

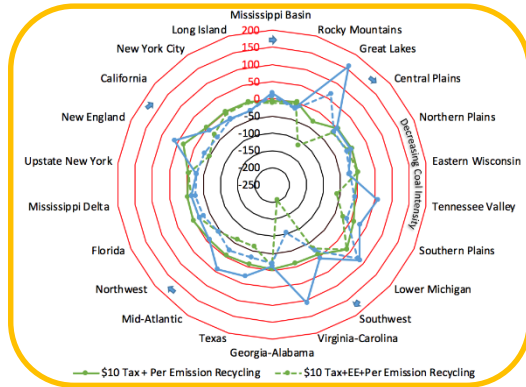
Enabling the Great Energy Transition: Technology & Policy Challenges & Opportunities



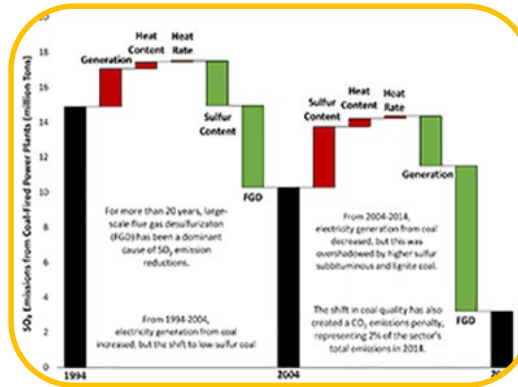
Dr. Marilyn A. Brown
Regents & Brook Byers Professor of Sustainable Systems
Georgia Institute of Technology

Fries Lecture at Georgia Southern University
September 18, 2018

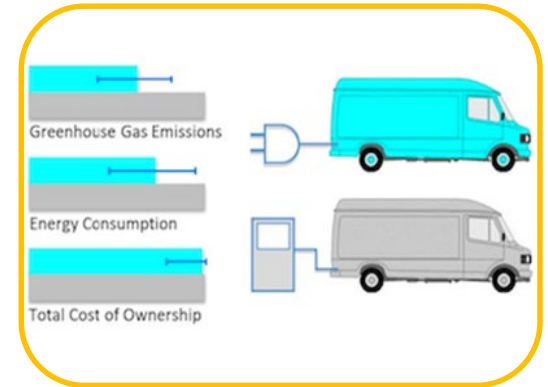
GT Climate and Energy Policy Lab



Winners & Losers
(\$/capita)



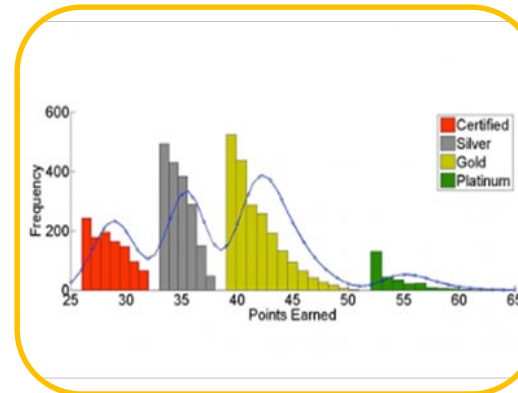
U.S. SO₂ Emissions:
Shifting Factors



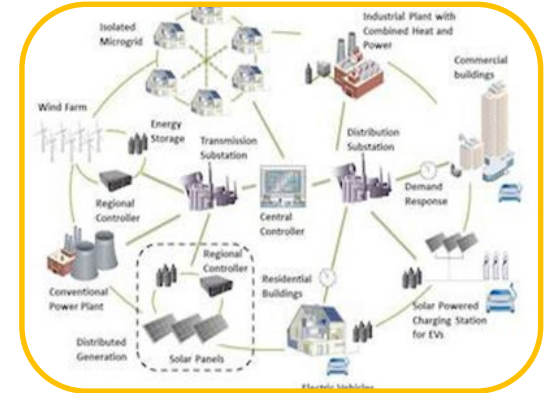
Electric Urban Delivery
Trucks



Climate and Energy
Laboratory Faculty



Point Distribution for
New LEED Construction



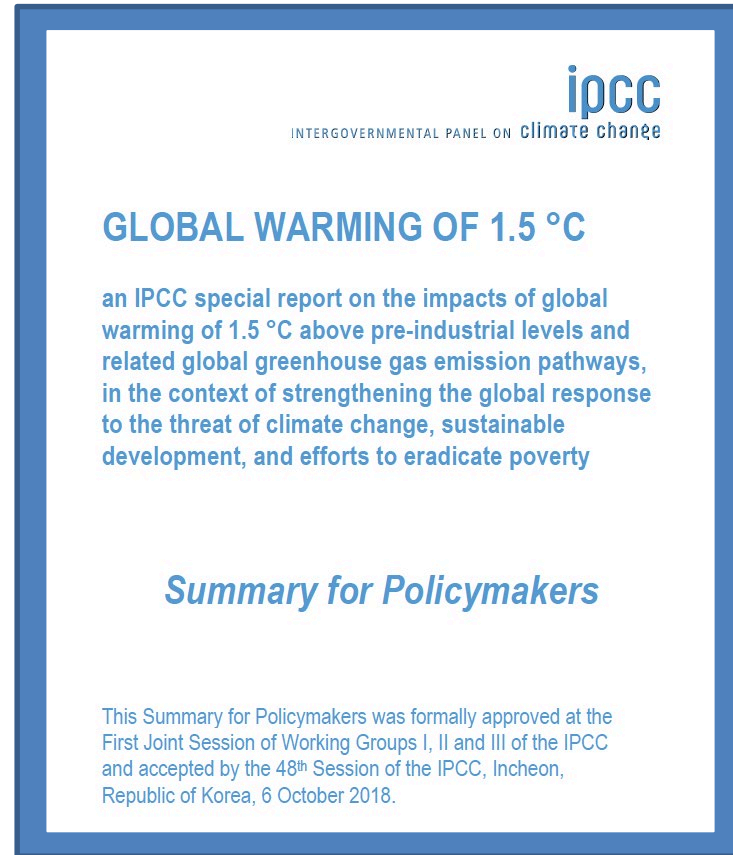
The Emergence of
Smart-Grid Policies

Last Week: Release of Latest UN Climate Change Report

The IPCC — an international group of scientists — released a detailed report describing the damaging impacts of global warming of 1.5°C above pre-industrial levels.

Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels.

Global warming is likely to reach 1.5°C between 2030 and 2050 if greenhouse gas emissions continues to increase at the current rate.



Then Hurricane Michael Came Barreling out of the Gulf of Mexico

The Florida Panhandle
was hit hard.

But so was the
agriculturally-intensive
Southwest region of
Georgia, home to poultry
and hog farming as well as
cotton, pecan and peanut
production. For some of
these crops, Michael hit at
their peak production time.

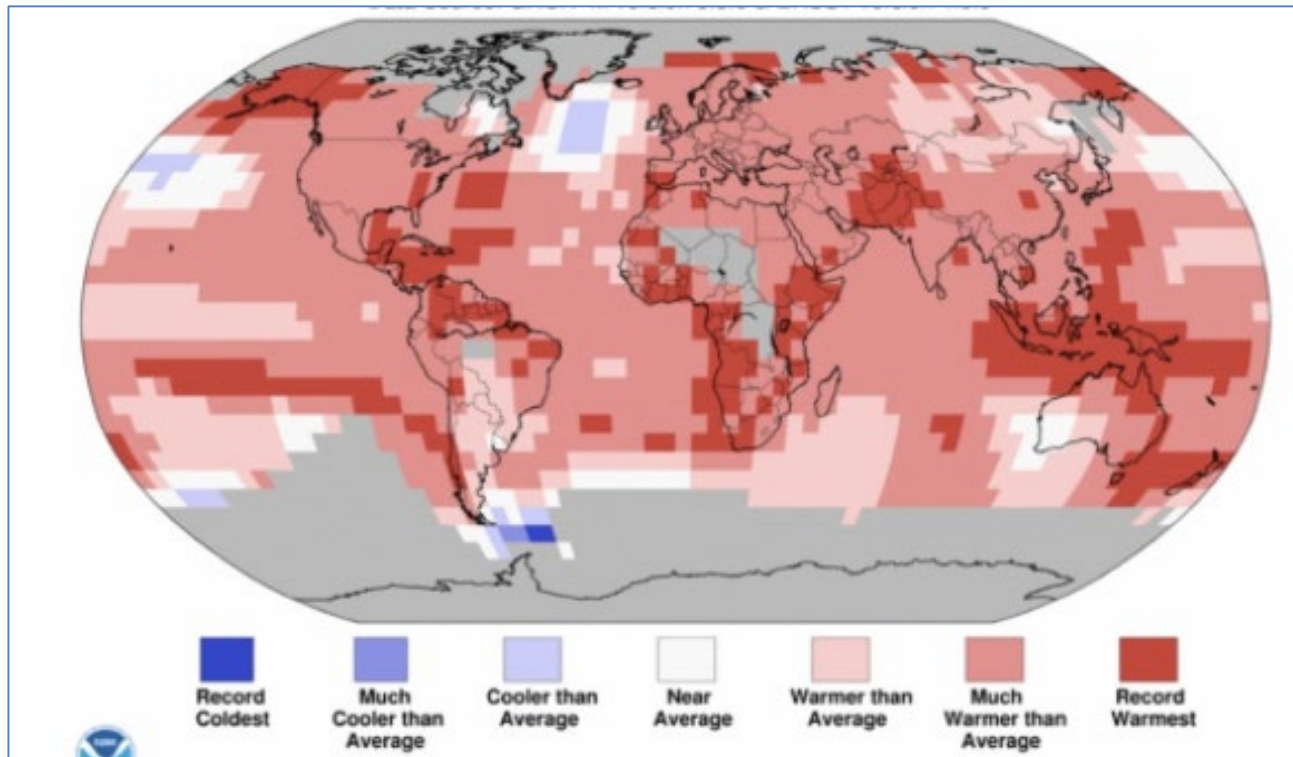


https://www.washingtonpost.com/outlook/2018/10/14/hurricanes-like-michael-show-why-we-cant-ignore-climate-change/?utm_term=.984cd67c2560



<https://www.forbes.com/sites/marshallshepherd/2018/10/13/the-hidden-tragedy-of-hurricane-michael-and-georgia-agriculture-how-it-affects-you/#7efc17151513>

2016=Hottest Year on Record



2016 temperatures compared to normal around the globe (NOAA)

“...human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming”

(National Climate Assessment Special Report 2017)

2017 = 2nd Hottest Year on Record



<https://www.nytimes.com/2018/08/17/books/review/rising-elizabeth-rush.html>

This warming trend has been driven largely by increased carbon dioxide and other GHGs.

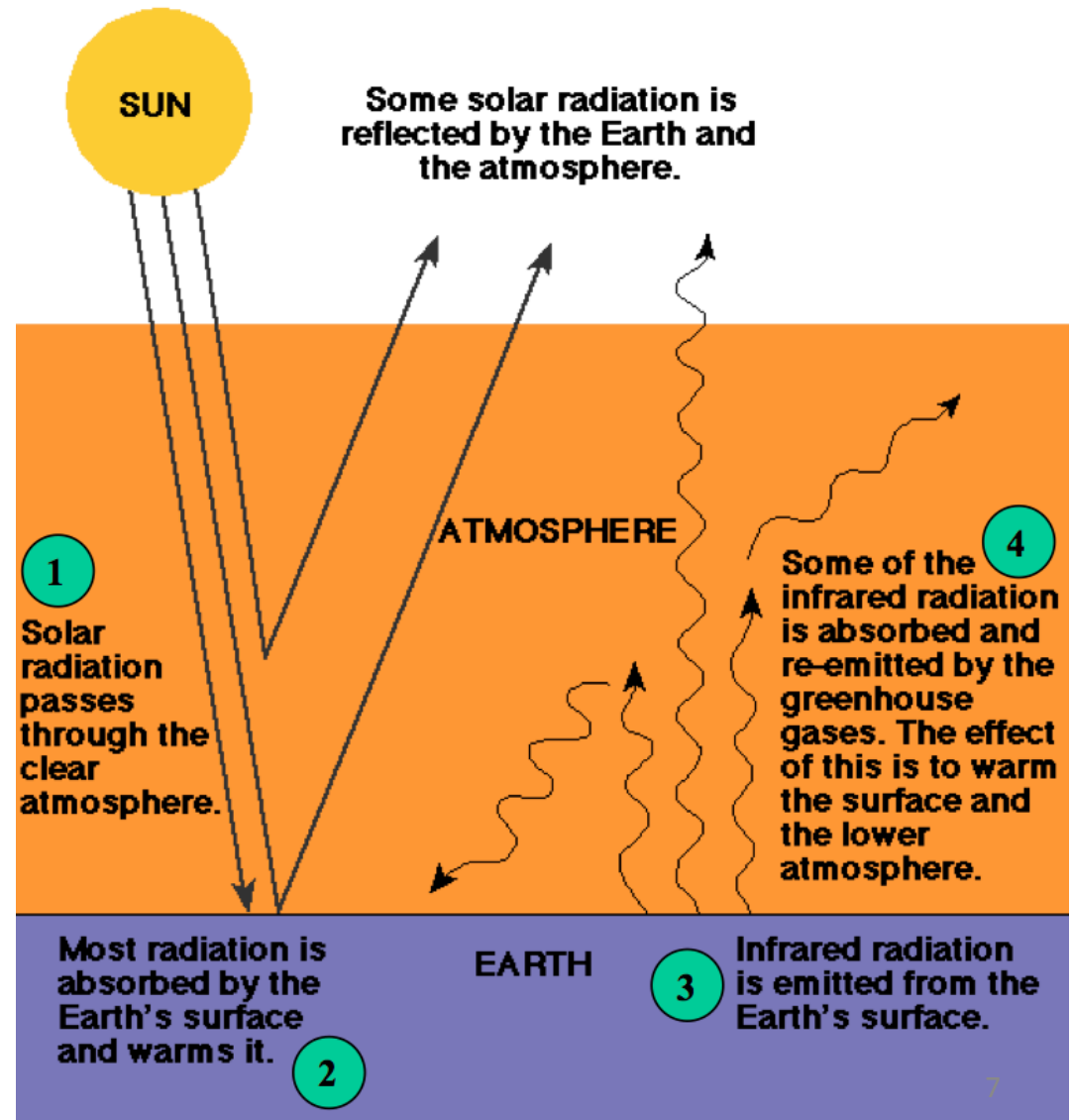
The “Enhanced” Greenhouse Effect

Greenhouse gases trap heat at the earth’s surface and prevent it from escaping.

The most abundant GHGs are naturally occurring:

- water vapor (H_2O)
- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)....

But human actions are “enhancing” this natural greenhouse effect -- primarily from the burning of fossil fuels.



Global Climate Policy is Moving Forward with the 2015 Paris Agreement



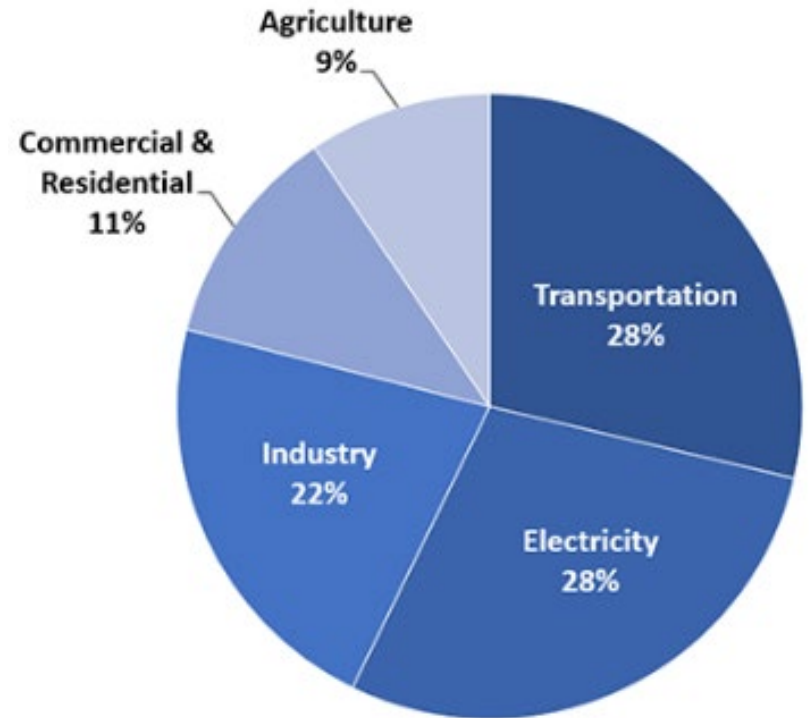
- “strengthen the global response to the threat of climate change by...Holding the increase in the global average temperature to **well below 2°C above pre-industrial levels** and to pursue efforts to limit the temperature to 1.5°C above pre-industrial levels,...

Electricity Systems Offer Low-Cost Greenhouse Gas Reductions (especially CO₂)

“Abatement” costs in electricity generation are consistently shown to be cheaper and easier than in:

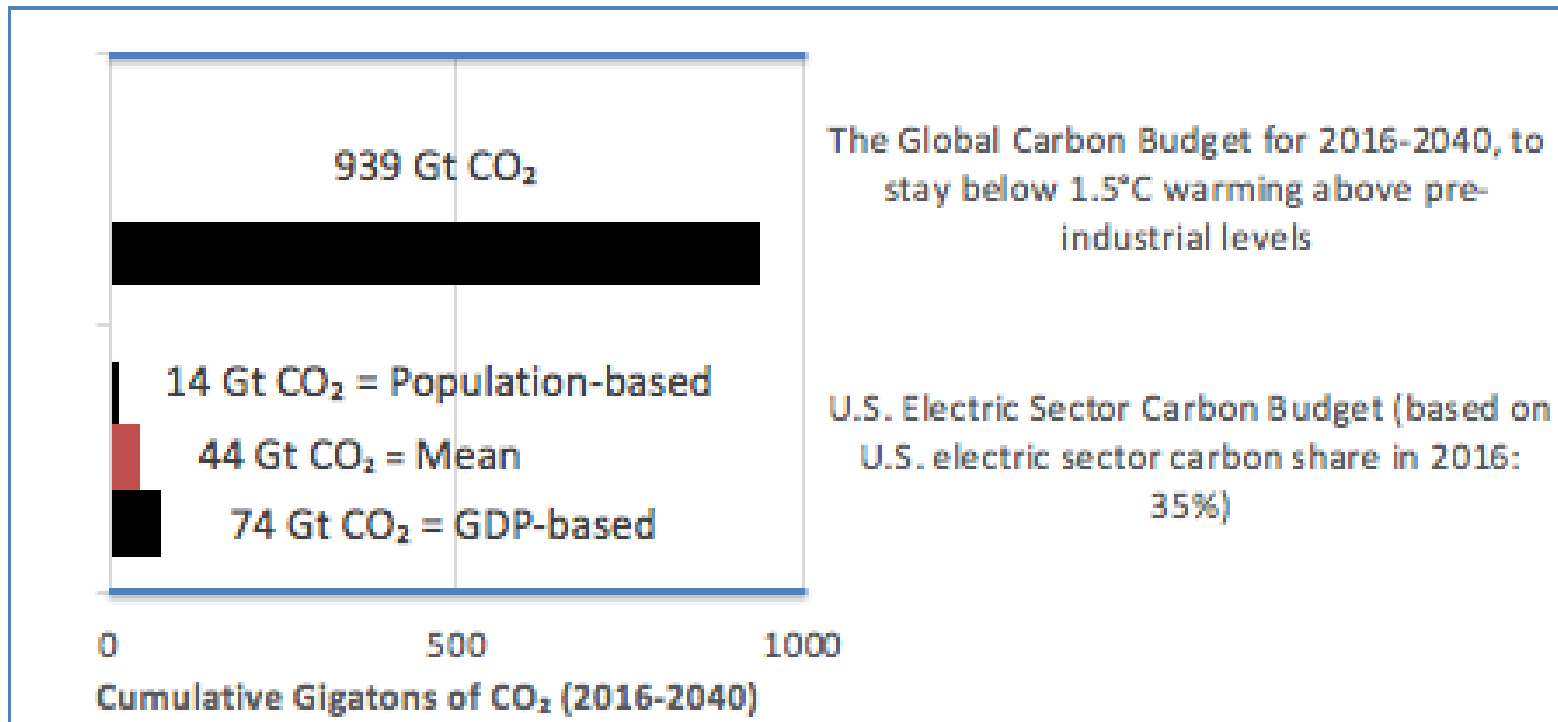
- most end use (housing, transport) or
- intermediate sectors (industry, freight, agriculture)

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2016



What is 1.5°C Budget for the U.S. Electricity Sector?

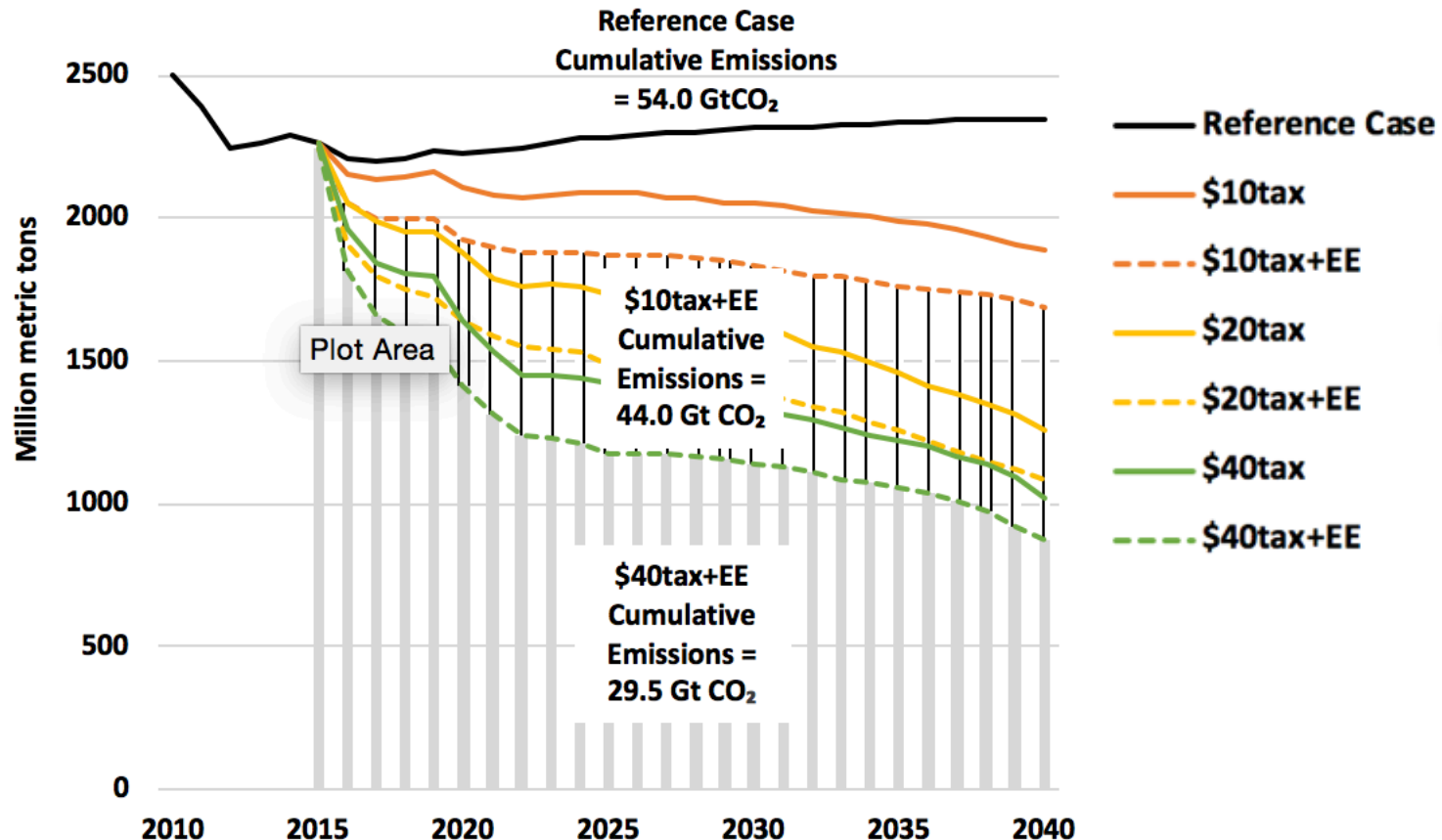
Equally weighting global “equity” and “inertia”, a 25-year carbon budget for the U.S. electric sector = **44 Gt CO₂**.



Source: Brown, Marilyn A. and Yufei Li. 2018. “Carbon Pricing and Energy Efficiency: Pathways to Deep Decarbonization of the U.S. Electric Sector,” *Energy Efficiency* 1-19, <https://doi.org/10.1007/s12053-018-9686-9>.

Results: CO₂ Emissions from the U.S. Electric Sector Across Mitigation Scenarios

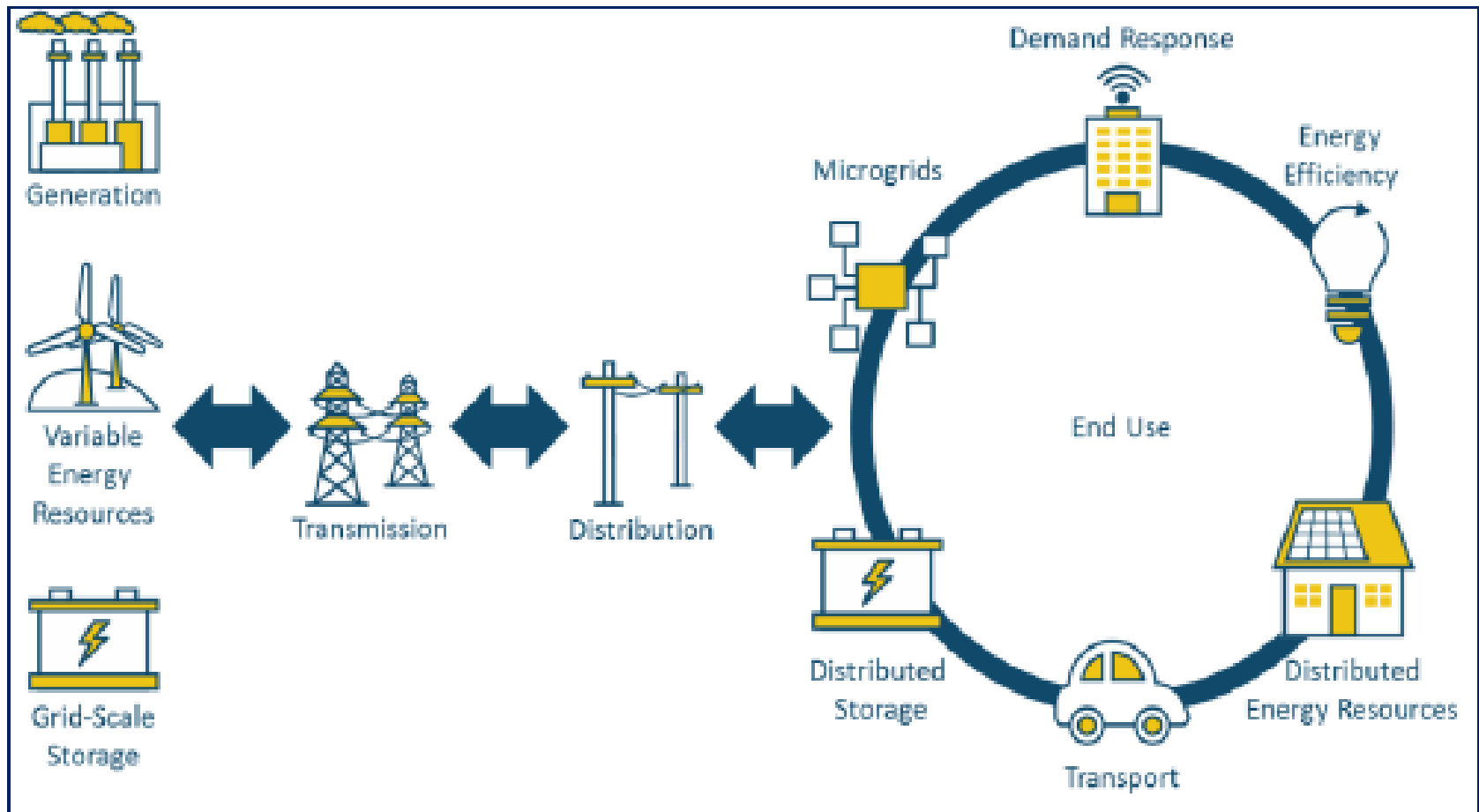
Current policies would lead to 54 GT CO₂ in the U.S. electric sector from 2016-2040



A \$10 tax/ton of CO₂ with strong energy efficiency could reduce this to 44 GT CO₂.

The Electricity Supply Chain is Transforming

And the utility business model is beginning to change, too.



Source: DOE. 2017. Quadrennial Energy Review: Transforming the Nation's Electricity System, Figure S-3

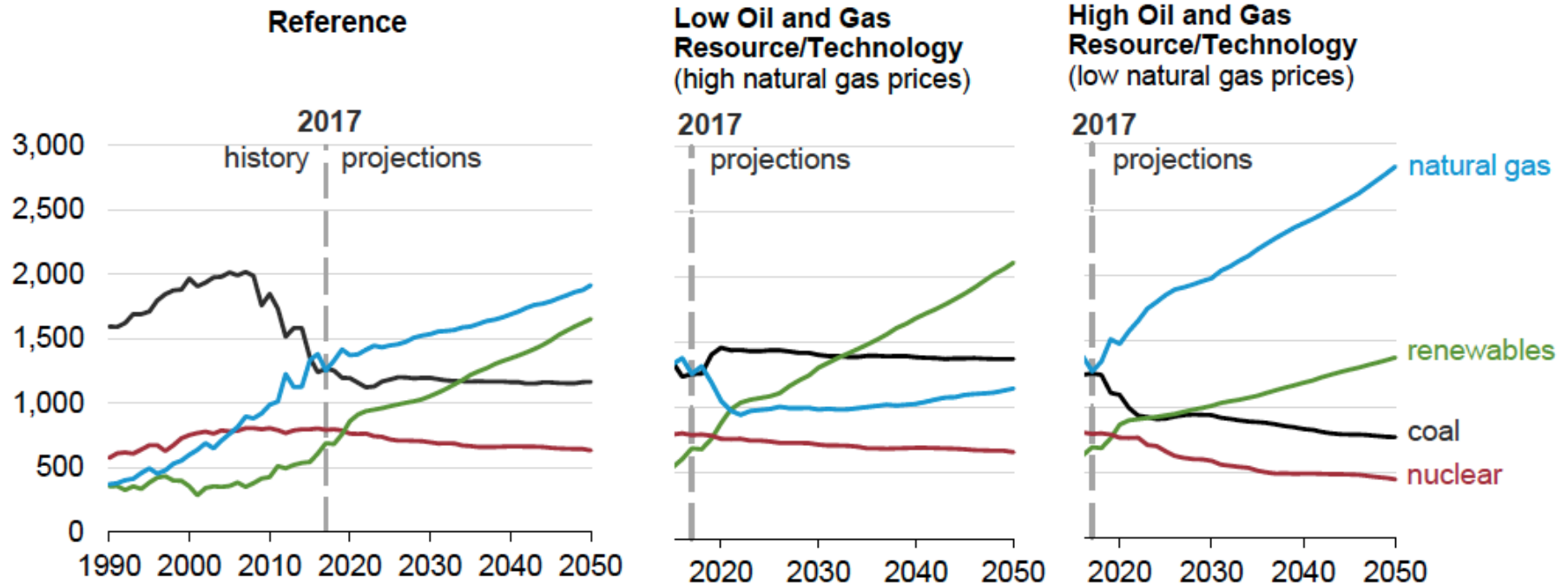
Electricity Resources are Becoming More Distributed

- >14 million electric customers are supplying power back into the grid.
- Distributed solar capacity is now nearly 1% of total U.S. generating capacity (14 GW).
- >80 GW of combined heat and power now accounts for ~8% of total U.S. generating capacity.
- >16 million customers participate in wholesale or utility demand response or time-varying rate programs.
- The charging cycles of 535,000 EVs are now being managed.

EIA Forecasts that Natural Gas will Outcompete Renewables

But supply-side energy forecasts are wide-ranging.*

Electricity generation from selected fuels
billion kilowatthours

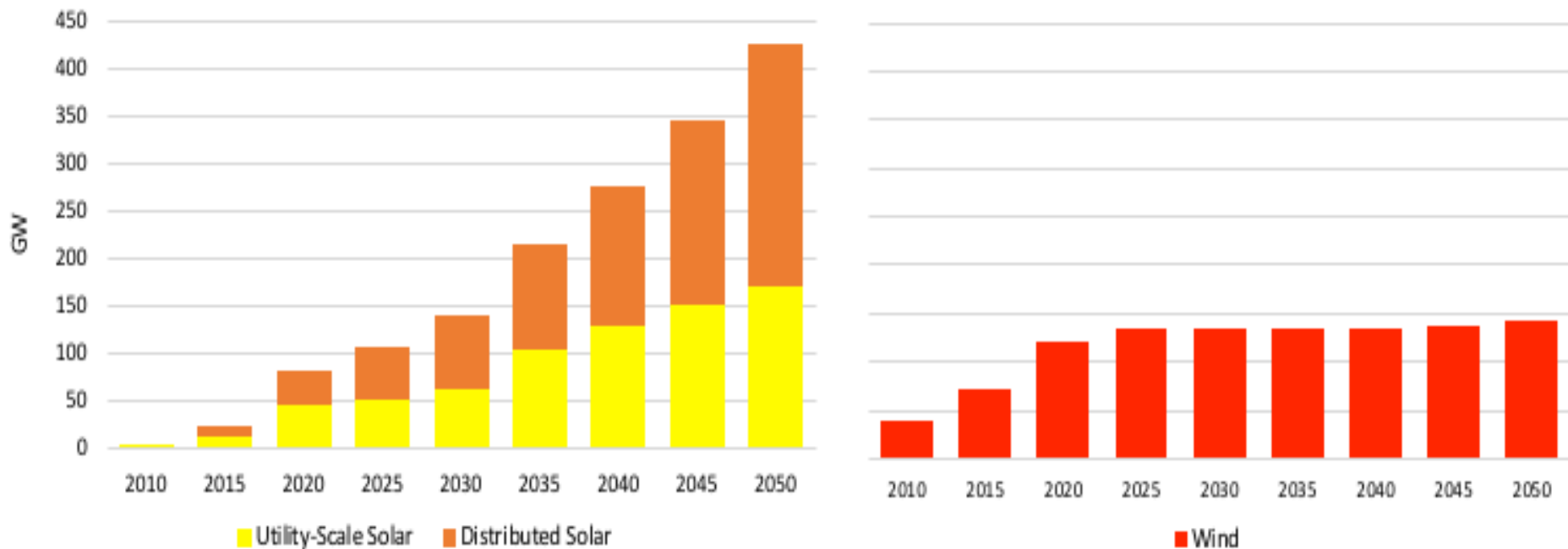


EIA=Energy Information Administration

*See: "The Next Financial Crisis Lurks Underground Fueled by Debt and Years of Easy Credit."
By Bethany McLean NYTimes, Sept. 1, 2018

Solar May Soon Eclipse Wind

And distributed solar may surpass utility-scale solar.
What policies are needed for peer-to-peer exchanges?

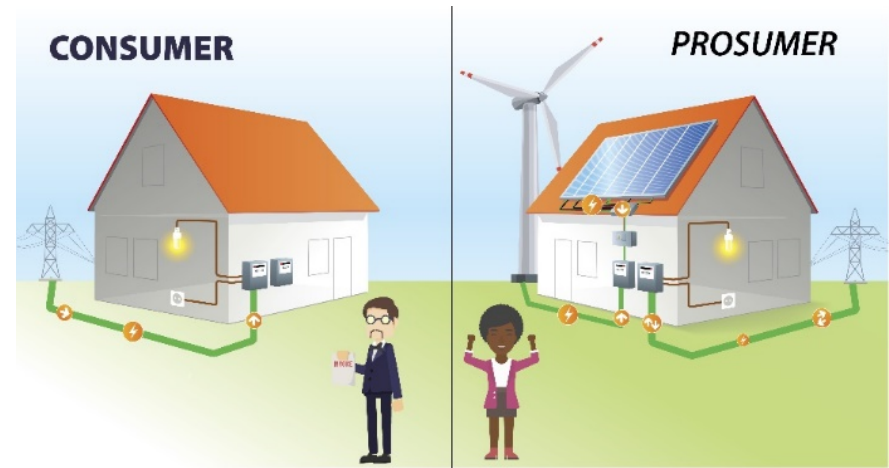


Utility-scale and distributed solar eclipse wind.

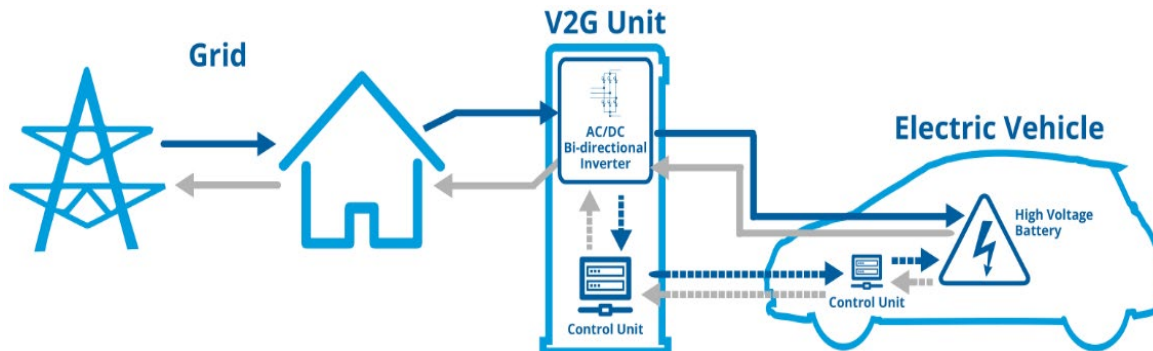
Source: Energy Information Administration. 2018. *Annual Energy Outlook 2018*, On-Line Data.

“Prosumers” and the “Sharing Economy” are Emerging

- Consumers are becoming producers – “Prosumers”
 - Facilitated by the falling cost of solar panels
 - Home battery systems are on the move
 - Many more EV models available and a growing charging infrastructure



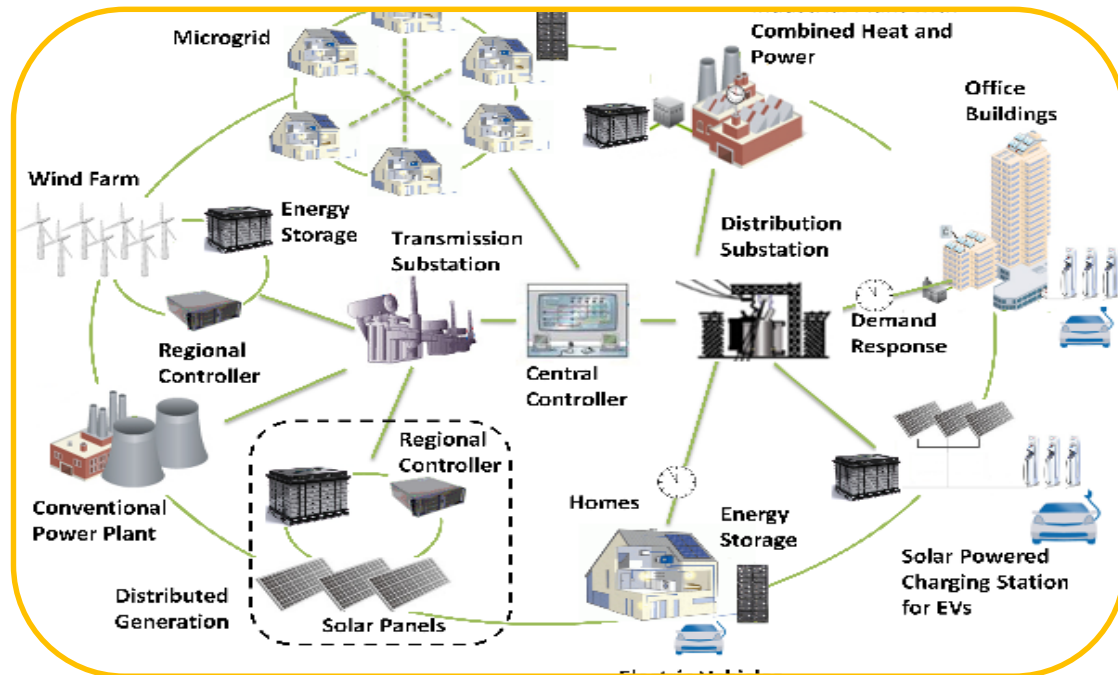
Grid-integrated vehicles could become another form of “prosumerism”



Transportation & Electricity: A Beneficial Merger

More renewable
electricity + more
electric vehicles:
“complementary”
trends:

- ✓ With renewables,
EVs are even cleaner
- ✓ With EVs, the grid
can be better
balanced



Brown, Marilyn A., Shan Zhou, and Majid Ahmadi. 2018. "Governance of the Smart Grid: An international review of evolving policy issues and innovations," *Wiley Interdisciplinary Reviews (WIREs): Energy and Environment*.

The Power of Consumers

Smart meters provide two-way communication:

- ✓ Powerful when combined with real-time electricity pricing
- ✓ WiFi enabled; controlled from computers & cell phones
- ✓ Interfaced with in-home, in-office, and smart phone displays

Sensors for temperature, humidity, motion, and light eliminate wasted energy (and improve comfort).

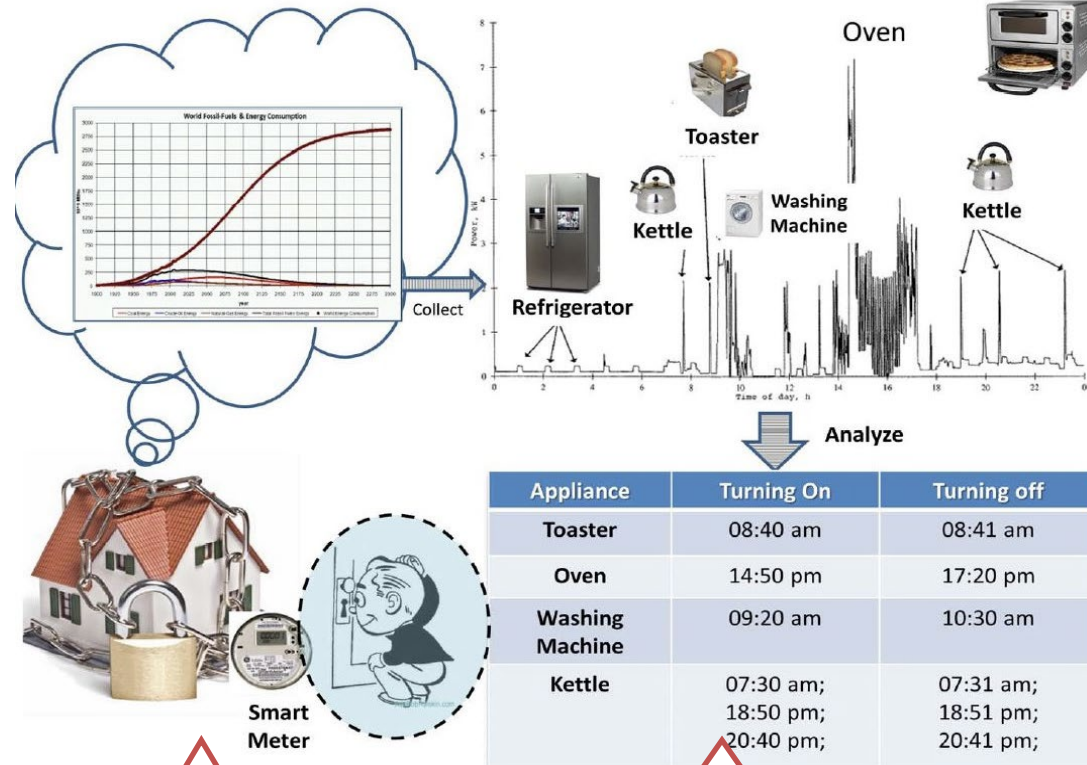


Thermostats that Learn



Is Data Privacy a Problem?

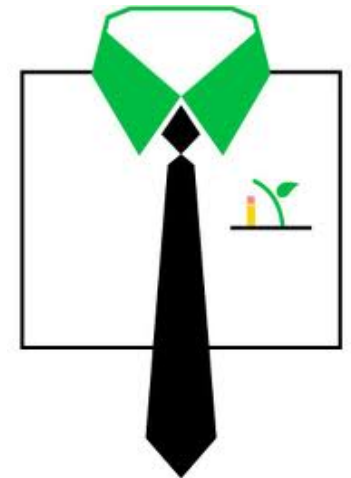
- Communications between smart appliances is often **wireless**—enabling eavesdroppers
- Eavesdropper can find user **signatures**:
 - Discern daily schedules of residents
 - Identify the best times for a burglary
 - Detect the expensive appliances, alarm systems, or medical equipment



70M smart meters were installed in US by end of 2016

17.7B IoT connected devices were installed in U.S. by end of 2016

Changing the Jobs Narrative



The U.S. has about 75,000 jobs in coal mining. Automation has had a major impact on this workforce: autonomous trucks work the Powder River Basin....

See: 30-minute CNN discussion: 175,000 live “hits”

https://www.facebook.com/cnn/videos/10156318782866509/?hc_ref=NEWSFEED

Solar Projects and Jobs in Georgia

FORT BENNING

- Location: near Columbus, GA
- Date Installed: June 2016
- Capacity: 30 MW
- Area: 240 acres
- Cost: \$75 million
- Partners: US Army, Georgia Power

HAZLEHURST II

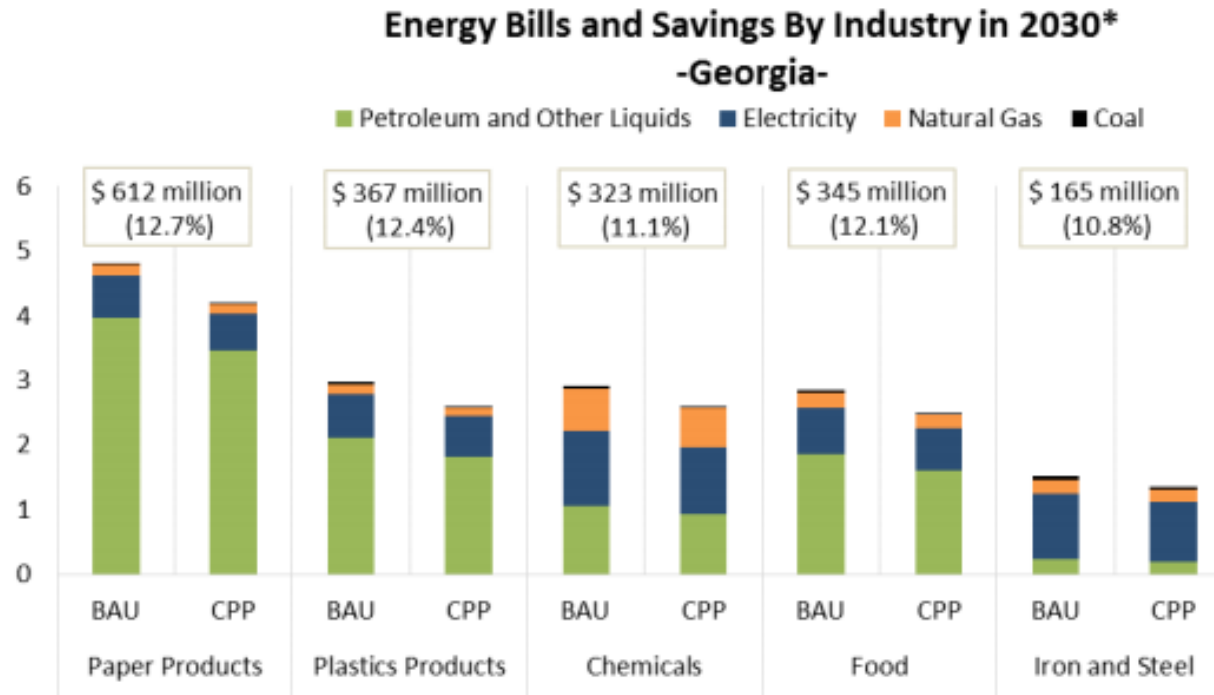
- Location: Hazlehurst, GA
- Date Complete: October 2016
- Capacity: 52 MW
- Area: 450 acres
- Partners: Silicon Ranch, Greenpower EMC

Georgia had 3,924 solar jobs in 2016.

<https://cepl.gatech.edu/sites/default/files/attachments/CEPL Presentation GAsolar Jan13.pdf#>

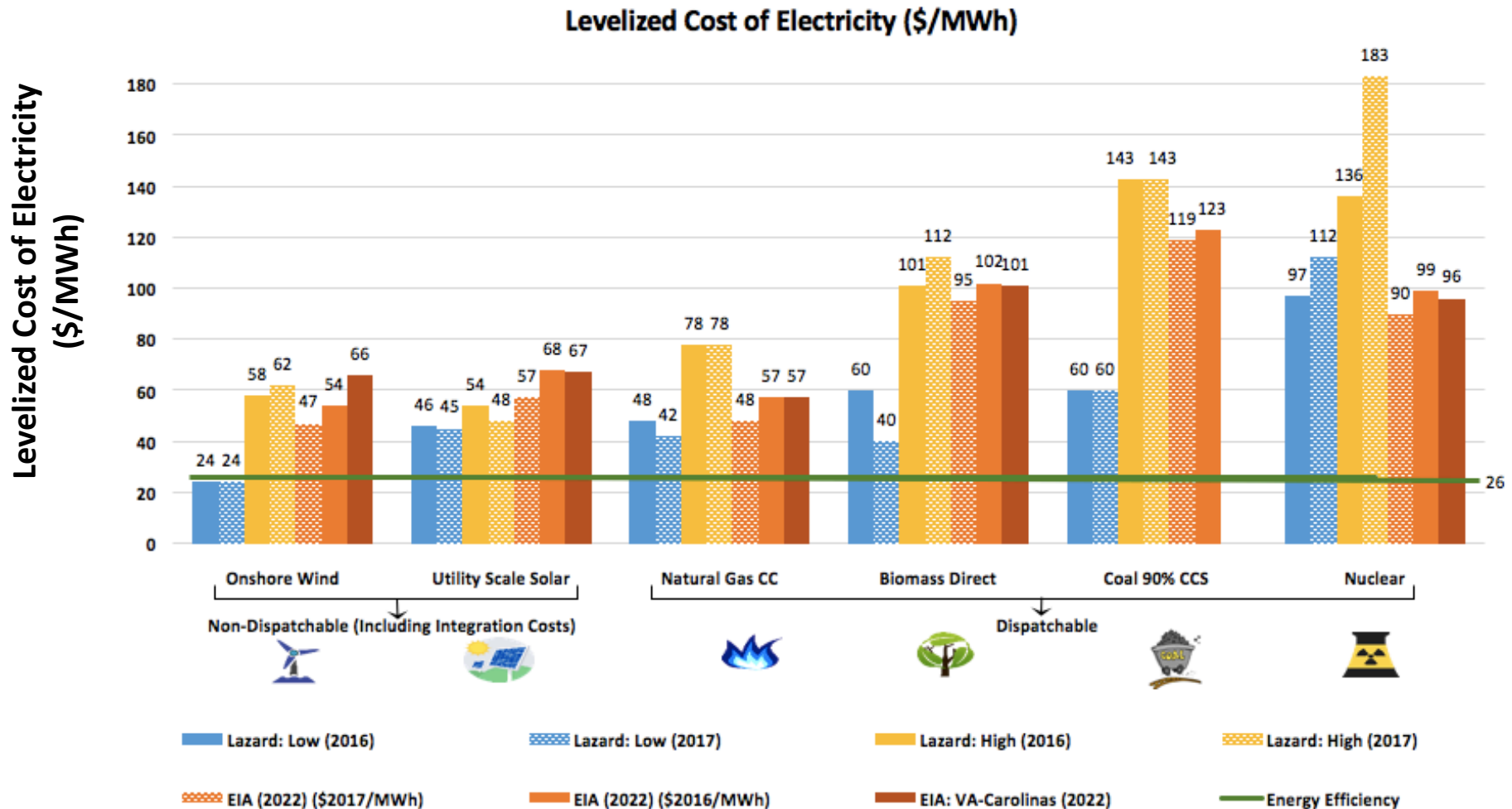


15X More Jobs in Energy-Efficiency in Georgia



About 66,200 Georgians work in energy efficiency related businesses. The state's energy efficiency economy includes traditional HVAC, efficient lighting, and advanced materials and insulation.

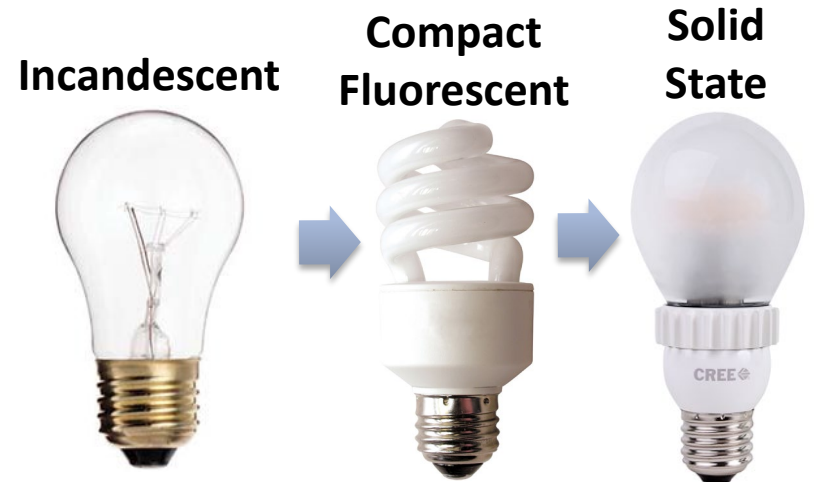
Energy Efficiency is the Least Cost Energy Resource



Energy Efficiency Involves Purchase and Usage Behaviors

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

Avoiding the ubiquitous use of fully lit and conditioned spaces



Watts	60	14	11
Lumens per Watt	14	64	84

Cities are First Responders, For both Mitigation and Adaptation



Source: NASA Goddard Space Flight Center, Conceptual Image Lab



Established June 2016

"The largest global coalition of cities committed to climate leadership, building on the commitments of more than **7,100** cities from **119** countries and **six** continents, representing more than **600** million inhabitants, over **8%** of the world's population"

~600 Compact cities commit to reducing GHG emissions by nearly **1 billion tons** annually by 2030, or **11.6 billion tons** between 2010 and 2030.

~6,000 cities of the EU Covenant of Mayors projected to have an estimated reduction of **240 Megatons of CO₂e**, a reduction of **27%** by 2020.

Atlanta's Climate Leadership

Unanimously passed by City Council



- 100% of **electricity** consumed in Atlanta will be “generated” from clean energy resources



- To be enacted by the Mayor's Office of Resilience

Subsidies and Incentives

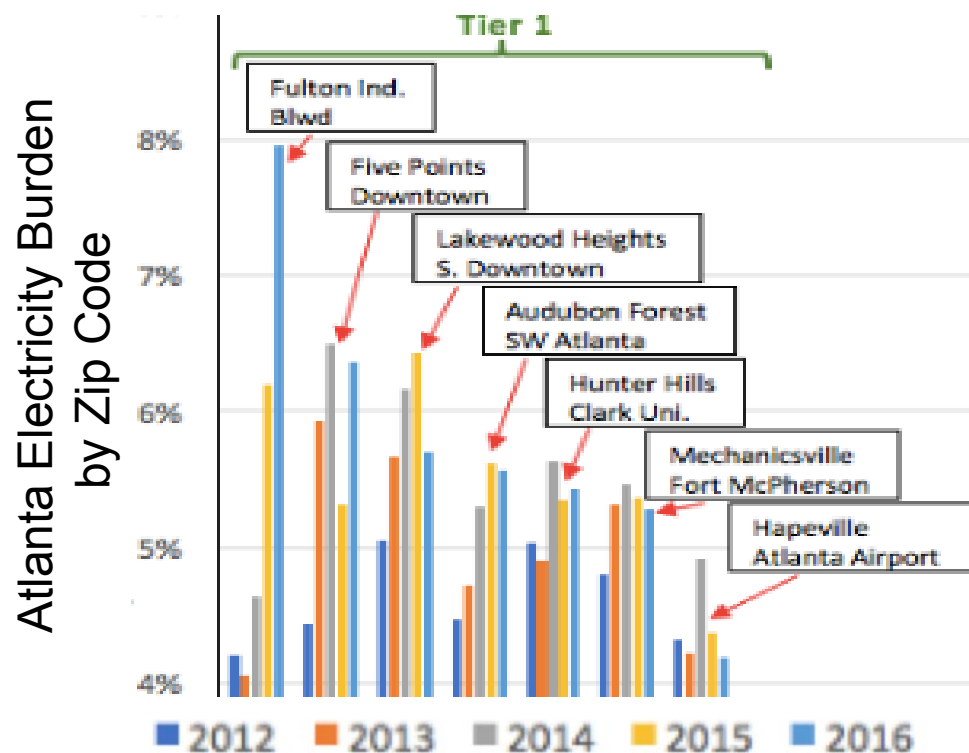
- While financial subsidies can promote energy efficiency, they are not a panacea
- Households responses to identical incentives vary by a factor of 10, depending on:
 - incentive design & marketing strategies
 - consumer trust & social norms
 - cognitive effort & rational inattention
 - environmental attitudes
 - time preferences (people with lower discount rates invest more in EE)
 - loss aversion, habit & status quo bias, and more....

Climate Policies Must Consider Equity

	All households	Low-income households*
1	Memphis (6.2%)	Memphis (13.2%)
2	Birmingham (5.3%)	Birmingham (10.9%)
3	New Orleans (5.3%)	Atlanta (10.2%)
4	Atlanta (5.0%)	New Orleans (9.8%)

Data analytics combined with focus groups can help visualize and understand the problem.

- Energy burden is emerging as a “material” issue for investor-owned utilities.
- It influences the quality of life of our students in off-campus housing.
- The challenge is to convert “shared values” into solutions.



Energy Benchmarking

Policies like energy benchmarking can tackle inequities:

- Reduce information asymmetries in the marketplace
- Allow real estate markets to operate more efficiently
- Raise the value of high performance buildings and empower tenants



In the Long-Run

The greatest opportunities are likely to lie in:

- Technological innovations
- Social movements & new business models
- Infrastructure investments, and
- Cultural changes

To realize bold decarbonization goals will require:

- engagement of the full range of social and economic sciences
- natural sciences, engineering, and planning
- an understanding of how human choices and behaviors are shaped.

Conclusions

- The clean energy transformation has begun.
- A great deal is at stake, and delay is costly.
- More research is needed to develop smart technology, but new business models and smart policies are equally important.
- That's why my graduate students land jobs in so many different places, with incredible impact.

GT Graduates from the Climate and Energy Policy Lab Are Making a Difference



For More Information

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