Recent North American Energy Use and GHG Trends: Will the Cycle be Unbroken?

Adapted from:

State of the State of the Carbon Cycle 2

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Outline of the talk

- Background: The SOCCR2 report
- Theoretical cycles in long-term economic growth and North American energy use and GHG emissions
- Trends in energy use and GHG emissions in North American and the USA, 2003-2016
- Influencing factors in current trends
- Future projections: Will the cycle be broken?
- Conclusions
- So what?

Background

Background

- The 2nd State of the Carbon Cycle Report was published in November 2018 (https://www.globalchange.gov/content/about-soccr-2);
- The Second State of the Carbon Cycle Report (SOCCR2) was led and developed by the Carbon Cycle Interagency Working Group (CCIWG) under the auspices of the U.S. Global Change Research Program (USGCRP).
- The report contributed to the Fourth National Climate Assessment (NCA4). SOCCR2 was designed as a special interagency assessment focused on the advances in the science and the understanding of the carbon cycle across North America since the first SOCCR (2007).

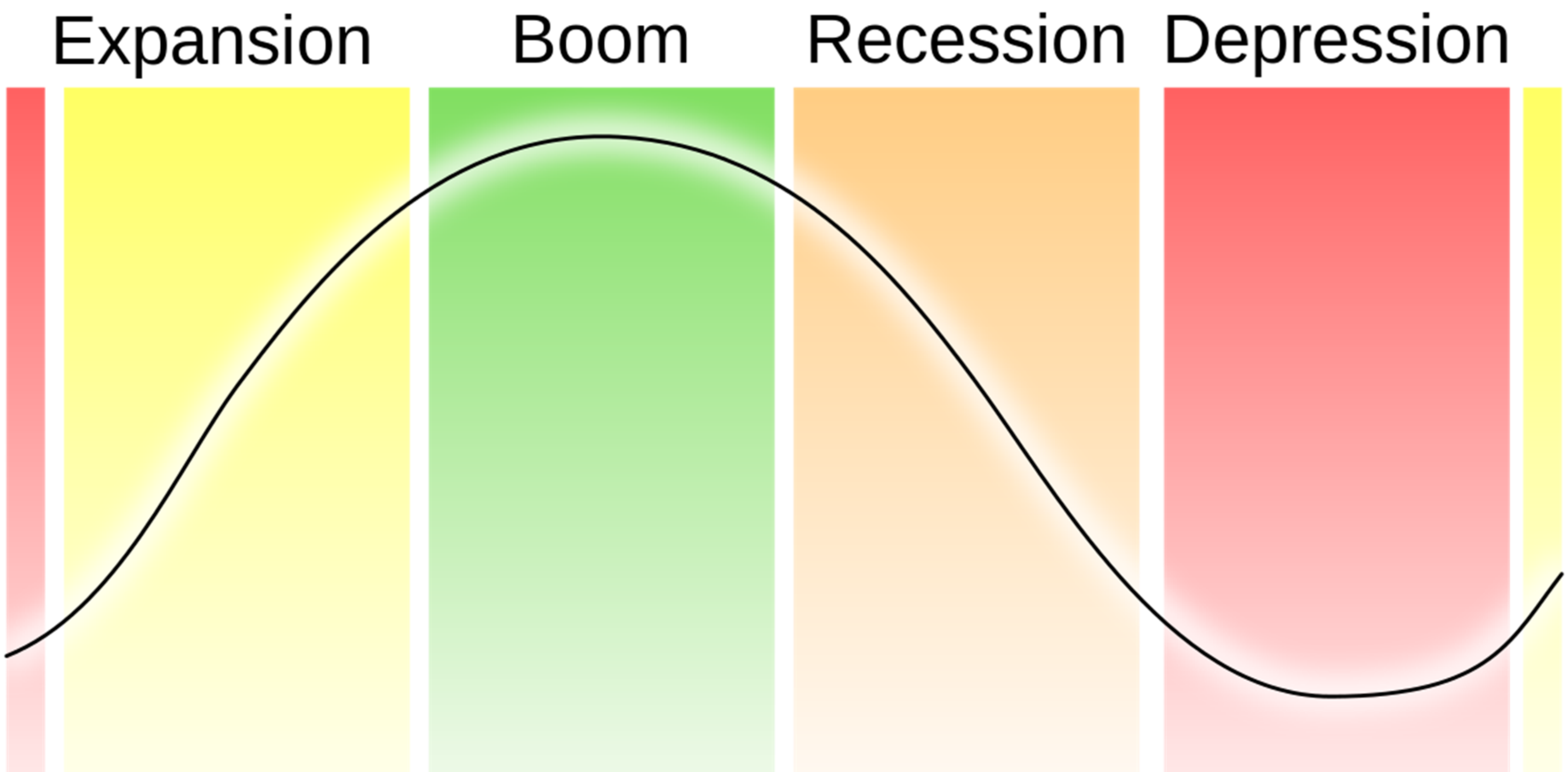
Background

- The SOCCR2 report focused on carbon cycle processes, stocks, fluxes, and interactions with global-scale carbon budgets and climate change impacts in managed and unmanaged systems.
- The report includes an assessment of the carbon stocks and fluxes in soils, water (including near-coastal oceans), vegetation, aquatic-terrestrial interfaces (e.g., coasts, estuaries, wetlands), human settlements, agriculture, and forestry. It considers relevant carbon management science perspectives and science-based tools for supporting and informing decisions, as addressed in and related to a U.S. Carbon Cycle Science Plan (2011) and other documents, such as the USGCRP Strategic Plan (2012-2021) and the Global Change Research Act (1990).

Background

- North America is defined as including the territories of Canada, Mexico and the United States;
- The SOCCR2 report trend analysis focuses largely on what happened after 2003 (which is the end year for the first SOCCR report);
- The energy chapter specifically identifies components of the system, emphasizes the role of the North American energy use's contribution to the global carbon cycle, examines the underlying factors that influence these trends and describes plausible energy futures;

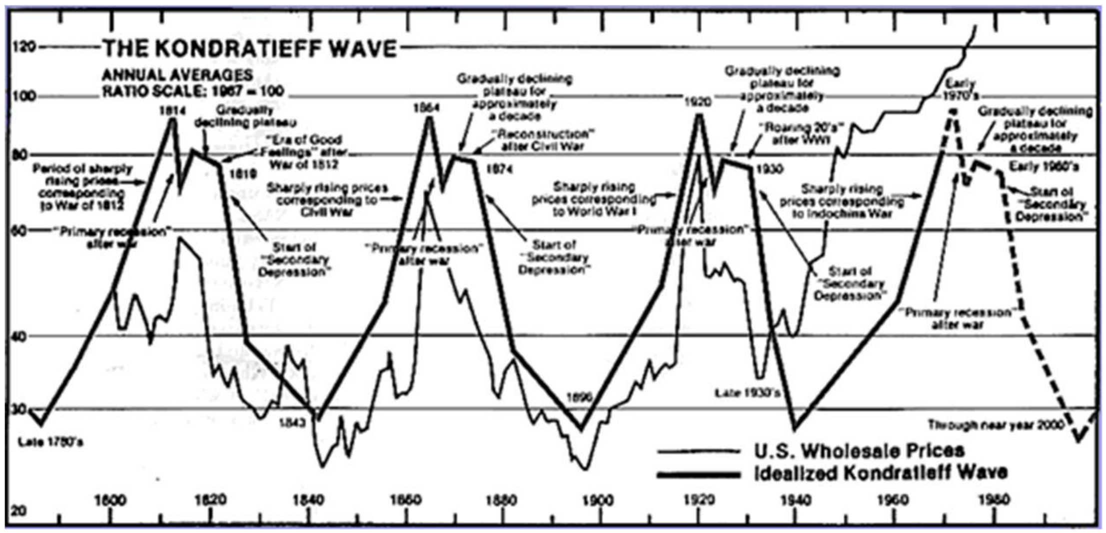
Theoretical Cycles in Long-term Economic Growth and North American Energy Use



Long term economic growth cycles

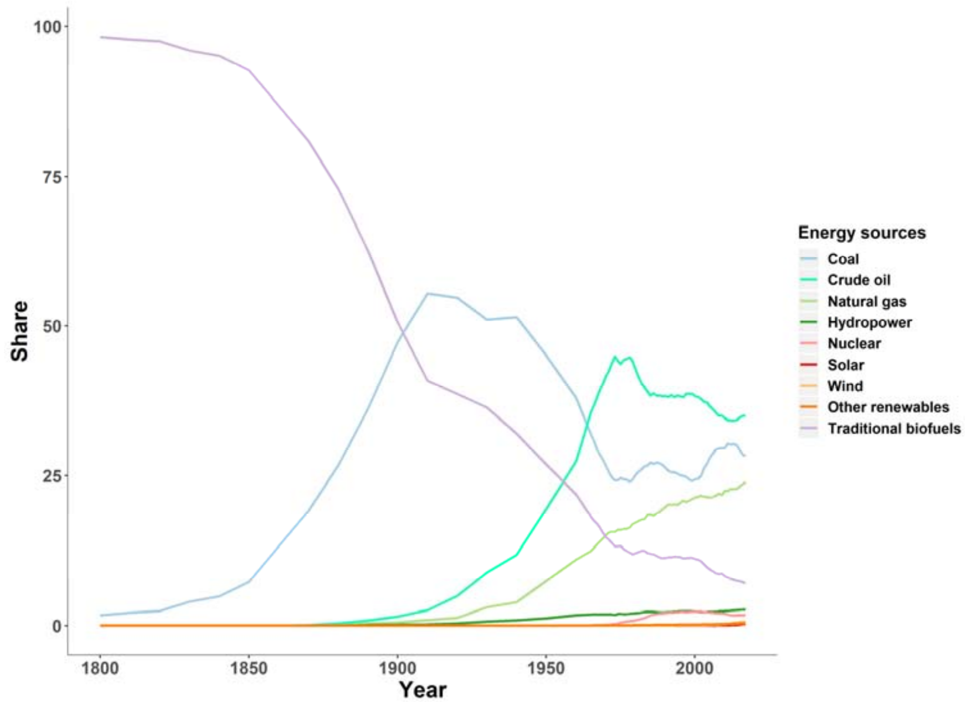
- Russian economist, Nicolai Kondratieff identified long term, 45-60 year, cyclical patterns in contemporary capitalist development, through the study of global GDP;
- These cycles are underpinned by shifts in technologies, advances in knowledge and new social conditions which result in the decline in previous manufacturing processes and economic institutions and the opening up of new markets, creating new forms of wealth generation and subsequent economic growth
- Four previous growth cycles ended in growth periods around 1835, 1890, 1935 and 1980. The fifth cycle's low growth period was around 2008

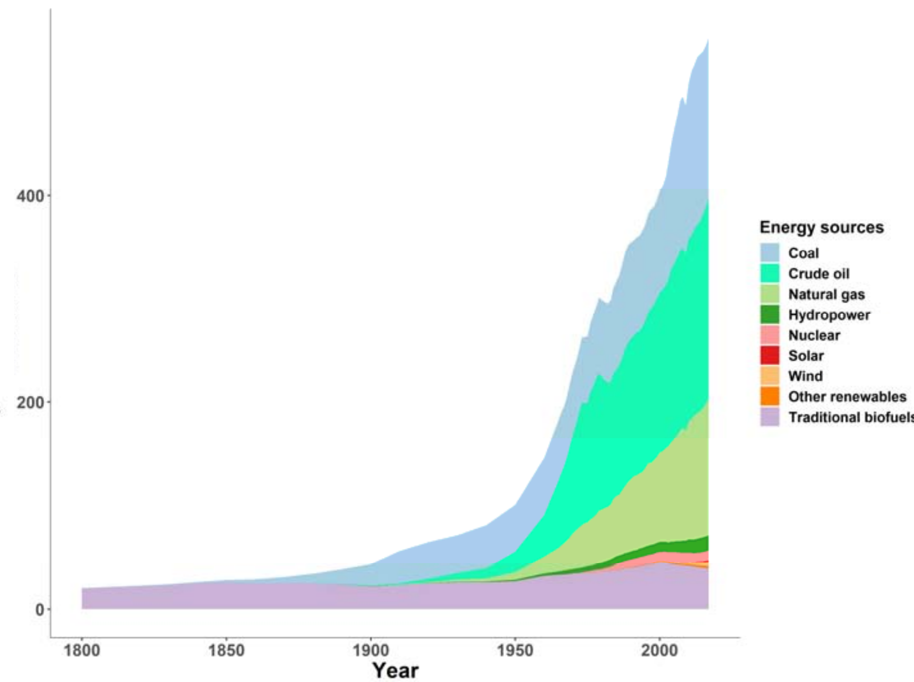
Typical depiction of Kondratieff waves



Early cycles were associated with advances in new energy sources (mostly fossil fuels) and machinery that took advantage of these new sources, including the steam engine, the internal combustion engine, turbines, power plants, electric traction, appliances, etc.

Global energy fuel transitions and economic cycles

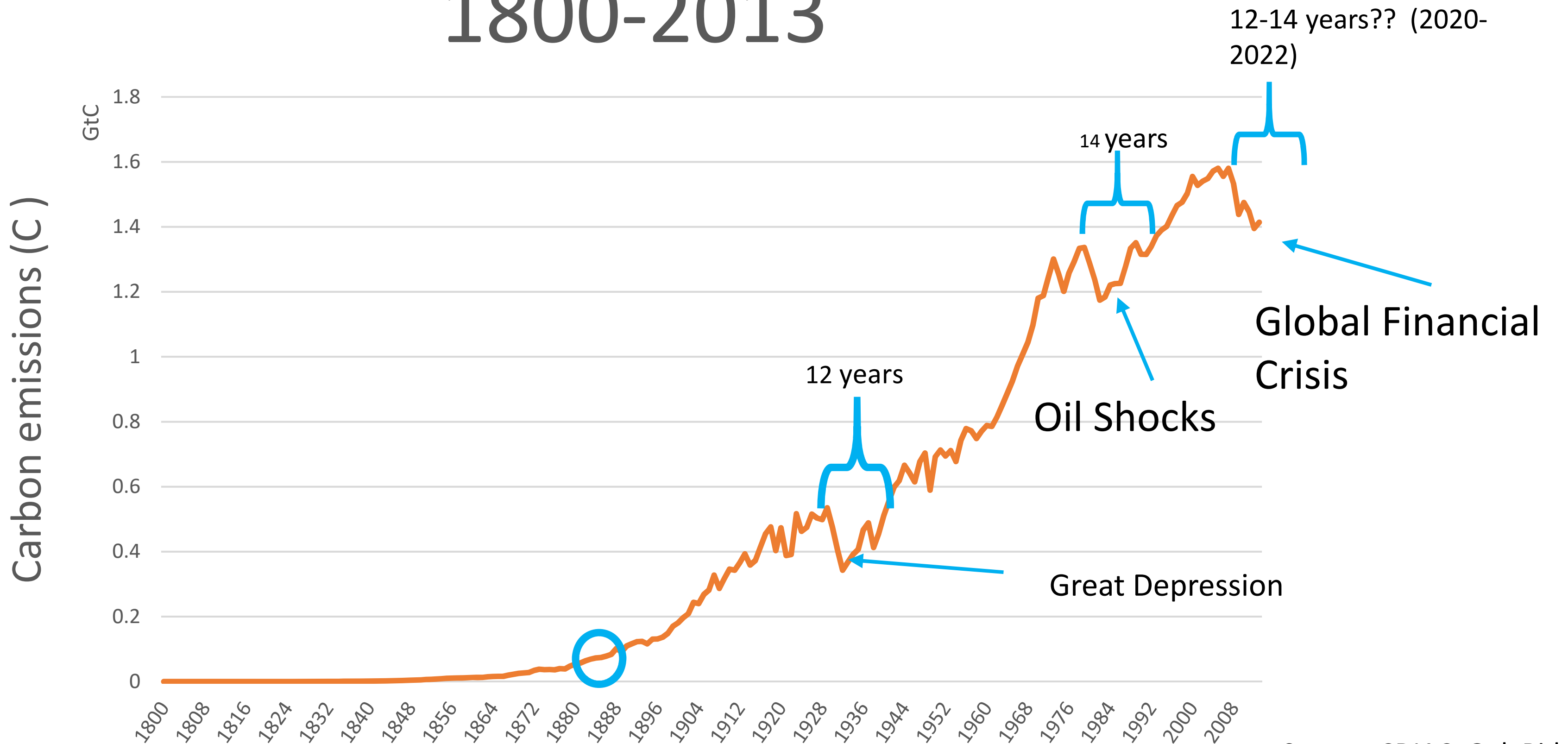




The economic cycles of growth were associated with both global energy transitions in fuel use and increases in total energy demand

Source: Our World in Data

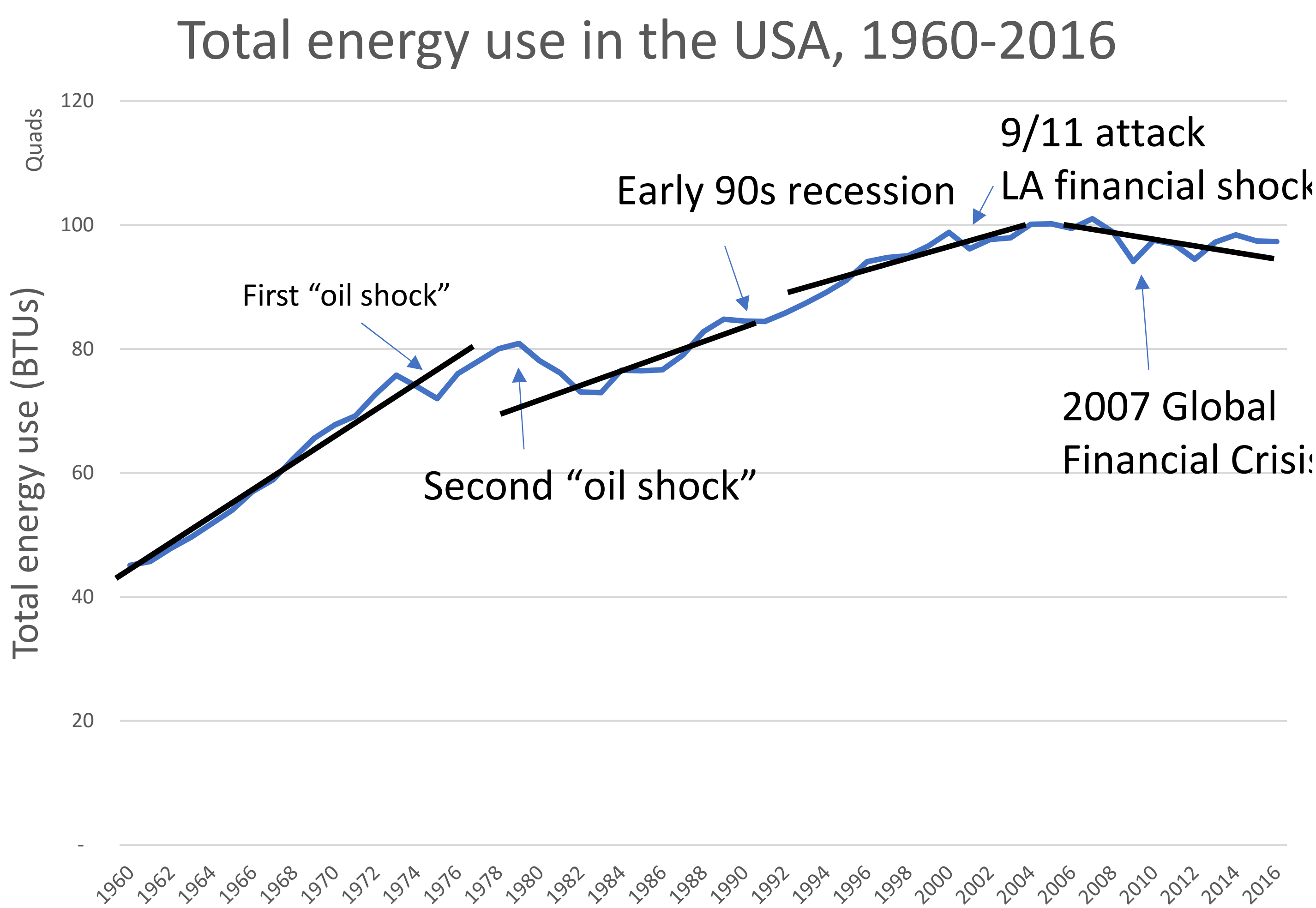
US carbon emission history, 1800-2013



Source: CDIAC, Oak Ridge Lab

Are long term economic cycles *still tightly* linked to fossil fuel energy use and hence GHG emissions in North America and the USA?

- We use this question as a vehicle to explore trends in energy use and GHG emissions over the past 10-15 years and evaluate projection of energy futures for the region
- Current trends suggest that the past may not be prologue for the future



Total energy use in the USA, 1960-2016
Quads
Total energy use (BTUs)
120
100
80
60
40
20
-
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
First "oil shock"
Second "oil shock"
Early 90s recession
9/11 attack
LA financial shock
2007 Global
Financial Crisis

Trends suggest that past relationships may not predict future energy use and GHG emissions

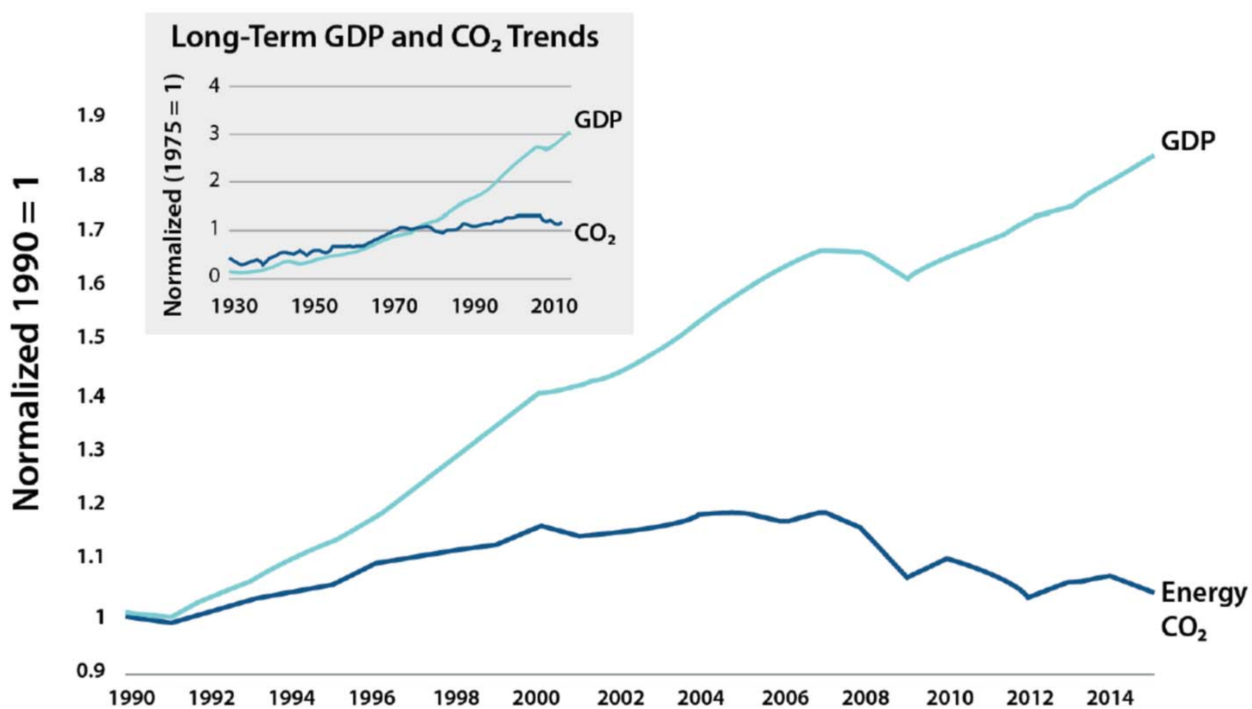
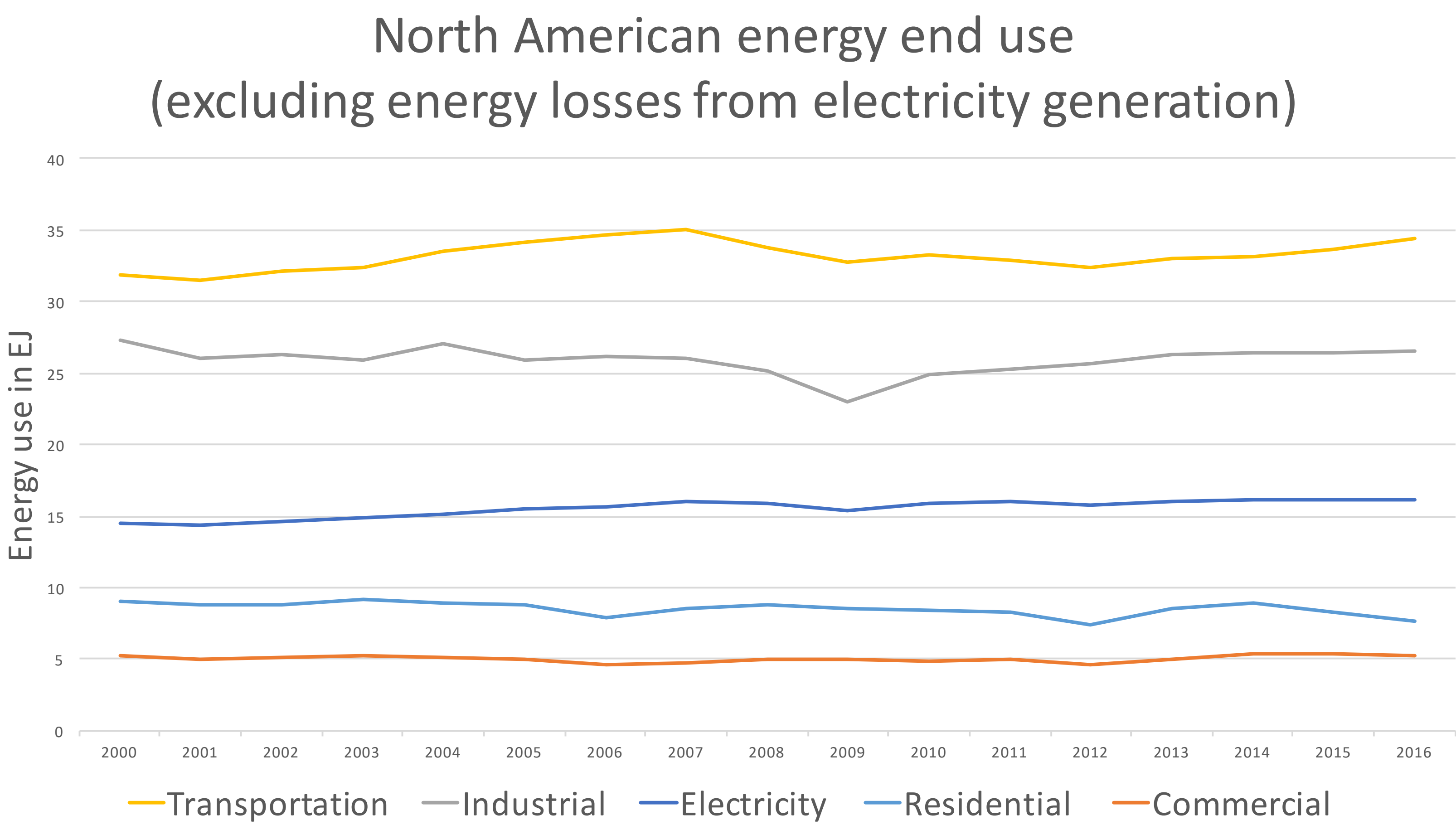
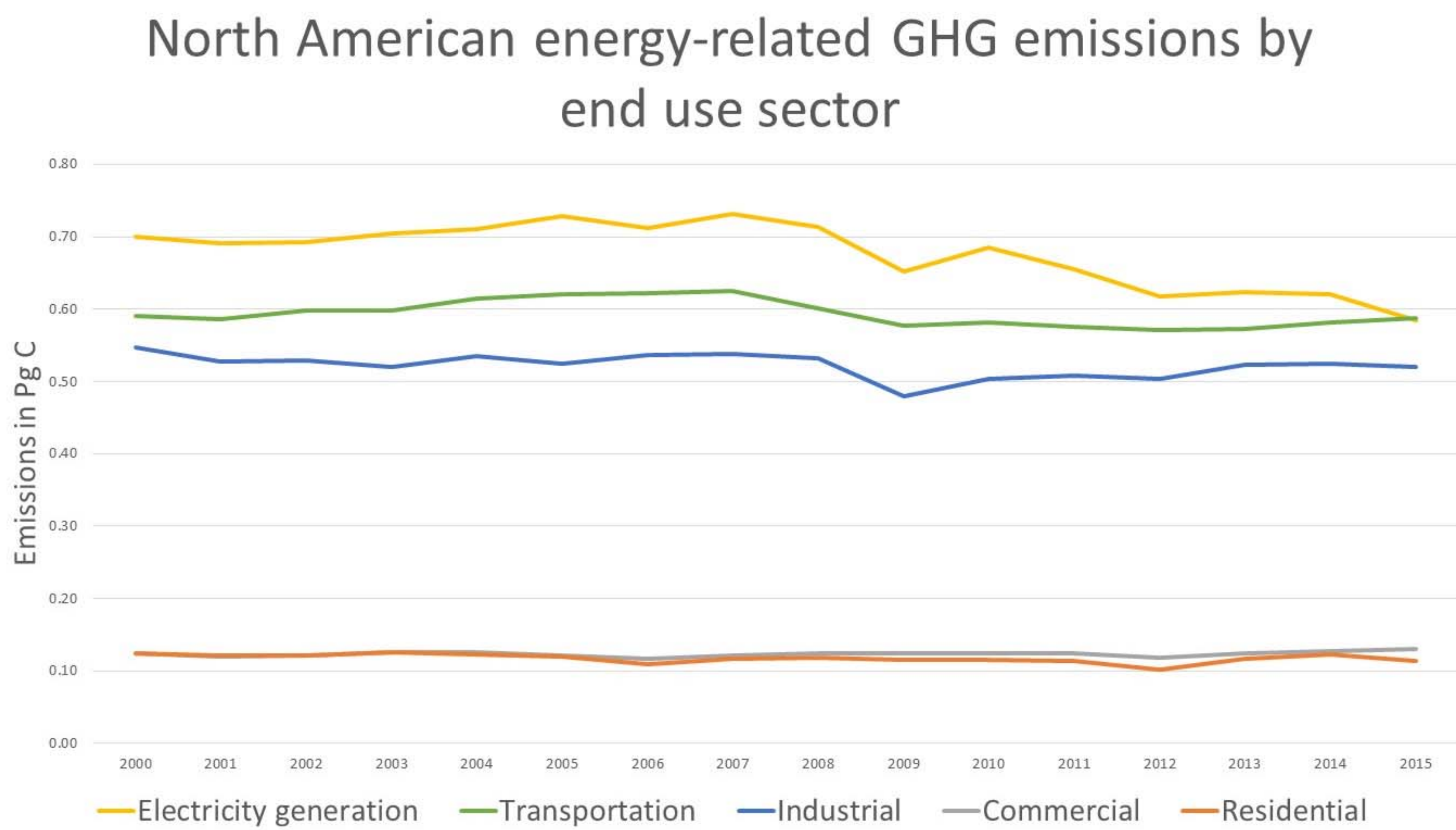


Figure 3.1. U.S. Energy Carbon Dioxide (CO_2) Emissions and Gross Domestic Product (GDP).

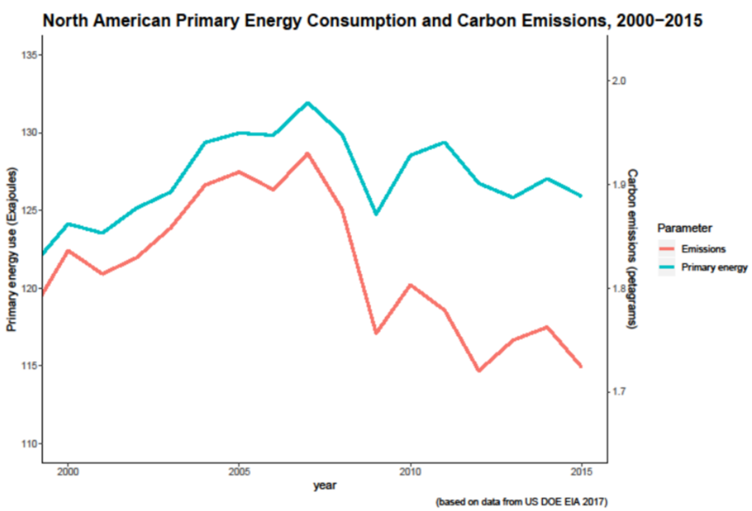
Source, Adapted from White House, 2016

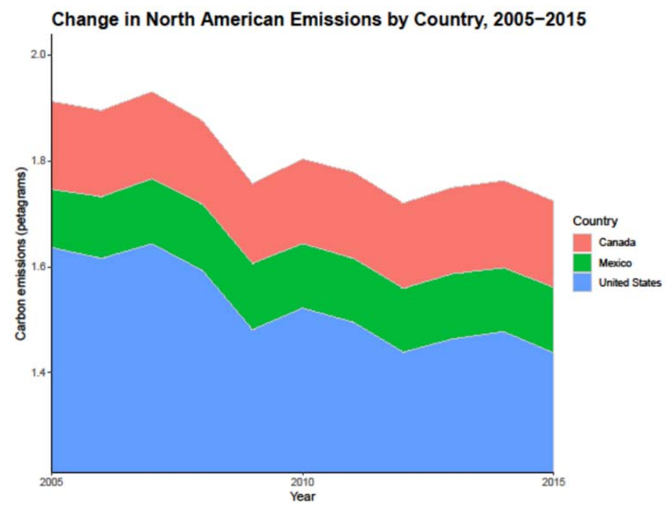
Trends in energy use and GHG emissions in North America and the USA since 2003


North American energy end use
(excluding energy losses from electricity generation)
Energy use in EJ
40
35
30
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Transportation
Industrial
Electricity
Residential
Commercial


North American energy-related GHG emissions by end use sector
Emissions in Pg C
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Electricity generation
Transportation
Industrial
Commercial
Residential

By 2015, energy use / GHG emissions were at 18-20 year lows



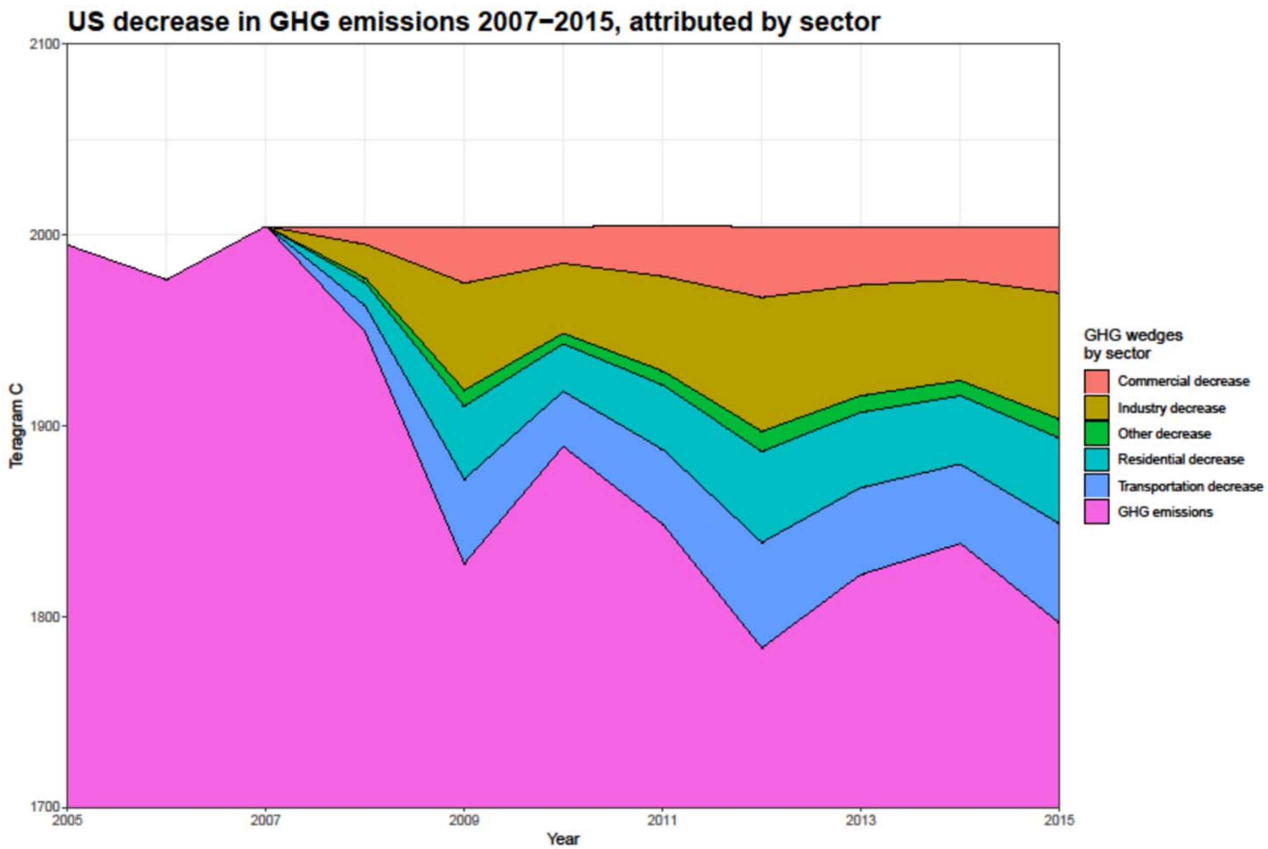


North American energy use in 2015 (125.9 EJ) was the lowest in 18 years (approximately similar to 2002-03 levels)

North American GHG levels in 2015 (1.72 Pg C) were the lowest in 20 years (approximately similar to 1996-97 levels)

Between 2007 and 2015, the total drop in carbon (C) emissions for North American was approximately 0.17 Pg/year, a cumulative 10% decrease, and an annual decline of 1.4%

The USA was responsible for approximately 99% of the decrease, Canada's emissions also fell and Mexico's increased slightly



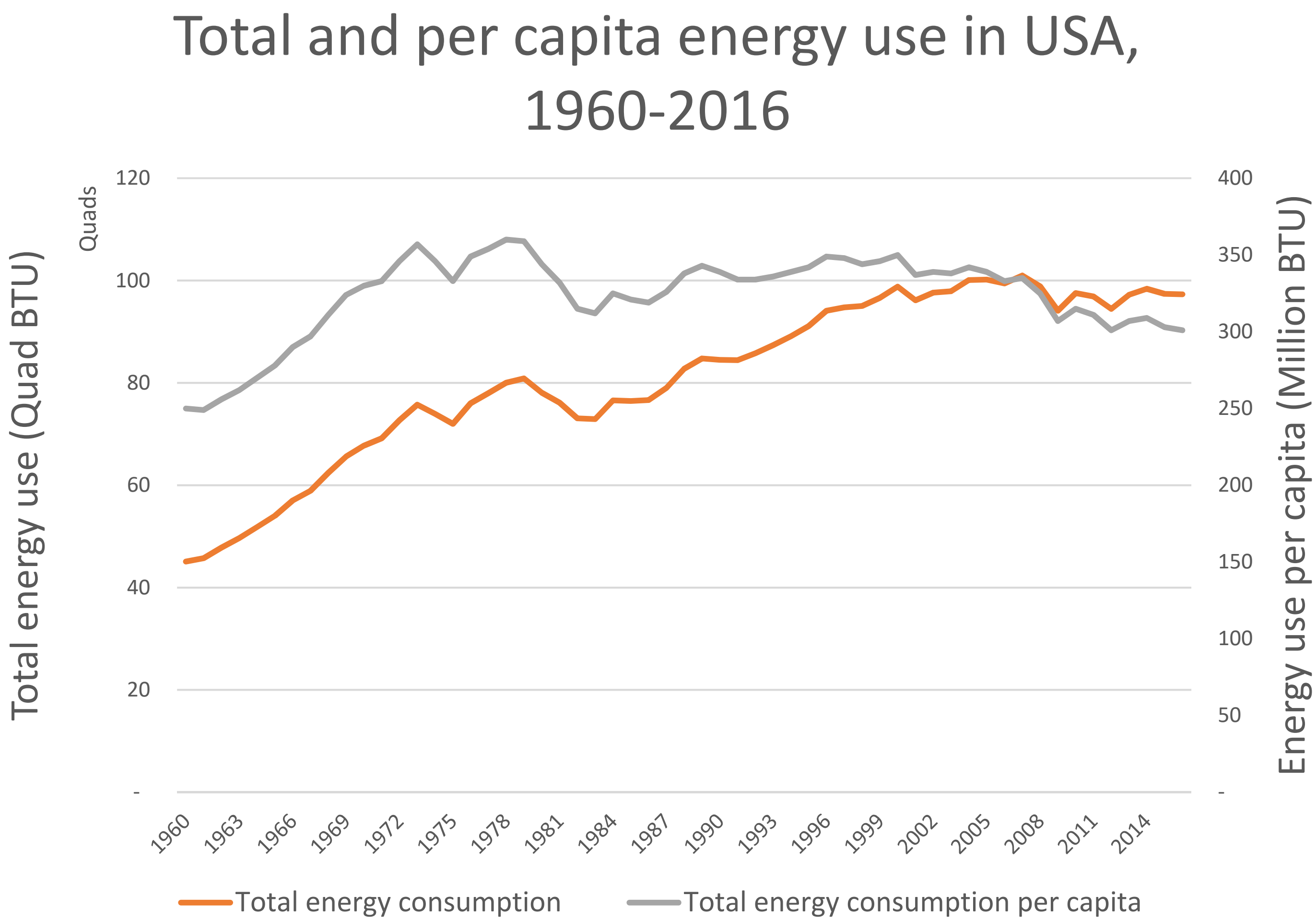
Source: EPA, 2017

US average share of decrease in GHG by sector when electricity is separated from end uses:

Transport :	27.5%
Electricity generation:	54.6%
Industry	17.4%
Commercial:	-1.6%
Residential:	0.8%
Other:	1.2%

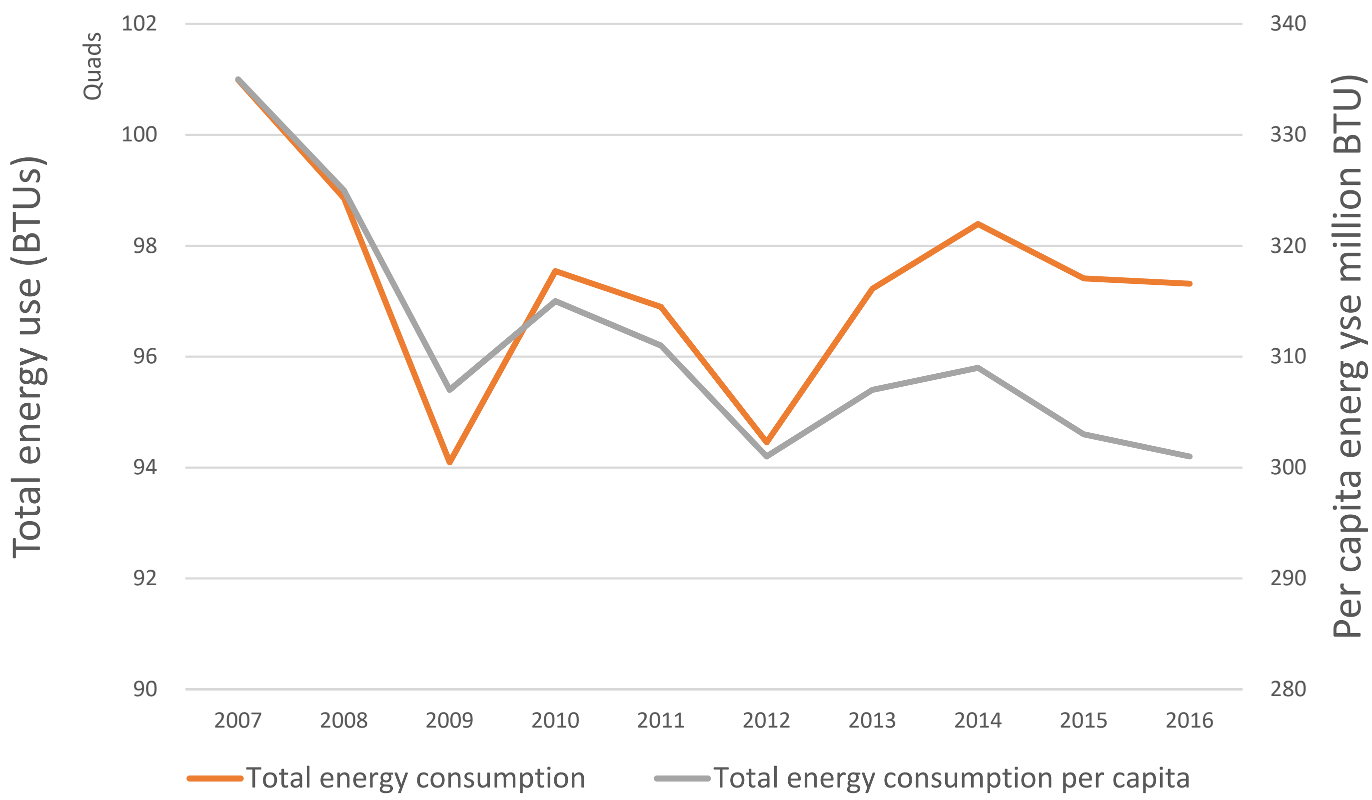
An approximate cumulative savings of 1.3 Pg C from 2007 levels to 2015.

Savings were approximately 1.5 Pg C by 2016 (EPA 2019)



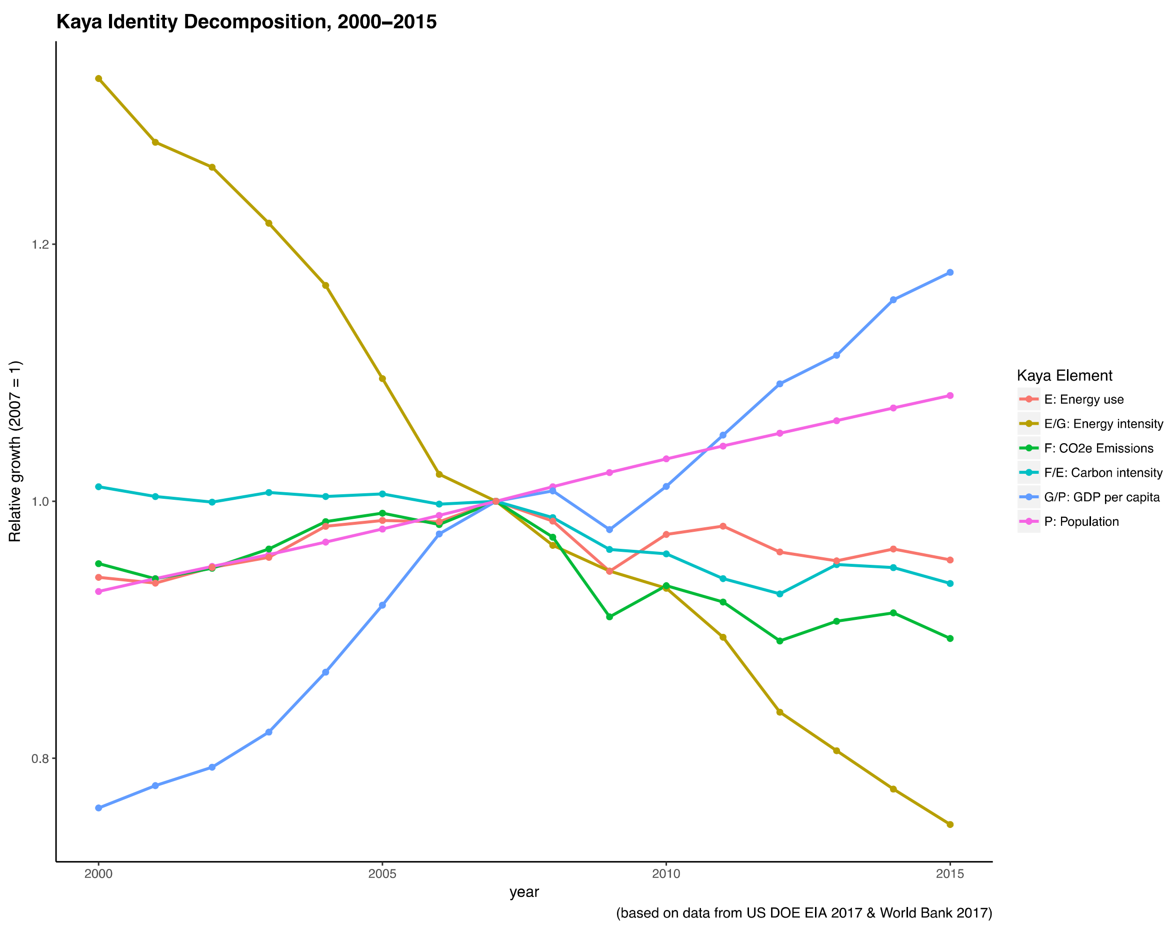
Total and per capita energy use in USA, 1960-2016
Quads
Total energy use (Quad BTU)
Energy use per capita (Million BTU)
120
100
80
60
40
20
-
400
350
300
250
200
150
100
50
-
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
Total energy consumption
Total energy consumption per capita

Total and per capita energy use in the USA, 2007-2016



Source: DOE EIA, 2018

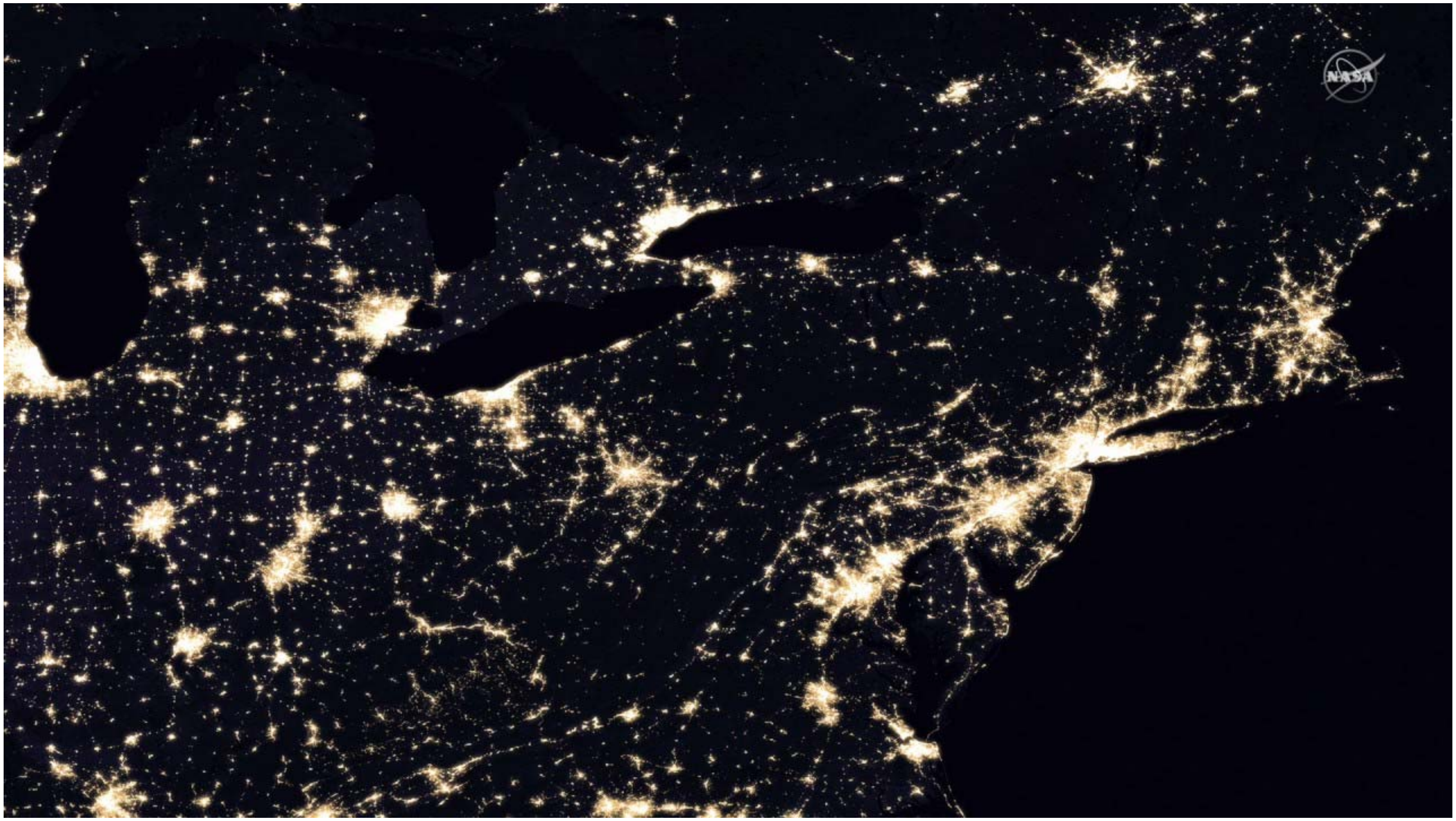
Lower energy and carbon intensities despite population and economic growth



3 major takeaways from the energy trend analyses

1. Energy use and GHG emissions have declined from 2007 to 2016. By 2017, estimates suggest levels remained lower than 2007, (although in 2018 early evidence suggests a trend reversal in GHG emissions)
2. The energy system related reasons for the declining trends include factors that have decreased energy and carbon intensities while population and GDP have risen
3. Energy intensities declines are predominately due to increased efficiencies, and lower overall energy use, while decreases in carbon intensities are largely due fuel switching and an increase in renewables

Factors influencing energy use and GHG trends in North America

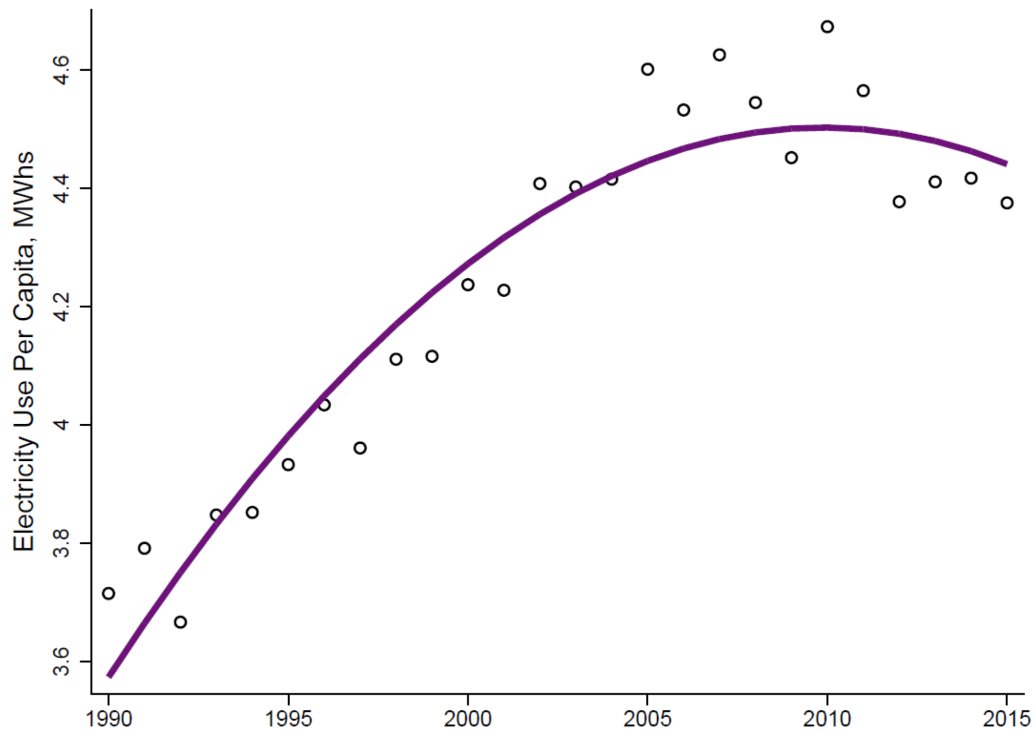


Major factors influencing lower energy use and GHG emissions

1. Lower energy use per capita combined with increased end use efficiency
2. Shift in fossil-fuel-fired power plants to higher efficiency, using advanced technologies (single-cycle gas turbine to combined cycle turbine), and lower emissions (shifting dispatch of electric generators to lower-emitting units)
3. Increased renewable energy use

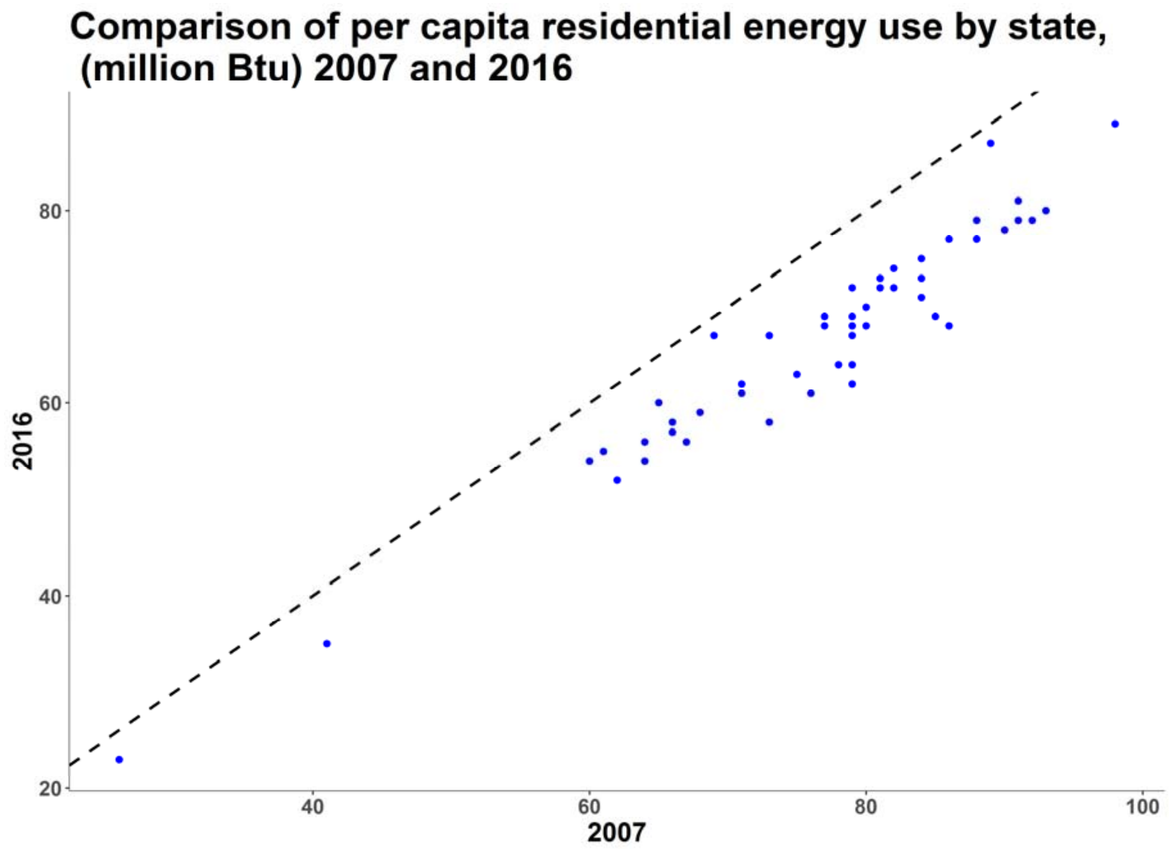
Lower residential energy use

- American households use less electricity than they did five years ago. U.S. residential electricity consumption per capita 1990-2015. Consumption dipped significantly in 2012 and has remained flat, even as the economy has improved considerably (Lucas Davis, 2017).

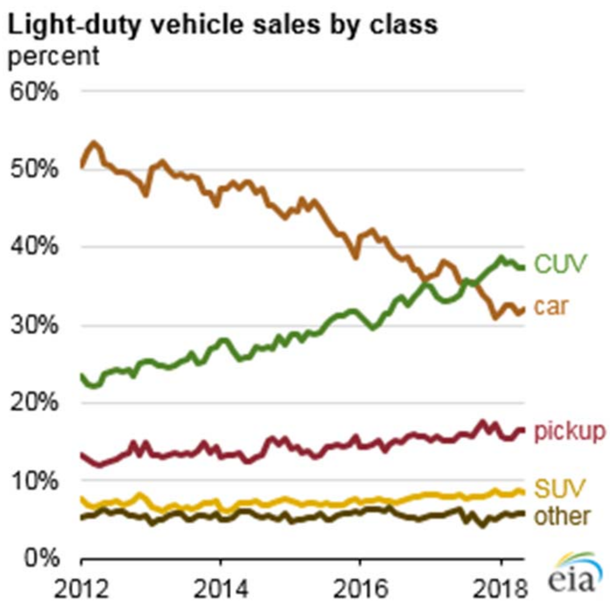


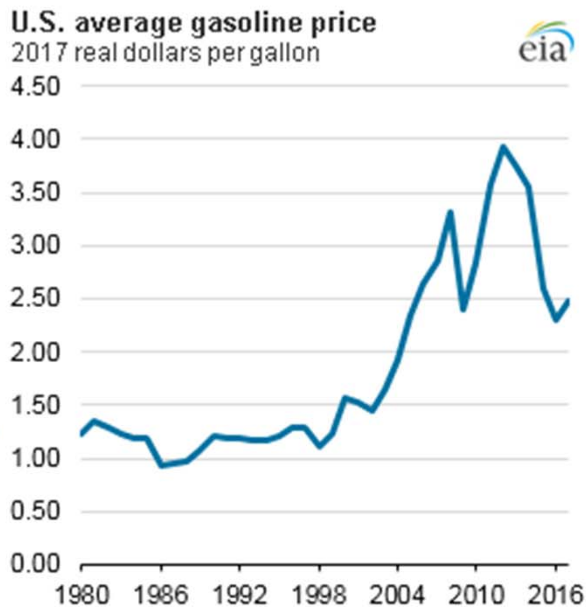
Lower residential energy use

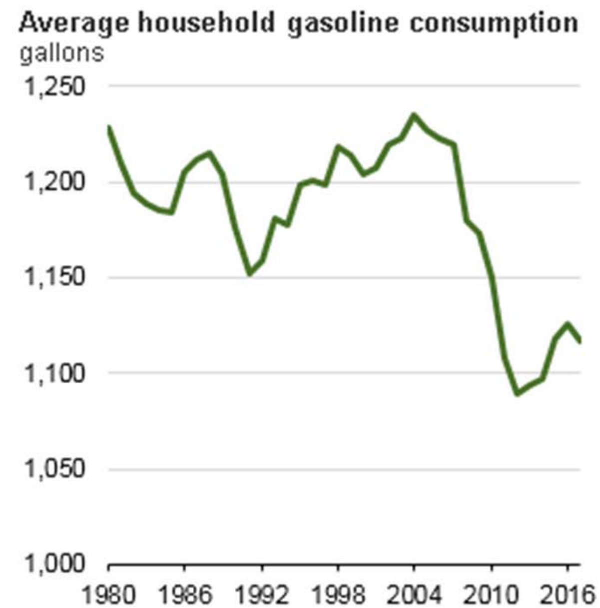
- Across the USA, by state, total residential energy use per capita in 2016 was lower than residential per capita energy use in 2007

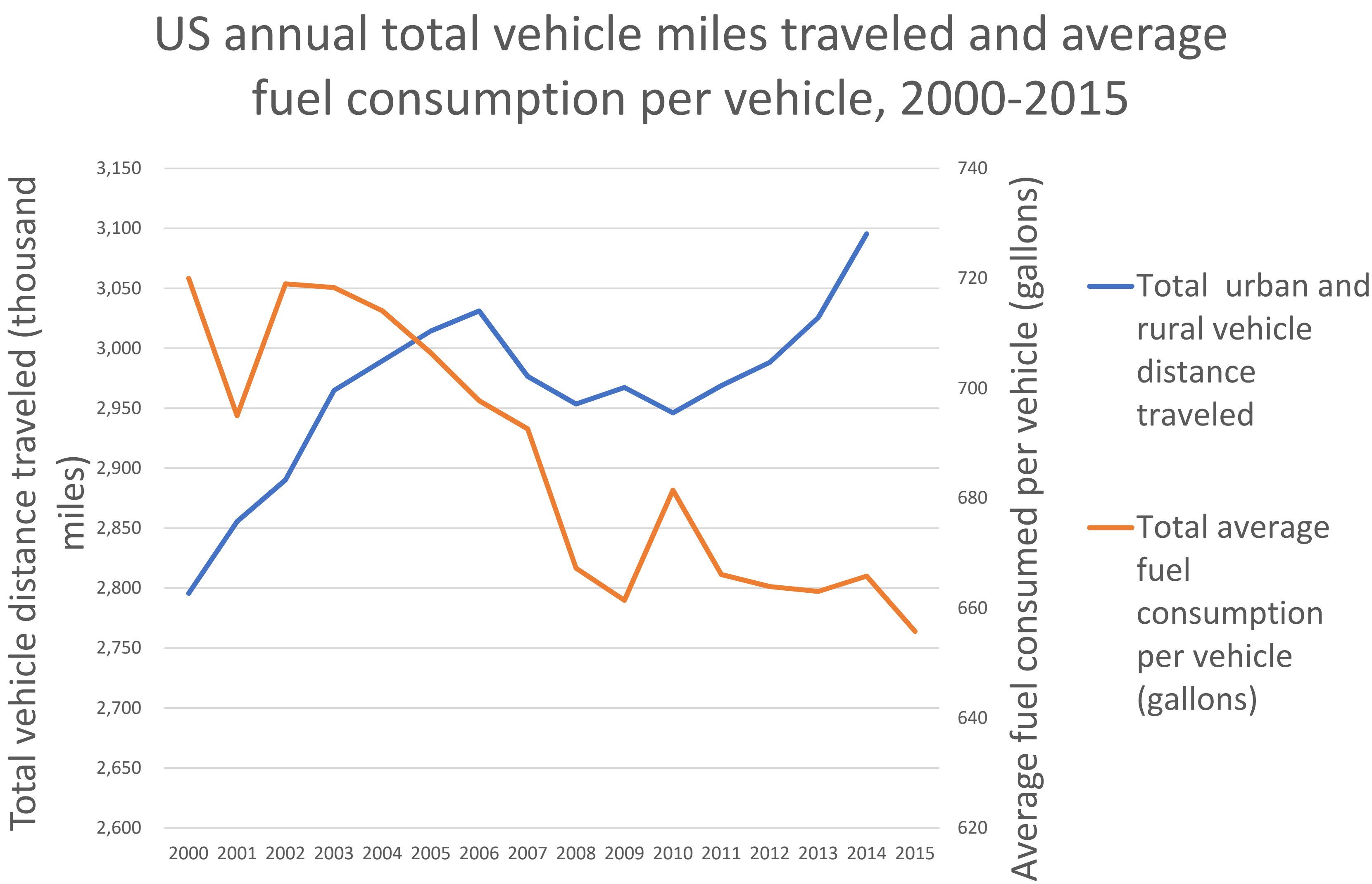


Changing on-road vehicles and declines in household consumption of gasoline



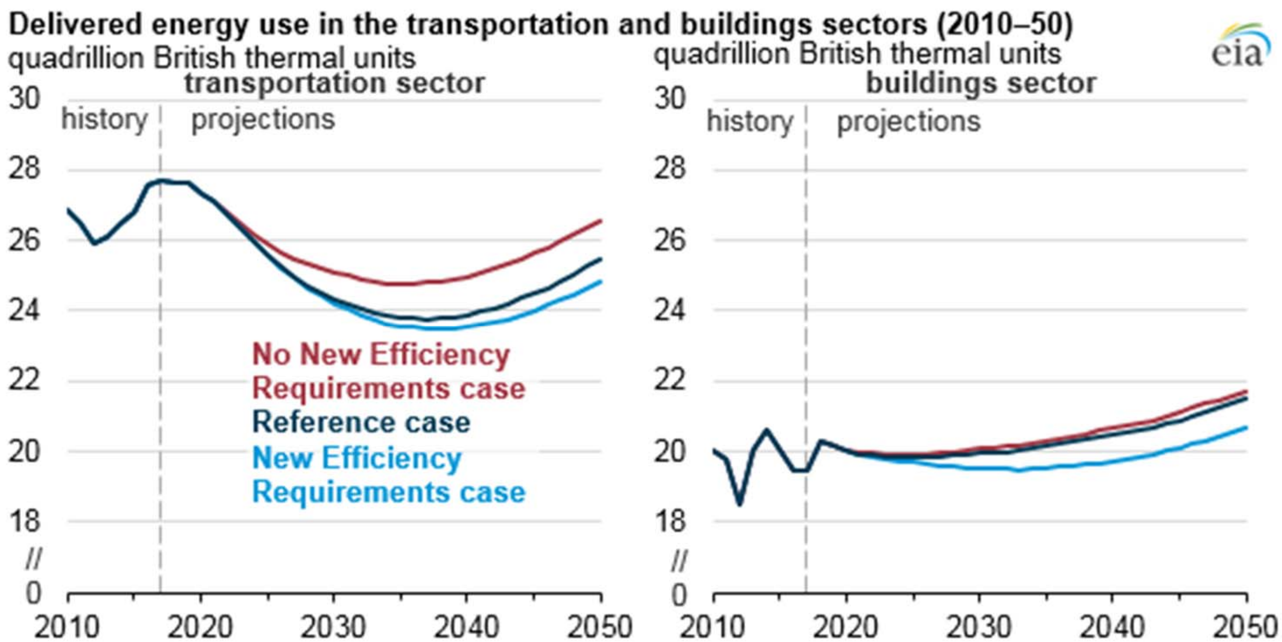






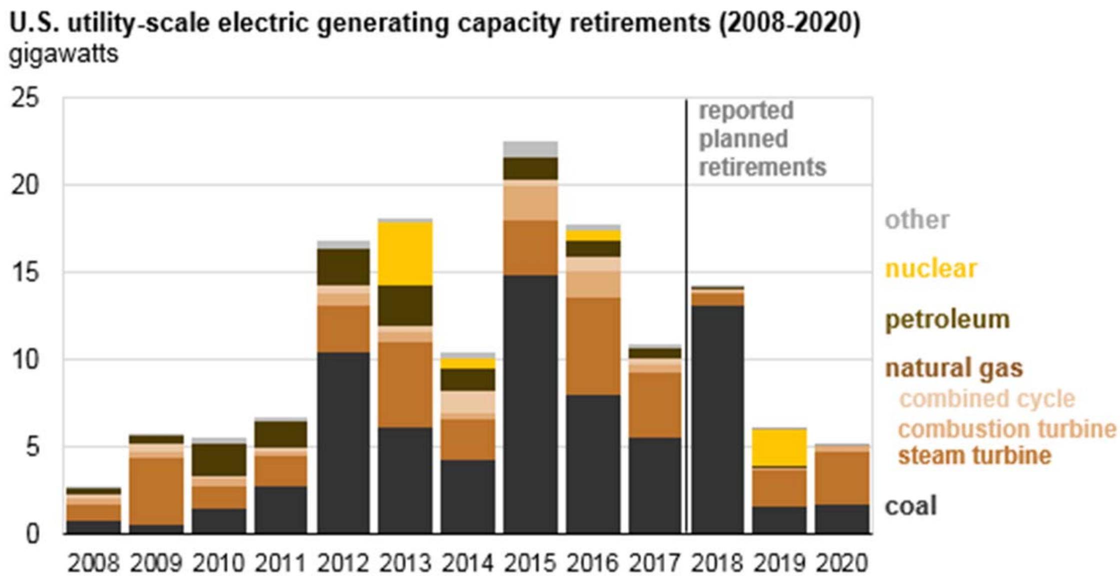
US annual total vehicle miles traveled and average fuel consumption per vehicle, 2000-2015
Total vehicle distance traveled (thousand miles)
Average fuel consumed per vehicle (gallons)
3,150
3,100
3,050
3,000
2,950
2,900
2,850
2,800
2,750
2,700
2,650
2,600
740
720
700
680
660
640
620
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Total urban and rural vehicle distance traveled
Total average fuel consumption per vehicle (gallons)

Decreased energy intensities due to greater efficiencies



Fuel economy standards have affected vehicle efficiency, DOE “Today in Energy” 3 August 2012
Changing energy efficiency and fuel economy standards affects energy consumption, DOE “Today in Energy” 2018

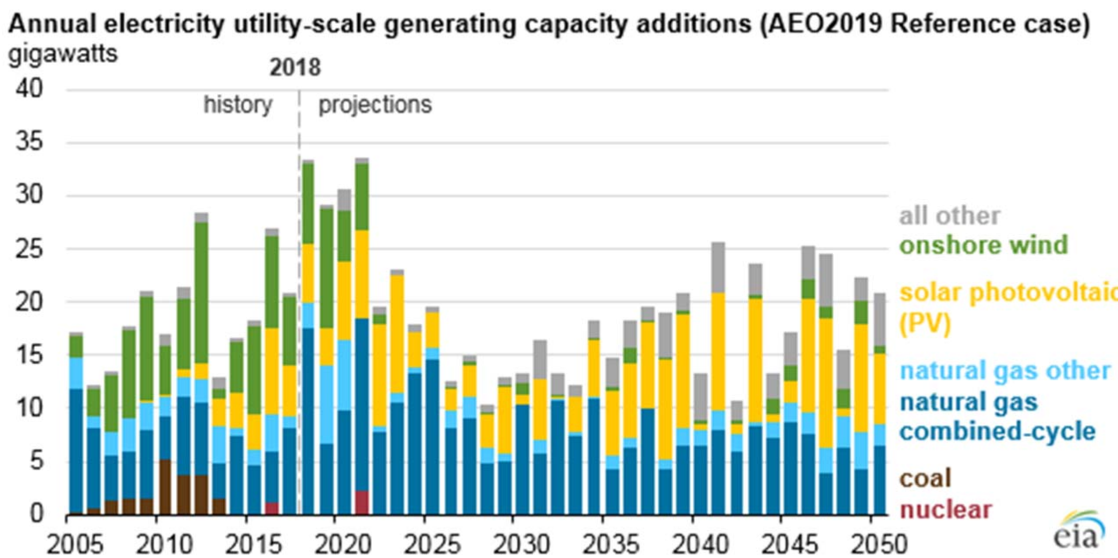
Retiring higher emitting power plants



DOE, EIA, 2018

Nearly all of the utility-scale power plants in the United States that were retired from 2008 through 2017 were fueled by fossil fuels. Of the total retired capacity, coal power plants and natural gas steam turbines accounted for the highest percentages, 47% and 26%, respectively. Most of the planned retirements through 2020 will also be coal plants and natural gas steam turbines, based on information reported to EIA.

Building more efficient and a lower emitting power plants

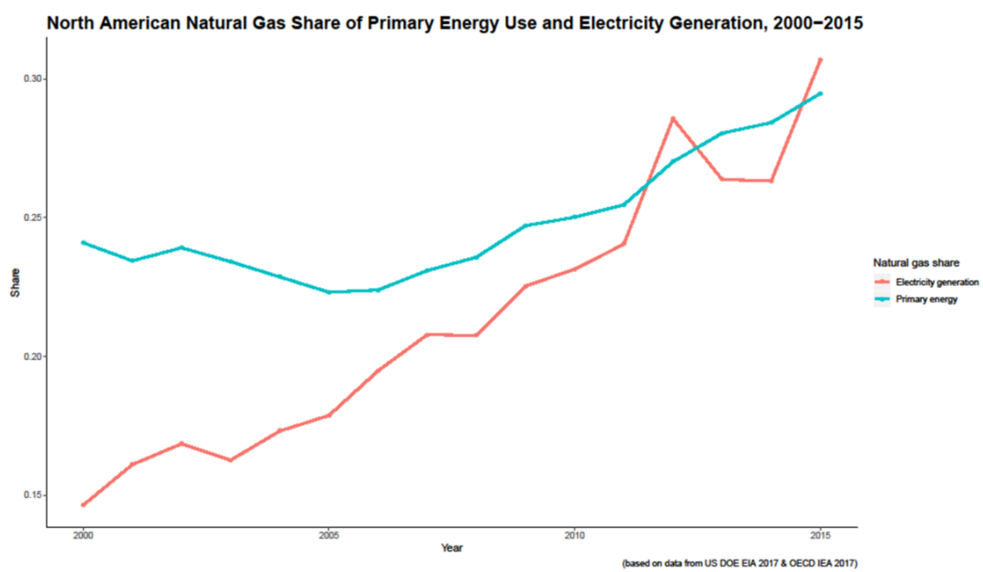


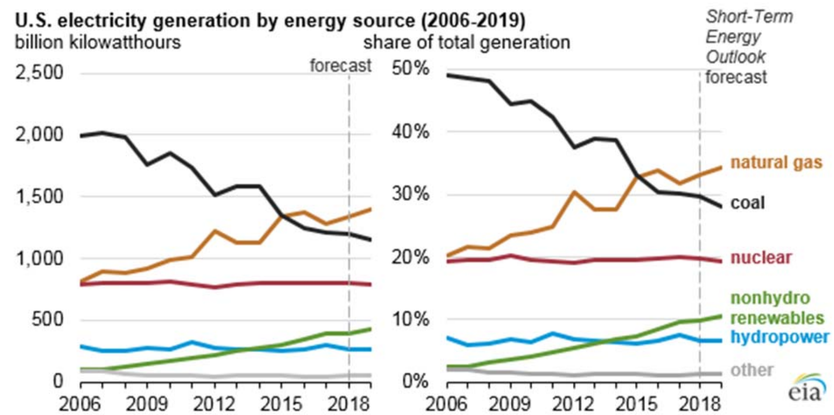
DOE, EIA, 2019

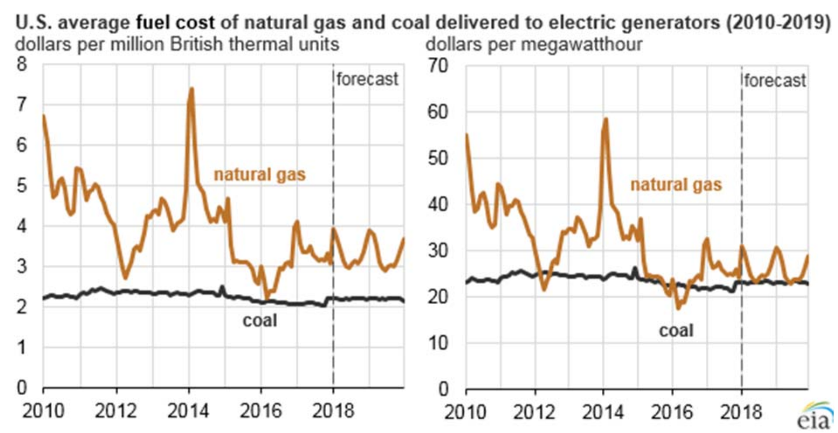
Utilities in the US have been largely building new natural gas combined cycle and other gas power plants along with wind and solar.

EIA's long-term projections show that most of the electricity generating capacity additions installed in the United States through 2050 will be natural gas combined-cycle and solar photovoltaic (PV).

Decrease carbon intensities due to fuel switching from coal to natural gas







Coal and natural gas generation shares over the past decade have been responsive to changes in relative fuel prices. Natural gas now accounts for almost 30% of the total primary energy supply for the region and over 30% of fuel for electricity generation

DOE EIA, 2018

Decreased carbon intensities due to increases in renewables

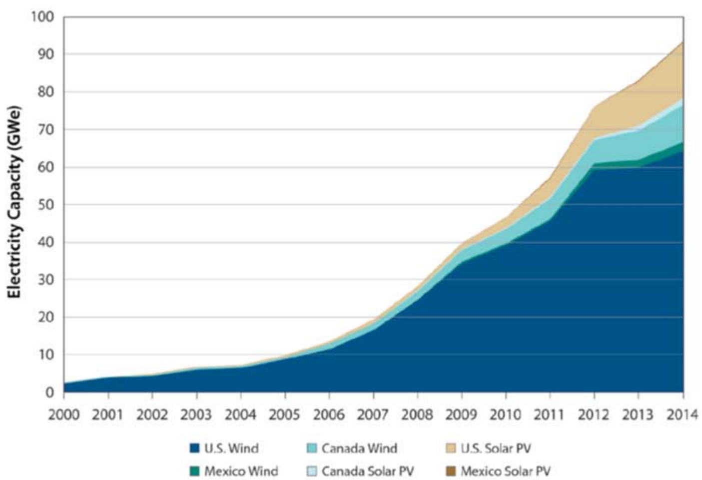


Figure 3.6. North American Wind and Solar Net Capacity, 2000 to 2014. Key: GWe, gigawatt electrical; PV, photovoltaic. [Data source: IEA 2018.]

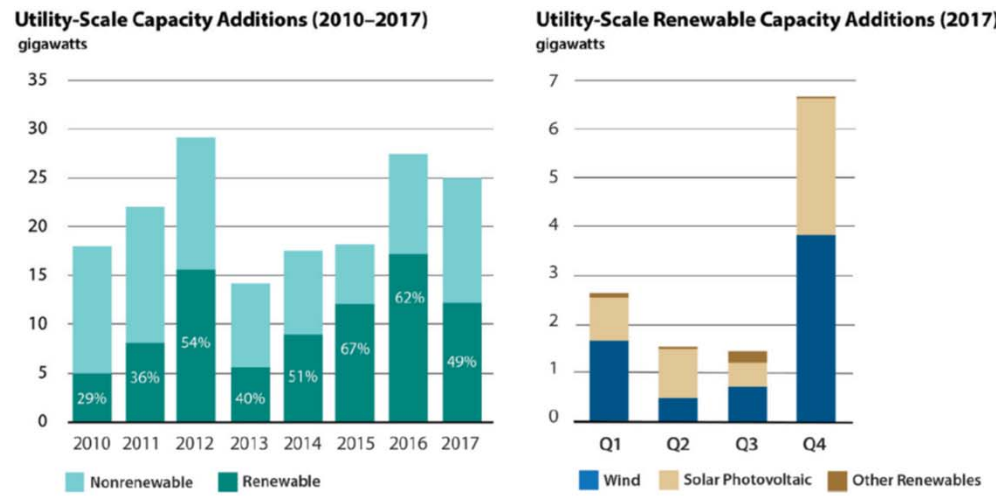


Figure 3.8. Renewable Generation Capacity (2010 to 2017) and Utility-Scale Additions, 2017. [Figure source: Redrawn from EIA 2018b.]

For North American electricity, the contribution of nonhydro renewables (e.g., wind, solar, and biomass) to total power generation grew from 2.4% in 2004 to 6.1% in 2013, translating into a 10.6% annual average increase, or an additional 220 PJ of renewable energy into the North American electrical system annually. In 2018, about 10% of total U.S. energy electricity generation use was from non-hydro renewable sources (EIA 2018).

Caveats and questions

- Is methane (natural gas) a true bridge fuel or are uncounted fugitive emissions, flaring and other losses overwhelming gains in reductions?
- Have we accounted for the true costs in bio-fuels including those related to land use change in locations other than those for bio-fuel production?
- Is our aging infrastructure influencing emissions?
- How have the changes in energy policy over the last two years, changed energy use and GHG trends?

Trends summary

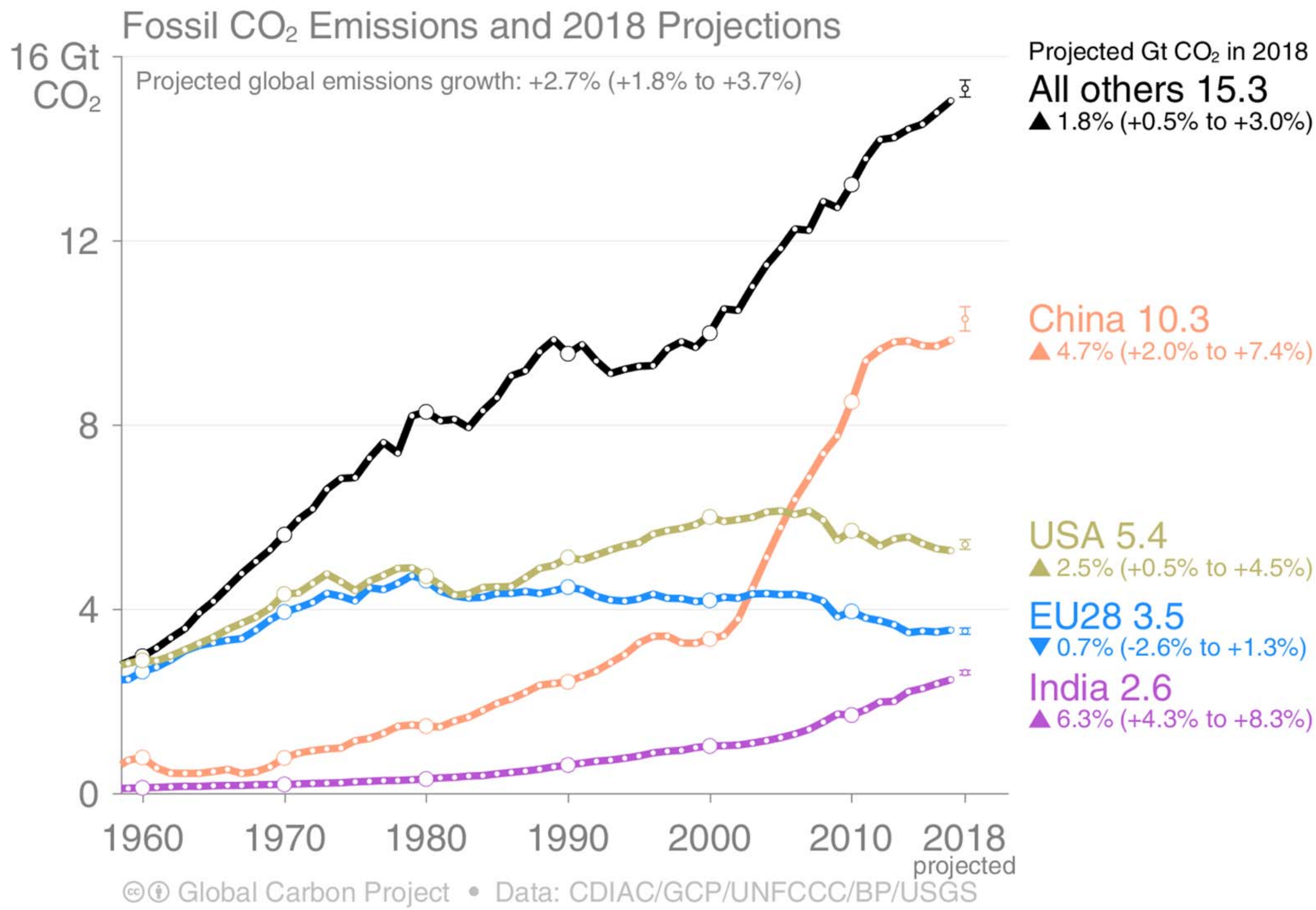
- Historically, we have experienced downturns in economic activity and subsequent downturns in energy use and GHG emissions. Previously high levels were then exceeded within 12-14 years of the initial shock
- North American economies, lead by the US, have been on a downward trend in energy use and GHG emissions over the past 10-12 years, initially spurred by a financial crisis, but subsequently continued under conditions of economic growth (over 11 million jobs added to economy from 2010 – 2016)

What are the energy use and GHG futures for the North American energy system?

Will the cycle be unbroken?

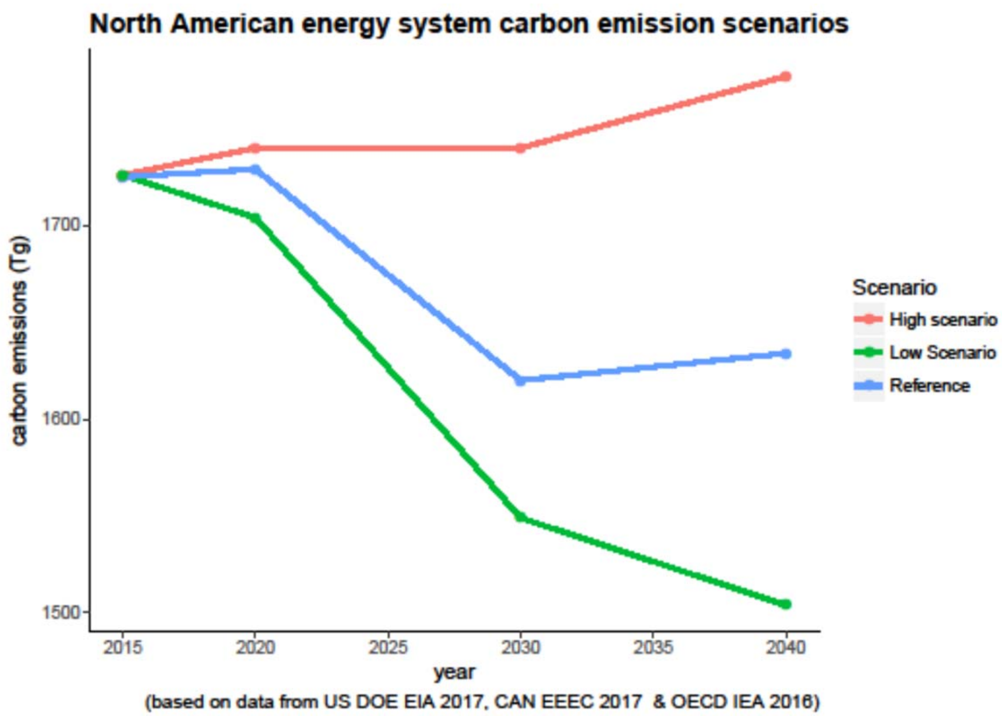
Emissions Projections for 2018

Global fossil CO_2 emissions are projected to rise by 2.7% in 2018 [range: +1.8% to +3.7%]
The global growth is driven by the underlying changes at the country level.



Source: CDIAC; Jackson et al 2018; Le Quéré et al 2018; Global Carbon Budget 2018

Regional emissions projections vary widely

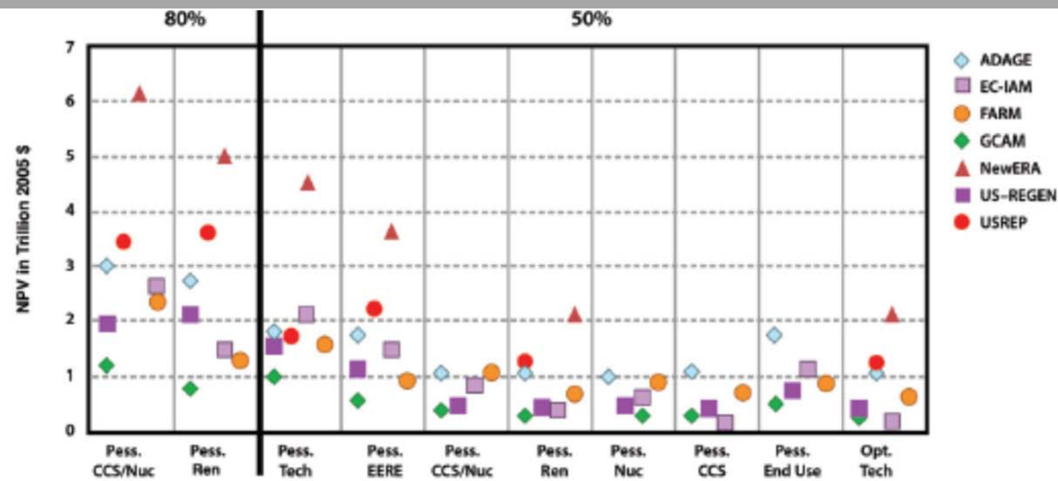


National projecctions bu scenario type, 2015-2040
(Tg C)

		2040 Reference	2040 High	2040 Low
Canada	173	180	193	168
Mexico*	118	124	140	78
USA	1,434	1,330	1,445	1,259
North America	1,725	1,634	1,777	1,504
Percent change		-5.3	3.0	-12.8

Note: IEA projection

Exploratory scenarios suggest that emissions can be reduced 80% (from 2005 levels) by 2050



Net Present Value of Mitigation Costs from 2010 to 2050 from Seven Different Models. The measures presented are the total mitigation costs for 50% and 80% reductions in carbon emissions. Results suggest that total mitigation costs across pessimistic and optimistic technology assumptions are $1 trillion to $2 trillion (US$ 2005) for 50% reductions in GHG emissions and $1 trillion to $4 trillion (US$ 2005) for 80% reductions in GHG emissions. Among the caveats to these analyses, each of the models has different capabilities to calculate underlying metrics, so an assessment of costs generally must include different metrics across models, and these results do not include economy-wide impacts from the assumptions. Key: NPV, net present value; Pess., pessimistic; CCS, carbon capture and storage; Nuc, nuclear, Ren, renewables; Tech, technology; EERE, end-use energy and renewable energy; Opt., optimistic. [Figure source: Redrawn from Clarke et al., 2014, used with permission of *The Energy Journal*, conveyed through Copyright Clearance Center Inc.]

Future scenario summary

- Future projections suggest that energy use and GHG emissions can increase by 3% or decrease by 13% from 2015 levels
- On the other hand, research also suggests it is possible to reduce our energy use and GHG emissions to between 50-80% of 2010 emissions by 2050:
    - These reductions are not drive by ***technology and markets alone.*** Policy is necessary to help in the radical transition.
    - The cumulative cost of this change is approximately $1-4 trillion ($2005) present value

Conclusions and summary

Conclusions and summary

- The North American energy use and related carbon emission have declined from 2007 to 2016
- These declines were driven by decreases in energy intensities, resulting from more efficient energy technologies and lower energy use and decreases in carbon intensities, driven by increased renewables and fuel switching (particularly in the natural gas transition)
- Notwithstanding the significant GHG savings with the declines in emissions over the past several years (1.5 Pg C), the downward trend is not enough to put the region and the US on a 2° trajectory, nor do technologies and market conditions promise similar future reductions

Conclusions and summary

- It is possible, however, to meet the 2° challenge, but it will cost between $1-4 trillion (US$2005) and will require policy actions to enhance efficiency, reduce waste and increase non-fossil based energy usage

So what? Why should we care?

5 reasons to care about energy use and GHG trends and energy futures

1. Energy is an essential part of our daily lives and is fundamental to our well-being. Access to reliable, plentiful and cheap energy has been a major contributor to the success of the USA, as we always have been a major energy consumer
2. Using energy does not come without a price, however, including: 1) the direct cost ($) of energy, 2) the use of a non-renewable resource, and 3) environmental externalities

5 reasons to care about energy use and GHG trends and energy futures

3. Understanding how to use energy wisely with greater efficiency and cleaner sources will reduce financial costs, increase the lifespan of the resources and lower pollution levels.
4. Of this last concern, pollution includes local concerns, such as those related to the ambient air and water quality threats as well as land degradation.
5. It also includes reducing risks of climate change and threats to future generations of Americans

END

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https://carbon2018.globalchange.gov/chapter/3/