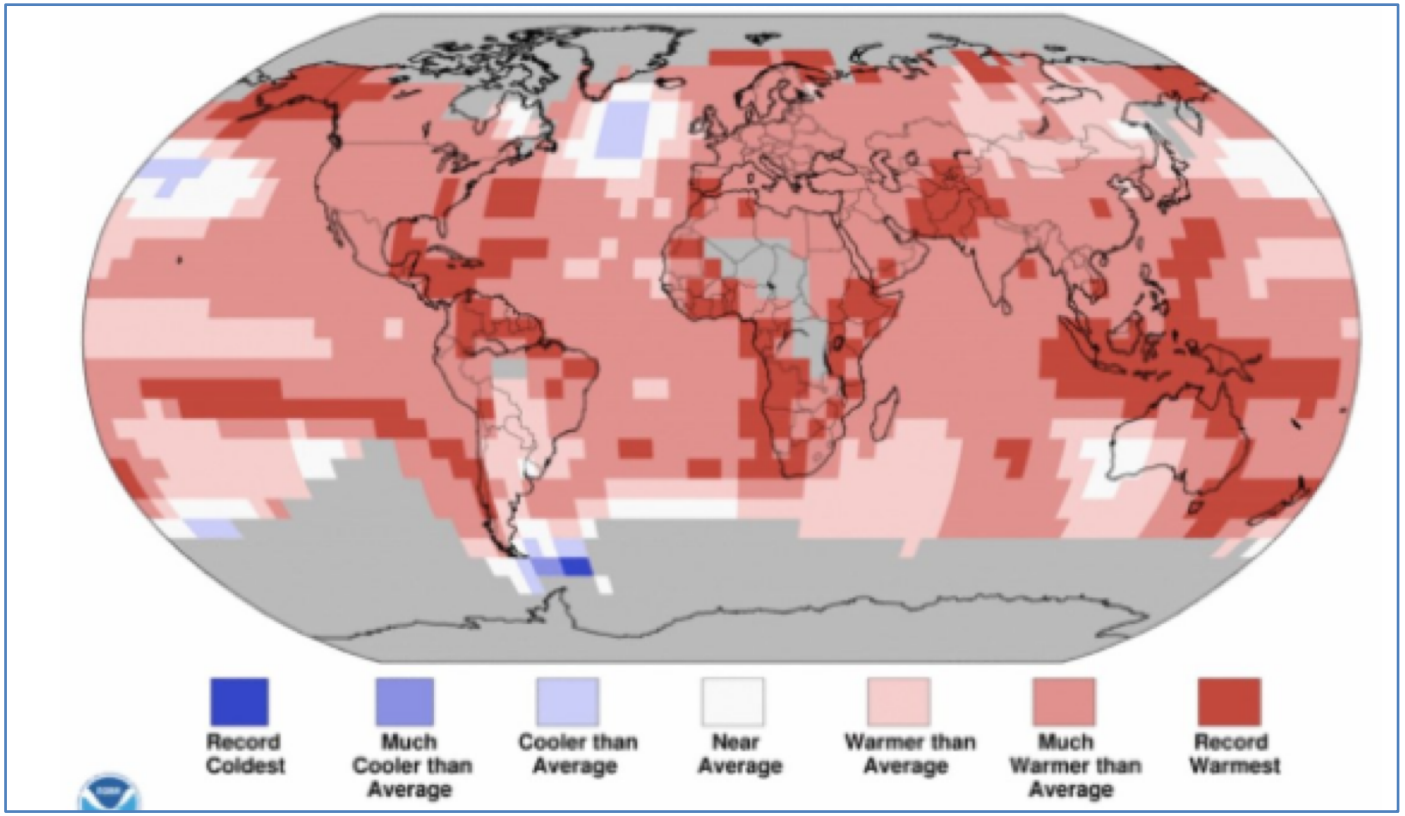
Empowering the Great Energy Transition While Fossil Fuels are Still Abundant: The U.S. Challenge

Dr. Marilyn A. Brown
Regents' & Brook Byers Professor of Sustainable Systems
Georgia Institute of Technology

Oxford University Center for the Environment
Energy Colloquium, School of Geography & the Environment
June 18, 2019

The Energy-Climate Nexus

2016 temperatures compared to normal around the globe (Source: NOAA)



2015-18 = Four Hottest Years on record

"…human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming …."

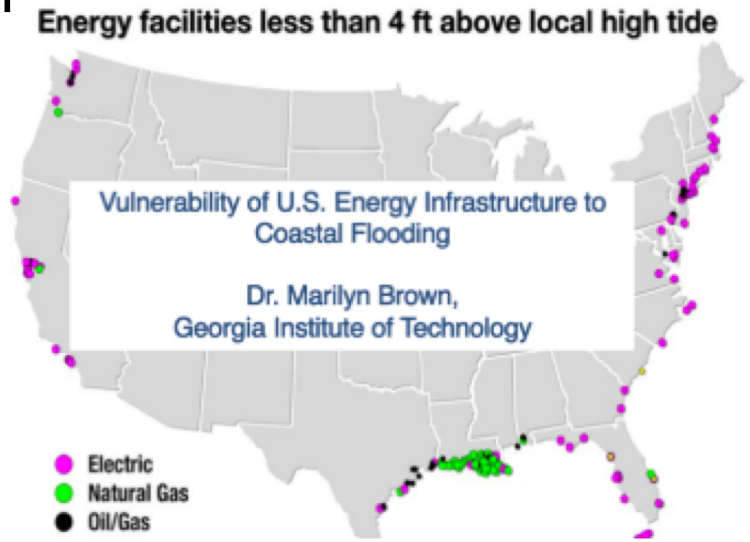
(Source: National Climate Assessment Special Report 2017)

Sea Level: A Rising Concern

The ultimate melting of ice sheets in Greenland and Antarctica could result in sea-level rise of 80 meters.

- ✓ Greenland: 6-7 m
- ✓ West Antarctica: 6-8 m
- ✓ East Antarctic Ice Sheet: 65-67 m

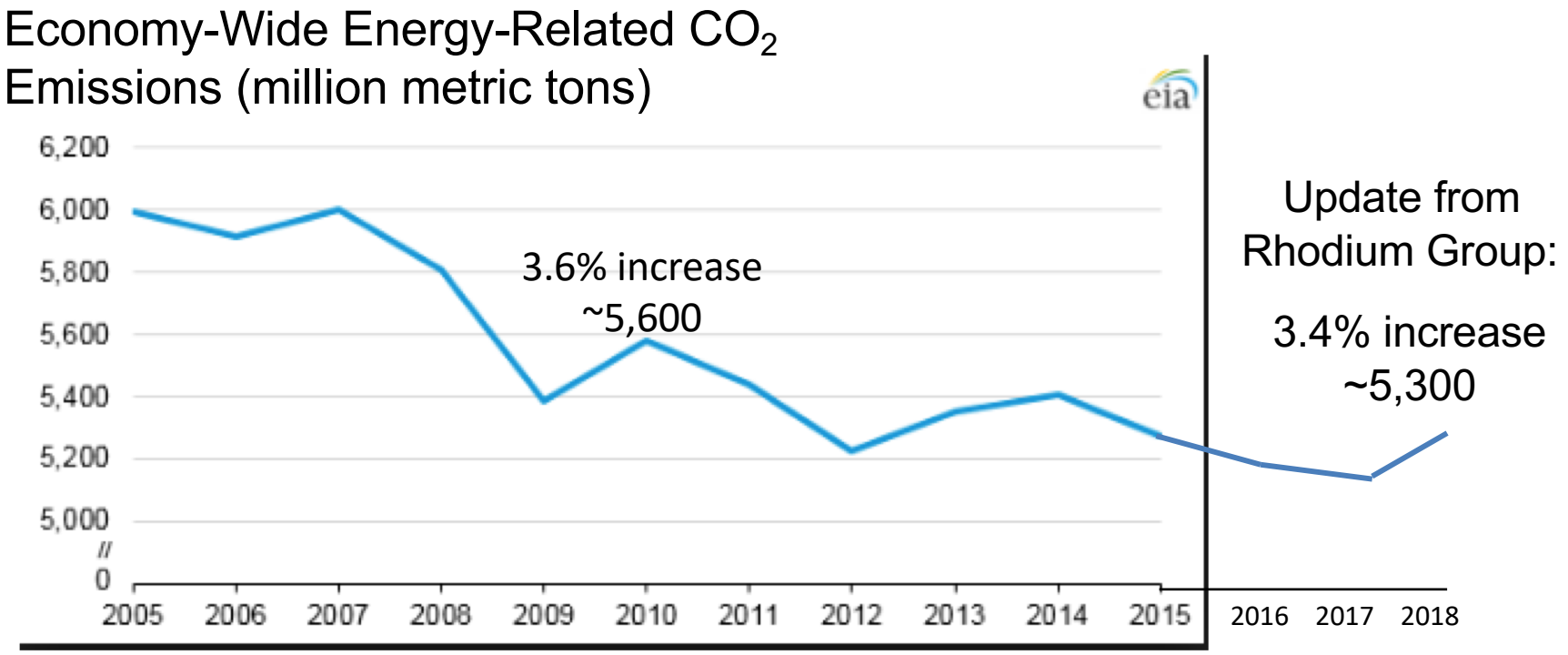
But global warming does not provide enough heat to melt all of the ice sheets suddenly; there is time for mitigation and adaptation.



Source: Brown (2018) Geographical Sciences Committee of the National Academies
https://www.youtube.com/watch?v=91rLXoqreic&t=460s

How is the U.S. Responding?

After a 10% decline (2005-2015) in CO_2, the U.S. bounced back with an increase of 3.4% in 2018.

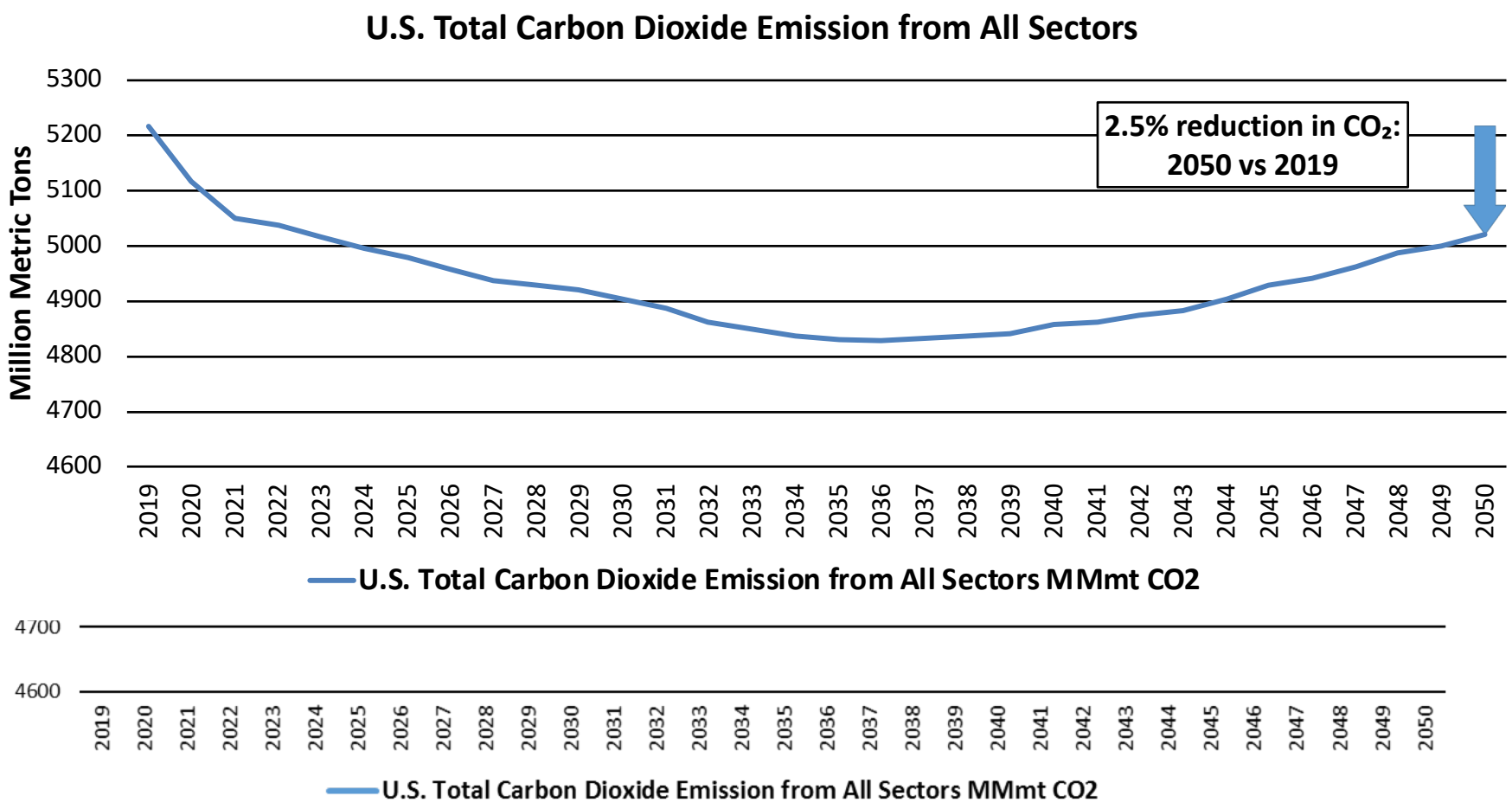


Notable increases in emissions from **natural gas, trucks, and air travel.**

Source for updates: https://tinyurl.com/yb8ekn8d

U.S. CO_2 Emissions are Far Off Track for Global Climate Goals

Annual Energy Outlook 2019
with projections to 2050



Sources: EIA, *Annual Energy Outlook 2019.* https://tinyurl.com/E-Outlook-2019

How can the U.S. Transition to Clean Energy W/out a Price on CO_2?

Marilyn Brown
@Marilyn_Brown1

Marilyn A. Brown is a Regents' and Brook Byers Professor of Sustainable Systems in the Georgia Institute of Technology's School of Public Policy.

Atlanta, GA

CEPL.gatech.edu

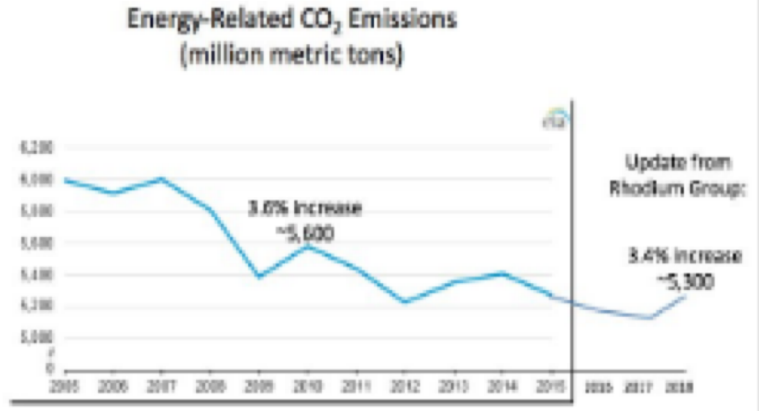
Joined September 2012

66 Photos and videos

Tweets | Tweets & replies | Media

Marilyn Brown @Marilyn_Brown1 · 3m

One more time: CO2 emissions rose by ~3.4% in 2018 after 3 years of decline, due primarily to more natural gas-fired electricity, trucking, and air travel. How can the U.S. transition to clean energy when fossil fuels are so abundant and their carbon emissions aren't taxed?



Who to follow · Refresh · View all

Kim Cobb @cora... Follow

Serve-Learn-Susta... Follow

John A. Lanier @jo... Follow

Find people you know

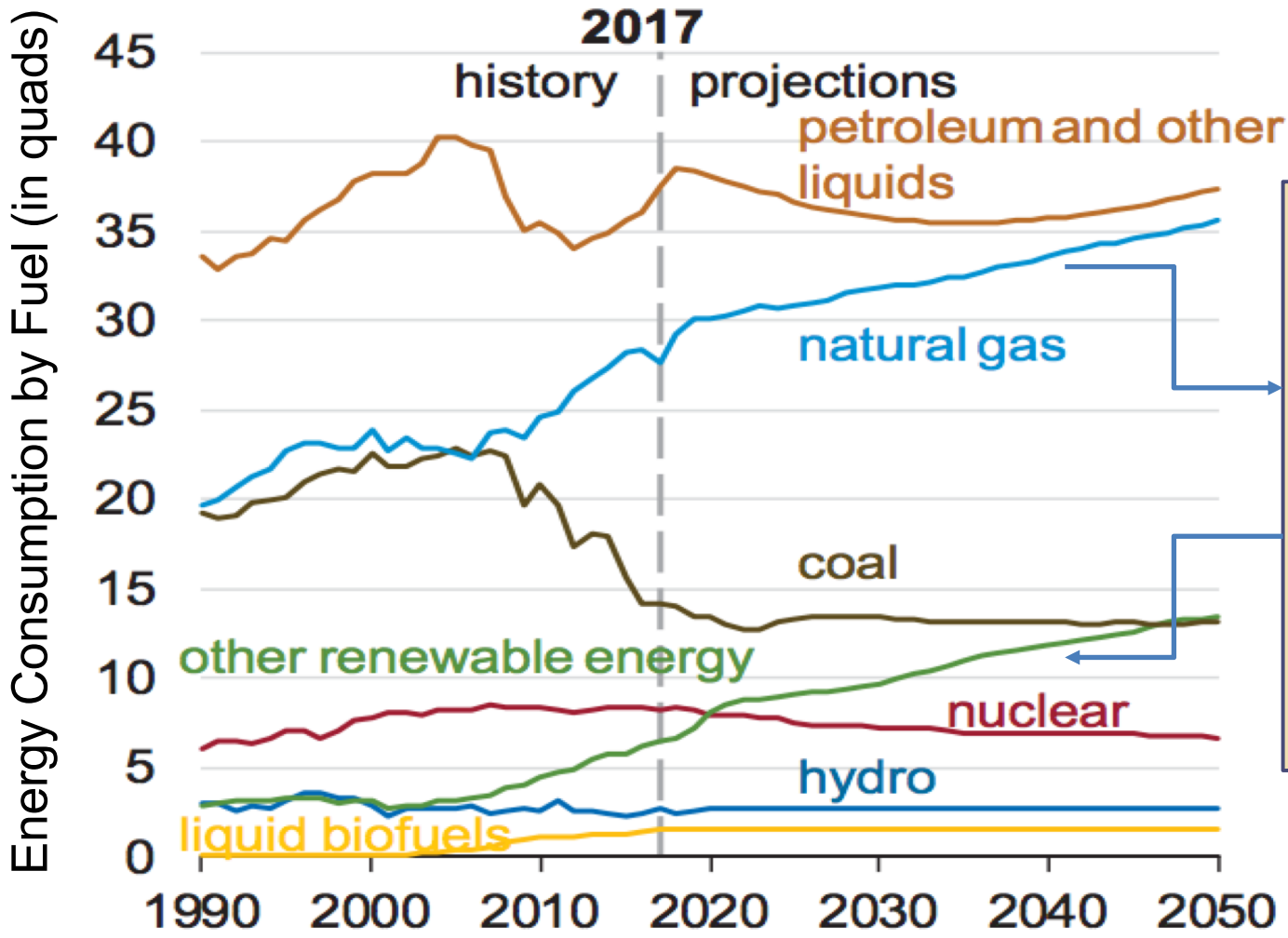
Trends for you · Change

#WednesdayWisdom
64K Tweets

#TheLiesWeAllTellOurselves
5,598 Tweets

#LawEnforcementAppreciationDay
7,302 Tweets

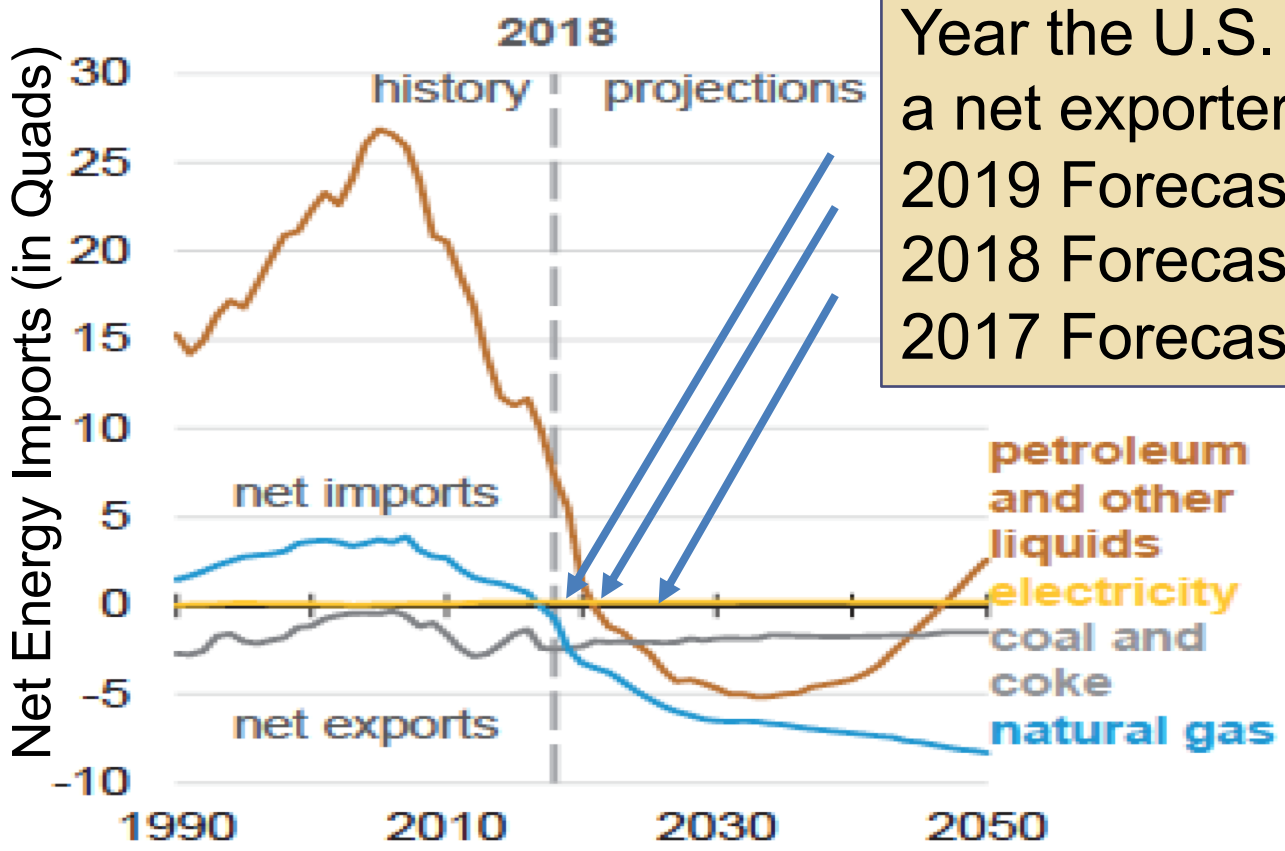
The U.S. Fuel Mix is Evolving



Natural gas is expected to grow the most, but solar and wind are also on the rise. Coal & nuclear decline slightly.

Source: EIA, *Annual Energy Outlook 2018*

The U.S. Will Soon be a Net Energy Exporter (First Time Since 1953)



Year the U.S. becomes a net exporter:
2019 Forecast = 2020*
2018 Forecast = 2022
2017 Forecast = 2026

It is particularly difficult to reset the U.S. energy system, at a time when fossil fuels are so abundant and cheap.

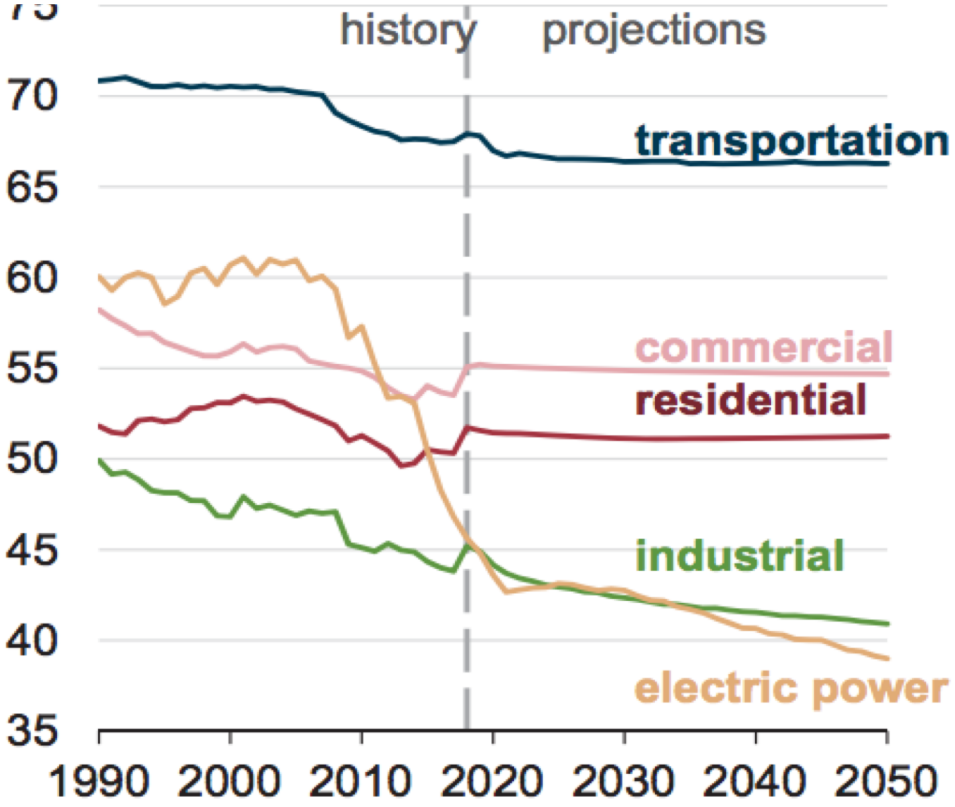
Sources: EIA, *Annual Energy Outlook 2019*, 2018* and *2017*

U.S. Liquified Natural Gas (LNG) is Fueling Asia

- U.S. natural gas trade was historically from Canada and to Mexico by pipeline.
- It will soon be dominated by liquid natural gas (LNG) shipped in tankers to distant ports.
- How “long” is the natural gas “bridge” to clean energy?

In Clean Energy, the Power Sector is Leading the Way

CO_2 intensity by end-use sector (Metric tons of CO_2/GBtu) in 2018



U.S. CO_2 intensity is declining … especially in the electric power sector.

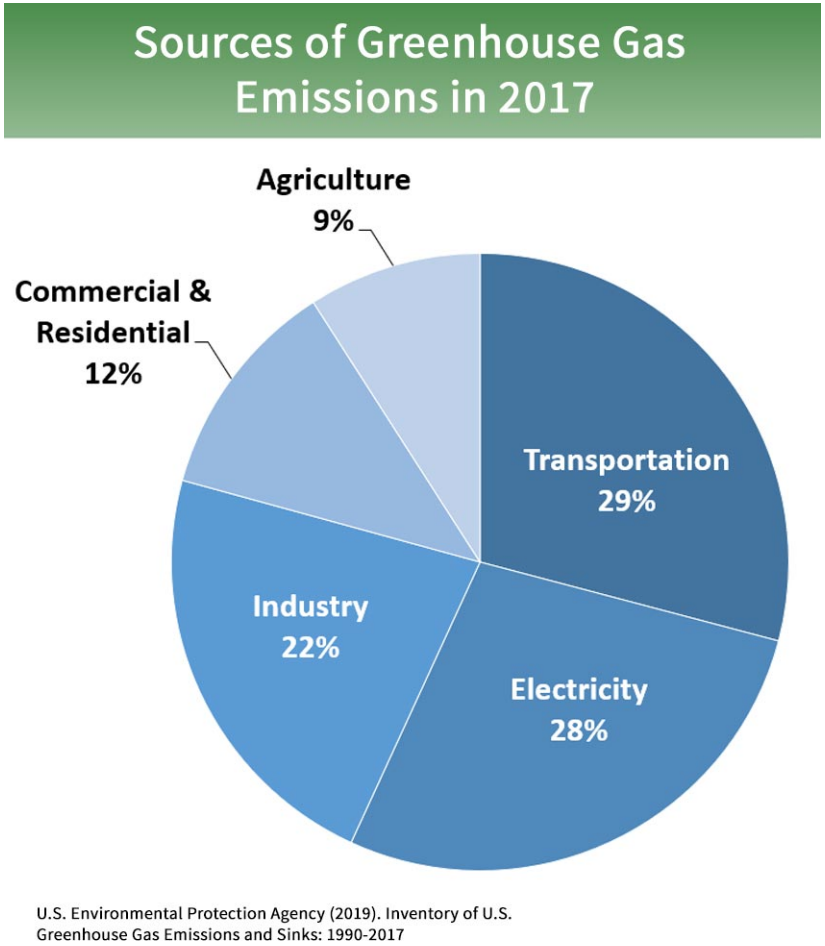
Sources: EIA, *Annual Energy Outlook 2019*

Electricity Systems Offer Low-Cost CO_2 Reduction Potential

"Abatement" costs in electricity generation are consistently cheaper and easier than in:

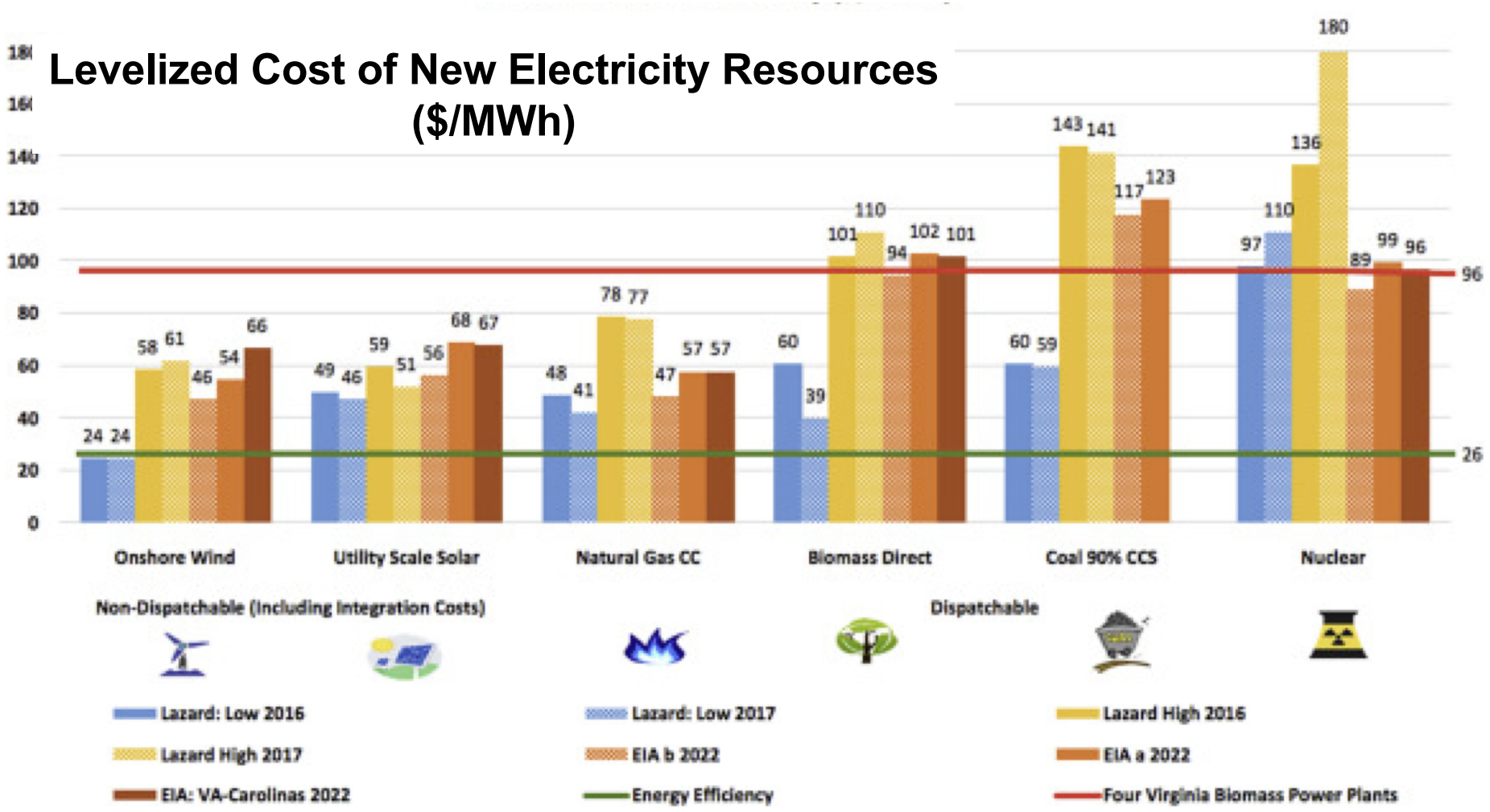
- most end use (housing, transport) or
- intermediate sectors (industry, freight, agriculture)

Source: IPCC, 2014



Electricity = 35% of U.S. CO_2 emissions

Energy Efficiency is the Least-Cost Energy Resource in the U.S.



Source: Brown, et al. (2019) "The Economic and Environmental Performance of Biomass Power as an Intermediate Resource for Power Production," *Utilities Policy,* 58: 52-62. https://authors.elsevier.com/a/1YzH53Peo9VR76

Carbon Pricing is Gaining Traction: (1) Carbon Dividends Plan

A Carbon Tax with Revenues Recycled to Households

A Conservative Answer to Climate Change

Enacting a carbon tax would free up private firms to find the most efficient ways to cut emissions.

By George P. Shultz and James A. Baker III
Updated Feb. 7, 2017 7:07 p.m. ET

"I really don't know the extent to which it is man-made, and I don't think anybody can tell you with certainty that it's all man-made, … the **risk** is sufficiently strong that **we need an insurance policy** and this is a damn good insurance policy."

James Baker, February, 2017

Carbon Pricing is Gaining Traction: (2) Green New Deal

Introduced by Rep. Alexandria Ocasio Cortez (of NY) and Senator Ed Markey (of Mass).

The idea is to transition to 100% renewables by 2030.

Equivalent to ~ \$60/tCO_2 carbon tax .

Cost of transitioning the grid into 100% renewables ~ \$700 billion to \$1 trillion annually.

Will create new jobs and infrastructures.

One way to collect the required revenue is to collect carbon taxes.

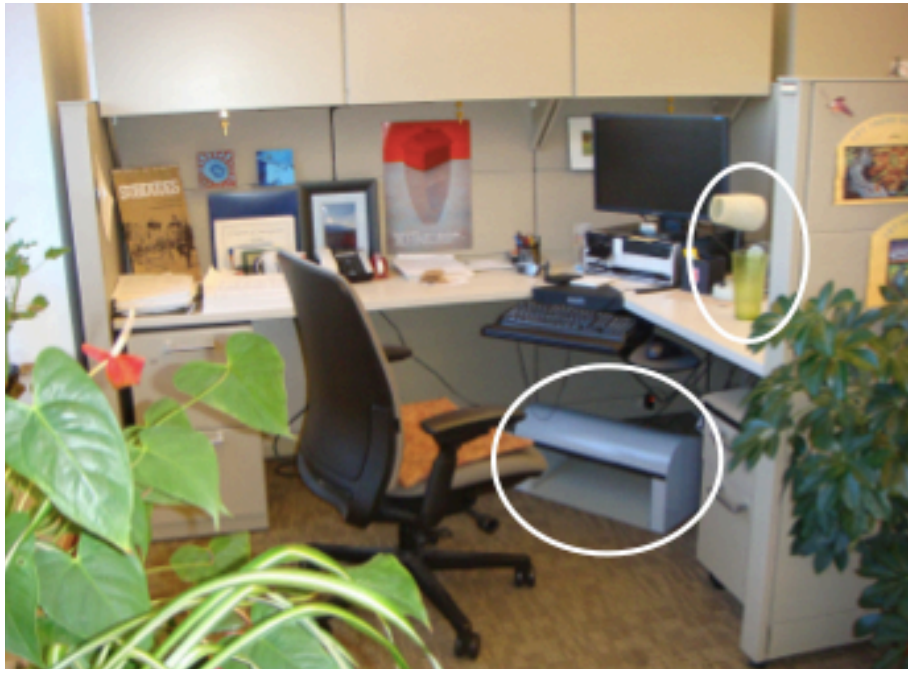
The Modeling of Energy Efficiency Policies is Often Flawed

- Most modeling platforms do not compete energy supply and demand resource options
  - ✓ Integrated Planning Model (IPM) used by EPA (2015)
  - ✓ the Haiku model used by Resources for the Future
  - ✓ US-REGEN used by the Electric Power Research Institute
  - ✓ FACETS-ELC used by Wright and Kunudia (2016)
  - ✓ MARket ALlocation (MARKAL)
- They assume an exogenous reduction of energy demand.
- The National Energy Modeling System (NEMS) treats EE as endogeneous.

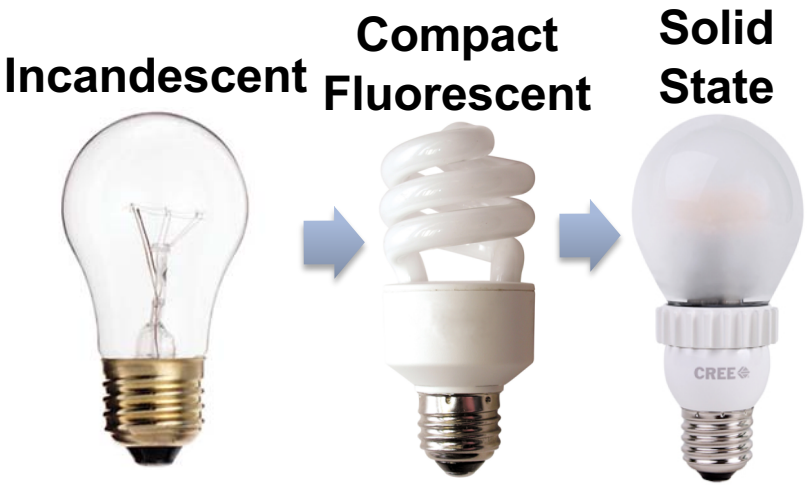
Source: Marilyn A. Brown, et al. 2017. “Exploring the Impact of Energy Efficiency as a Carbon Mitigation Strategy in the U.S.” *Energy Policy,* 109: 249-259.

Energy Efficiency Involves Purchase and Usage Behaviors

- **Energy Efficiency Improvement** – Increasing the services provided per unit of energy consumed.



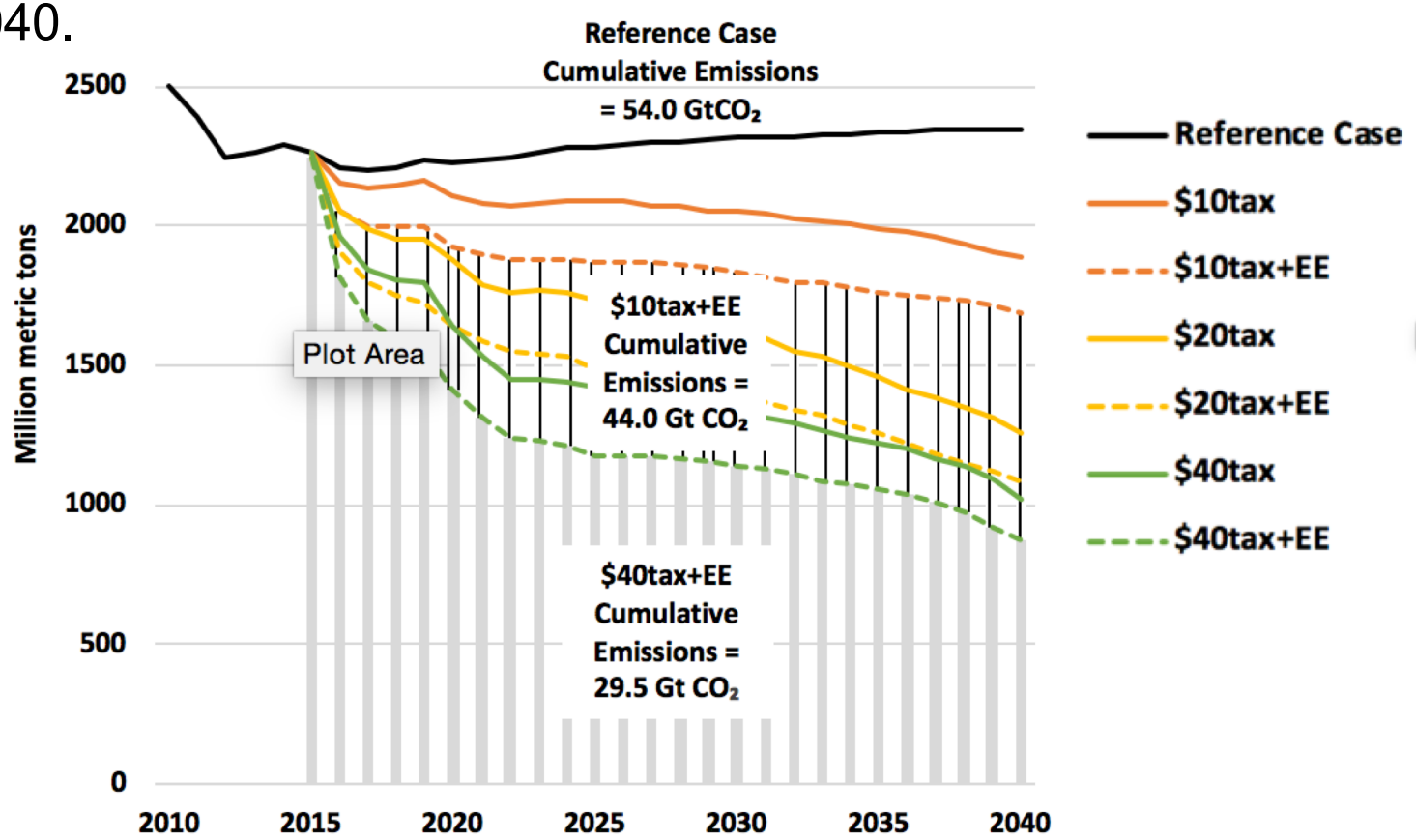
e.g., avoiding ubiquitous lights & space conditioning.



Watts	60	14	11
Lumens/Watt	14	64	84

Carbon Taxes with Energy Efficiency Can Achieve Deep Decarbonization at Low Cost

Current policies would lead to 54 GT CO_2 in the U.S. electric sector from 2016-2040.

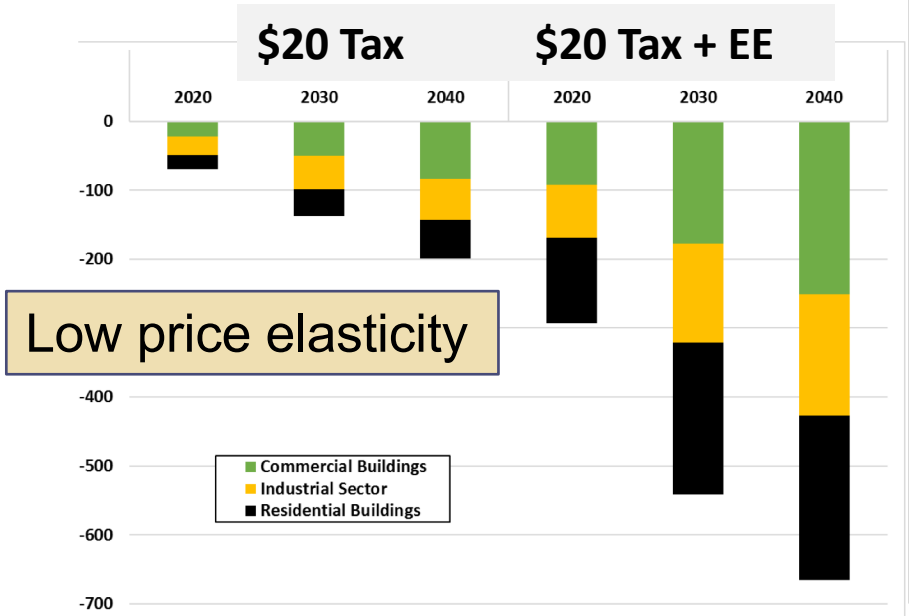


A \$10 tax/ton of CO_2 with strong energy efficiency could reduce this to 44 GT CO_2.

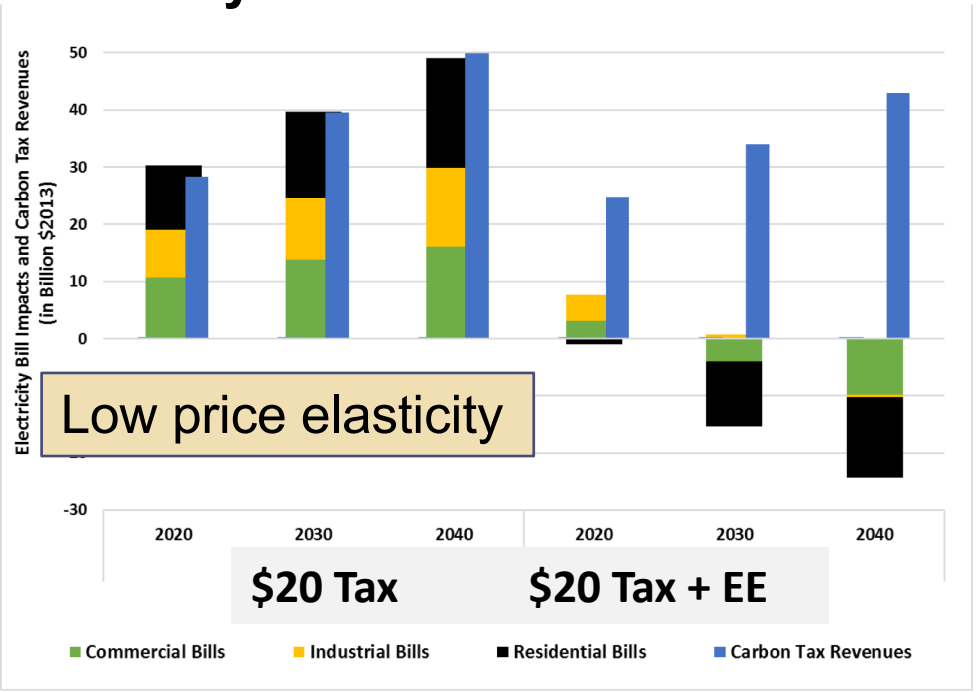
Source: Brown, M. A., & Li, Y. (2018). Carbon pricing and energy efficiency: pathways to deep decarbonization of the US electric sector. *Energy Efficiency*, 12(2), 463-481, https://doi.org/10.1007/s12053-018-9686-9.

Household Dividends Reduce Energy Burdens

Electricity demand reduction In Billion kWh



Electricity bills & carbon tax revenues



- A $25 carbon tax would cut CO_2 emissions significantly (from 1,900 to 400 million tons), but would reduce electricity demand only slightly.
- With EE policies, demand reduces further, especially in the residential sector (black bar above).
- Adding energy efficiency coupled with a carbon tax reduce the cost of climate policy.

Measuring the Cost of Climate Policy

Cost of climate policy =

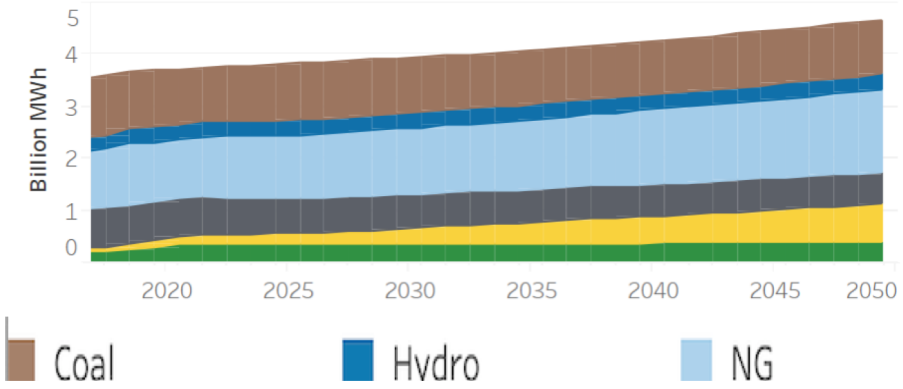
Utility Resource Costs	+	Energy Efficiency Costs	–	Carbon Tax Recycling

(Environmental benefits > welfare losses.)

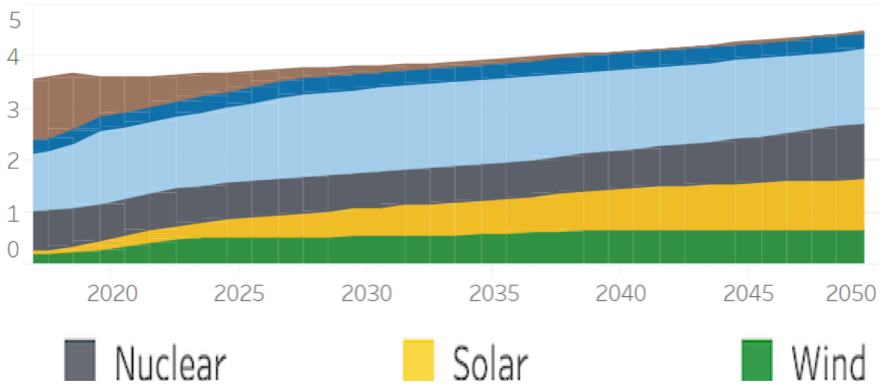
Source: Brown, M. A., Kim, G., Smith, A. M., & Southworth, K. (2017). Exploring the impact of energy efficiency as a carbon mitigation strategy in the US. *Energy Policy,* 109, 249-259.

Transitioning the Grid with a Carbon Tax: Impacts on Carbon & Energy

EIA Forecast



Carbon Tax Scenario



Coal Hydro NG Nuclear Solar Wind

Natural gas is forecast to continue to grow its share of electricity generation thru 2050, and while coal use declines, it remains the second largest fuel in the power mix. Nuclear and hydro remain relatively flat, and while wind continues to grow for a decade, it is eclipsed in 2035 by rapidly growing solar.

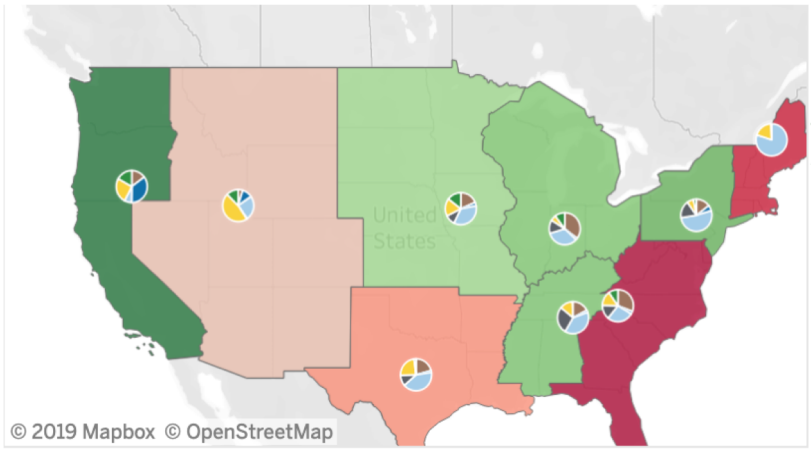
Carbon Intensity of the Electric Grid

(Pie charts shows shares of electricity generation from different fuels)

2030

Coal is largely eliminated from the electricity sector by 2030. In its place, natural gas grows rapidly thru 2030. Wind power expands 2020-25, but then remains flat while solar power grows rapidly, followed by an uptick in nuclear beginning in 2040. Demand for electricity reduces by only 3.7% in 2050 despite a carbon tax of $108.*

CO2 Intensity (No tax)

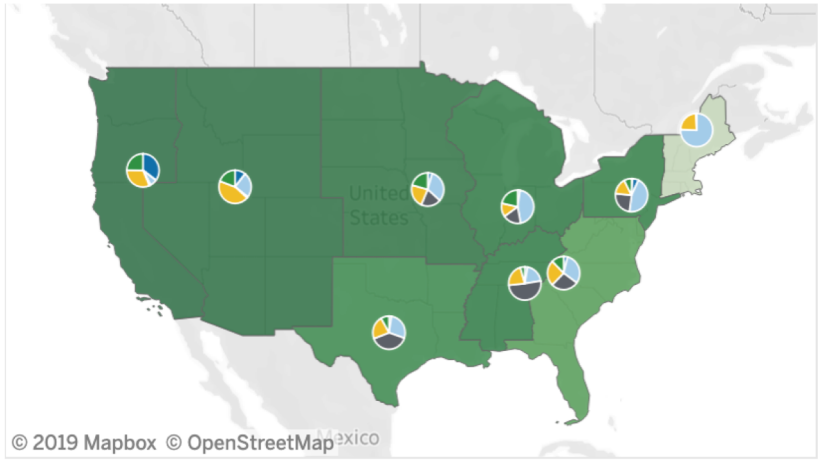


CO2 Intensity (TCO2 per MWh):

0.0593 0.7749

We model a $25 carbon tax implemented in 2020 and growing 5% annually, reaching $108 per metric ton of CO_2 in 2050. Tax revenues are returned to households.

CO2 Intensity (With $25 Tax)

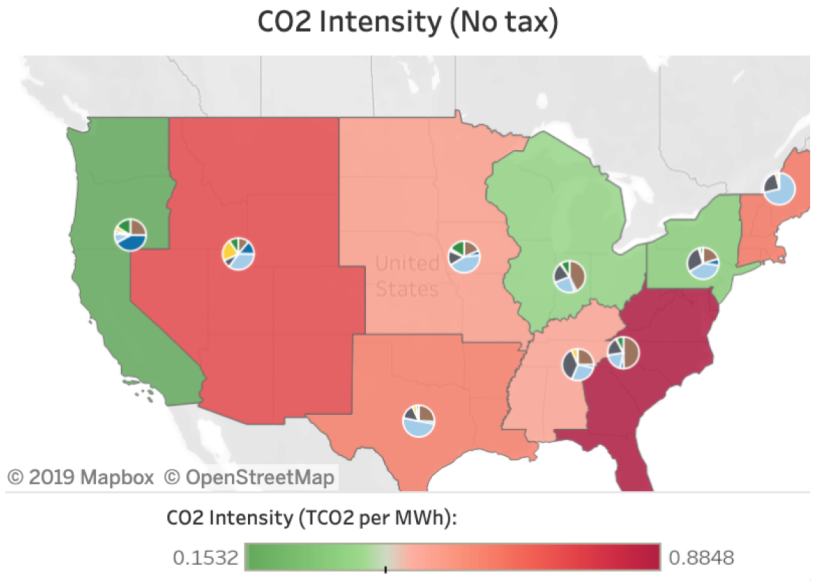


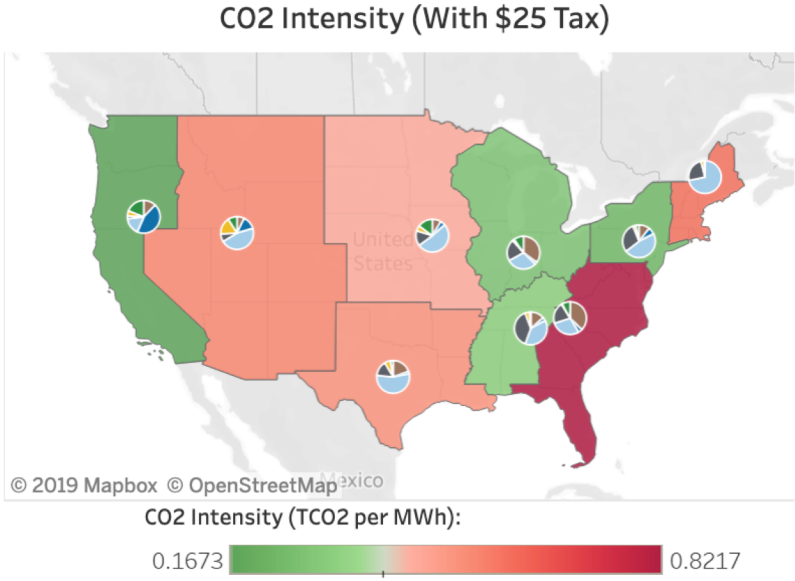
CO2 Intensity (TCO2 per MWh):

0.0476 0.4000

Impact of Carbon Pricing on Carbon Intensity: Regional Heterogeneities

EIA Forecast 2020 $25/tCO$_2$ Tax

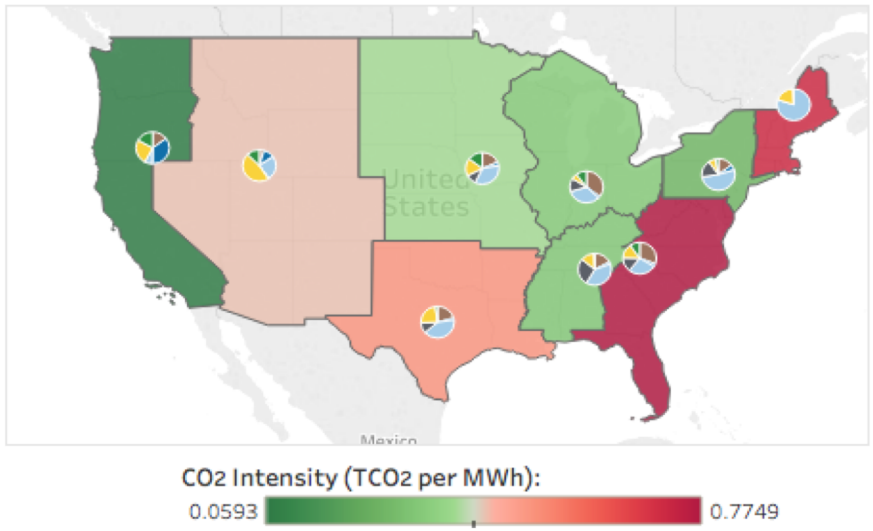




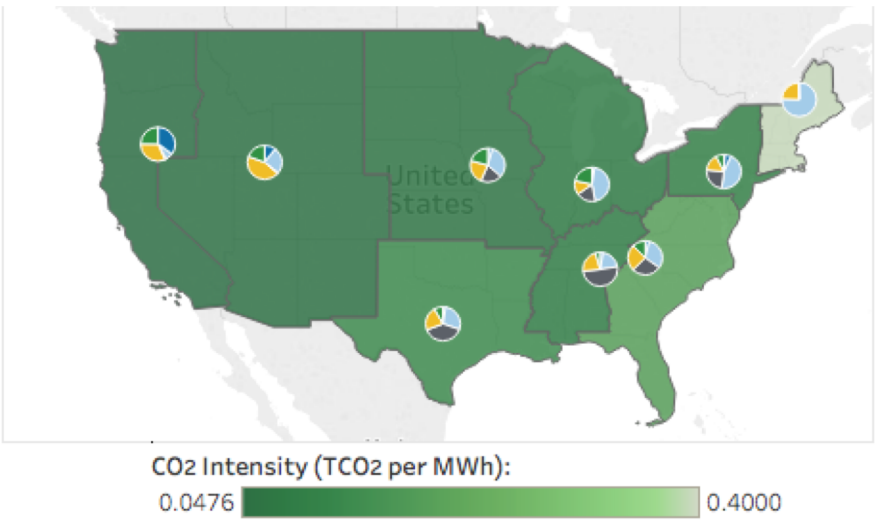
Our modeling of an escalating tax on CO_2 ($25-108/tCO2) from electricity highlights the largely overlooked regional complexities of a uniform environmental tax.

Impact of Carbon Pricing on Carbon Intensity: Regional Heterogeneities

EIA Forecast 2050 $108/tCO$_2$ Tax



2050

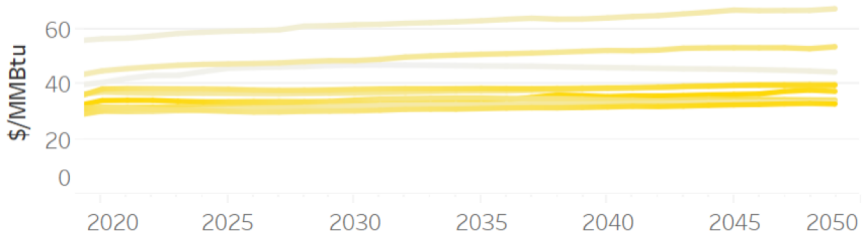


Per capita recycling of tax revenues would transfer wealth from the South and Central states to the Northeast and West.

Transitioning the Grid with a Carbon Tax: Economic & Employement Impacts

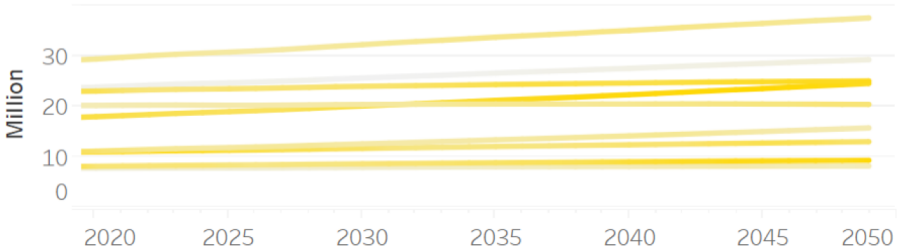
Electricity Price

(15% increase in 2030 and 24% increase in 2050)



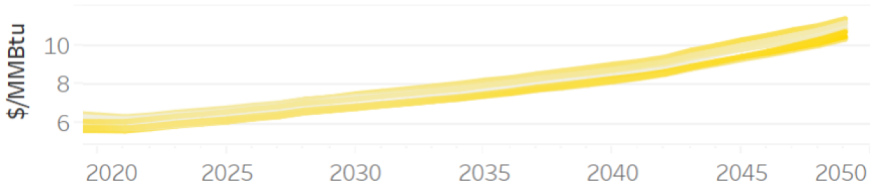
Employment

(511K new jobs in 2030 and 824K in 2050)



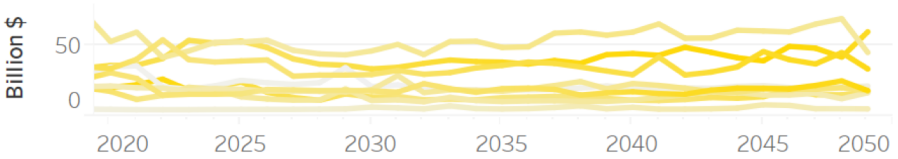
Natural Gas Price

(14% increase in 2030 and 19% increase in 2050)



Total Electricity Resource Costs

(HH dividends are > than HH bill increases)



Household Dividends from a Carbon Tax

With an escalating $25 carbon tax, households would receive dividends of $106 in 2020 increasing to $115 in 2050. This would transfer wealth to the Pacific region and the Northeast.

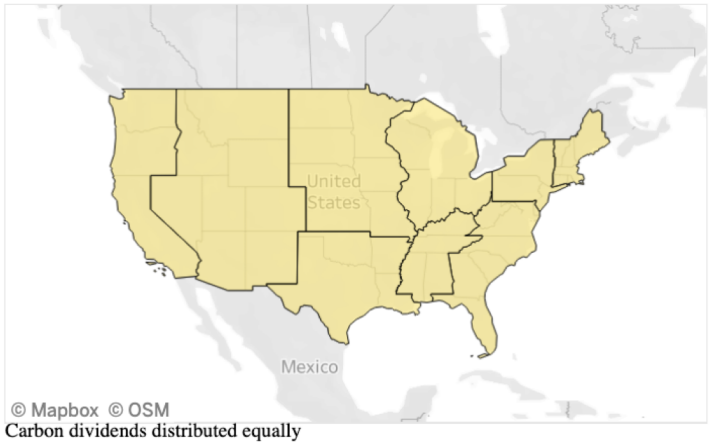
(Darker shades reflect higher dividends)

Year

1/1/2049 12:00:00 AM

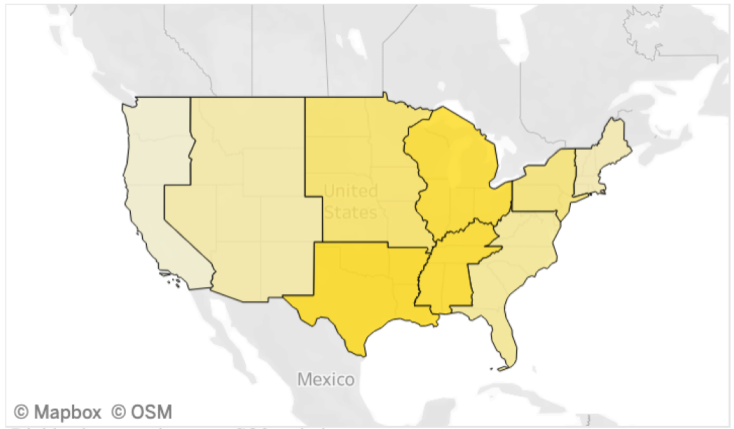
An escalating $25 carbon tax on electricity would reduce carbon emissions and increase jobs. Our modeling highlights the largely overlooked regional complexities of a uniform environmental tax.

If recycled based on regional CO2 emissions, dividends would be lowest in the Pacific region (ranging from $20-35) and highest in the 4 Central regions (ranging from ~$150-$200).



Carbon dividends distributed equally

0.0 204.7



Dividends proportionate to CO2 emissions

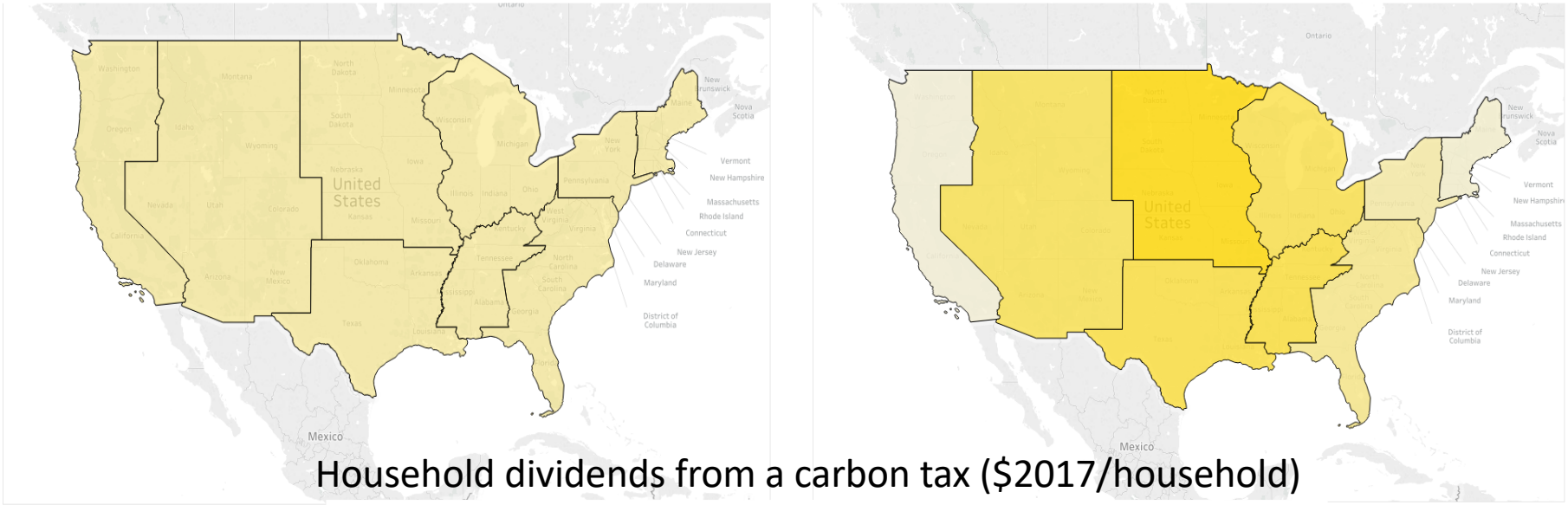
0.0 204.7

Impact of Carbon Recycling Scheme

Recycling Revenues Per Capita

2020

Recycling Revenues per tCO_2 Emitted



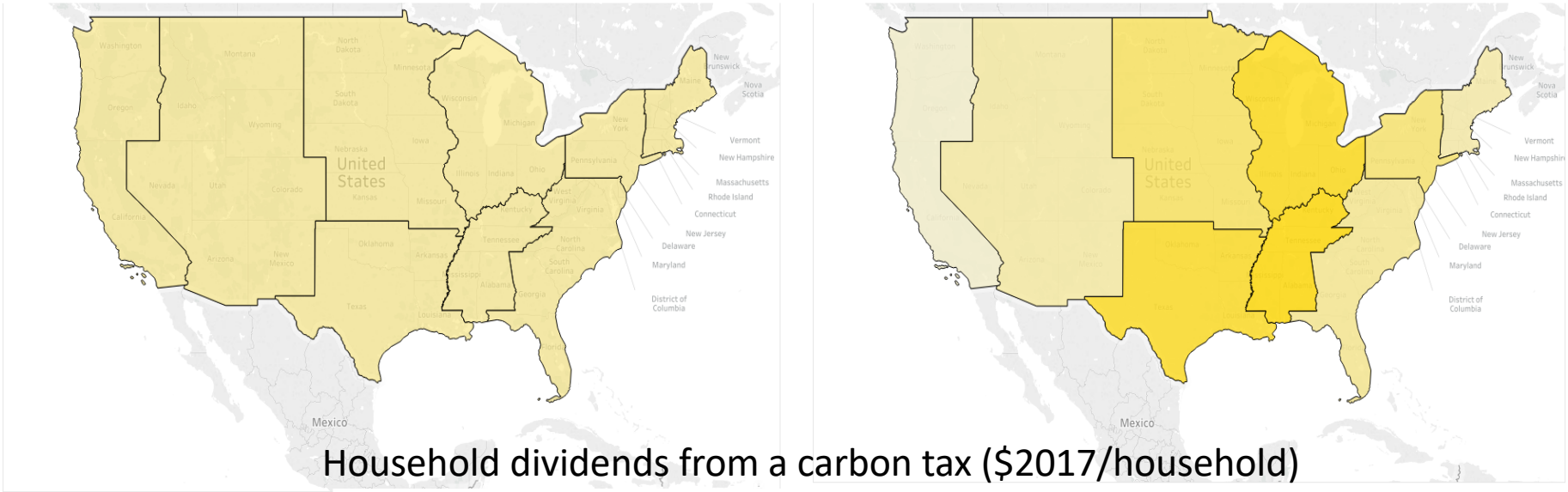
Per capita recycling of tax revenues would transfer wealth from the South and Central states to the Northeast and West.

Impact of Carbon Recycling Scheme

Recycling Revenues Per Capita

2050

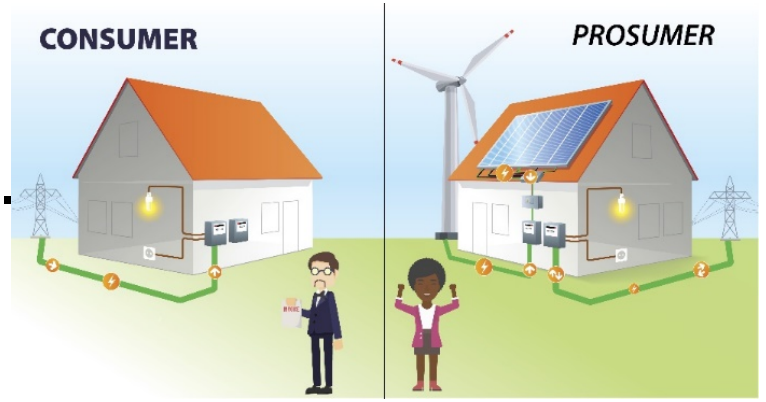
Recycling Revenues per tCO_2 Emitted



Per capita recycling of tax revenues would transfer wealth from the South and Central states to the Northeast and West.

Current Research: G2V and V2G

- Pairing storage with rooftop solar and EVs looks promising.
- The technologies are known, but the business models are unclear.

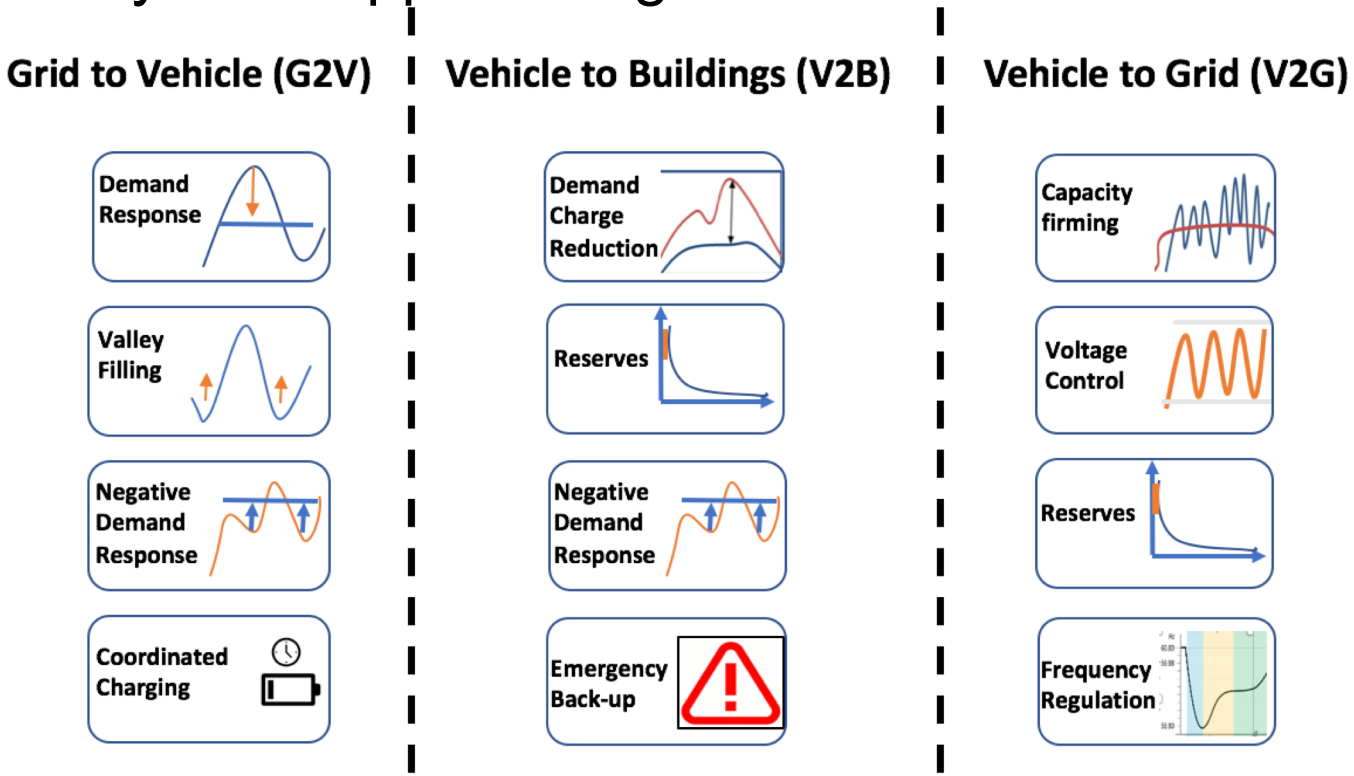


Source: Mateo Jaramillo, Tesla, June 19, 2017

Consumers are becoming producers ("Prosumers")

What Roles Could EVs Play?

- First, they can reduce GHG emissions compared to ICEs.
- And they can support the grid.

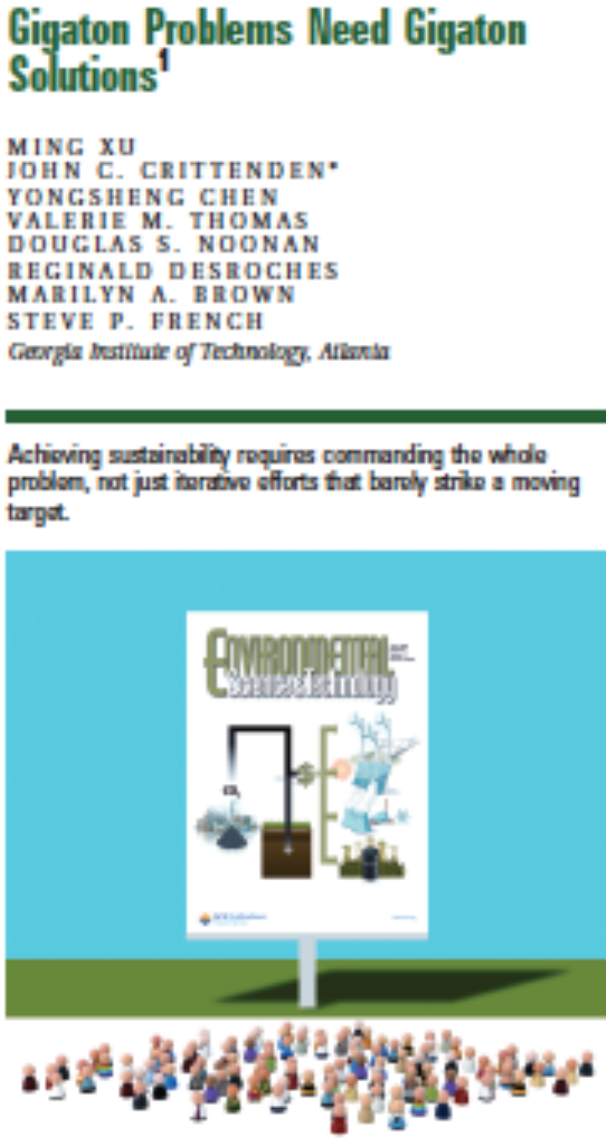


- How much are these grid services worth?
- What business models can be used to create value?

Source: Electricity Advisory Committee (EAC) 2018. *Enhancing Grid Resilience with integrated Storage from Electricity Vehicles* U.S. Department of Energy **https://tinyurl.com/EAC-GridResilience**

“Our Energy Destiny Lies with our Governments”—Fatih Birol, IEA

- “70% of all energy investments are government driven” … What are feasible policies?
- Can carbon tax revenues help fund infrastructure or must they be returned to household?
- A deep understanding of consumers, markets and policies is needed – a socio-economic technical perspective.



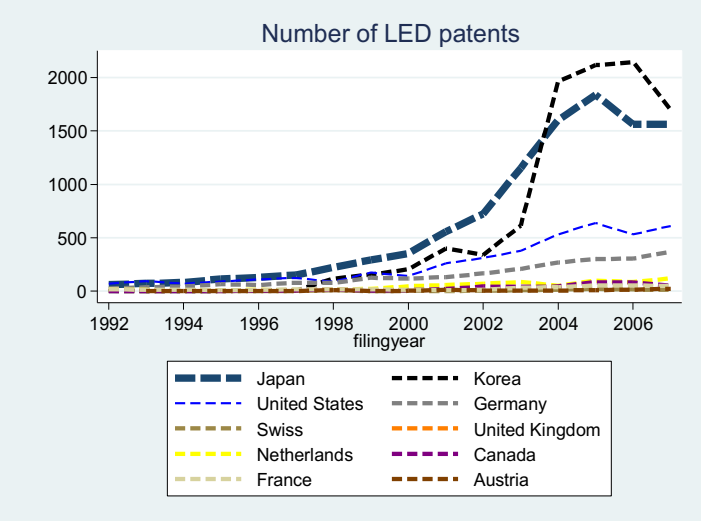
Gigaton Problems Need Gigaton Solutions[1]

MING XU
JOHN C. CRITTENDEN*
YONGSHENG CHEN
VALERIE M. THOMAS
DOUGLAS S. NOONAN
REGINALD DESROCHES
MARILYN A. BROWN
STEVE P. FRENCH
Georgia Institute of Technology, Atlanta

Achieving sustainability requires commanding the whole problem, not just iterative efforts that barely strike a moving target.

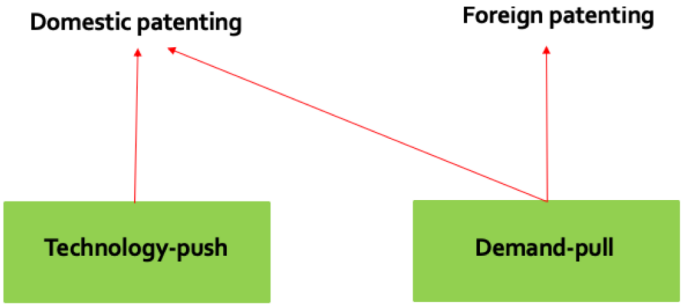
The International Domain of Policy and Innovation

- Domestic demand-pull & technology-push policies impact domestic lighting patenting.
- Domestic demand-pull energy-efficiency policy also stimulates foreign energy-efficiency inventive activity.
- If we only look at the effect of domestic energy policy on domestic innovation, we underestimate energy policies' overall influence.



The effect of domestic policies on foreign patenting

$$N_{i,j,t} = \beta_{12} + \beta_{22} MEPS_{i,t} + \beta_{32}\, MEPS\_CFL_{i,t} + \beta_{42}\, RD\&D_{i,t-1} + \beta X_{i,t} + \alpha_t + \gamma_i + \varepsilon_{i,t}$$



Source: Yeong Jae Kim and Marilyn A. Brown. (2019) "Impact of Energy-Efficiency Policies on Innovation: The Case of Lighting Technologies." *Energy Policy,* 128, 539-552.

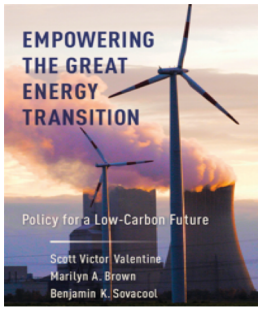
Conclusions

- As the U.S. energy economy booms, now is the time to invest in our future clean energy system.
- Carbon needs to be priced, and stronger energy-efficiency policies would help constrain costs.
- The current Administration's "dial back" of U.S. clean energy policies has been characterized by some as a return to the stone age, but the momentum of renewables will ultimately prevail.
- Wise recycling and investment of carbon tax revenues can be a powerful positive force.
- In sum, policy design matters!

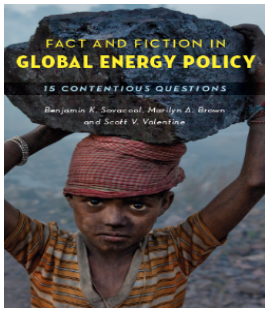
For More Information — and some late night reading??

Dr. Marilyn A. Brown, Regents' and
Brook Byers Professor of Sustainable Systems
School of Public Policy
Georgia Institute of Technology
Atlanta, GA 30332-0345
Marilyn.Brown@pubpolicy.gatech.edu
Climate and Energy Policy Lab:
www.cepl.gatech.edu

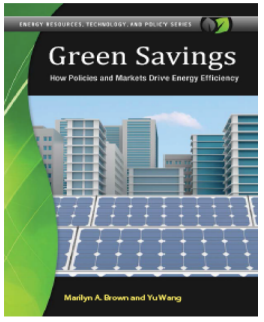
CLIMATE AND ENERGY POLICY LABORATORY
SCHOOL OF PUBLIC POLICY



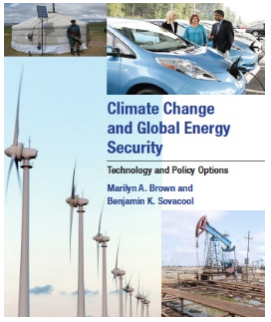
2019



2016



2015



2013