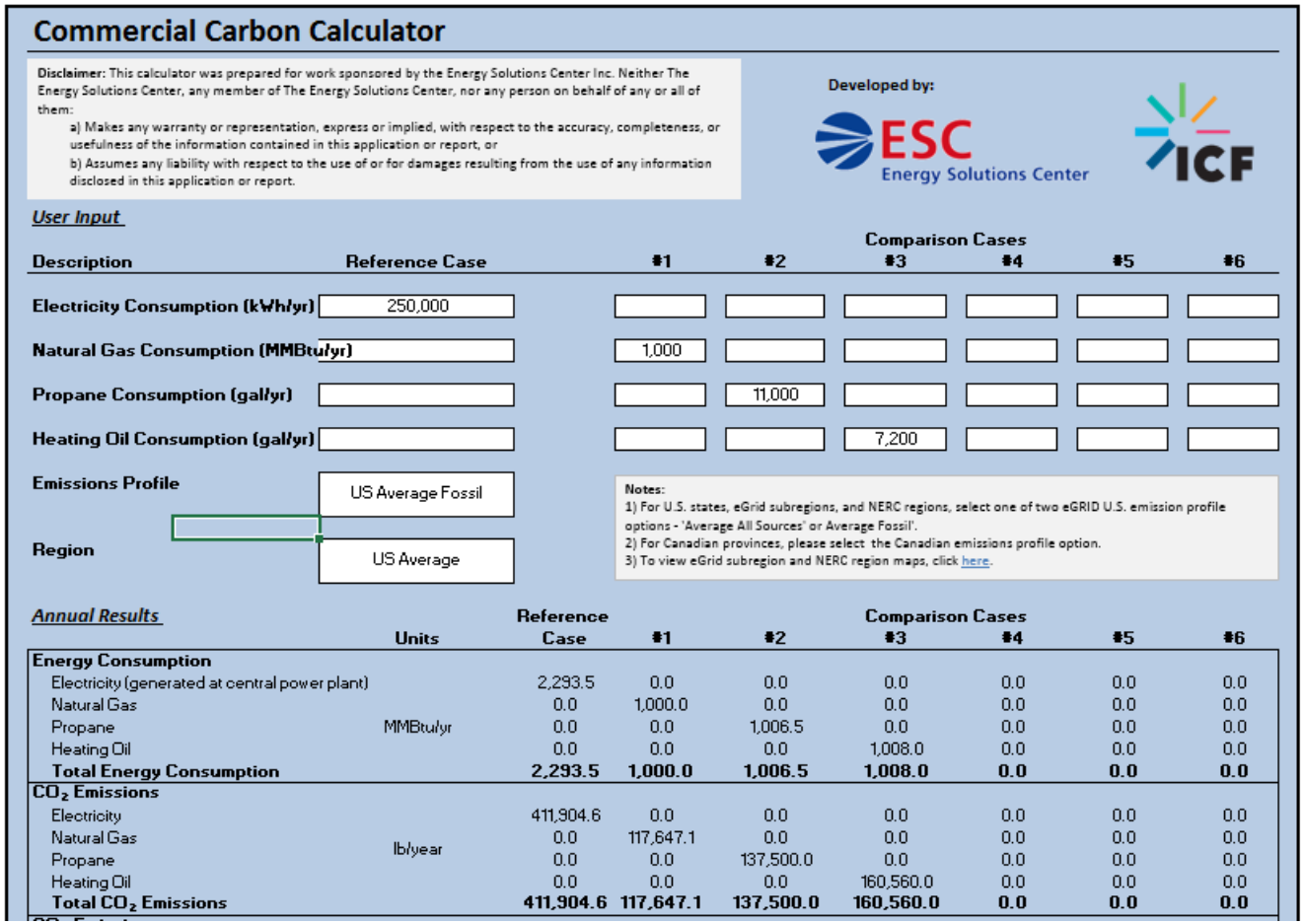
Calculates:

- CO_2
- NOx
- SO2
- Vehicles reduced
- Forest equivalent

Energy Types

- Natural gas
- Electric
- Propane
- Oil

ESC's Commercial Carbon Calculator



Commercial Carbon Calculator

Disclaimer: This calculator was prepared for work sponsored by the Energy Solutions Center Inc. Neither The Energy Solutions Center, any member of The Energy Solutions Center, nor any person on behalf of any or all of them:

a) Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this application or report, or

b) Assumes any liability with respect to the use of or for damages resulting from the use of any information disclosed in this application or report.

Developed by: ESC Energy Solutions Center, ICF

User Input

Description	Reference Case	Comparison Cases #1	#2	#3	#4	#5	#6
Electricity Consumption (kWh/yr)	250,000						
Natural Gas Consumption (MMBtu/yr)		1,000					
Propane Consumption (gal/yr)			11,000				
Heating Oil Consumption (gal/yr)				7,200			
Emissions Profile	US Average Fossil						
Region	US Average						

Notes:
1) For U.S. states, eGrid subregions, and NERC regions, select one of two eGRID U.S. emission profile options - 'Average All Sources' or Average Fossil'.
2) For Canadian provinces, please select the Canadian emissions profile option.
3) To view eGrid subregion and NERC region maps, click here.

Annual Results

	Units	Reference Case	Comparison Cases #1	#2	#3	#4	#5	#6
Energy Consumption								
Electricity (generated at central power plant)	MMBtu/yr	2,293.5	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas		0.0	1,000.0	0.0	0.0	0.0	0.0	0.0
Propane		0.0	0.0	1,006.5	0.0	0.0	0.0	0.0
Heating Oil		0.0	0.0	0.0	1,008.0	0.0	0.0	0.0
Total Energy Consumption		**2,293.5**	**1,000.0**	**1,006.5**	**1,008.0**	**0.0**	**0.0**	**0.0**
CO_2 Emissions								
Electricity	lb/year	411,904.6	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas		0.0	117,647.1	0.0	0.0	0.0	0.0	0.0
Propane		0.0	0.0	137,500.0	0.0	0.0	0.0	0.0
Heating Oil		0.0	0.0	0.0	160,560.0	0.0	0.0	0.0
Total CO_2 Emissions		**411,904.6**	**117,647.1**	**137,500.0**	**160,560.0**	**0.0**	**0.0**	**0.0**

Allows for before and after gas/electric use comparison.

Calculates:

- CO_2
- NOx
- SO_2
- Vehicles reduced
- Forest equivalent

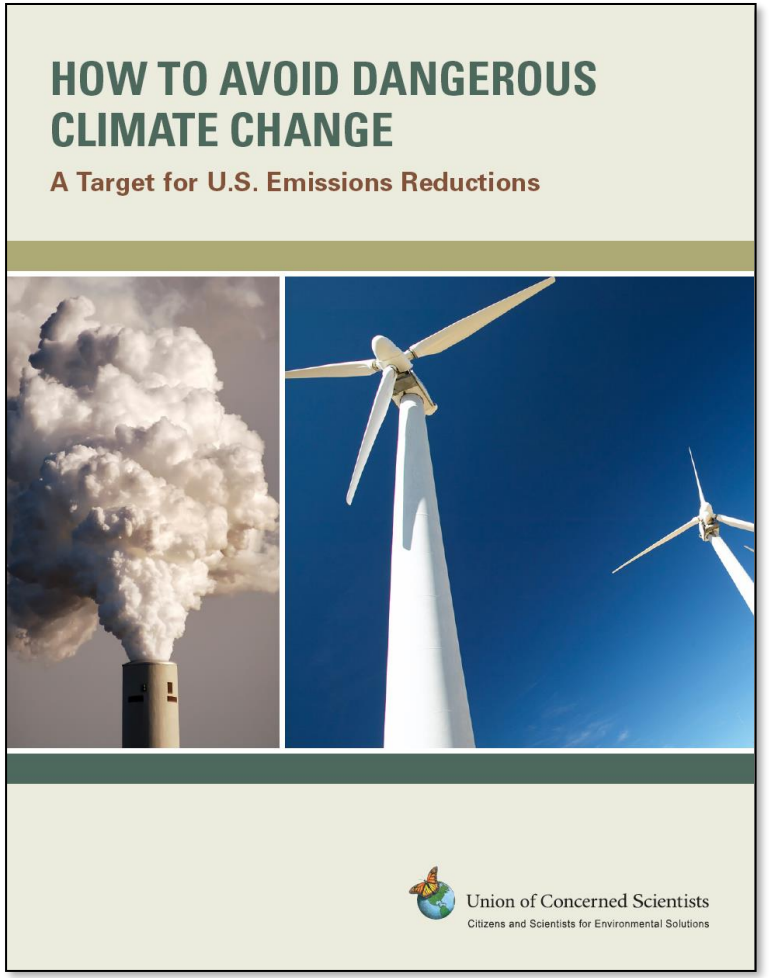
Excel based comparison tool.

Natural Gas is Key to **Reducing Our** Carbon Footprint

Natural gas emits significantly less CO2 than other fossil fuels and is a major part of the solution as we work towards a low carbon future.

Is It Already Too Late?

- Atmospheric levels of CO_2 and temperatures will likely continue to increase – even if we act NOW!
- Target: 80% Reduction in Annual CO_2 emissions by 2050
- Doable? YES!!
- Challenge? YES!!!



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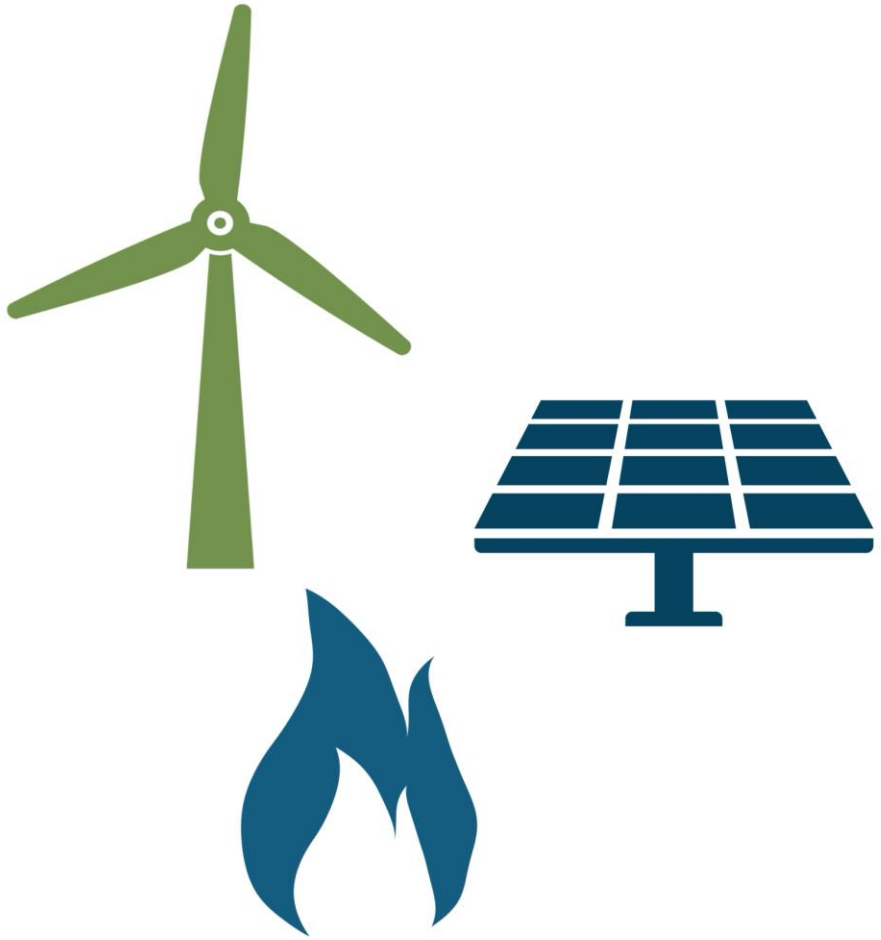
Natural Gas Offers Reliability and Stability

- Developments in wind and solar power are reducing the carbon footprint of the electric grid.
- These low-carbon energy sources require additional electric storage to offset the irregular power generated by solar or wind turbines.
- Natural gas offers reliability and stability to the energy system, especially in peak energy demand periods.
- Natural gas is less expensive and the perfect solution to allow renewable research and advancements to continue and thrive.



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Upgraded Natural Gas Pipelines Reduce Emissions by 73%[1]

- Better systems management[2]
- Diligent preventative maintenance
- Enhanced leak detection repair

According to the U.S. Environmental Protection Agency, from 1990 to 2018, upgraded pipelines have cut methane emissions from the gas transmission and distribution system by 73%

1 aga.org/news/news-releases/gas-utilities-support-methane-reduction-innovations/
2 https://www.aga.org/sites/default/files/legacy-assets/our-issues/Rewriting-Our-Energy Future/Documents/Rewriting%20Our%20Energy%20Future%20WEB%20FINAL.pdf

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Carbon-Neutral Renewable Energy

Renewable Natural Gas Reduces Carbon Emissions

Displacing carbon emitting gas with carbon neutral gas significantly lowers total greenhouse gas emissions.[1]

Biogas Refining Converts Methane into Carbon-Neutral Renewable Energy[2]

- The capture of biomethane at wastewater treatment plants, agricultural waste, waste processing facilities and landfills, prevents methane release into the environment.

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

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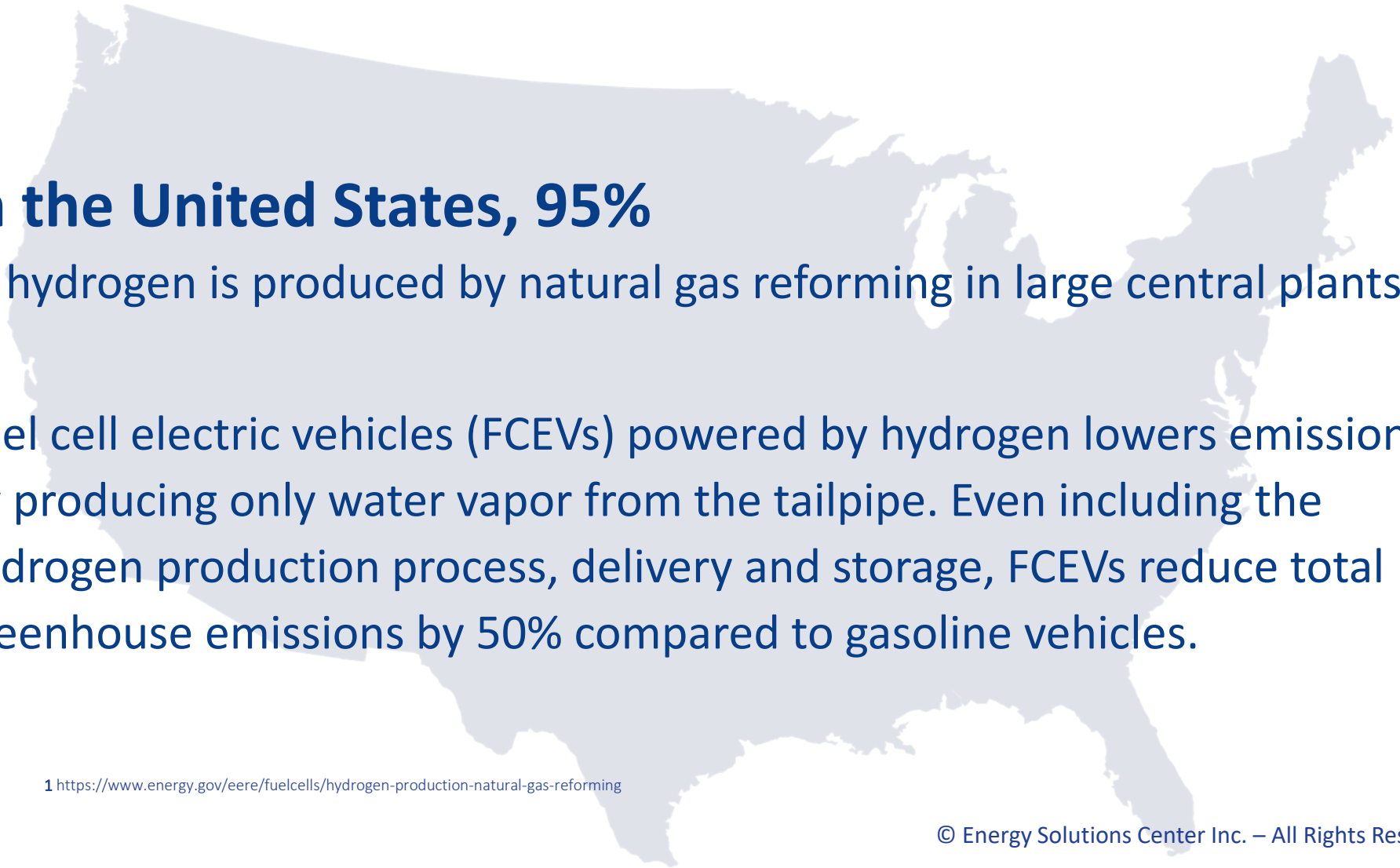
95% of Hydrogen Is Produced From Natural Gas



In the United States, 95%

of hydrogen is produced by natural gas reforming in large central plants.[1]

Fuel cell electric vehicles (FCEVs) powered by hydrogen lowers emissions by producing only water vapor from the tailpipe. Even including the hydrogen production process, delivery and storage, FCEVs reduce total greenhouse emissions by 50% compared to gasoline vehicles.

1 https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

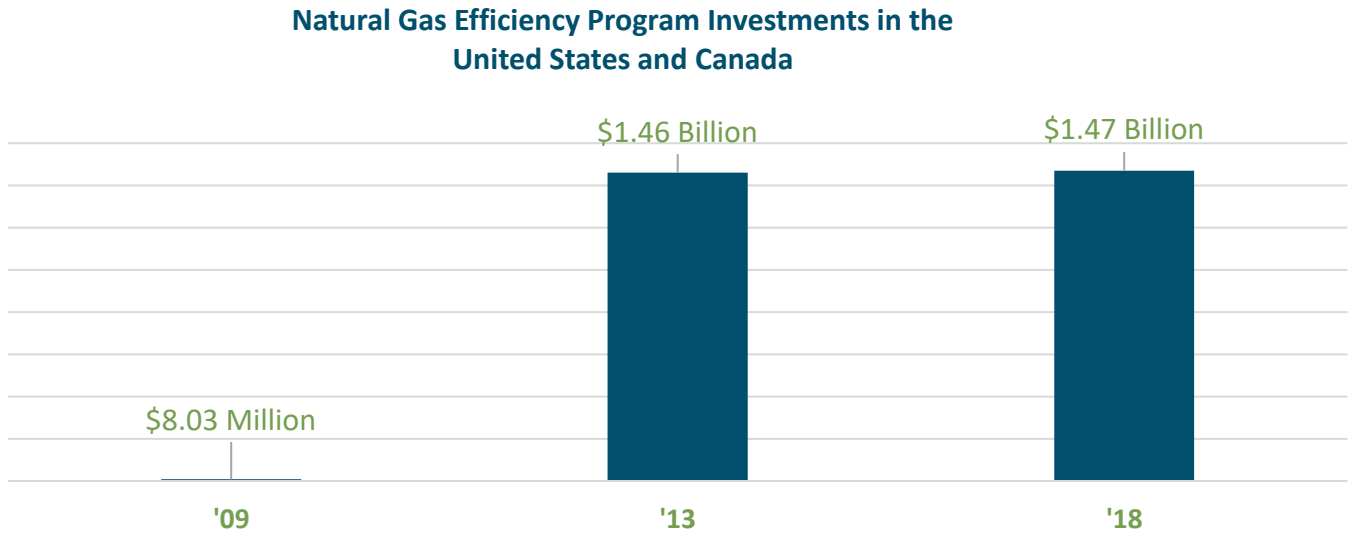
ESC

Gas Heat Pumps are Reliable & Save Energy

- Natural Gas Heat Pumps (GHP) function on similar principles as electric heat pumps with added performance and comfort during very cold weather.
- GHPs can extract heat from air, ground, or water sources.
- Gas Heat Pumps exceed 100% efficiency for heating.
- GHPs generally produce lower CO2 emissions compared to conventional systems.

Energy Efficiency Programs

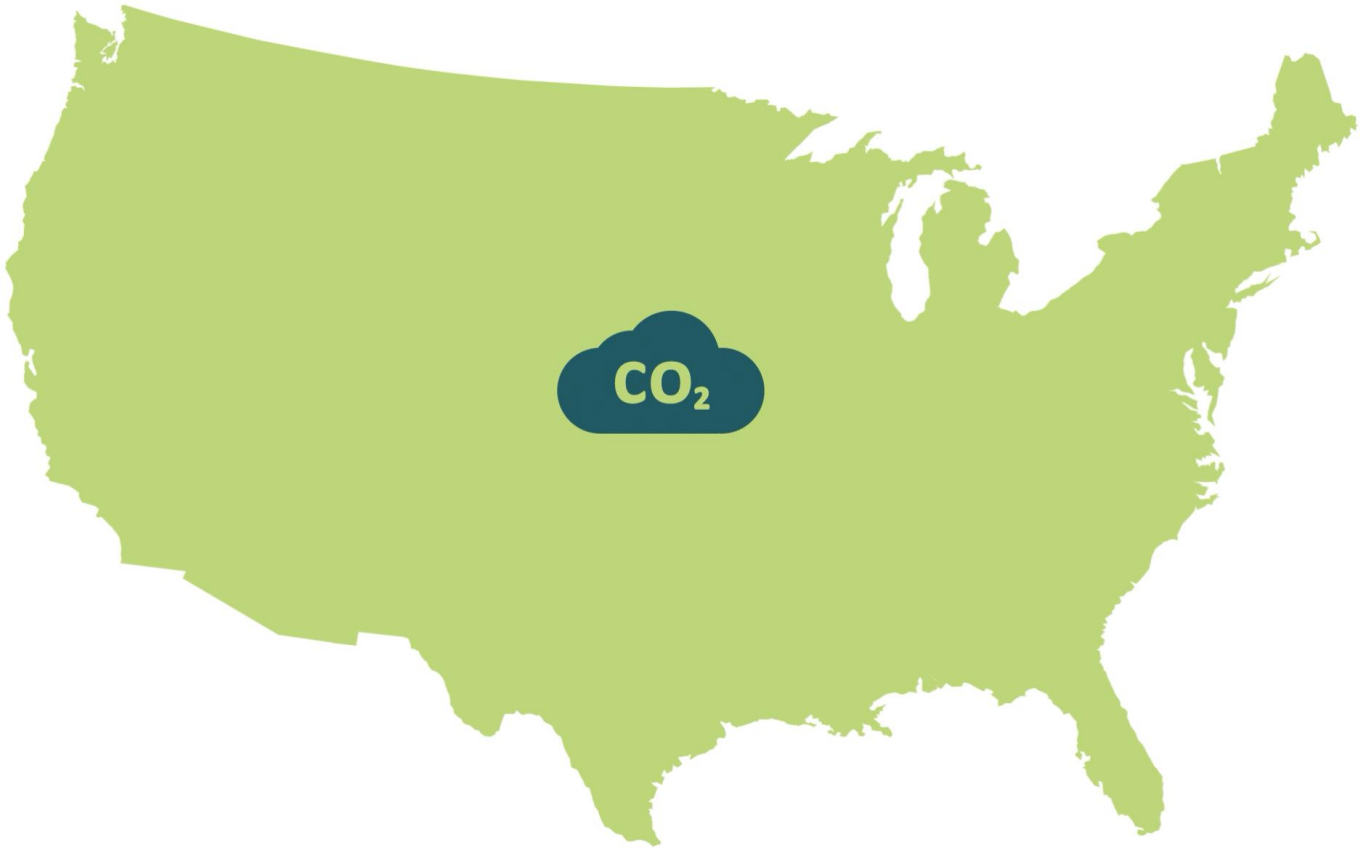
American and Canadian utilities funded almost $1.5 billion U.S. for gas efficiency programs that helped customers reduce their carbon footprint by 2.25 million metric tons of avoided CO^2. That is equivalent to almost 490,000 passenger vehicles taken off the road or over 270,000 homes' energy use for one year.



Source: https://dailyenergyinsider.com/news/26350-natural-gas-utilities-invested-1-47b-in-energy-efficiency-programs/

Carbon Capture and Carbon Sequestration Remove CO2 from the Atmosphere

- Carbon capture technology for natural gas fired power plants already exists.
- Department of Energy models show that technology improvements will lead to significant adoption.* Carbon sequestration is possible by piping CO^2 fertilizer into greenhouses for storing carbon in plants, using for industrial processes and goods, or injecting carbon dioxide deep below the Earth's surface to trap the carbon permanently below the impermeable seal.



* https://www.energy.gov/sites/prod/files/2017/01/f34/Carbon%20Capture%20Opportunities%20for%20Natural%20Gas%20Fired%20Power%20Systems_0.pdf

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Direct Use of Natural Gas

Direct Consumption of Natural Gas Maximizes Efficiency and Lowers Emissions

Direct use of natural gas for heating, cooling, water heating, cooking, and clothes drying cuts carbon emissions by almost 50%. Direct use is more efficient than consuming gas-fired electricity from the grid.*

Direct Consumption is 92% Efficient[1]

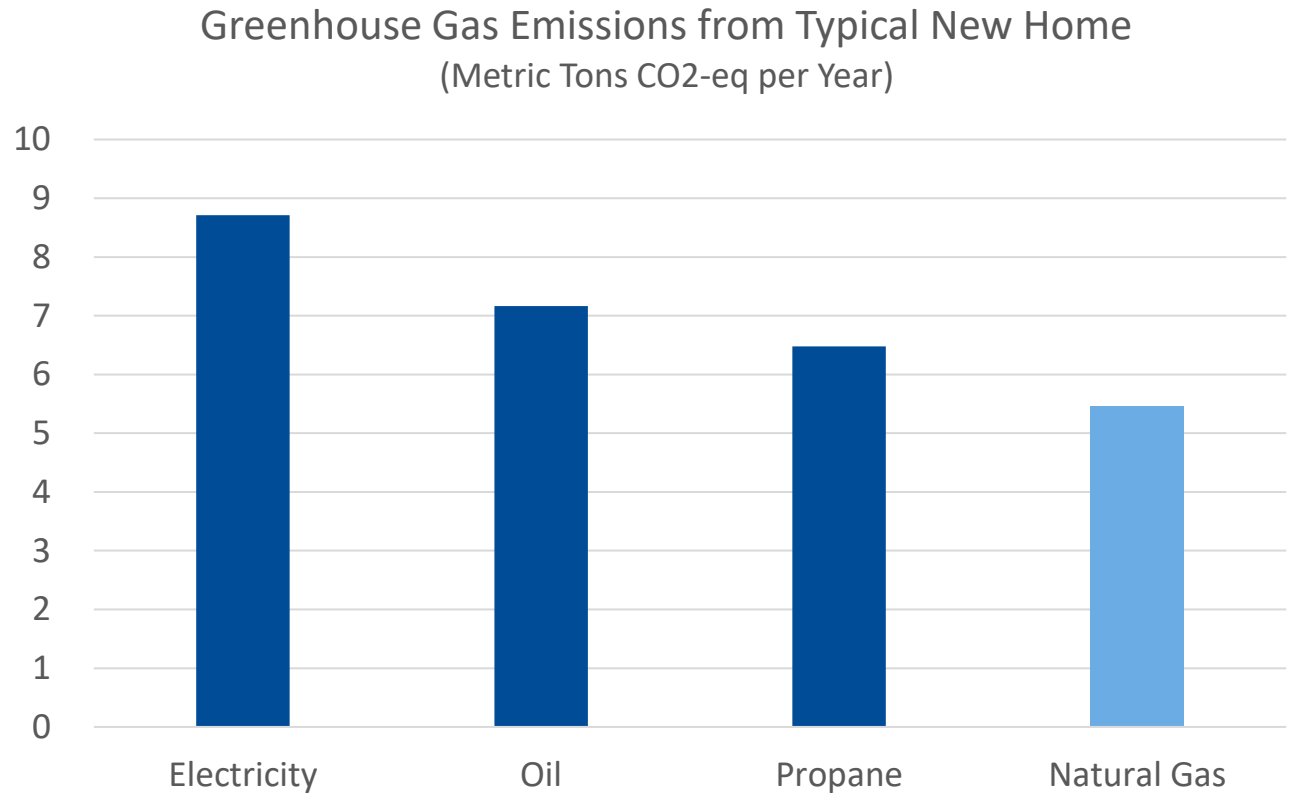
Households with natural gas appliances produce 22% fewer greenhouse gasses compared to electric-only homes.[2]

1 https://playbook.aga.org/reliable

2 https://playbook.aga.org/environment/

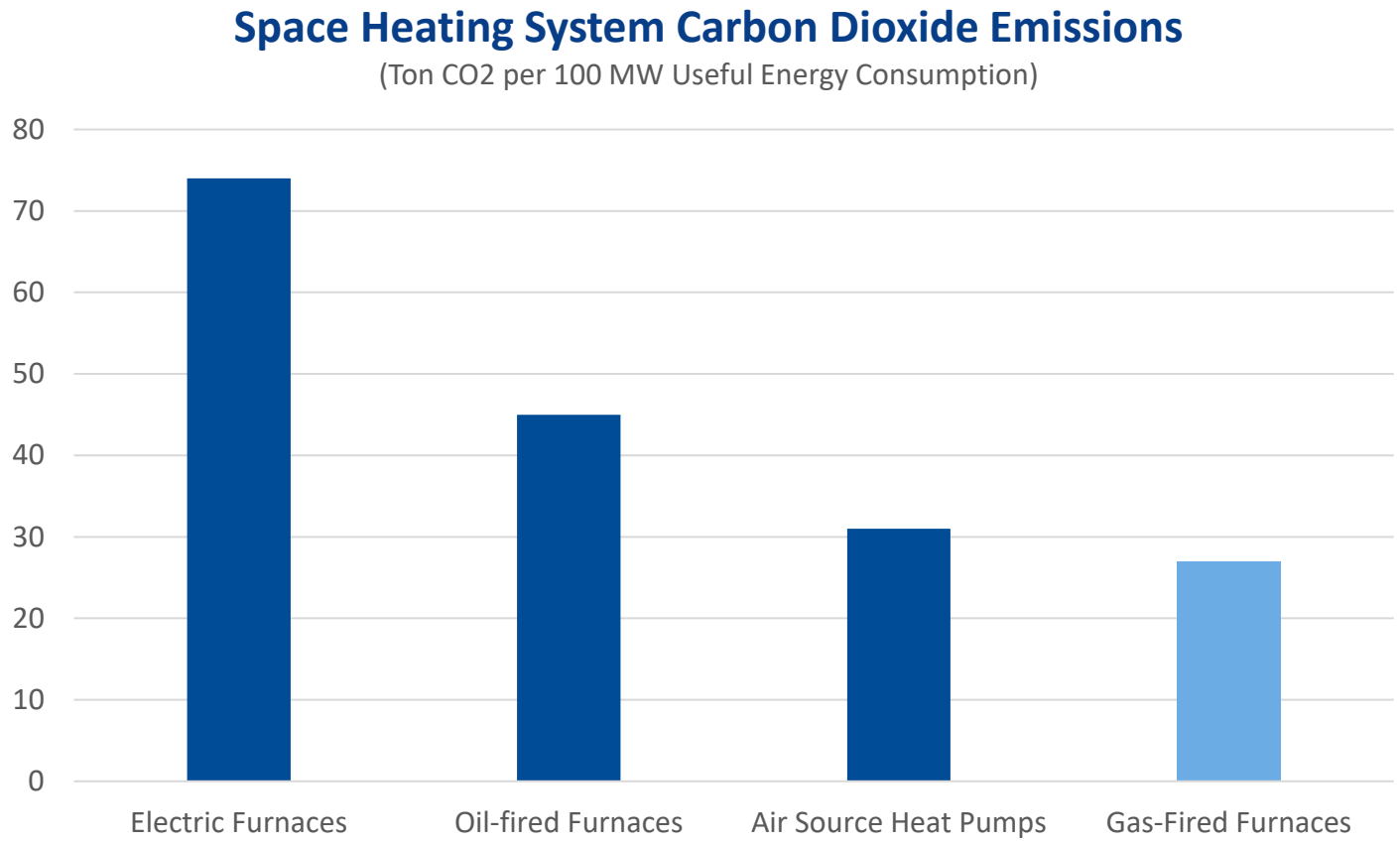
Fuels Used for Heating, Hot Water, Cooking, and Drying

Natural gas reduces greenhouse gas emissions in new homes



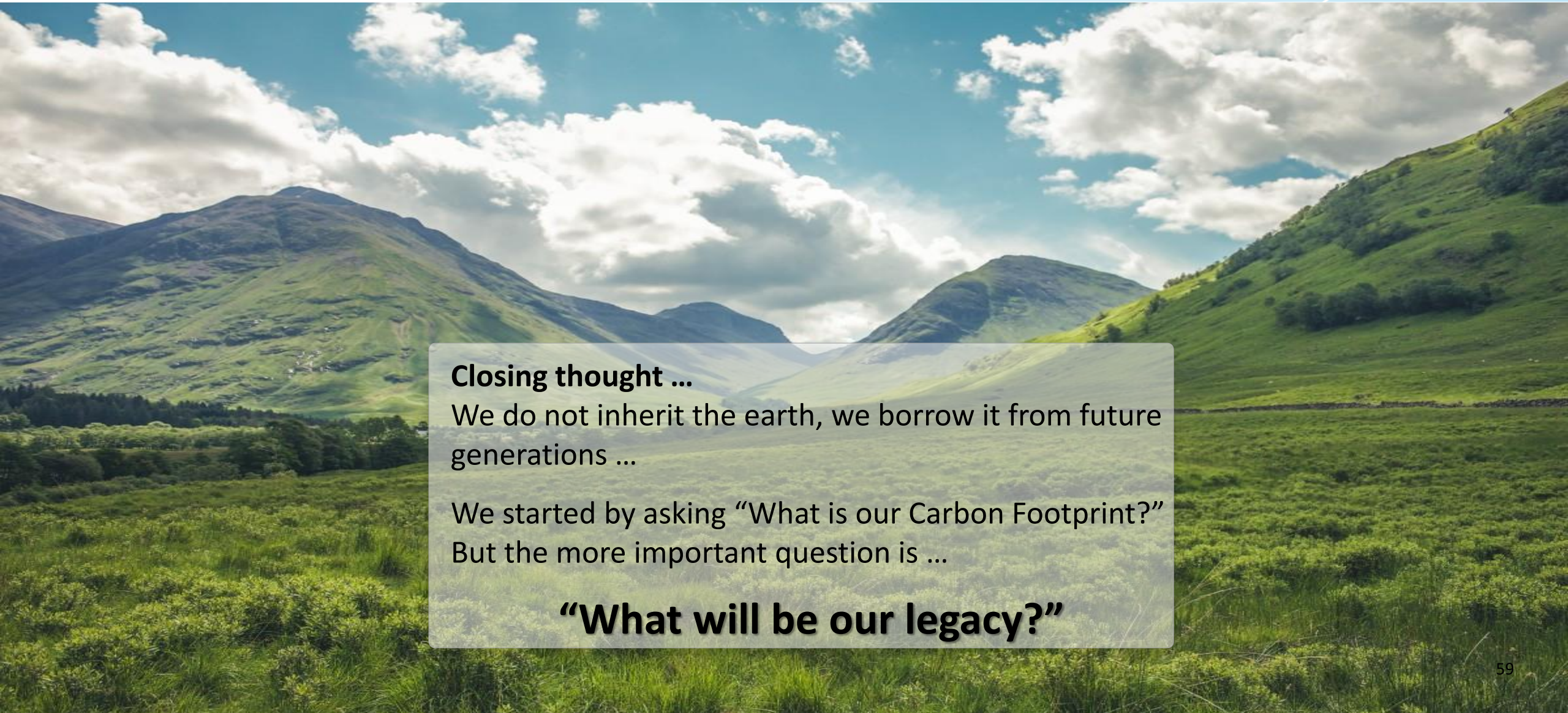
*Methane Emissions included
*Electricity Household uses Air Source Heat Pump
Source: AGA

Natural Gas Used Directly In Homes and Businesses Reduces CO2 Emissions



Source: AGA & MIT *Future of Natural Gas*
Appliance efficiencies Energy STAR compliant.

The New Energy Future



Closing thought …

We do not inherit the earth, we borrow it from future generations …

We started by asking “What is our Carbon Footprint?”
But the more important question is …

“What will be our legacy?”

Thank You

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