NARUC

Winter Committee Meetings

Committee on Electricity & Subcommittee on Clean Coal and Carbon Management

Moderator:

Hon. Jeremy Oden, Alabama

- *Joseph Giove, US DOE*
- *Dr. Carey King, University of Texas*
- *Dr. Josh Rhodes, University of Texas*

The Full Cost of Electricity (FCe-) Study & Texas CCS with EOR

Dr. Carey W. King and Dr. Joshua Rhodes

2017 NARUC Winter Committee Meetings

Subcommittee on Clean Coal and Carbon Management Meeting

February 13, 2017

Washington, D.C.

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Topics

- Summary of past analysis of large-scale coal-fired CCS in Texas
- Background on Energy Institute "Full Cost of Electricity" study
- Presentation of county-by-county estimation of Levelized Cost of Electricity (LCOE)

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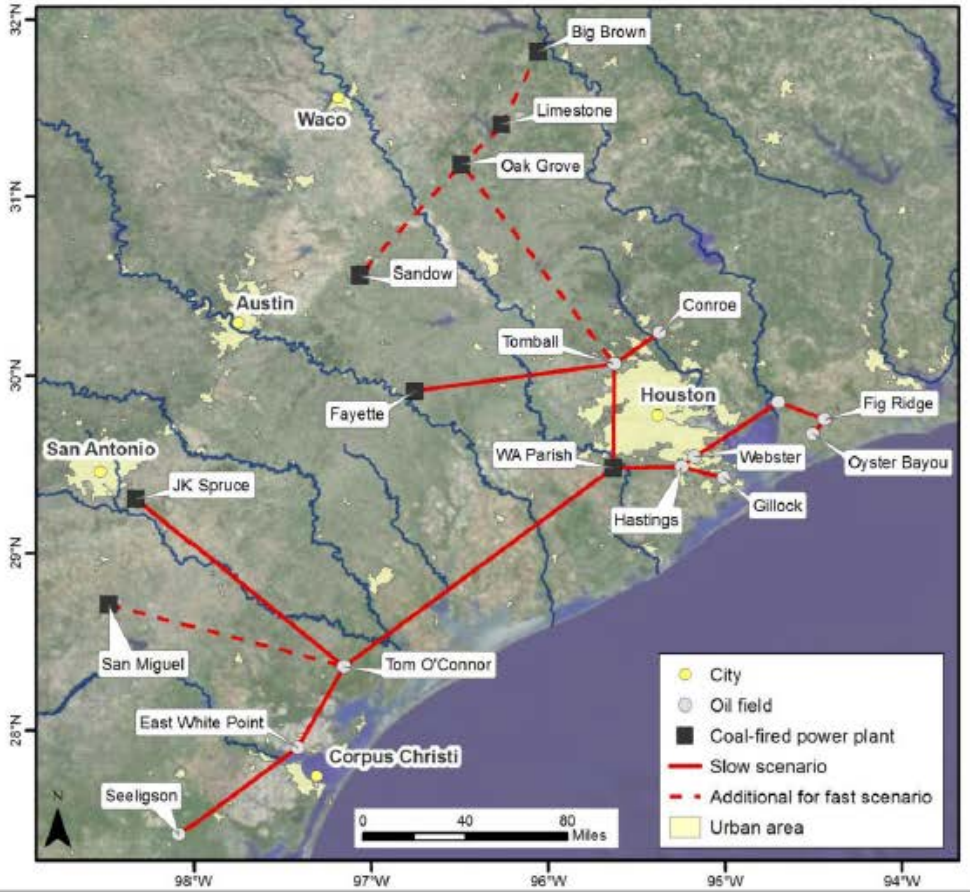
Texas-sized CO_2 Capture, Utilization (EOR), and Storage

OPEN ACCESS
IOP PUBLISHING
ENVIRONMENTAL RESEARCH LETTERS
Environ. Res. Lett. 8 (2013) 034030 (16pp)
doi:10.1088/1748-9326/8/3/034030

The system-wide economics of a carbon dioxide capture, utilization, and storage network: Texas Gulf Coast with pure CO_2-EOR flood

Carey W King[1], Gürcan Gülen[2], Stuart M Cohen[3,5] and Vanessa Nuñez-Lopez[4]



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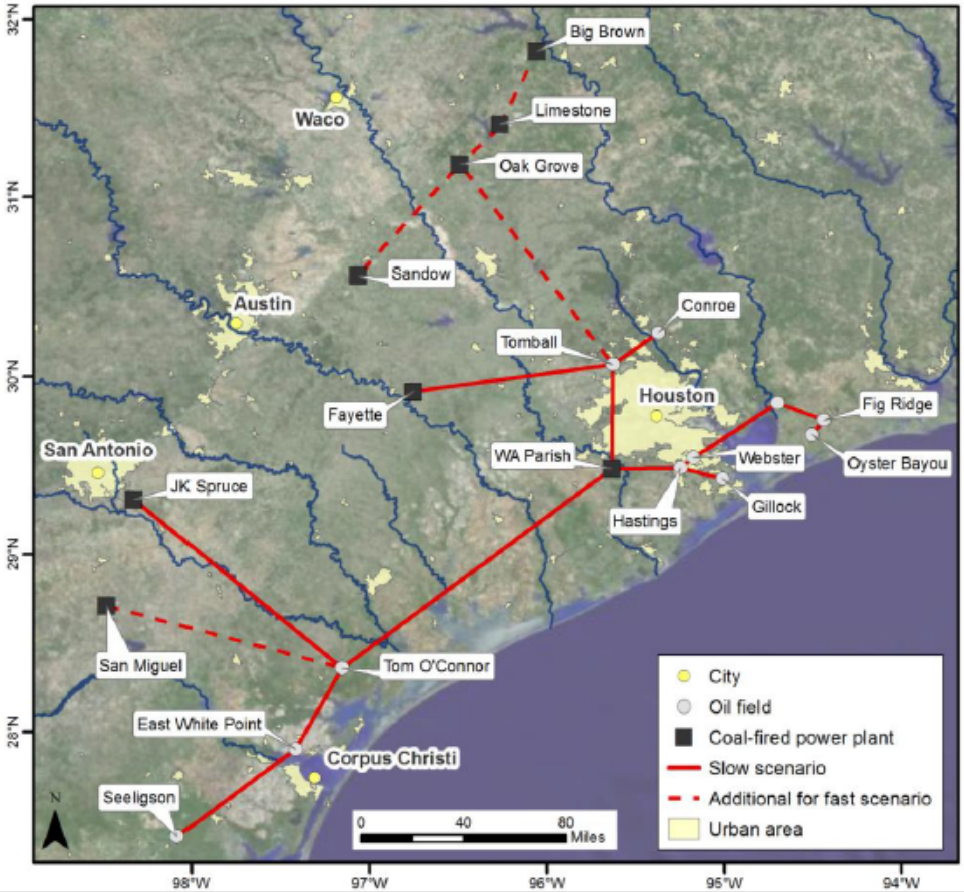
The system-wide economics of a carbon dioxide capture, utilization, and storage network: Texas Gulf Coast with pure CO_2-EOR flood

Carey W King[1], Gürcan Gülen[2], Stuart M Cohen[3,5] and Vanessa Nuñez-Lopez[4]

- 10 oil fields
  - Slow development: CO_2 from 3 coal EGUs
  - Fast development: CO_2 from 21 coal EGUs (13 power plants)
- Capture and store 90% of coal emissions (20 yrs)



There is net CO_2 storage for the EOR assumption of "pure CO_2 flood"

- "Slow" (3 coal EGUs) scenarios
  - 346 MMBBL production (20 yrs)
  - 223 $MtCO_2$ for EOR
  - 240 $MtCO_2$ captured and stored

- "Fast" (21 coal EGUs) scenarios
  - 480 MMBBL production (80% in 5 yrs)
  - 284 $MtCO_2$ for EOR
  - 1,500 $MtCO_2$ captured and stored

There is net CO_2 storage for the EOR assumption of "pure CO_2 flood"

- "Slow" (3 coal EGUs) scenarios
  - 346 MMBBL production (20 yrs)
  - 223 $MtCO_2$ for EOR
  - 240 $MtCO_2$ captured and stored

66 $MtCO_2$ stored overall (net)
Cost: 5-25 $/$tCO_2$

- "Fast" (21 coal EGUs) scenarios
  - 480 MMBBL production (80% in 5 yrs)
  - 284 $MtCO_2$ for EOR
  - 1,500 $MtCO_2$ captured and stored

1,100 $MtCO_2$ stored overall (net)
Cost: 7-18 $/$tCO_2$

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Full Cost of Electricity Study (FCe-)

Motivation for the Full Cost of Electricity

The Problem

- Advocacy groups sometimes discuss "their solution" without simultaneously considering others' actions, assets, and options
- One person's cost is another person's benefit

The Solution

- Provide quantitative structures to *simultaneously* combine *many* cost inputs
- Make data and quantification transparent to lay persons and policy makers

Products from the Full Cost of Electricity

Written Documents

- 11 white papers (4 more to come) and Executive Summary
- http://energy.utexas.edu/the-full-cost-of-electricity-fce/

Online Interactive Tools

- Levelized Cost of Electricity calculators
- http://calculators.energy.utexas.edu/

Blogs

- IEEE Spectrum "Energywise" blog series
- http://spectrum.ieee.org/static/the-full-cost-of-electricity

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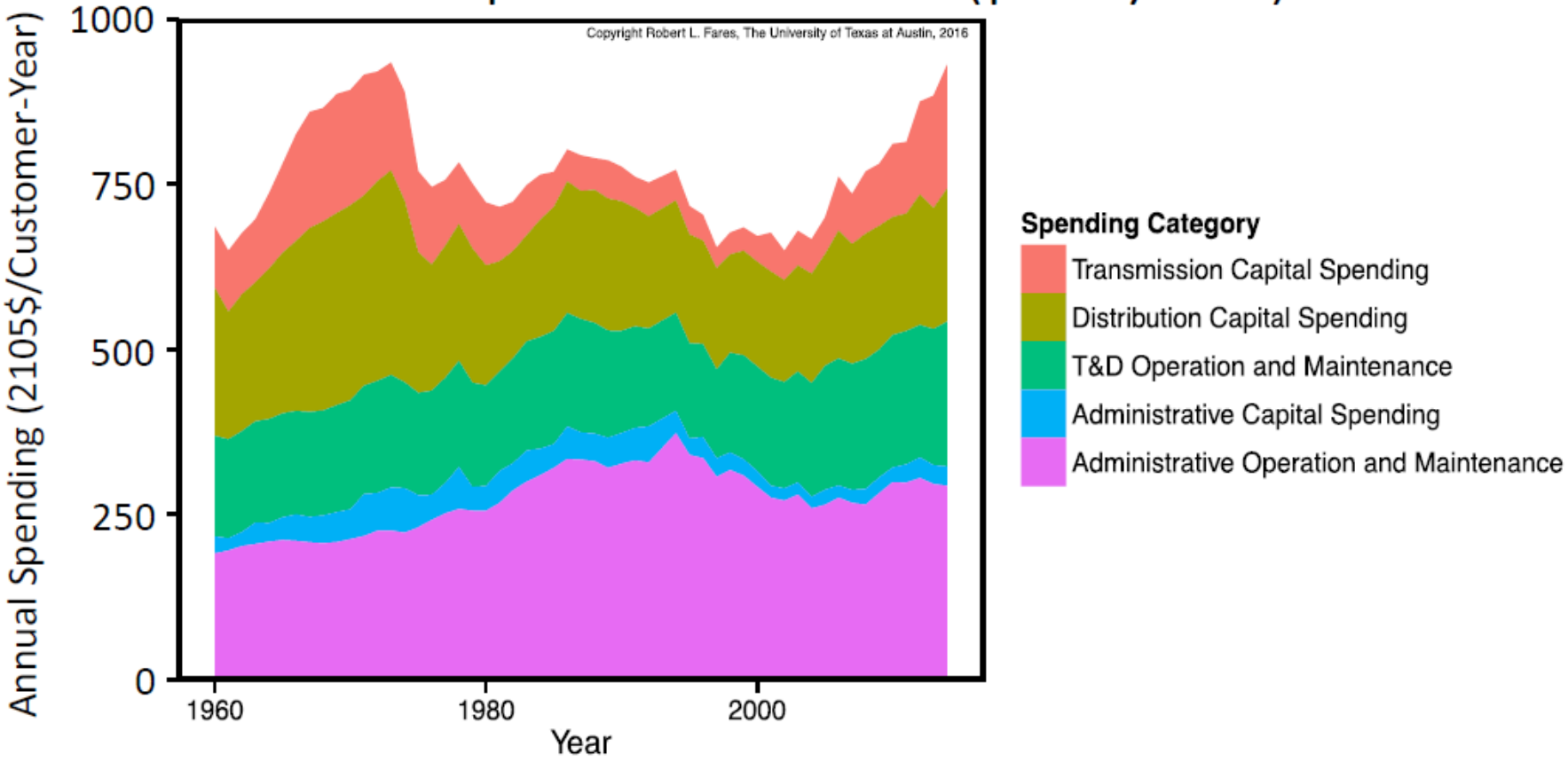
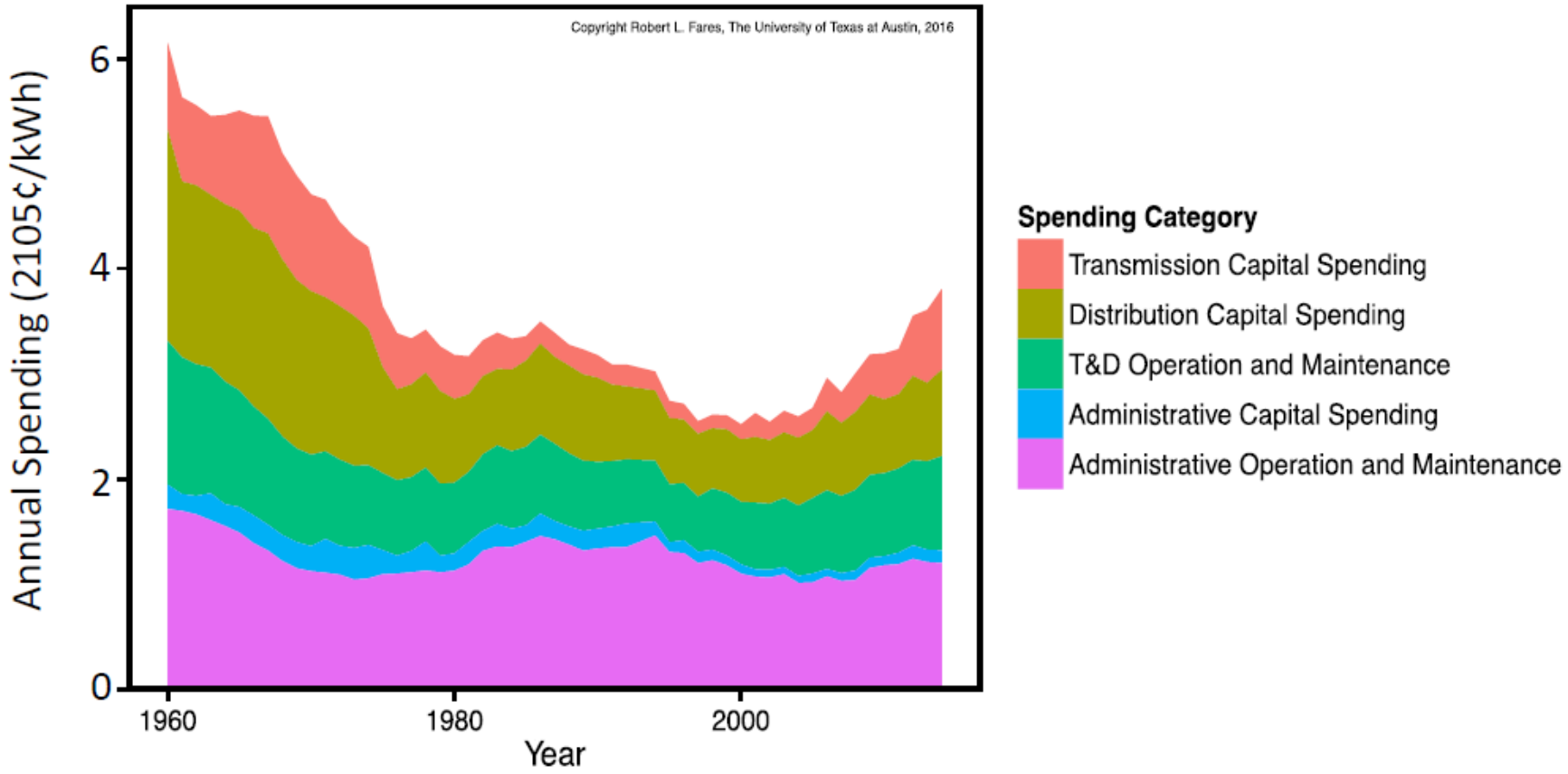
Sample FCe- Results:
Cost Trends for TD&A
(Transmission, Distribution, and Administration)

TD&A Costs Summary (1960-2014): Cost per customer (per year)



Electricity transmission, distribution, and administration costs each consist of upfront capital investments and recurring operation and maintenance costs. Total transmission, distribution, and administration costs have been $700–$800 per utility customer per year for much of the past 54 years.

TD&A Costs Summary (1960-2014): Costs per kWh



Average annual TD&A costs per kWh declined between 1960 and 1980, but have been approximately 2.5–3.5 ¢/kWh since 1980. The decrease between 1960 and 1980 was likely driven by increasing energy consumption rather than decreasing service costs.

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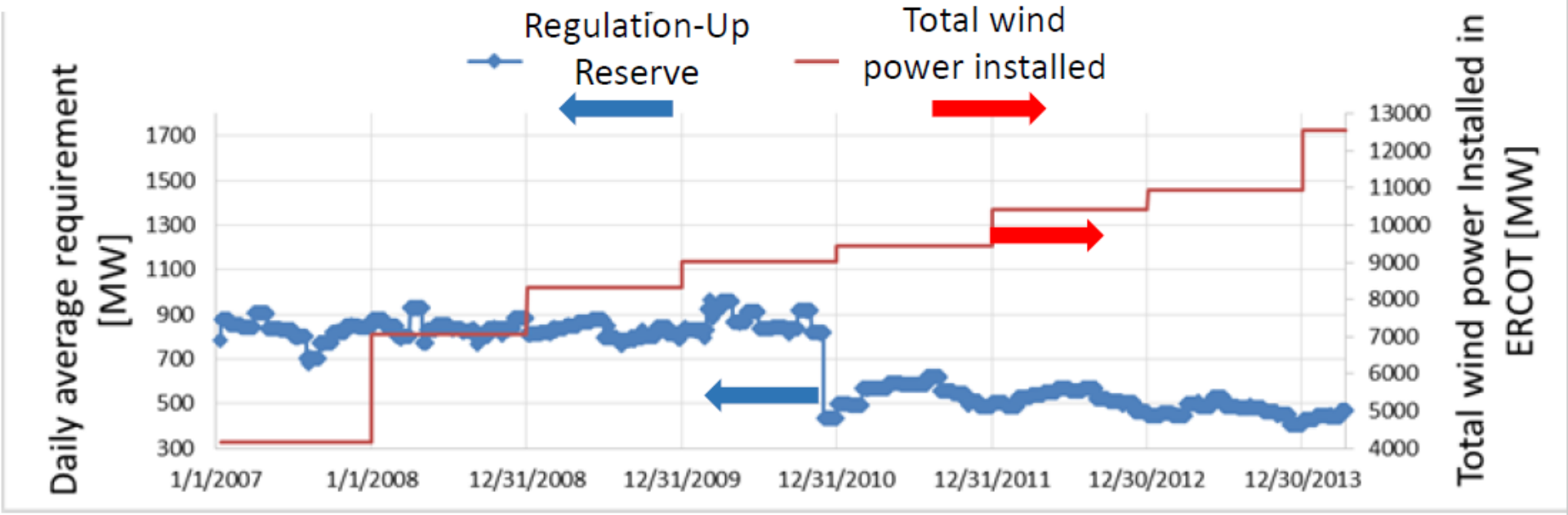
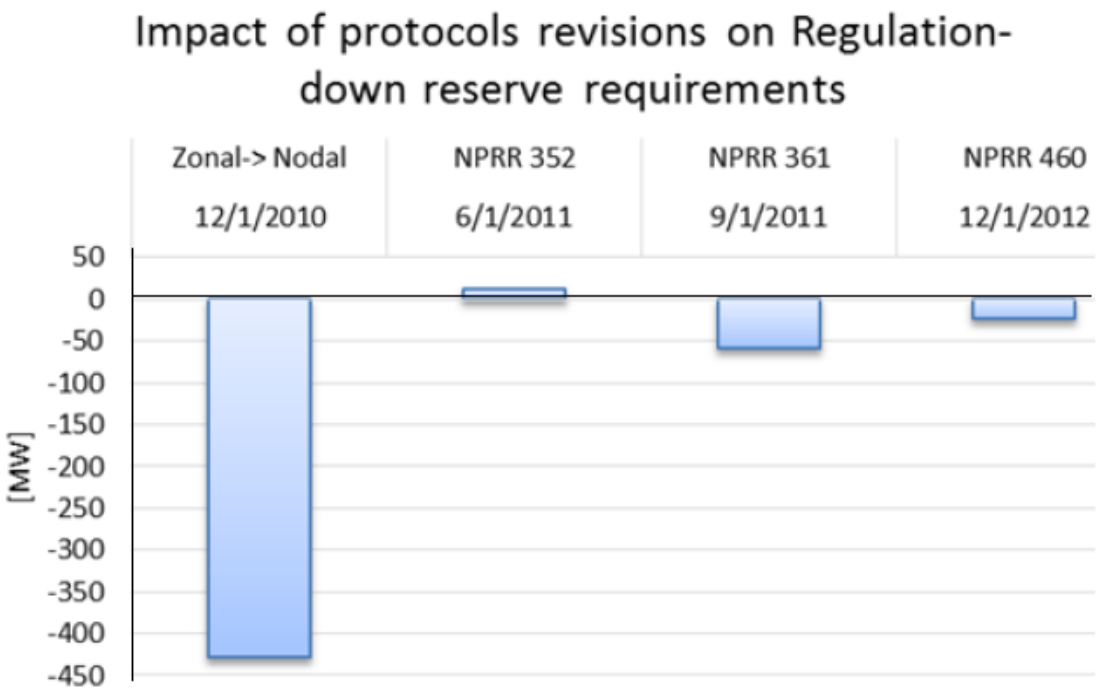
Sample FCe- Results:
Impact of renewable generation on operational reserves requirements (ERCOT)

Regulation reserve requirements declined as wind power increased



Market (ERCOT) protocols change over time too, not just renewables

- Change from the zonal to nodal market in 2010 has been more significant than the changes in reserve requirements due to increases in installed wind power capacity of around 8,000 MW during the period from 2007 to 2013.



- NPRR 352 (6/1/2011):
  - Improvements in prediction of the maximum sustained energy production after curtailment.
- NPRR 361 (9/1/2011):
  - Requires submission of 5 min resolution wind data for real time purposes.
- NPRR 460 (12/1/2012):
  - Increases wind generation resource ramp rate limitation from 10% per minute of nameplate rating to five minute average of 20% per minute of nameplate rating with no individual minute exceeding 25%.

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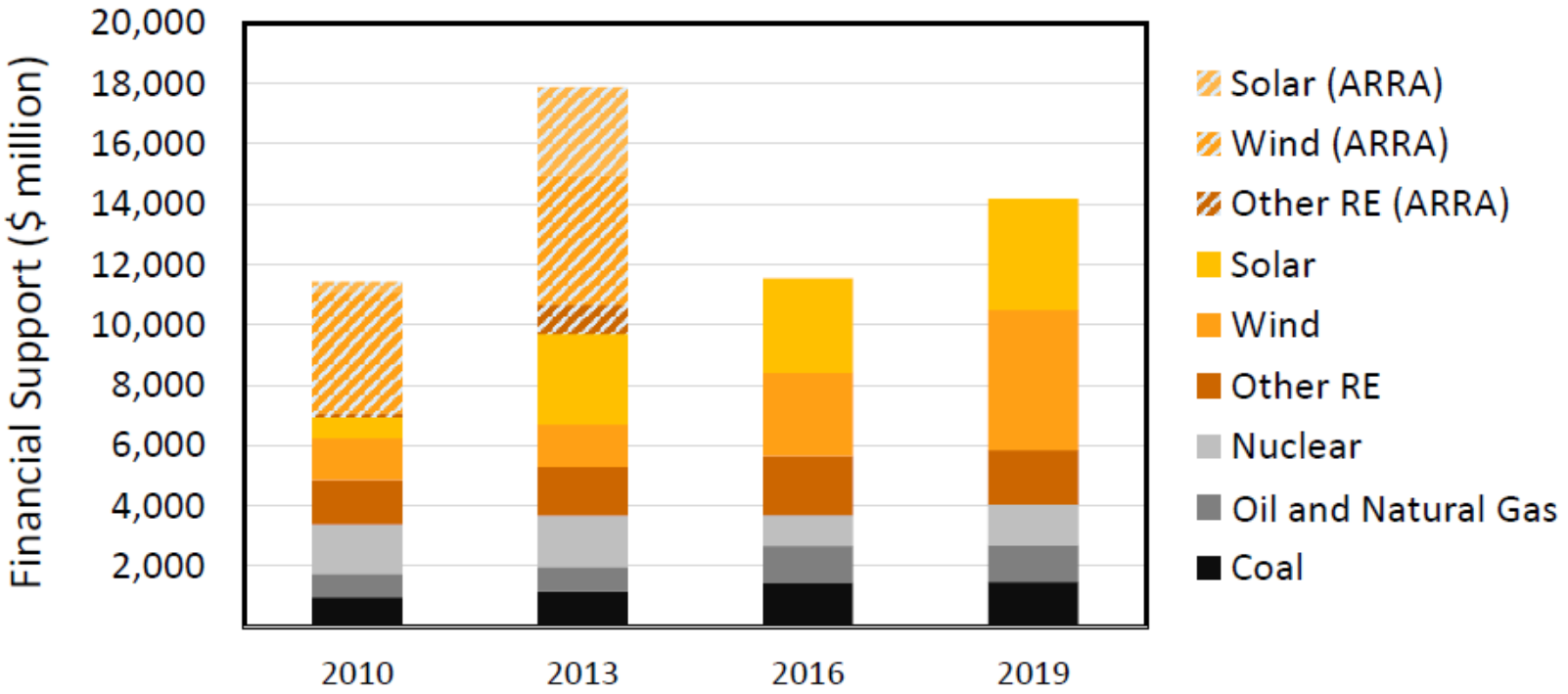
Sample FCe- Results: Federal Financial Support for Electricity

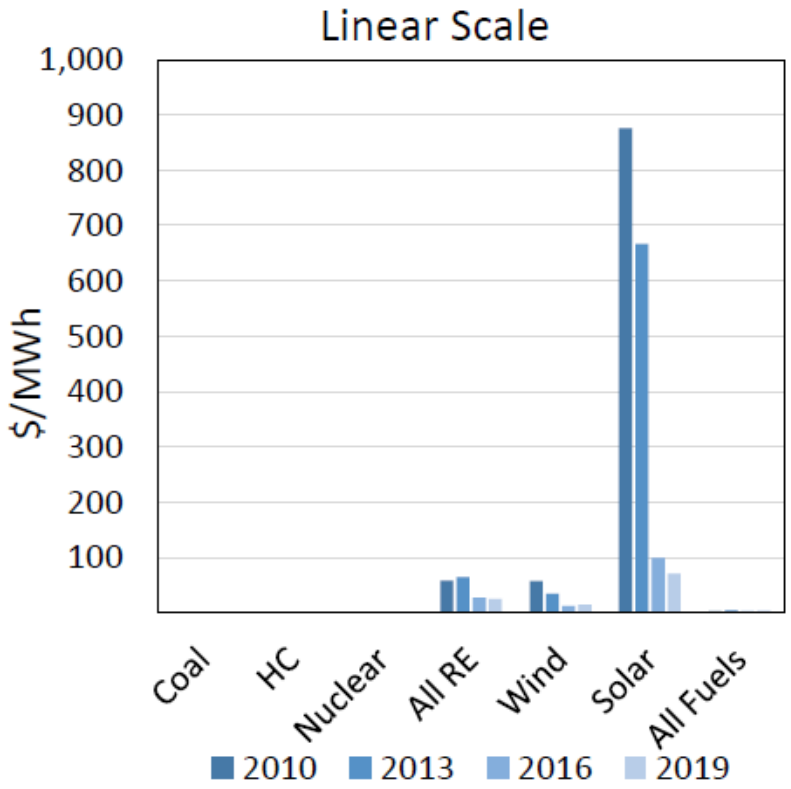
Federal Financial Support (leading to elec.) (7-14 billion $/yr, 2010s)

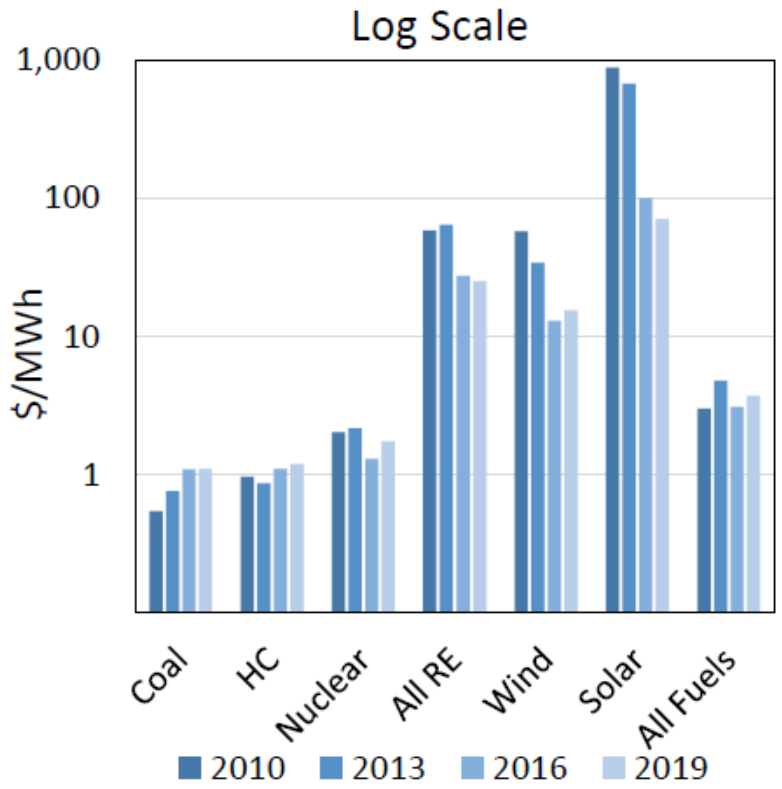


Total Federal financial support for the electricity-generating technologies ranged between $10 and $18 billion in the 2010s.

- The growth in perennial spending is attributable to renewables, especially wind.
- Stimulus funding (ARRA, Section 1603 grants): $4bn for RE funding in 2010, $8bn in 2013.
- Conventional technologies receive $3-4bn in the study years

Federal Financial Support (3-5 $/MWh overall, 2010s)





Considering total electricity-related support on a $/MWh basis, renewable technologies received 5x to 100x more support than conventional technologies.

- Depending on the year, fossil fuels and nuclear receive $0.5-2/MWh.
- Wind received $57/MWh in 2010 (anticipated falling to $15/MWh in 2019)
- Solar received $860/MWh in 2010 (anticipated falling to $70/MWh in 2019).

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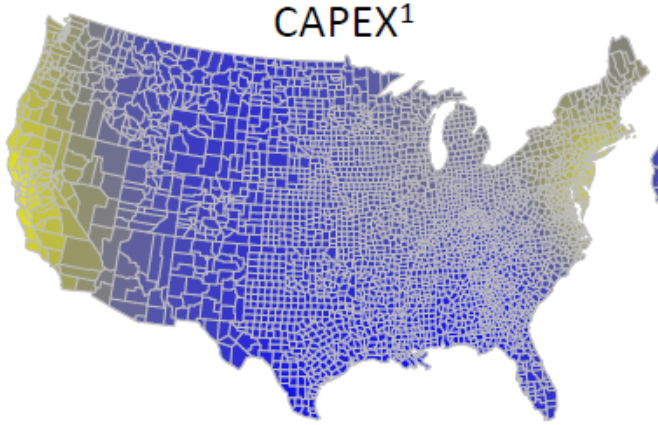
New U.S. Power Costs: by County, with Environmental Externalities

The national discussion of power plant costs often leaves out critical factors such as environmental externalities

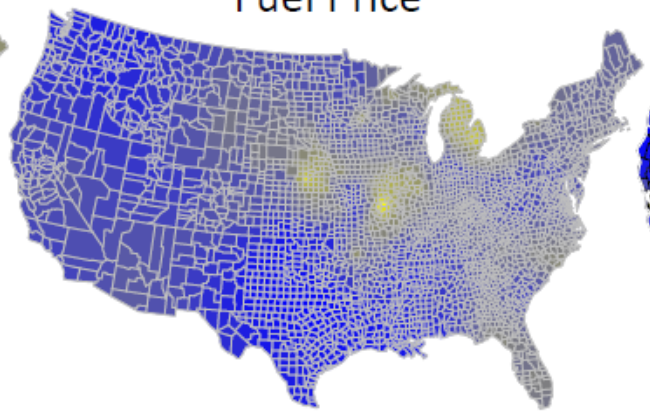
- Thus, we built a couple tools that allow people to have a meaningful conversations around the cost of electricity
- We use the simple, but flawed, metric of Levelized Cost of Electricity
- We realized that to have a national conversation, we would have to consider the different inputs on a spatial scale
  - The cost for every technology is not the same everywhere

Most aspects of the cost of electricity vary depending on where you are

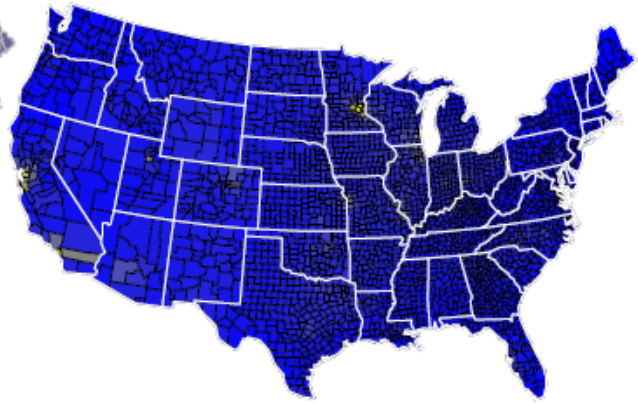
CAPEX[1]



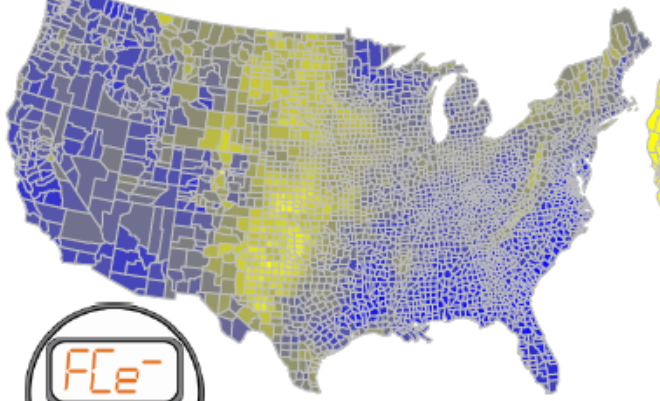
Fuel Price[2]



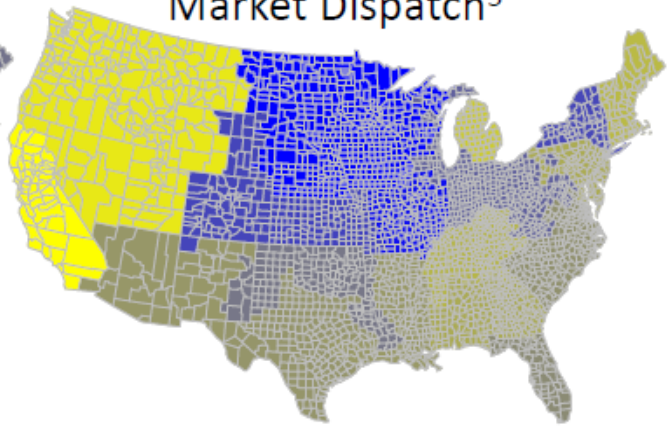
Pollutant Damages[3]



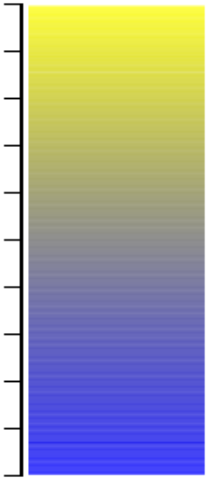
Renewable Resource[4]



Market Dispatch[5]



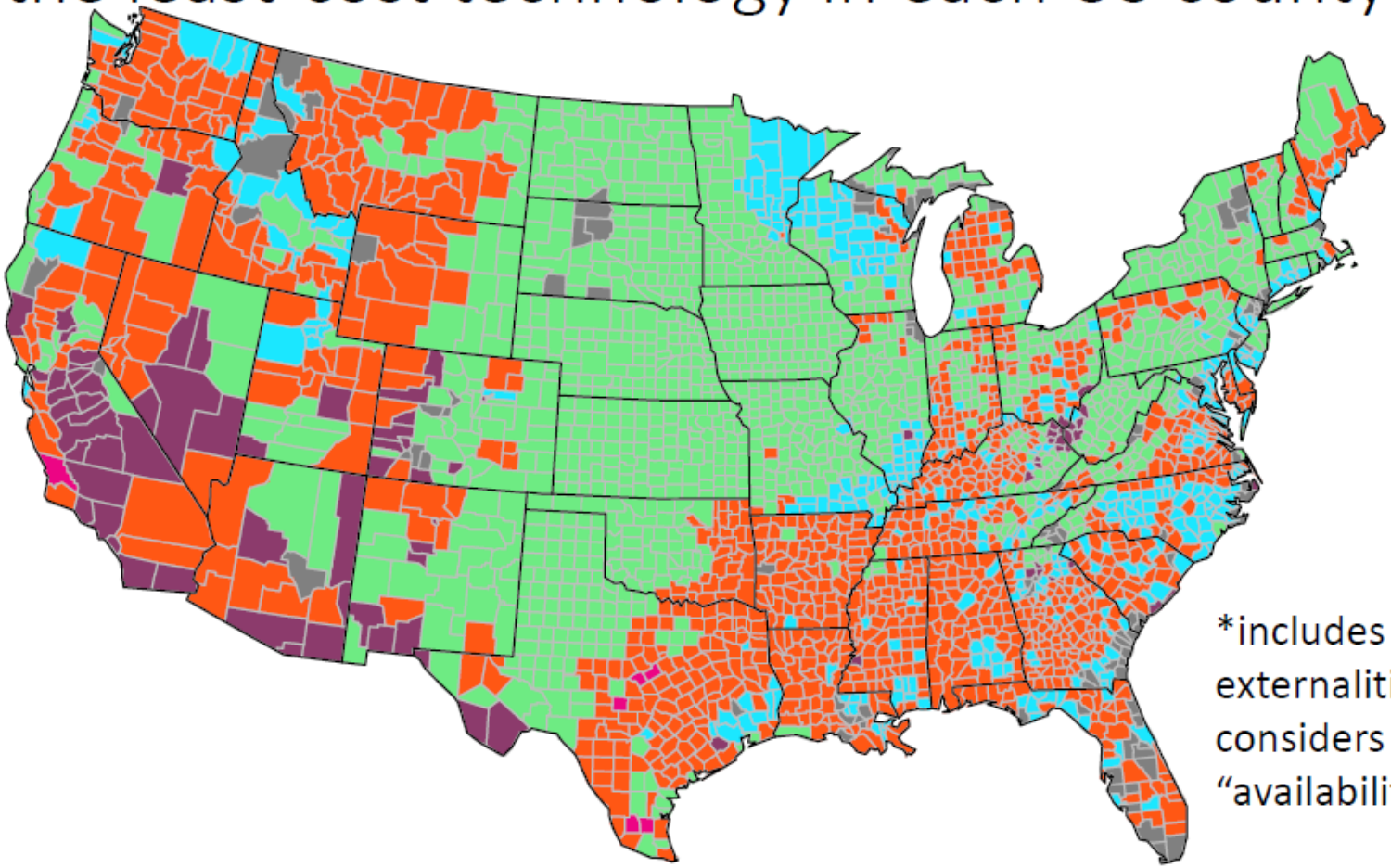
High



Low

1: Coal, 2: Natural gas, 3: NO_x, 4: Wind capacity factor, 5: NGCC plant capacity factors

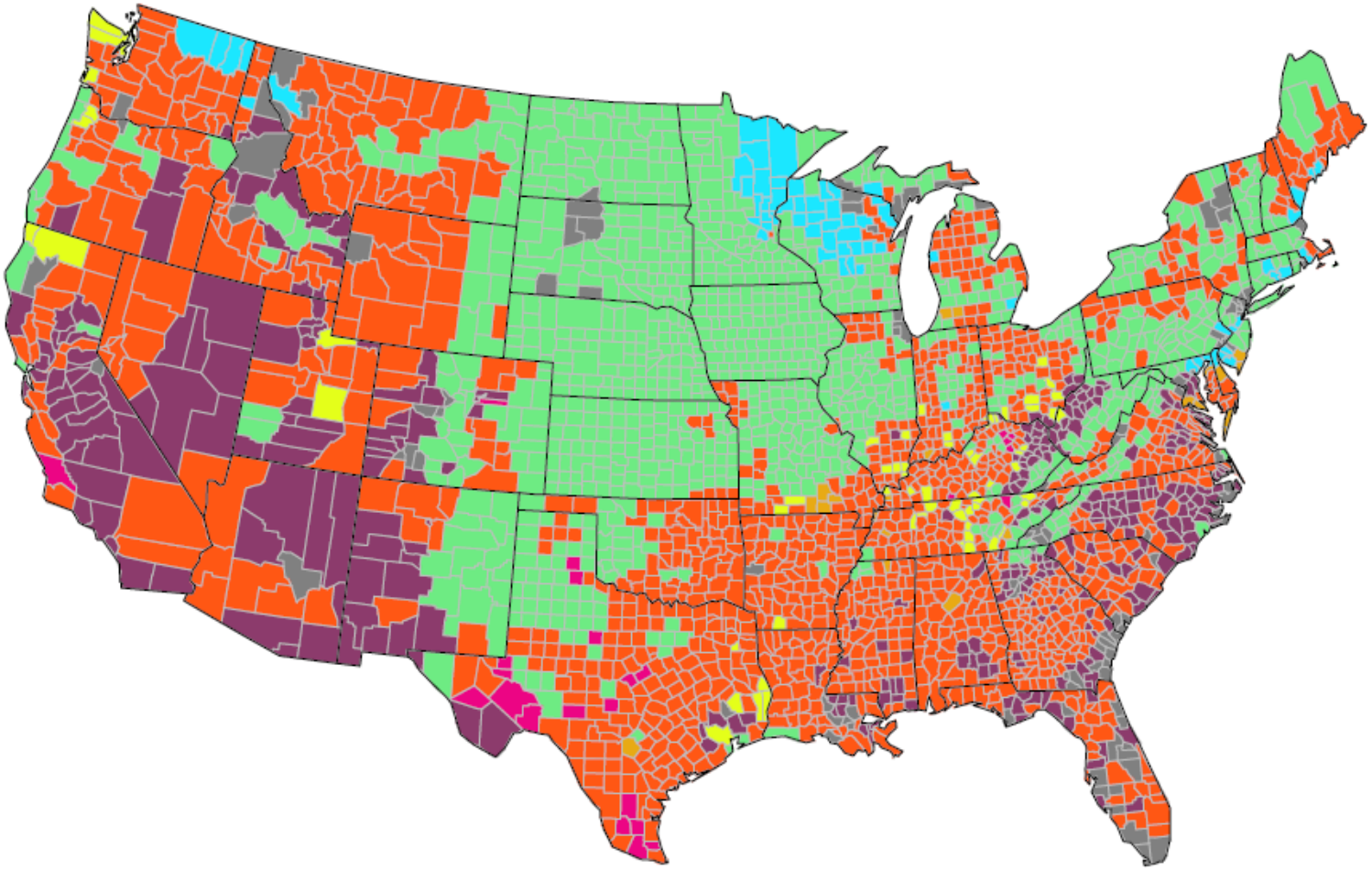
We took all the underlying maps from the previous slide for 12 technologies and found the least-cost technology in each US county



*includes a cost for externalities and considers "availability zones"

- Coal (BIT) (n = 0)
- Coal (BIT) CCS (n = 0)
- Coal (SUB) (n = 0)
- Coal (SUB) CCS (n = 0)
- CSP (n = 0)
- NGCC (n = 1127)
- NGCC CCS (n = 0)
- NGCT (n = 6)
- Nuclear (n = 398)
- Solar PV, resid. (n = 147)
- Solar PV, utility (n = 85)
- Wind (n = 1347)

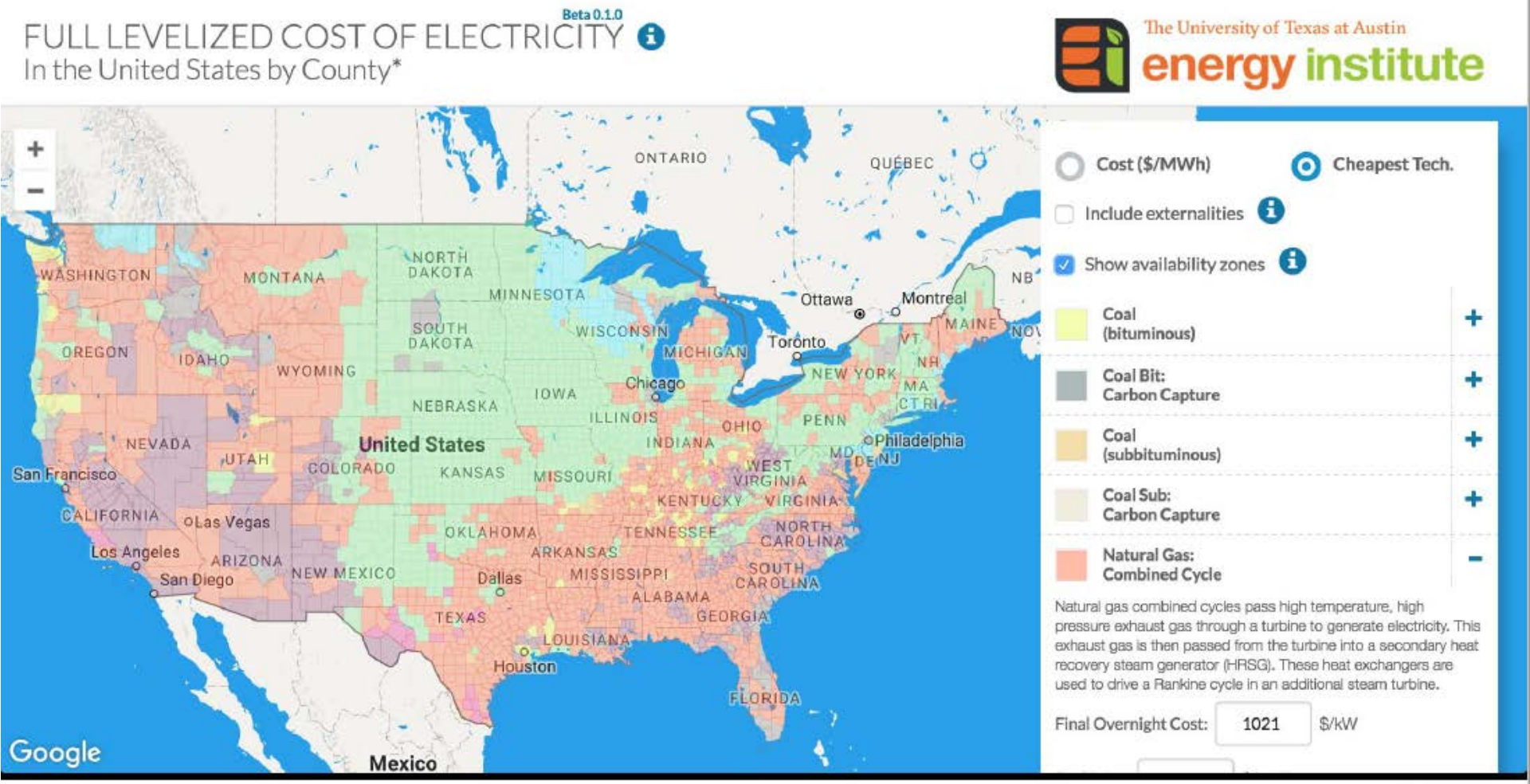
This is what the map looks like when there is no cost for externalities



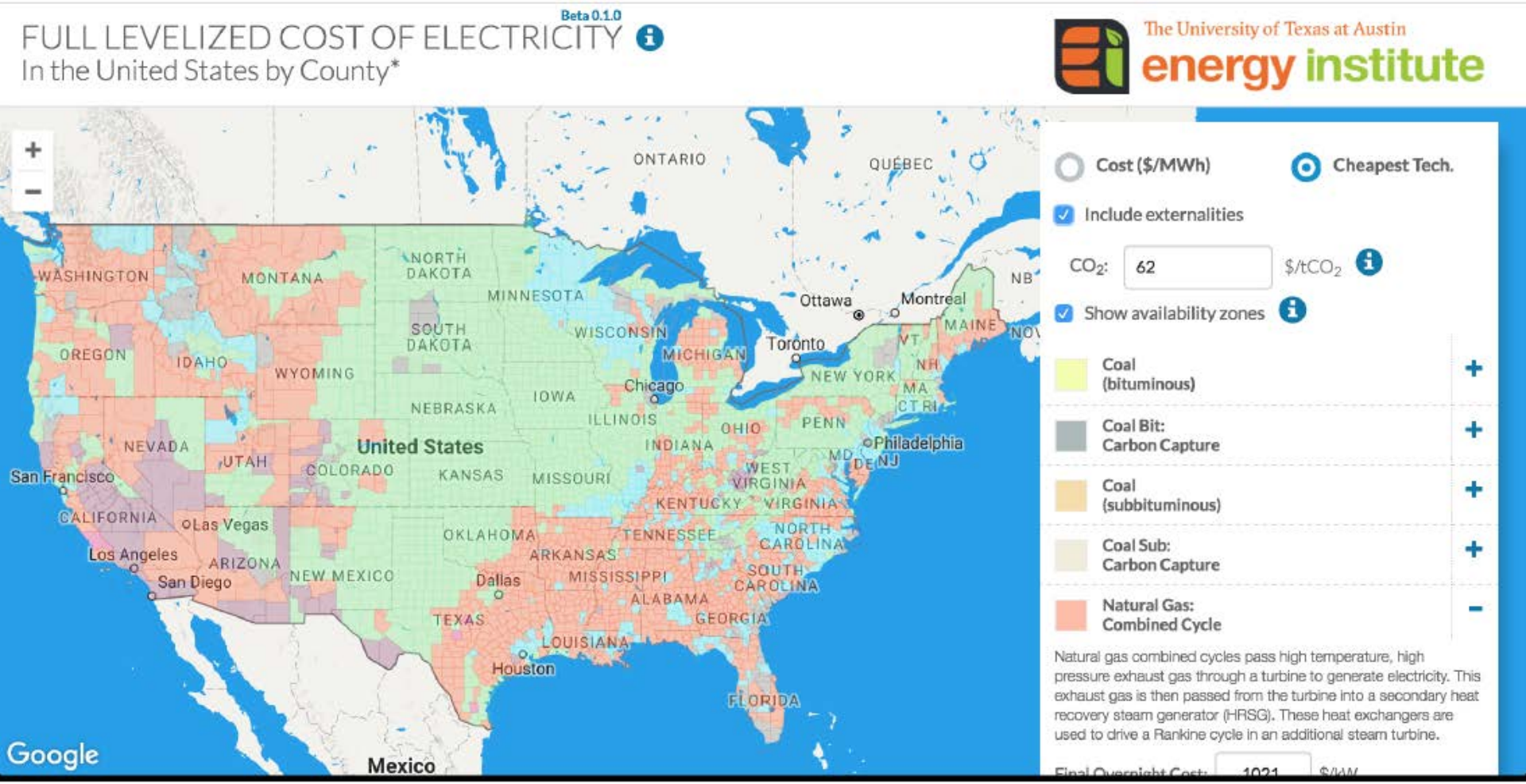
It all depends on where you are

- Input your own numbers!
  - http://calculators.energy.utexas.edu/lcoe_map/#/county/tech
- Want even more control (detail)?
  - http://calculators.energy.utexas.edu/lcoe_detailed/

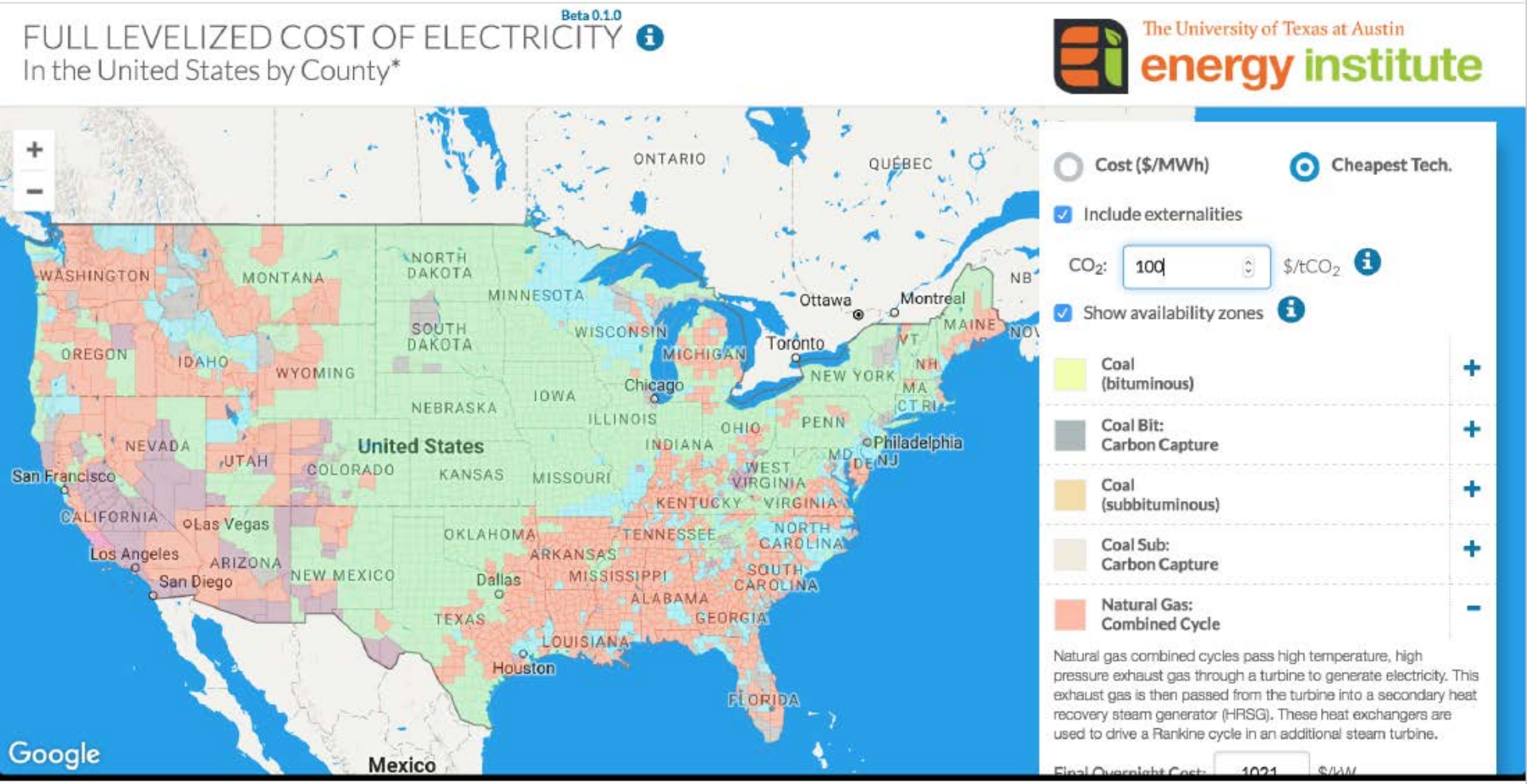
Reference case w/o externalities



Reference case with externalities



Reference case with $100/ton CO_2



Reference case with $1/W utility-scale solar

FULL LEVELIZED COST OF ELECTRICITY Beta 0.1.0
In the United States by County*

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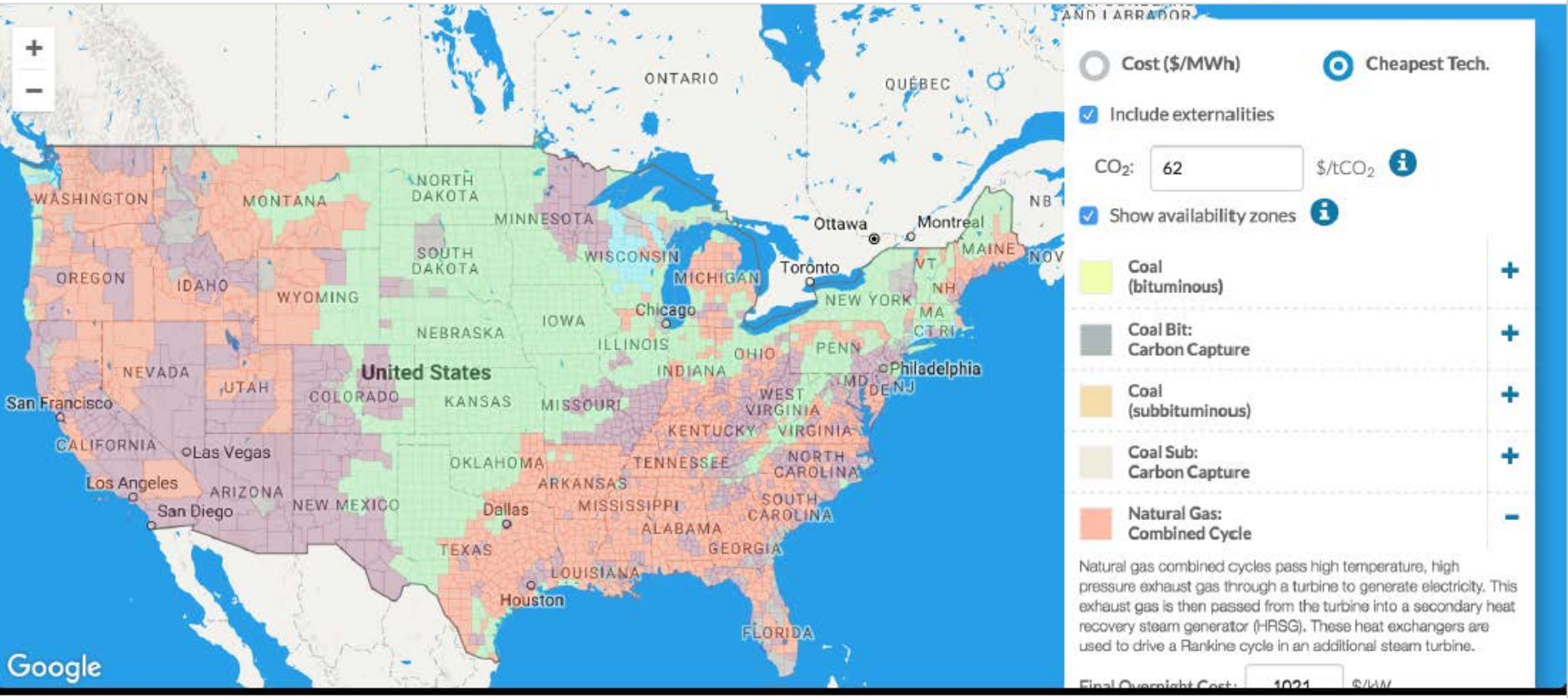

Reference case with $5/W nuclear (ref price: $8/W)

FULL LEVELIZED COST OF ELECTRICITY Beta 0.1.0
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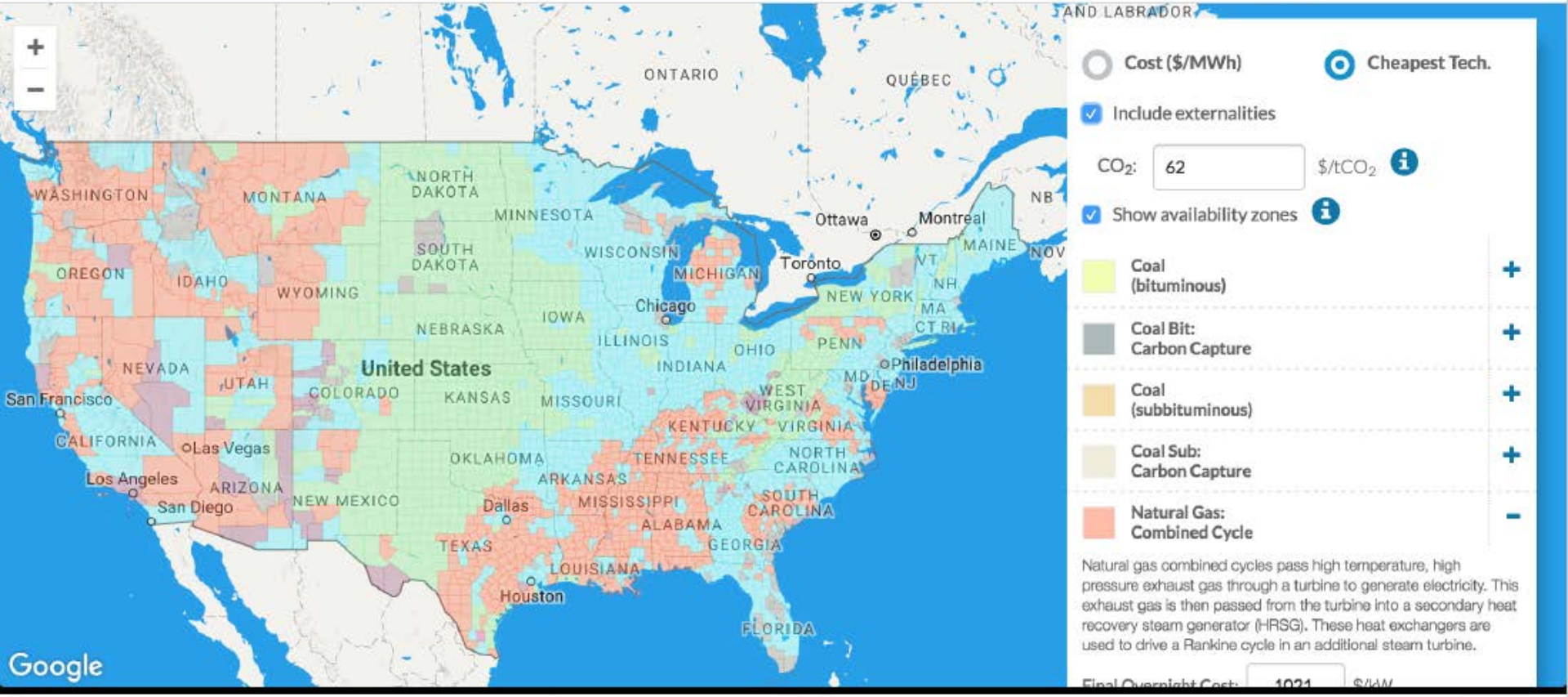

Thank You

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EXTRA

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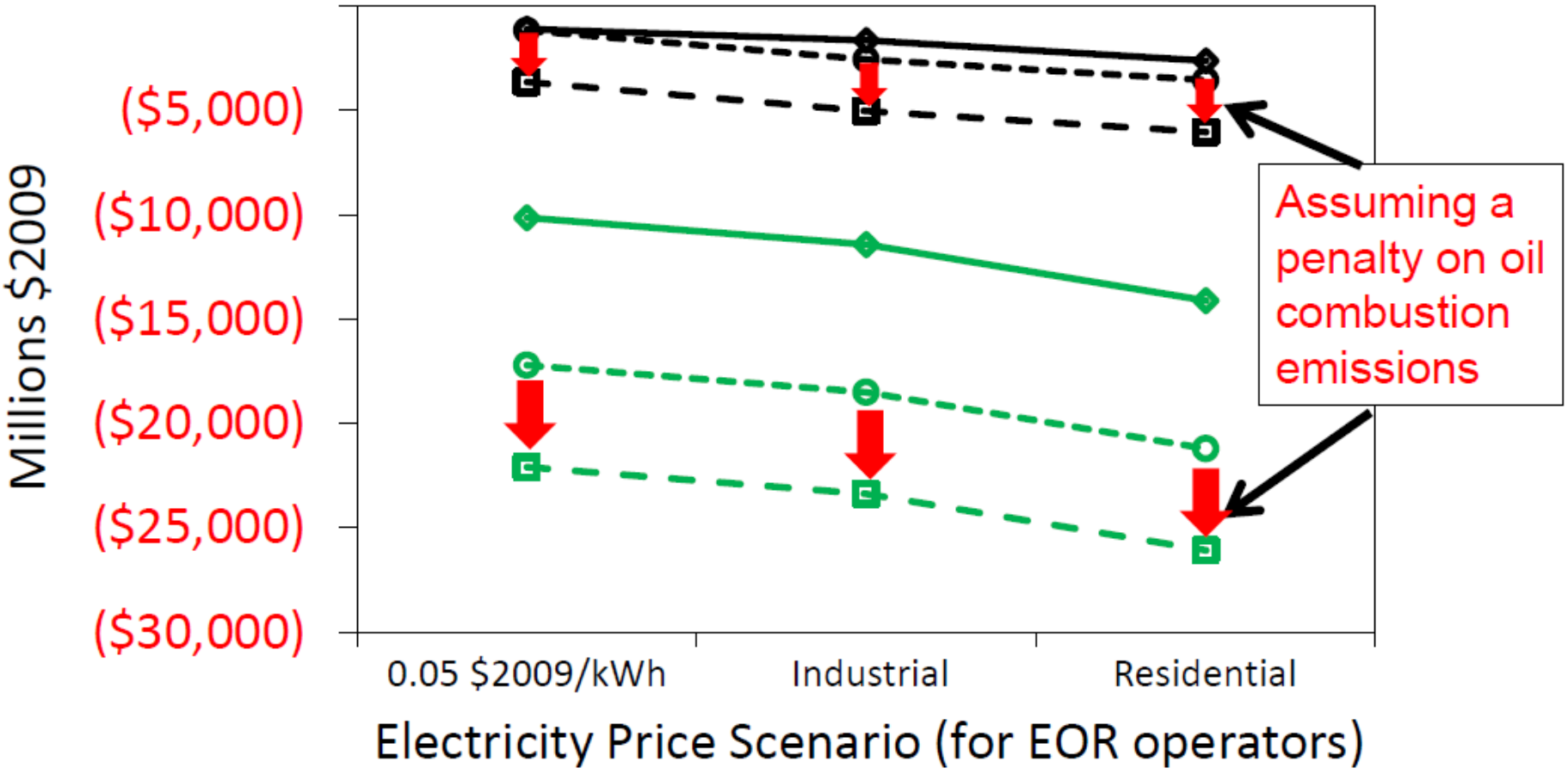
NPV of CCUS Network is always < 0; larger network more negative



We Thank our Diverse group of Sponsors

- Funding for the FCe- study came from a variety of industrial, governmental and non-profit organizations (including internal Energy Institute support)
- We thank
  - Austin Energy
  - City Public Service Energy
  - Chevron
  - ConocoPhillips
  - Cynthia and George Mitchell Foundation
  - Environmental Defense Fund, and
  - Sharyland Utilities

TD&A Costs are most accurately expressed by number of customers

Cost Category	Cost Per Customer (2015$/Customer-Year)	Cost Per Peak kW (2015$/kW-Year)	Cost Per kWh (2015¢/kWh)
Transmission	119 (R^2 = 0.459)	21 (R^2 = 0.399)	0.47 (R^2 = 0.373)
Distribution	291 (R^2 = 0.901)	52 (R^2 = 0.775)	1.1 (R^2 = 0.740)
Administration	333 (R^2 = 0.853)	61 (R^2 = 0.766)	1.3 (R^2 = 0.734)
Total	727 (R^2 = 0.886)	134 (R^2 = 0.781)	2.9 (R^2 = 0.747)

Transmission (high voltage and long-distance transport of electricity) costs are less than 20% of the total cost of TD&A. Both distribution and administration costs are each a significant portion (~ 40%) of total TD&A costs.

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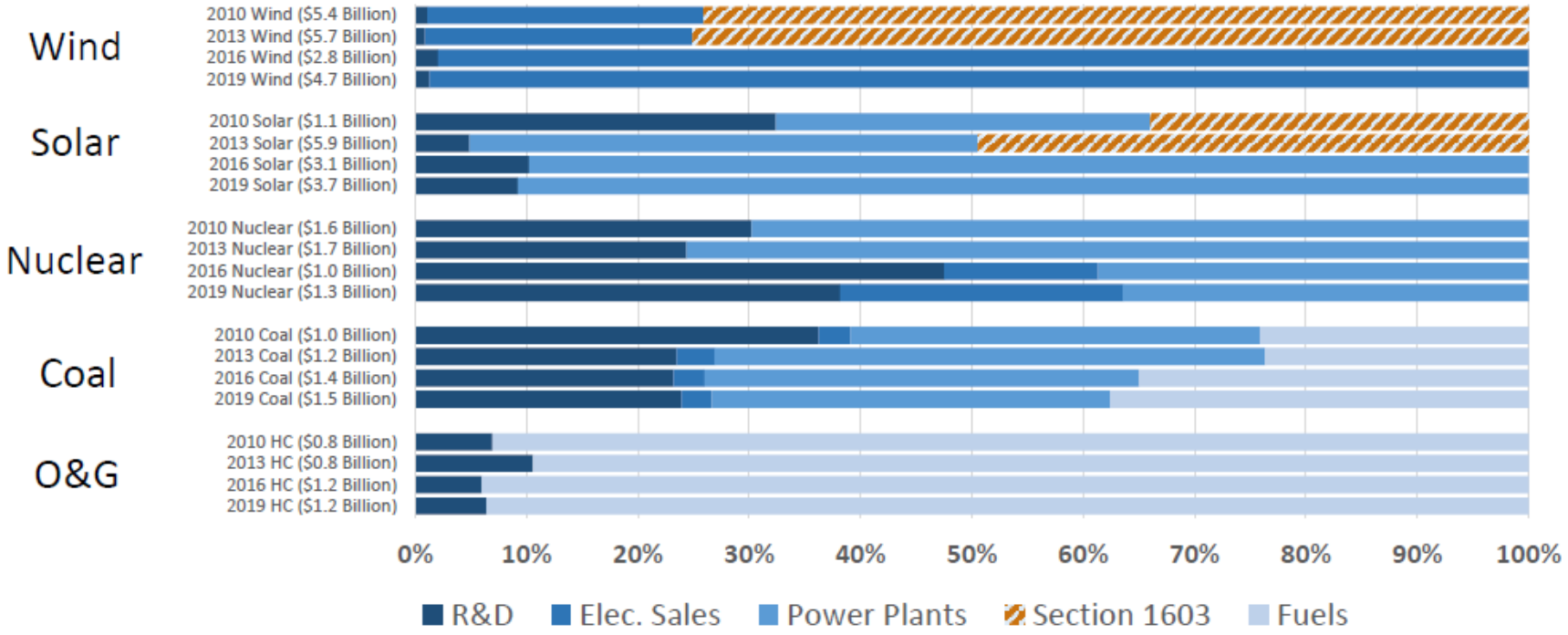
Federal Financial Support (subsidies) for Electricity

Motivation for Financial Support Report

- Consistent assessment of subsidies for electricity is a gap in literature.
- Where possible, this impact should be estimated per MWh and compared to levelized cost of electricity (LCOE).

- **Included:** direct expenditures, tax expenditures, guarantees
- **Excluded:** tech-neutral activity, credit subsidies, in-kind support (e.g., O&G royalties)

The Nature of Fossil and Renewable Supply Chains Dictates Type of Subsidy



Renewable generation is supported by direct subsidies while generation from fossil fuel power plants are supported via indirect subsidies.

- Renewable generation benefits from subsidies for R&D, elec. production, and cap. adds
- Fossil plants benefit from subsidies for fuel sales, fuel production, & pollution controls.
- Nuclear plants receive diversified support in the form of R&D funding, tax credits on electricity sales, and programs aimed at plant costs (decommissioning, insurance).

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