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THE ECONOMICS OF ELECTRIC POWER IN UNITED STATES

Dr. Erik Johnson

School of Economics

Georgia Institute of Technology

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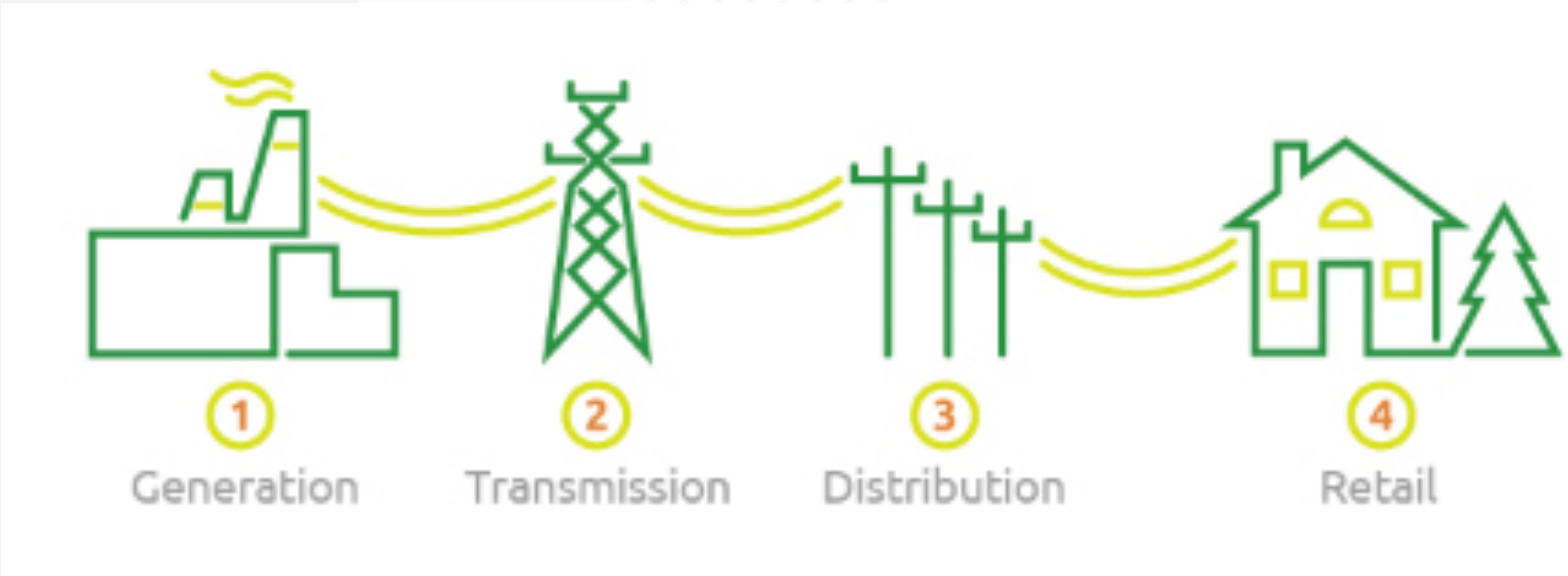
OUTLINE

1. Electricity Market Structures in the United States
2. The Southern Electricity Landscape
3. Renewables
4. Electricity and the Environment

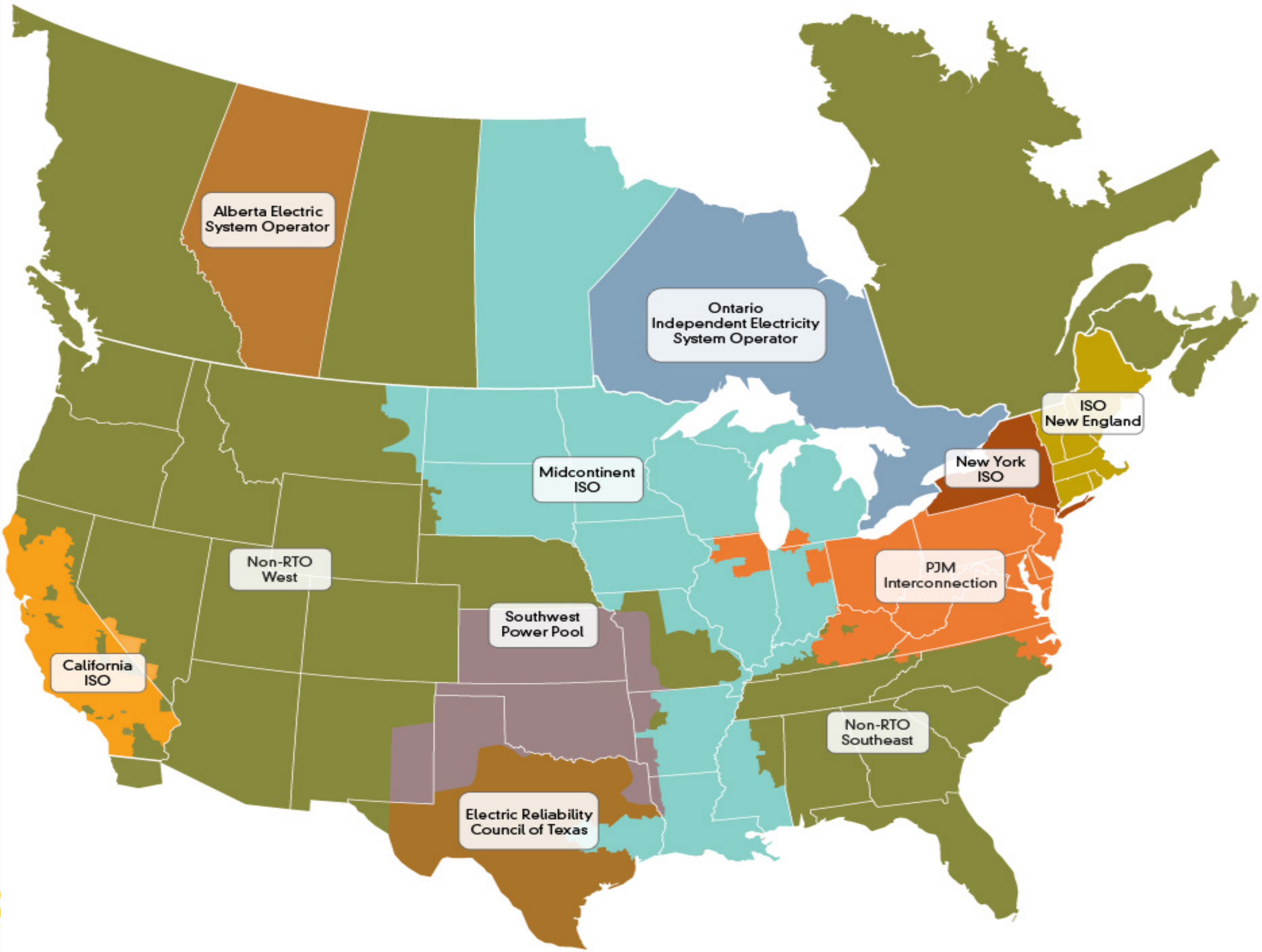
ELECTRICITY MARKET STRUCTURES



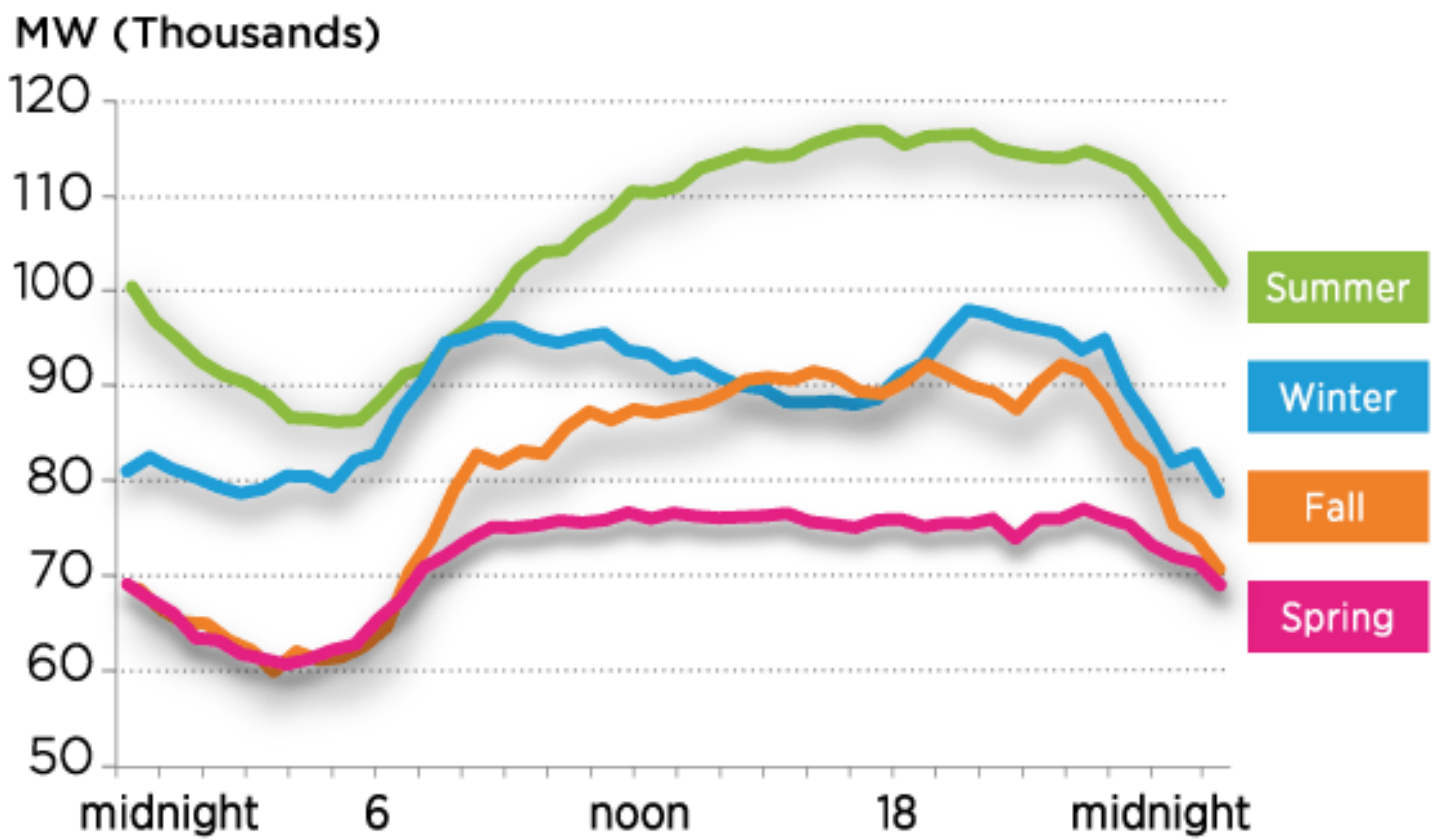
Competition? **Competition?**

- Public Utility Regulatory Policies Act (PURPA) – 1978
- Restructured wholesale and retail electricity

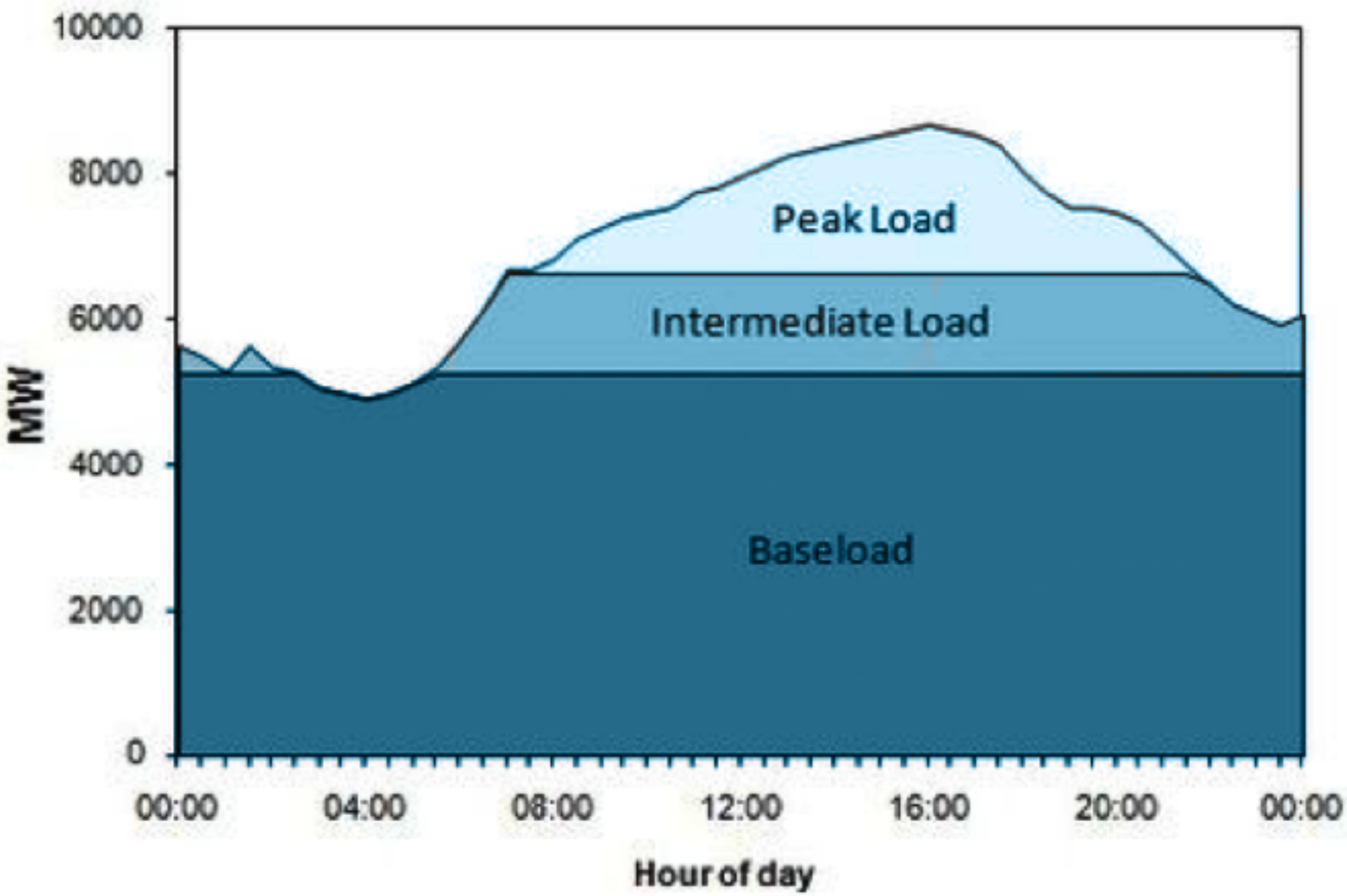
ELECTRICITY MARKET STRUCTURES



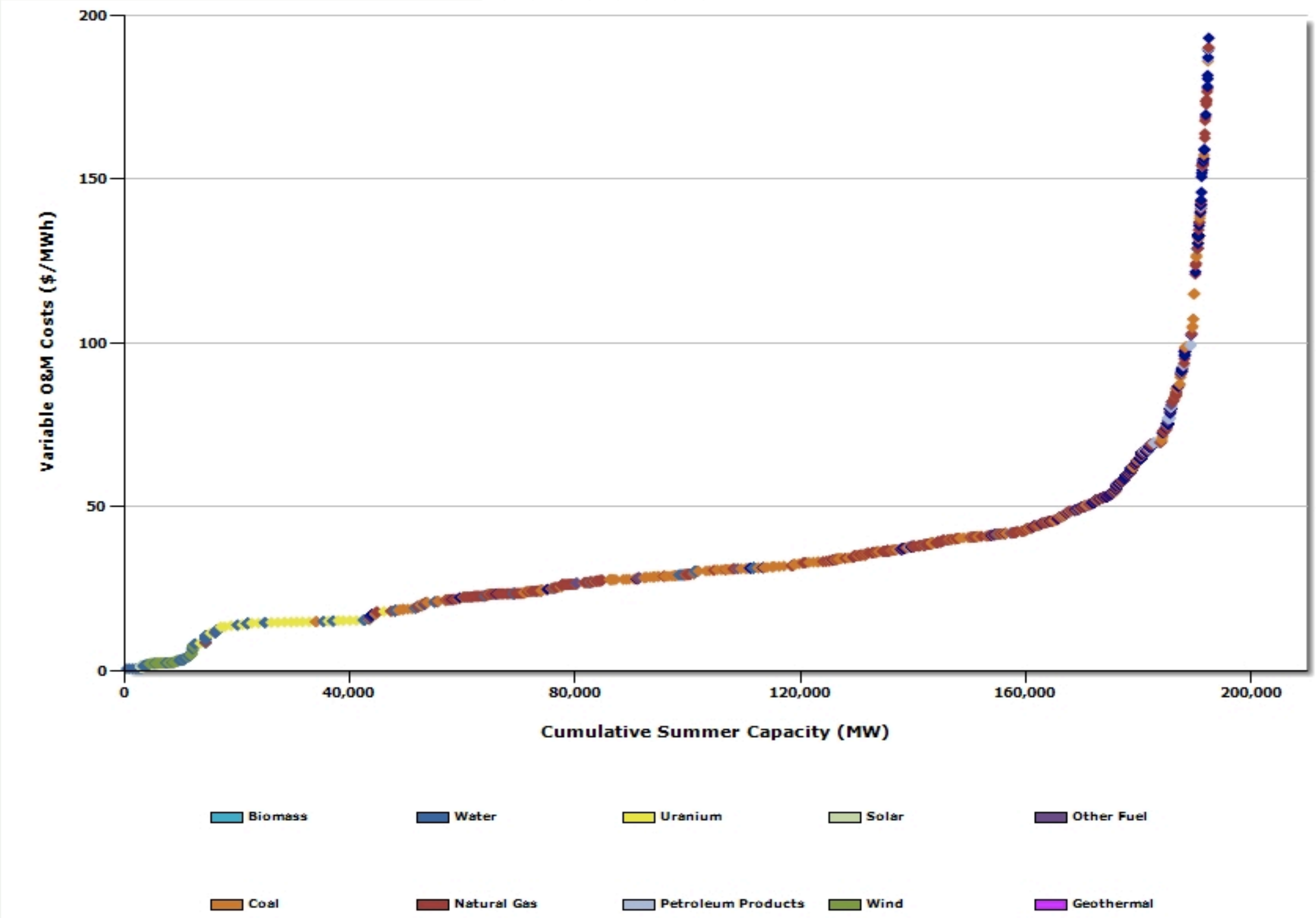
PJM SUPPLY CURVE



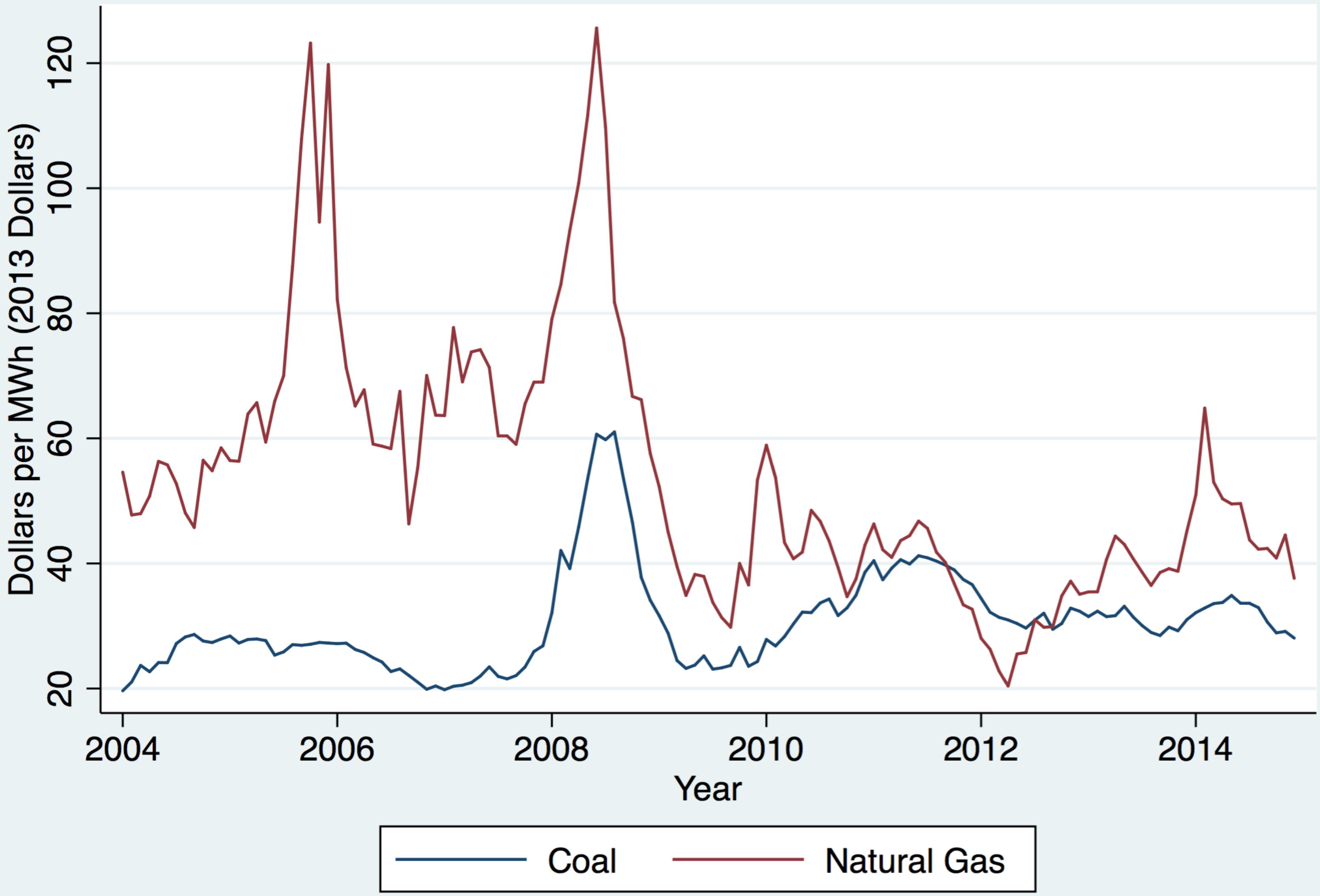
PJM SUPPLY CURVE



PJM SUPPLY CURVE

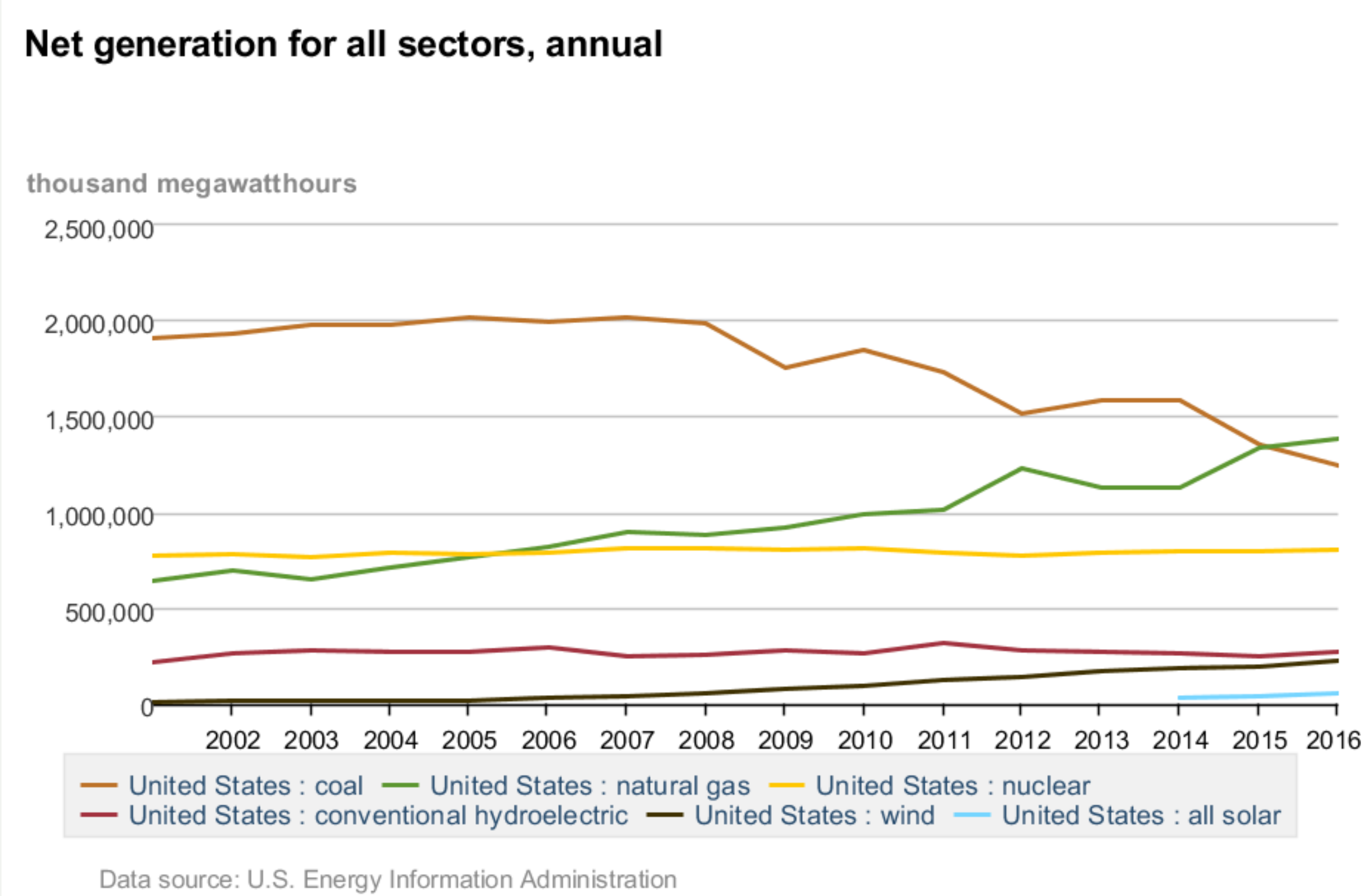


FRACKING HAS MADE GAS COMPETITIVE WITH COAL

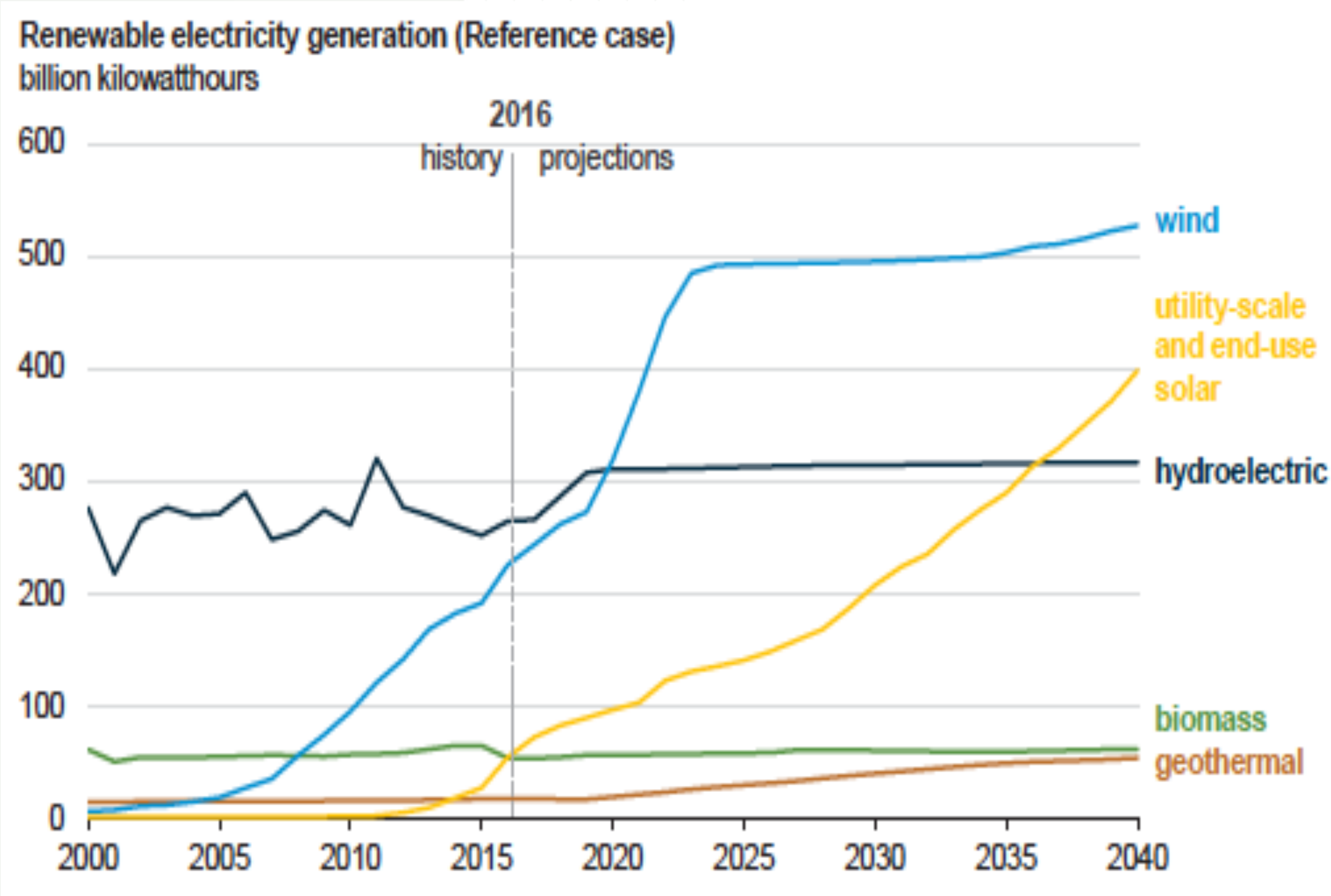


Source: Energy Information Administration

FRACKING HAS MADE GAS COMPETITIVE WITH COAL



RENEWABLE CAPACITY IS GROWING EVERYWHERE



LEVELIZED COST OF ELECTRICITY

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Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System LCOE	Levelized Tax Credit	Total LCOE including Tax Credit[1]
	U.S. Average LCOE (2015 $/MWh) for Plants Entering Service in 2022							
Dispatchable Technologies								
Advanced Coal with CCS[2]	85	97.2	9.2	31.9	1.2	139.5	N/A	139.5
Natural Gas-fired								
Conventional Combined Cycle	87	13.9	1.4	41.5	1.2	58.1	N/A	58.1
Advanced Combined Cycle	87	15.8	1.3	38.9	1.2	57.2	N/A	57.2
Advanced CC with CCS	87	29.2	4.3	50.1	1.2	84.8	N/A	84.8
Conventional Combustion Turbine	30	40.9	6.5	59.9	3.4	110.8	N/A	110.8
Advanced Combustion Turbine	30	25.8	2.5	63.0	3.4	94.7	N/A	94.7
Advanced Nuclear	90	78.0	12.4	11.3	1.1	102.8	N/A	102.8
Geothermal	91	30.9	12.6	0.0	1.4	45.0	-3.1	41.9
Biomass	83	44.9	14.9	35.0	1.2	96.1	N/A	96.1
Non-Dispatchable Technologies								
Wind	40	48.5	13.2	0.0	2.8	64.5	-7.6	56.9
Wind – Offshore	45	134.0	19.3	0.0	4.8	158.1	-11.4	146.7
Solar PV[3]	25	70.7	9.9	0.0	4.1	84.7	-18.4	66.3
Solar Thermal	20	186.6	43.3	0.0	6.0	235.9	-56.0	179.9
Hydroelectric[4]	58	57.5	3.6	4.9	1.9	67.8	N/A	67.8

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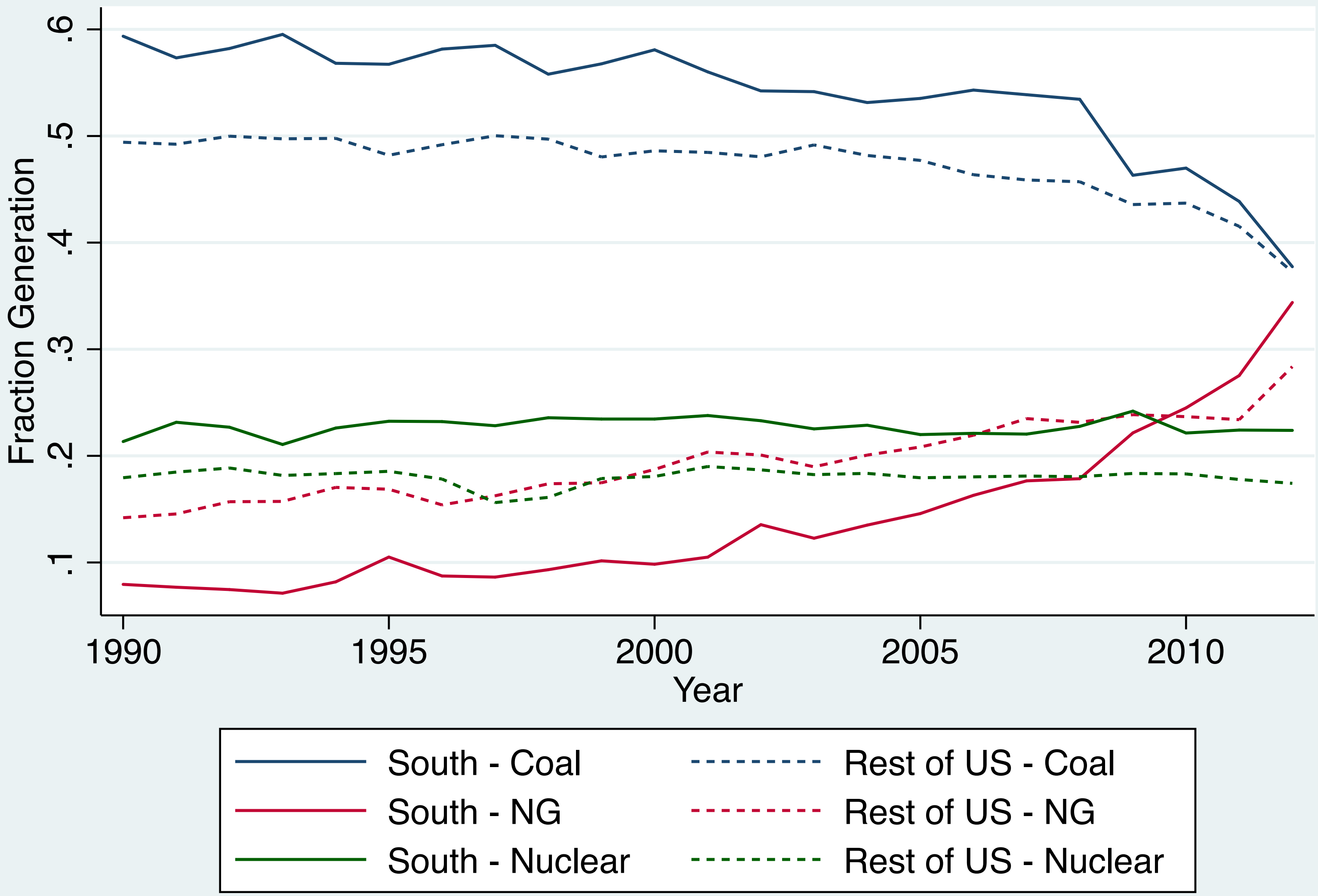
Vertically Integrated Electricity Providers

- Investments in new capacity approved by Public Service Commission

- Utility creates an Integrated Resource Plan
  - Forecasts future demand, retirements, investments
  - Plans how to make investments

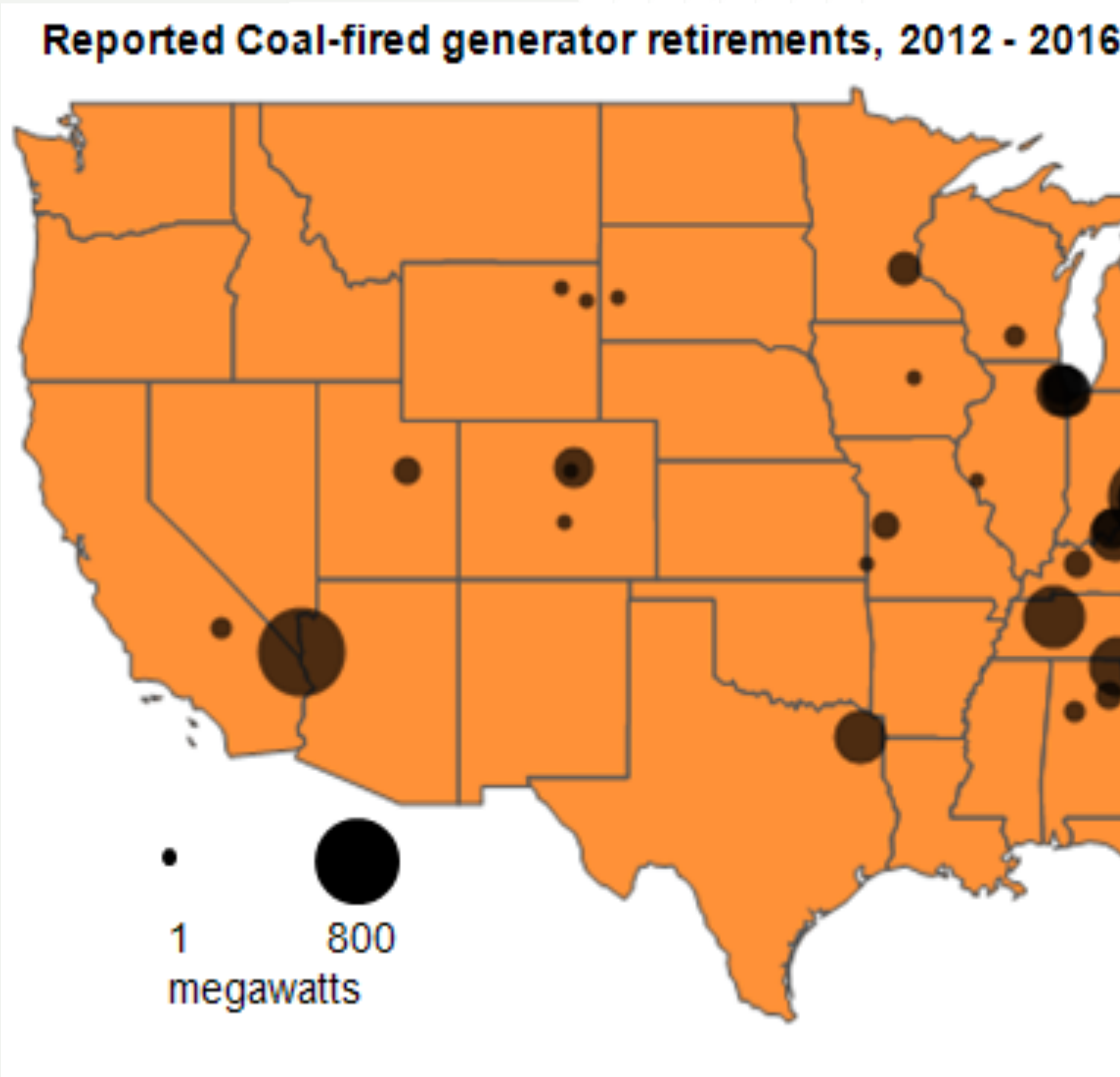
- Usually has a guaranteed rate of return on capital
  - Complete pass through of fuel costs

ELECTRICITY TRENDS HAVE BEEN AMPLIFIED IN THE SOUTH



Source: EIA Forms 906, 920, 923

MANY COAL POWER PLANTS HAVE BEEN RETIRED IN THE SOUTH



RIPE FOR RETIREMENT

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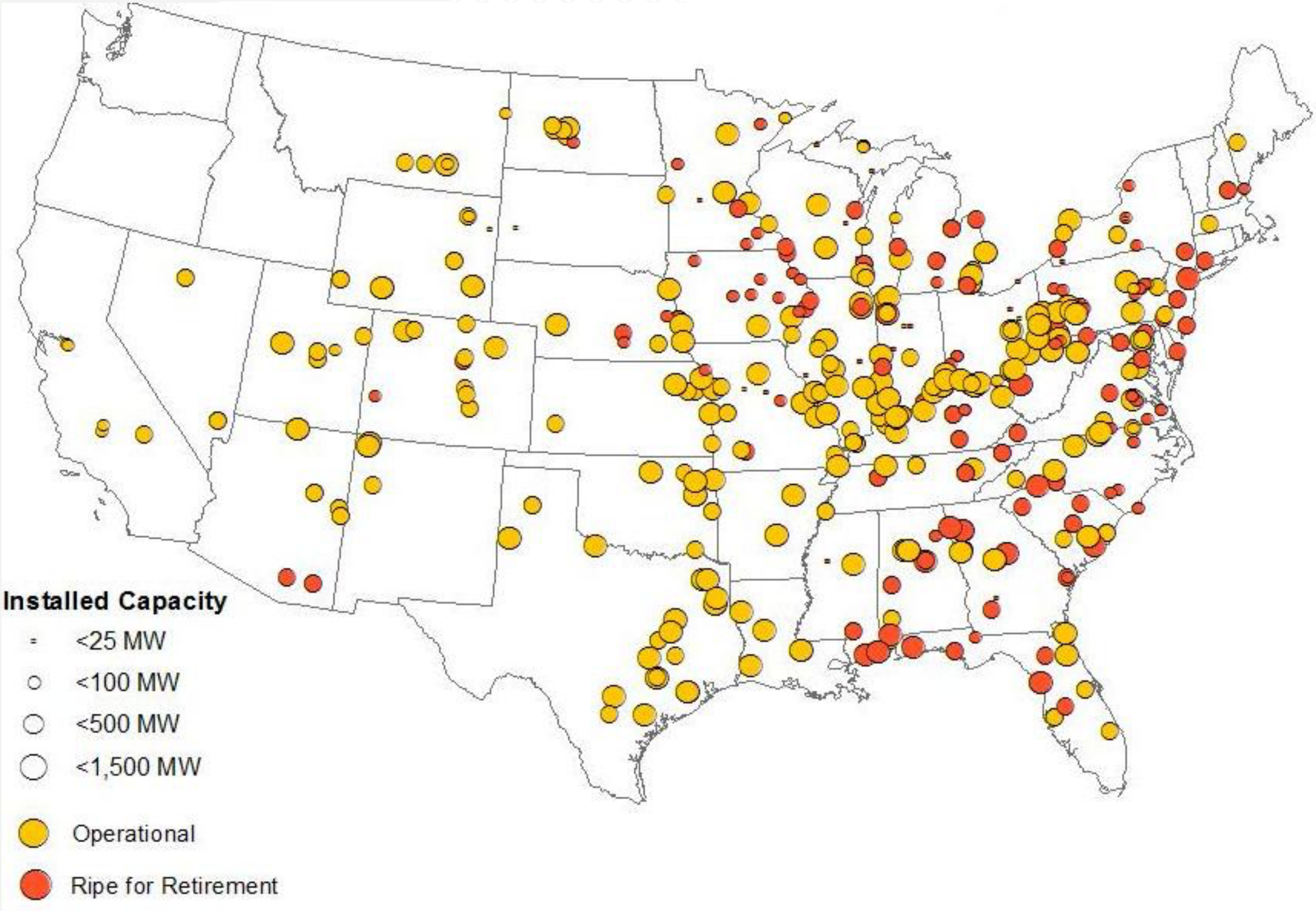

NUCLEAR!?!?

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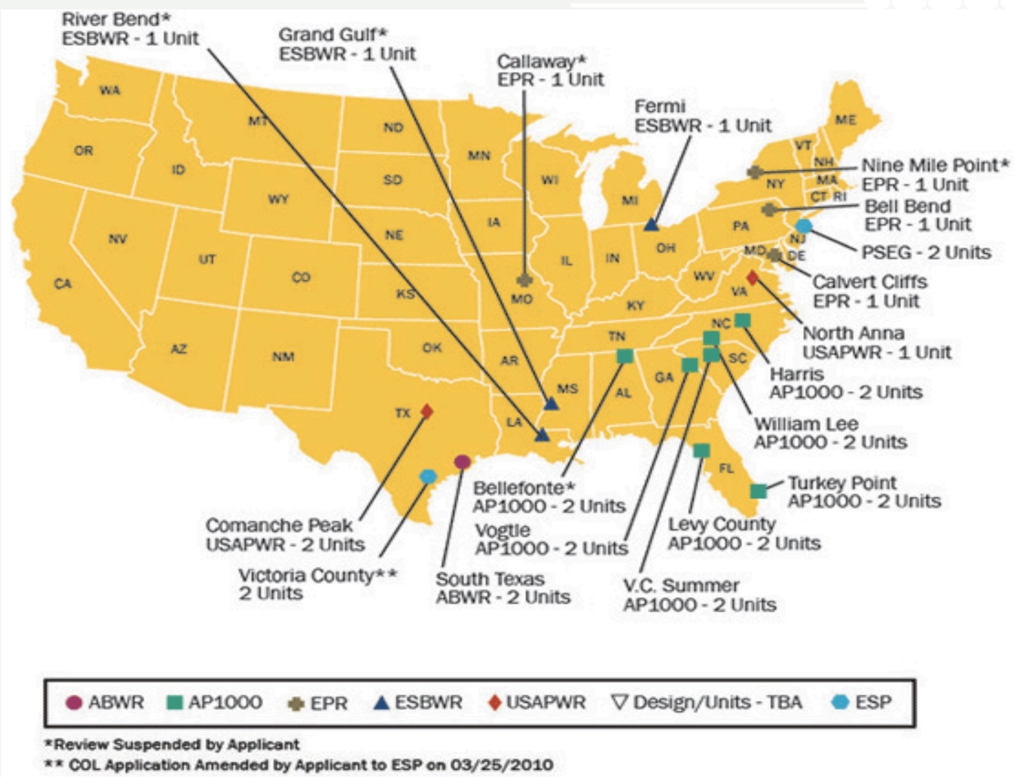
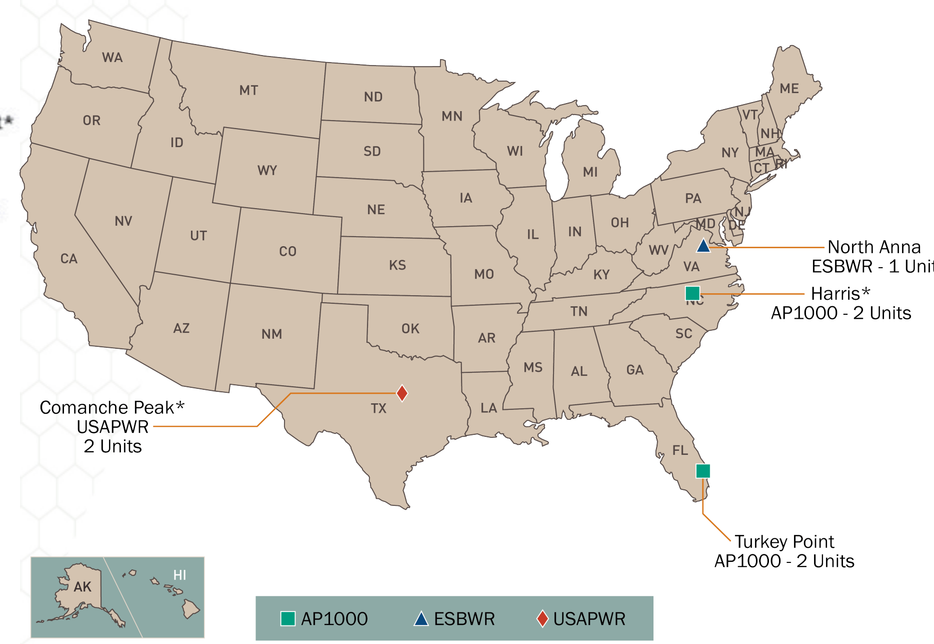
2010



2017

New Reactor Applications Under Review—Large LWRs+



*Review Suspended by Applicant

+Large LWRs—Large Light-Water Reactors, generally on the order of 1000 MW(e) or more

December 2016

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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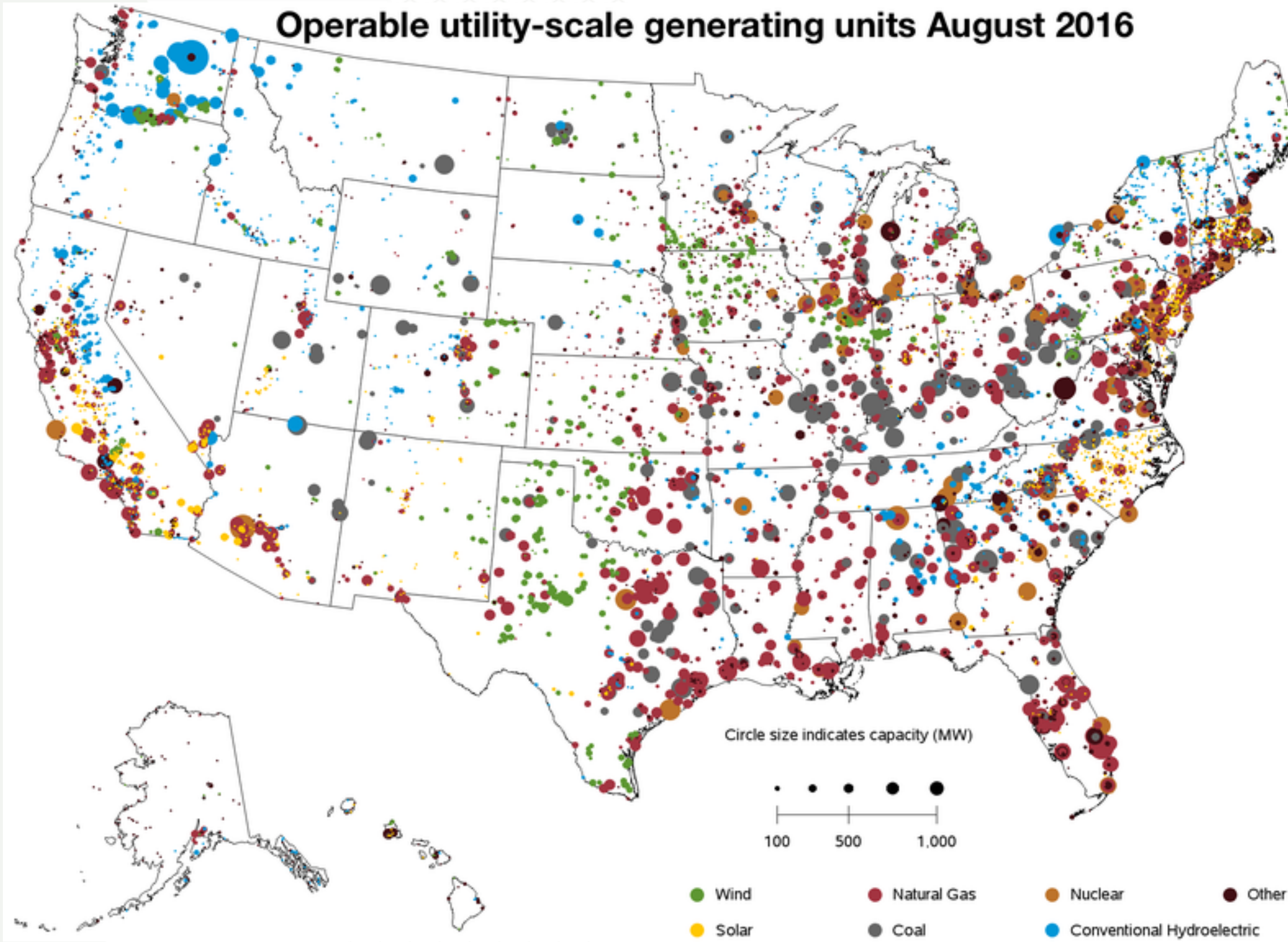
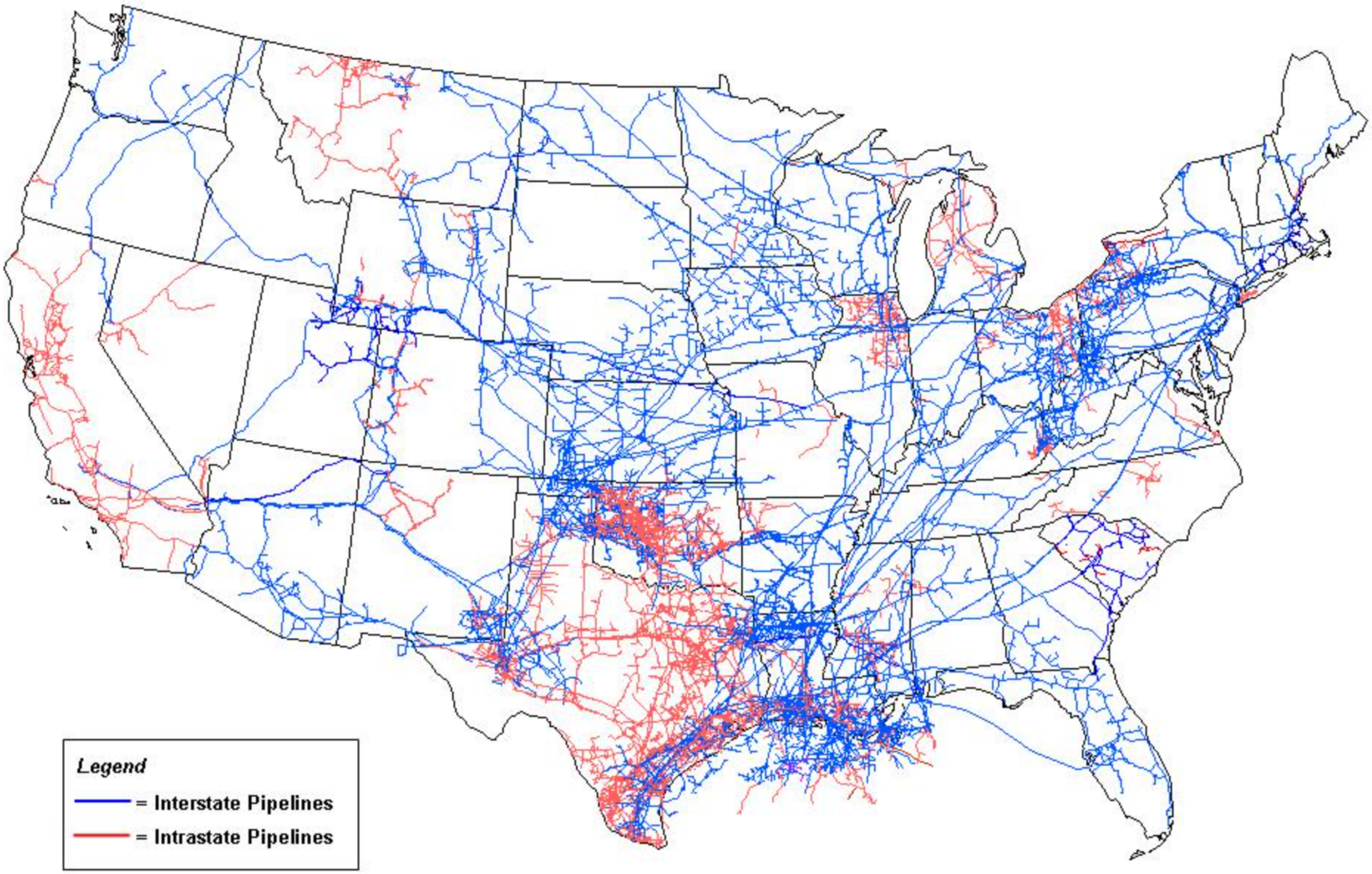
NATURAL GAS CAPACITY

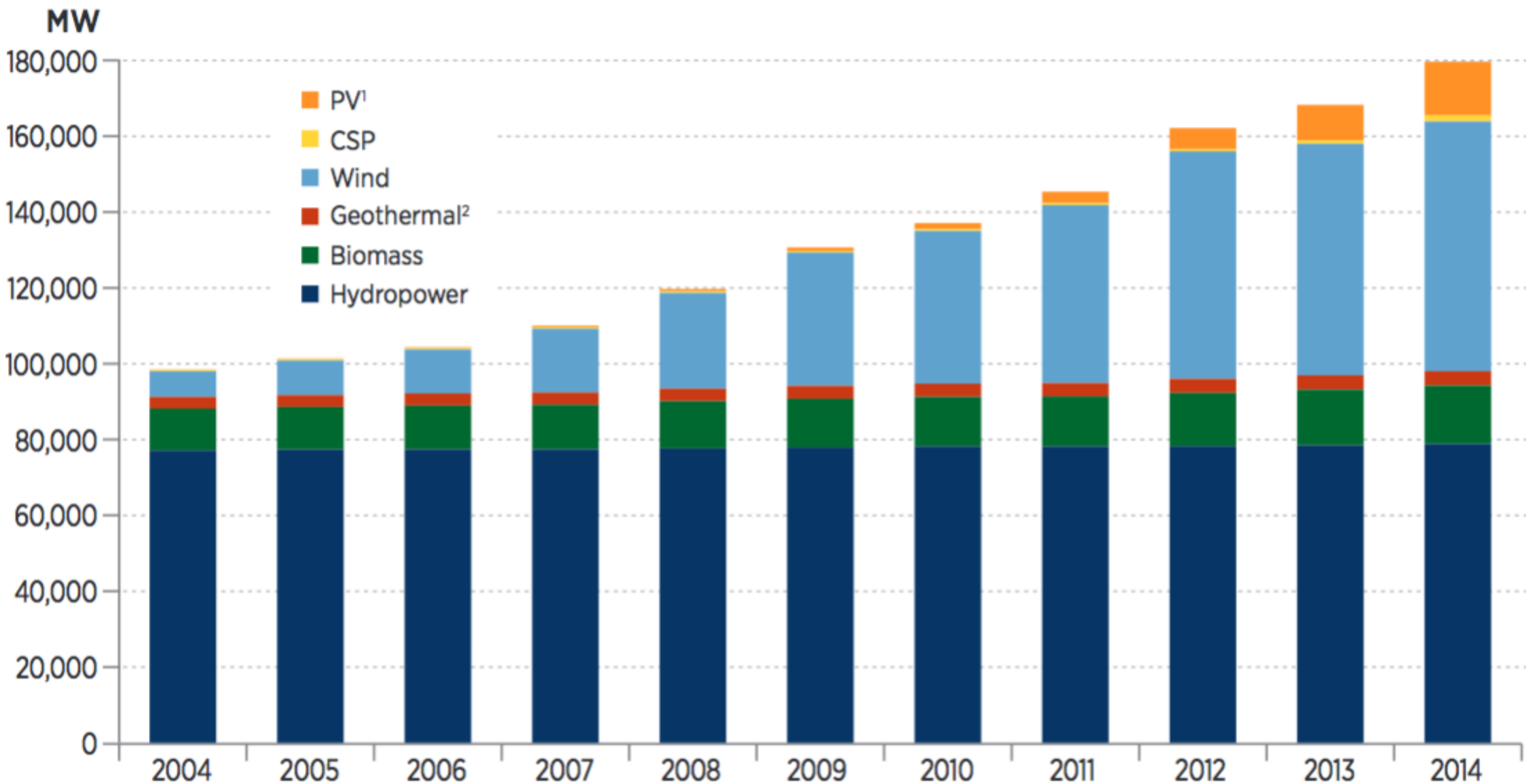


NATURAL GAS PIPELINES



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

RENEWALBES



MW
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
PV1
CSP
Wind
Geothermal2
Biomass
Hydropower
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

RENEWABLE PORTFOLIO STANDARDS

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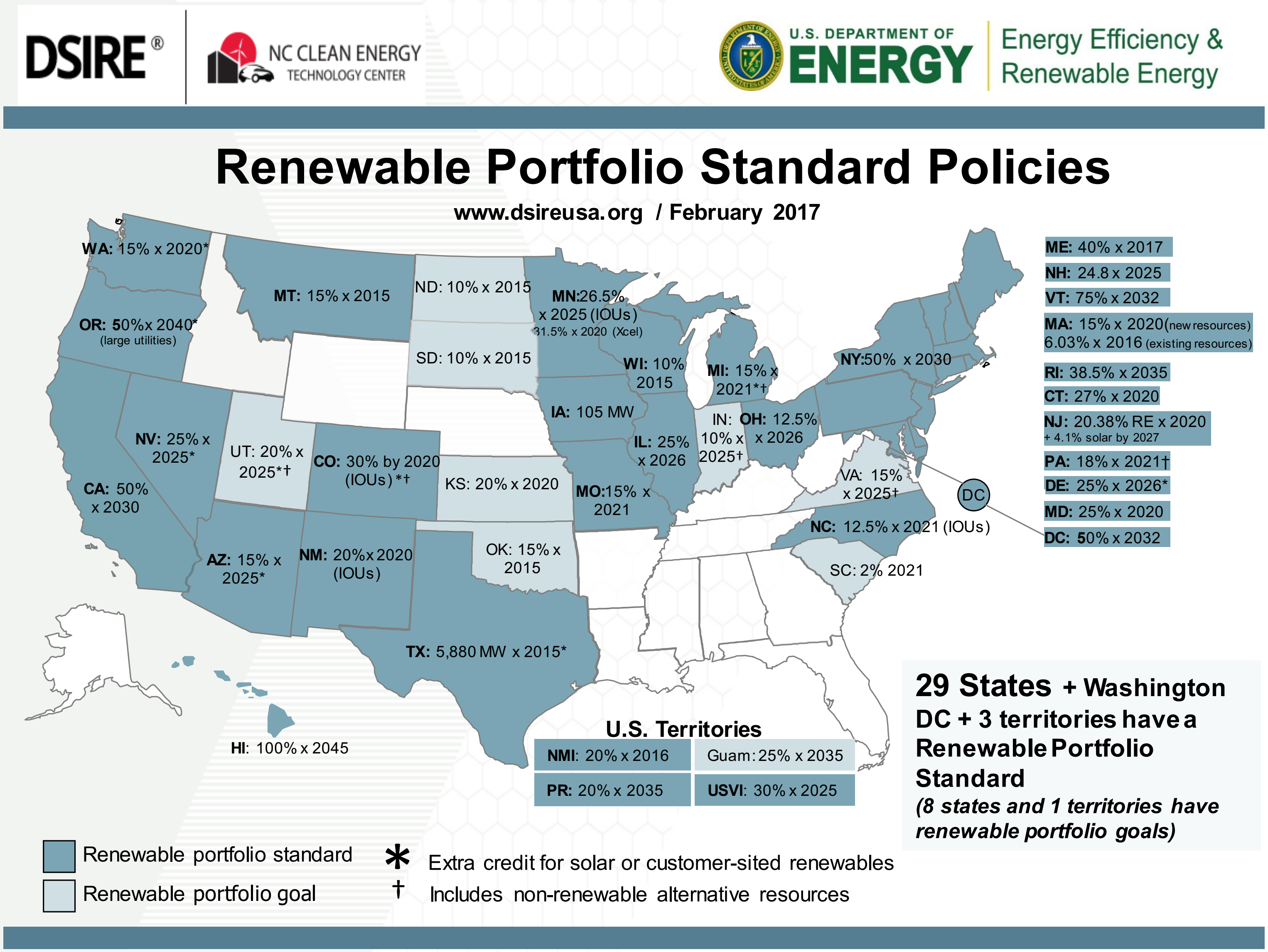

INEFFICIENT INVESTMENT AND ABATEMENT FROM RPS (1)

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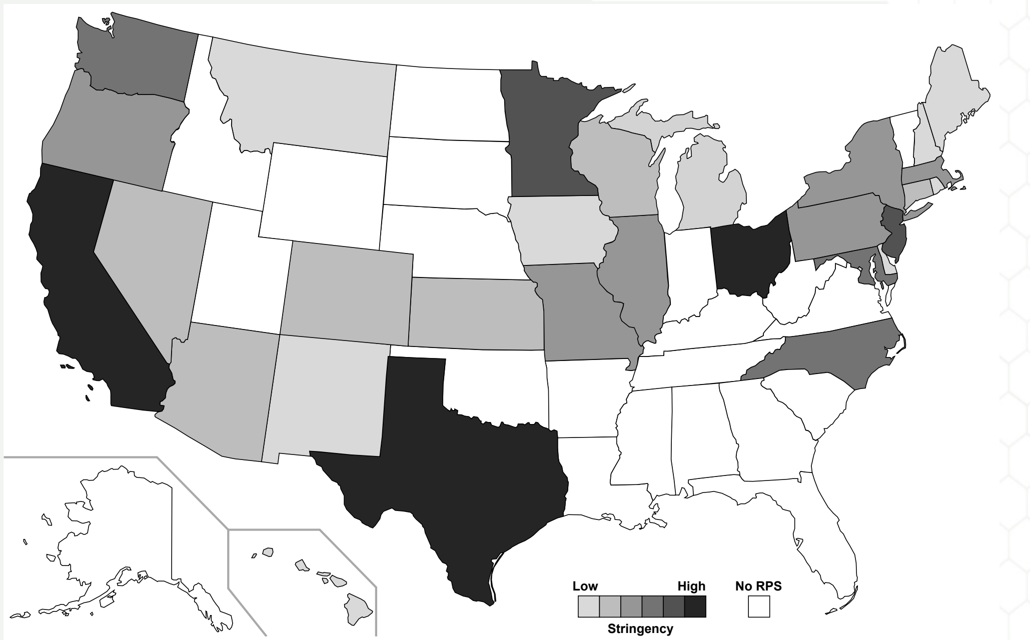
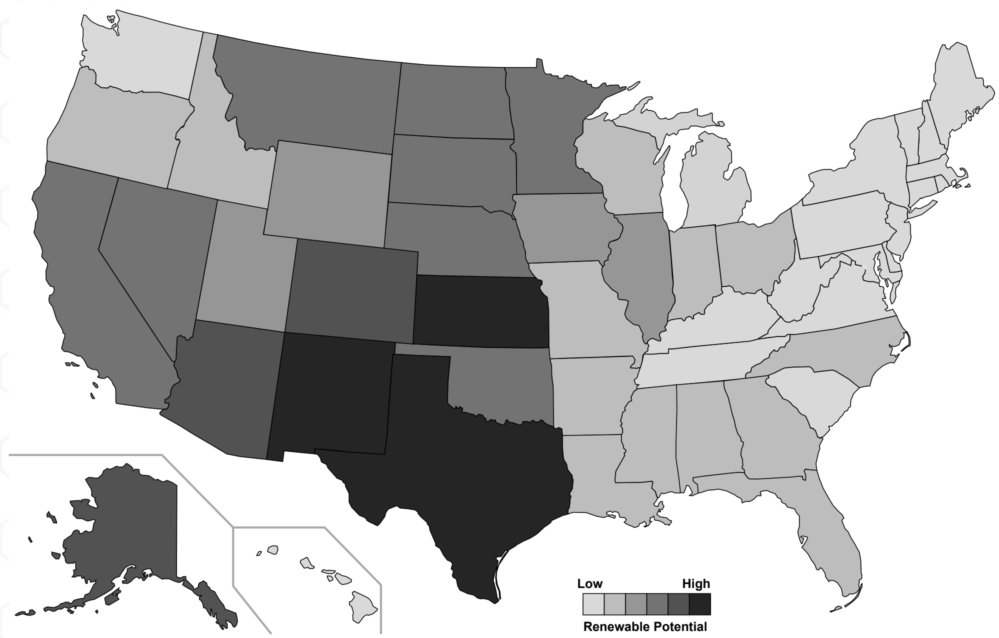
RPS Requirements in US

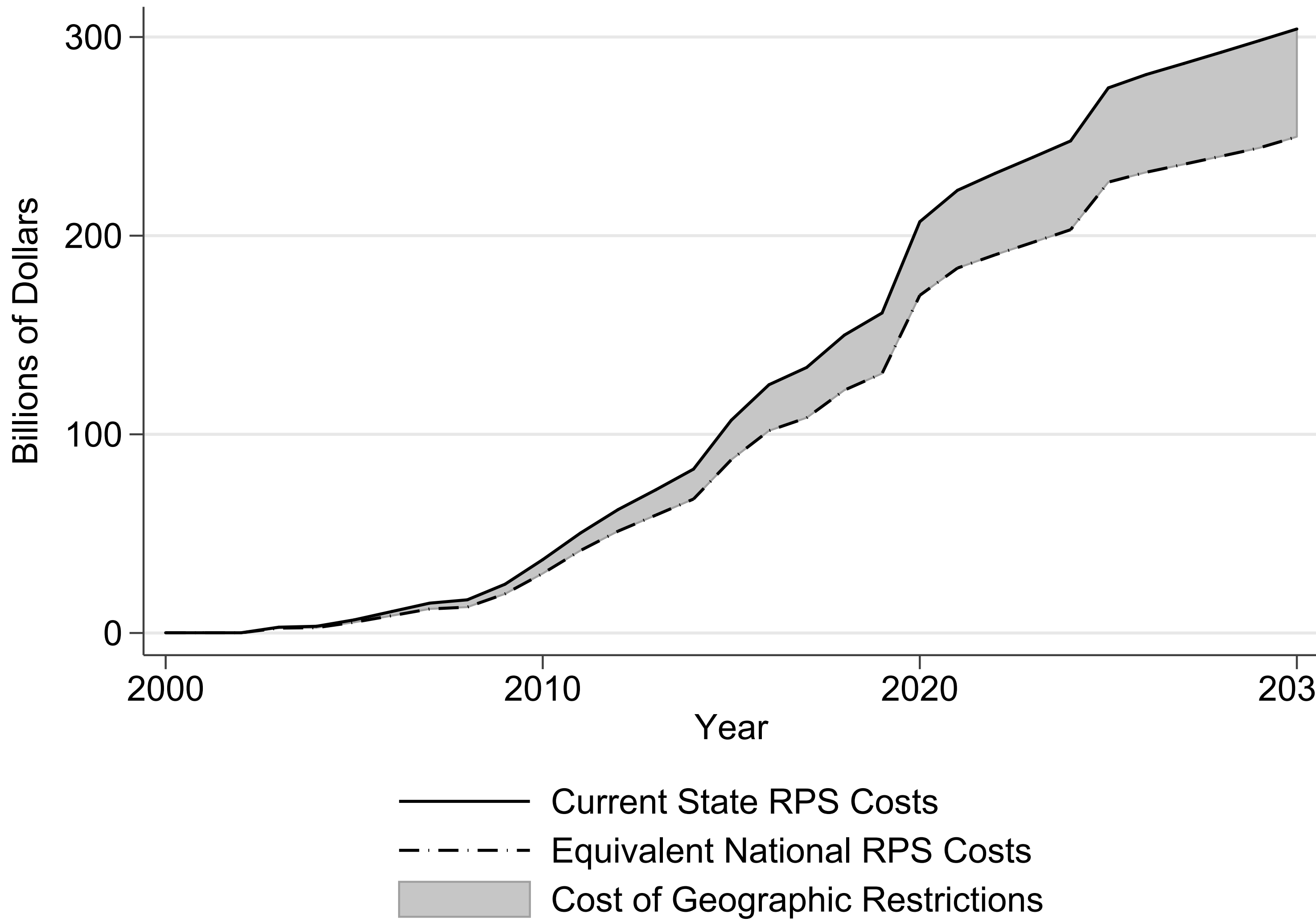


Renewable Potential in US



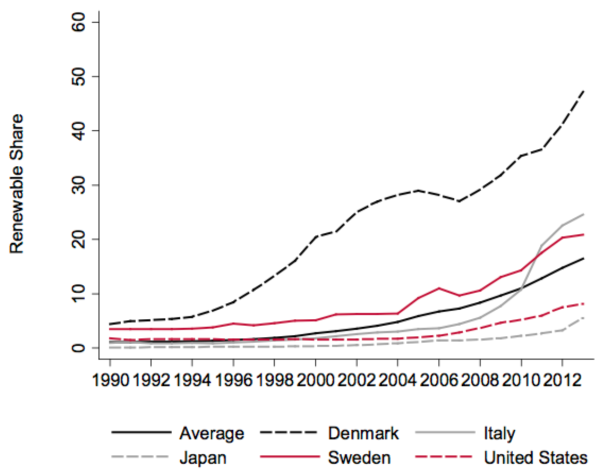
Source: Johnson, E. P. (2014). Measuring the Productive Inefficiency in Renewable Electricity Generation. *Mimeo*, 1–30.

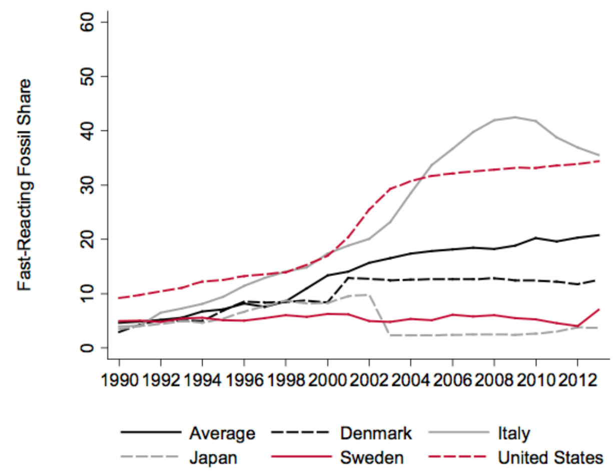
INEFFICIENT INVESTMENT AND ABATEMENT FROM RPS (2)

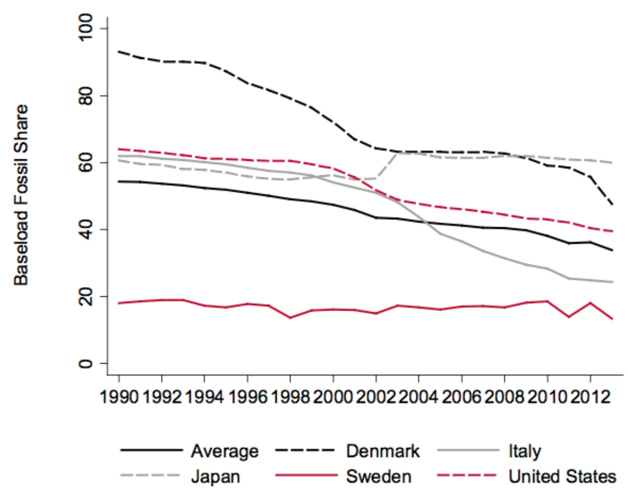


Source: Johnson, E. P. (2014). Measuring the Productive Inefficiency in Renewable Electricity Generation. *Mimeo*, 1–30.

RENEWABLES ARE COMPLEMENTS TO FOSSIL GENERATION







Source: Verdolini, E., Vona, F., & Popp, D. (2016). Bridging the Gap: Do Fast Reacting Fossil Technologies Facilitate Renewable Energy Diffusion. *NBER Working Paper 22454*.

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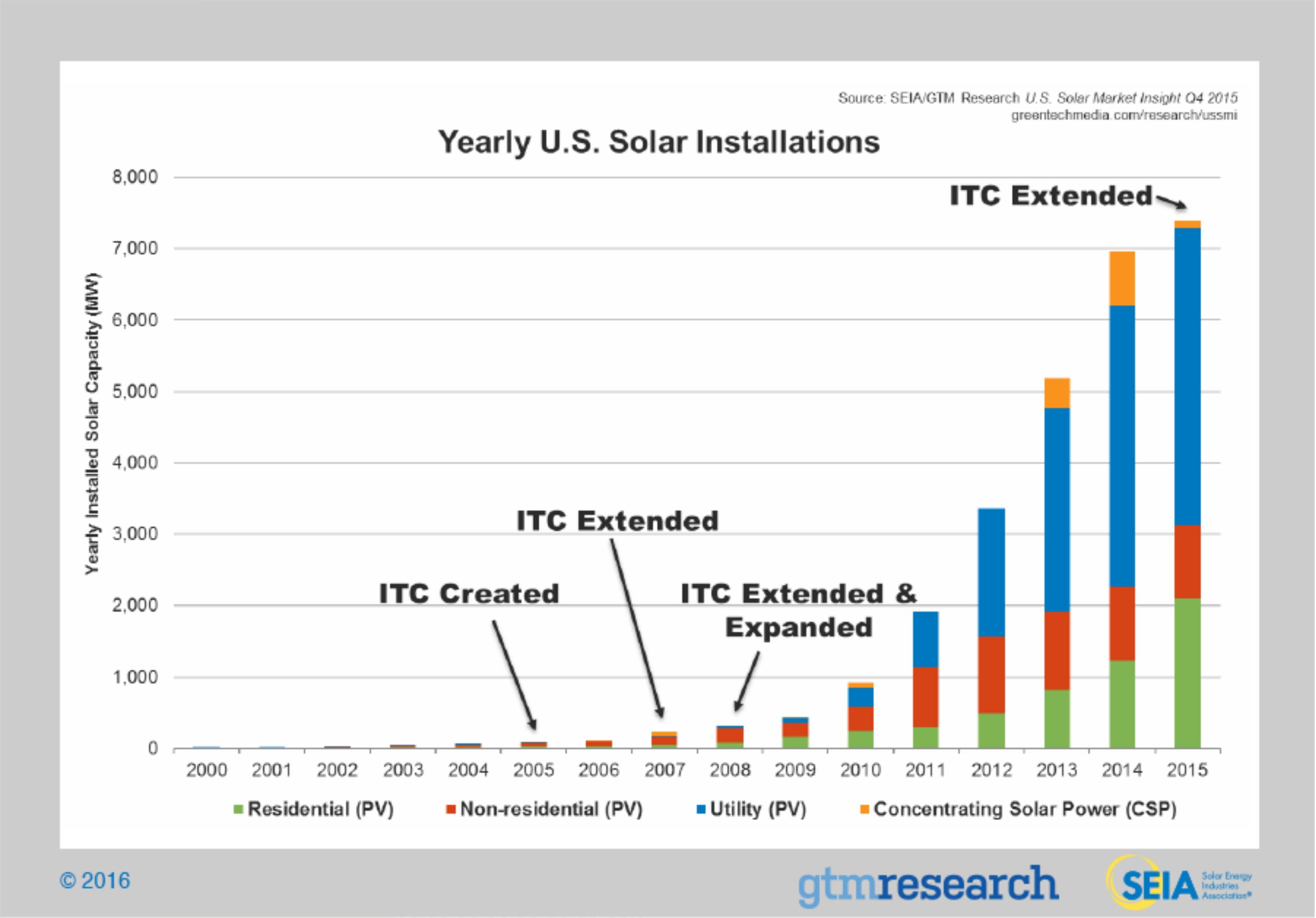
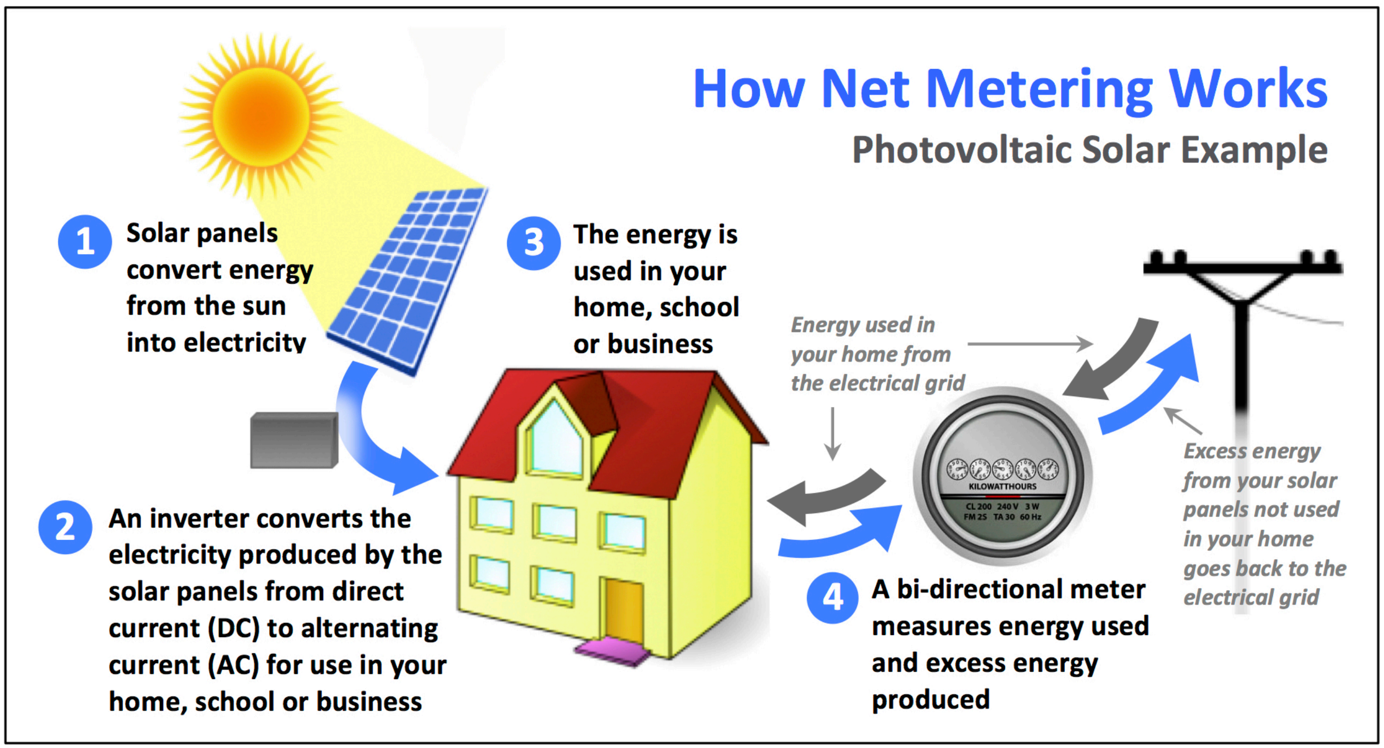
SOLAR CAPACITY IN US



NET METERING IN THE US

- 44 states had **net-metering** policies in 2015
- 22 states had **renewable portfolio standards** with solar or distributed generation carve-outs

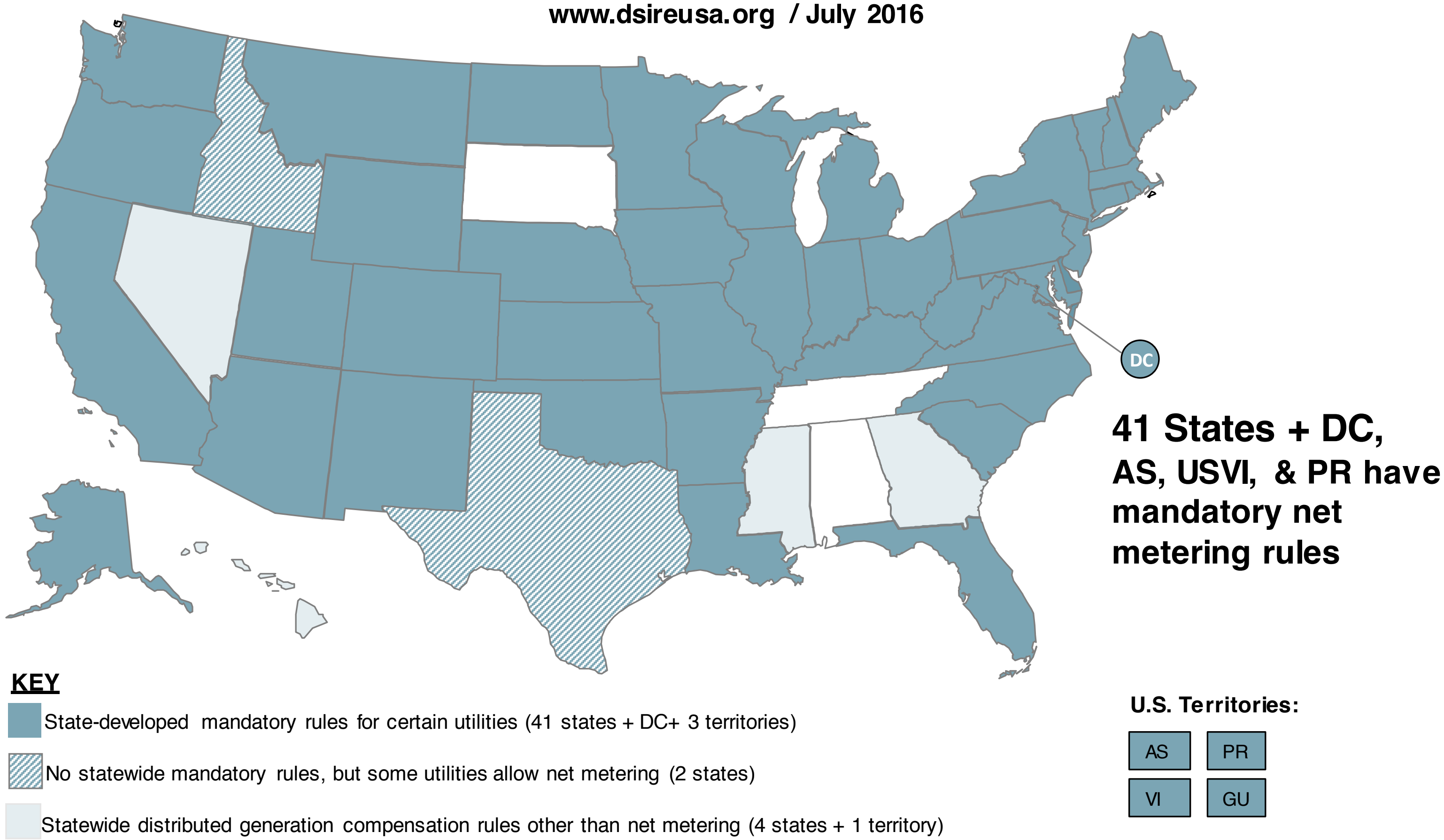


NET METERING

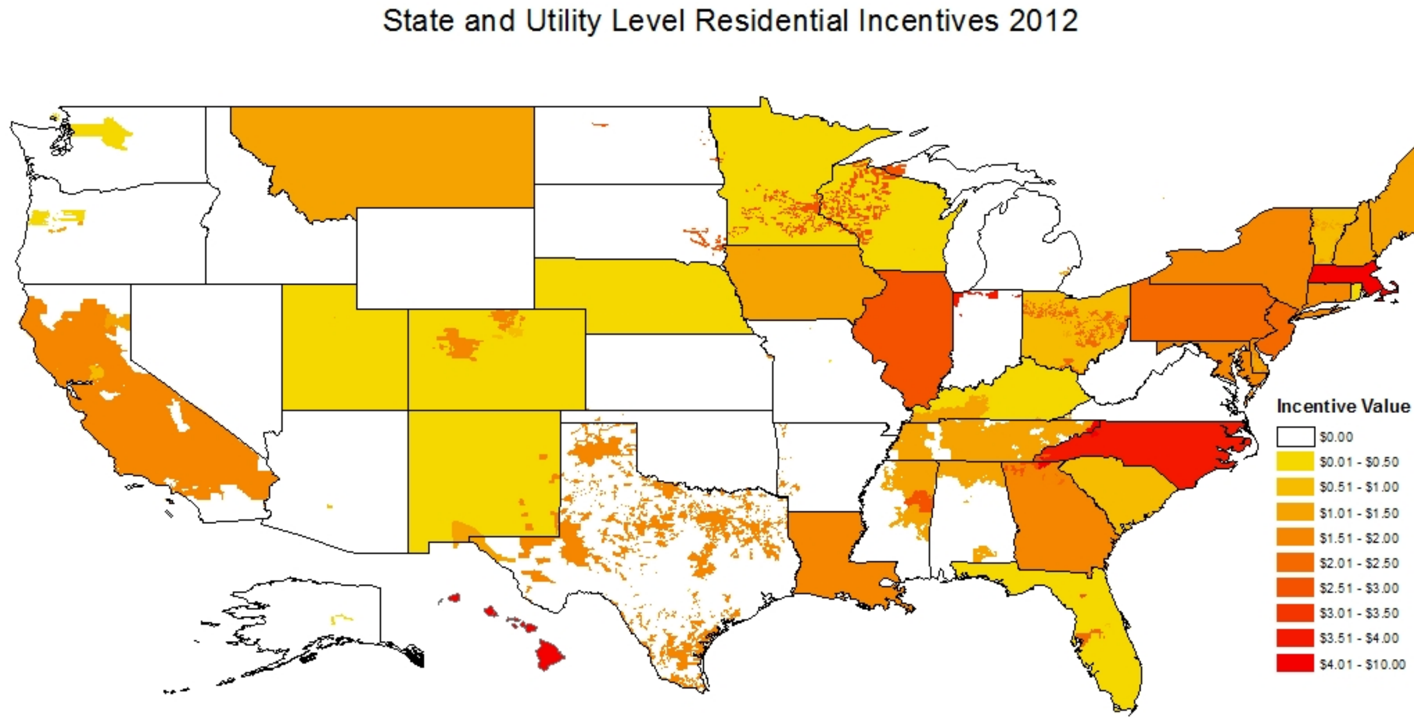
DSIRE® | NC CLEAN ENERGY TECHNOLOGY CENTER | U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Net Metering

www.dsireusa.org / July 2016



SOLAR SUBSIDIES BY STATE



Source: Johnson, E. & Matisoff, D. (2016). Everybody Loves Cash! The comparative effectiveness of solar incentives.

SOLAR CAPACITY ADDITIONS BY STATE

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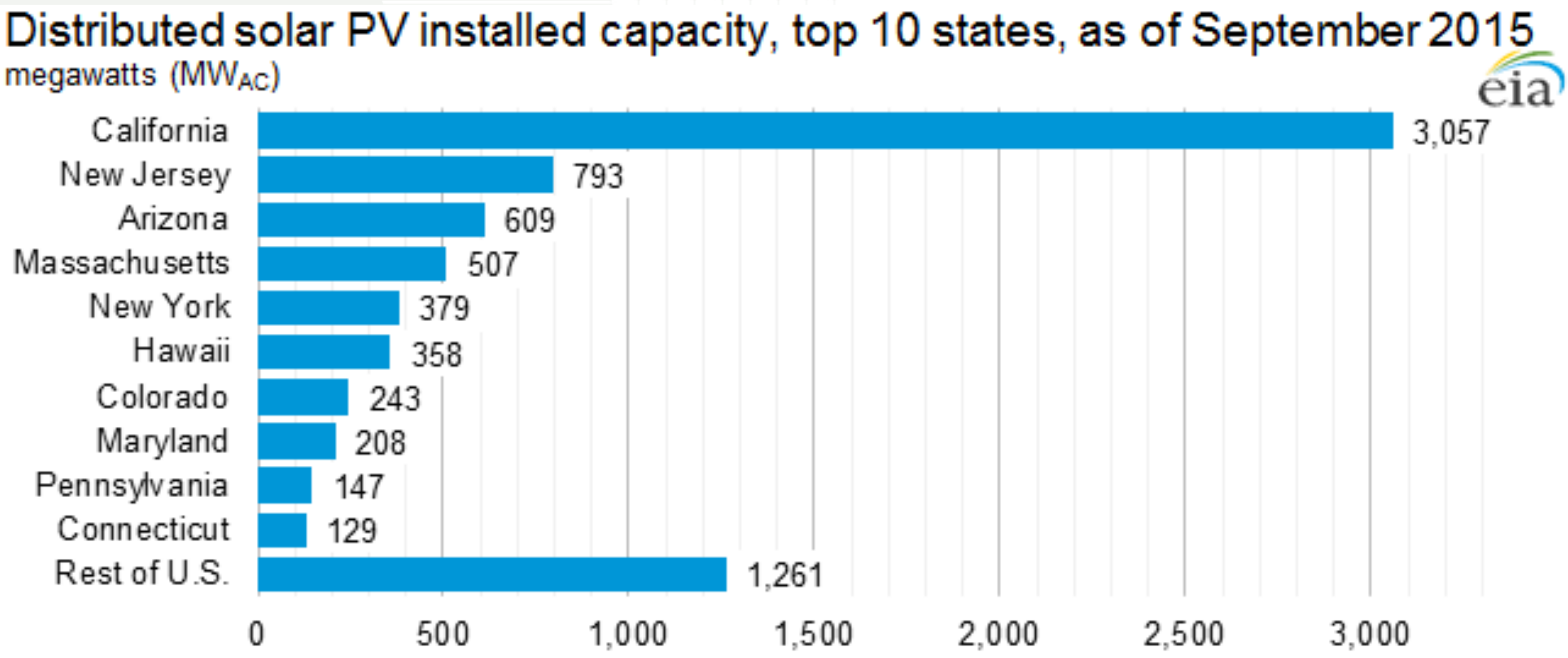

Source: U.S. Energy Information Administration, *Electric Power Monthly*

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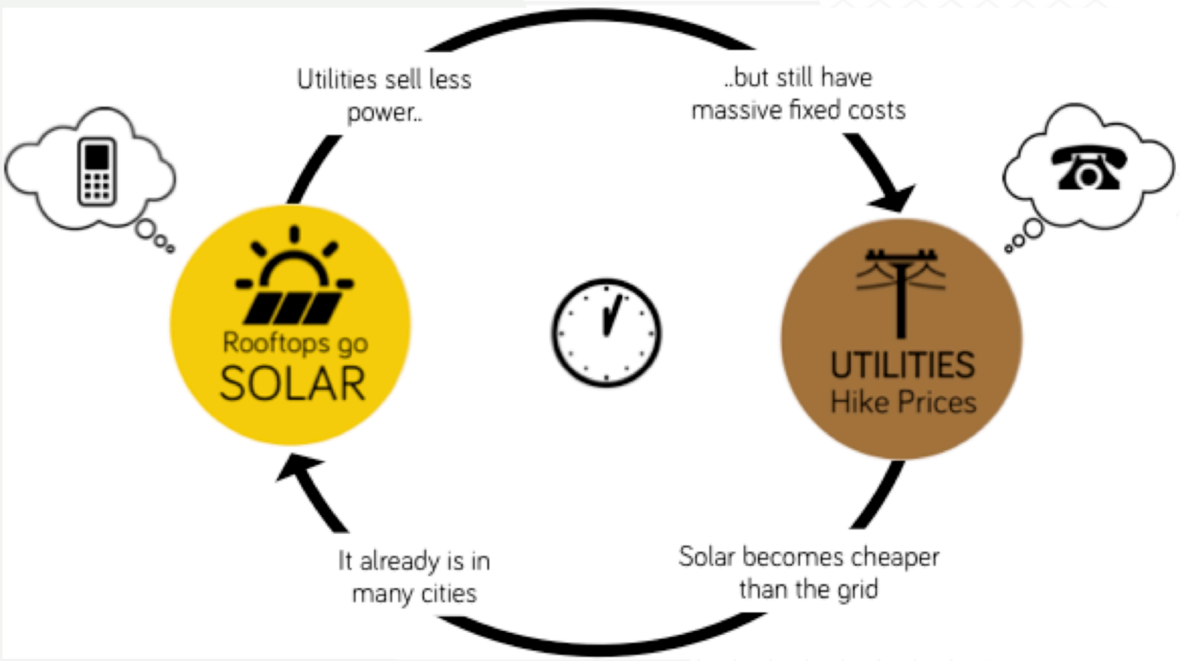
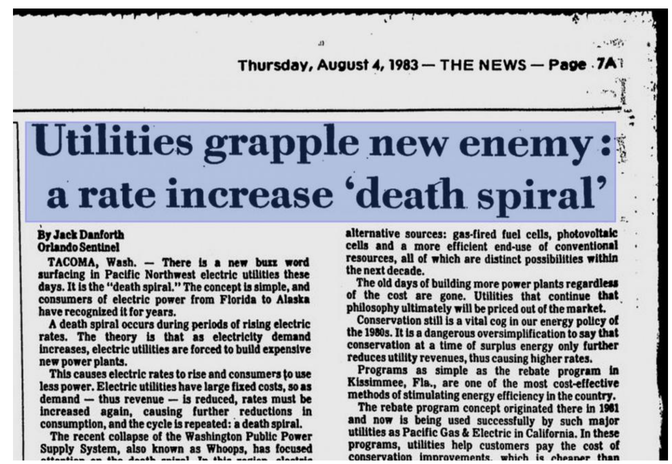
The Utility "Death Spiral"





Thursday, August 4, 1983 — THE NEWS — Page 7A

Utilities grapple new enemy: a rate increase 'death spiral'

By Jack Danforth
Orlando Sentinel

TACOMA, Wash. — There is a new buzz word surfacing in Pacific Northwest electric utilities these days. It is the "death spiral." The concept is simple, and consumers of electric power from Florida to Alaska have recognized it for years.

A death spiral occurs during periods of rising electric rates. The theory is that as electricity demand increases, electric utilities are forced to build expensive new power plants.

This causes electric rates to rise and consumers to use less power. Electric utilities have large fixed costs, so as demand — thus revenue — is reduced, rates must be increased again, causing further reductions in consumption, and the cycle is repeated: a death spiral.

The recent collapse of the Washington Public Power Supply System, also known as Whoops, has focused

alternative sources: gas-fired fuel cells, photovoltaic cells and a more efficient end-use of conventional resources, all of which are distinct possibilities within the next decade.

The old days of building more power plants regardless of the cost are gone. Utilities that continue that philosophy ultimately will be priced out of the market.

Conservation still is a vital cog in our energy policy of the 1980s. It is a dangerous oversimplification to say that conservation at a time of surplus energy only further reduces utility revenues, thus causing higher rates.

Programs as simple as the rebate program in Kissimmee, Fla., are one of the most cost-effective methods of stimulating energy efficiency in the country.

The rebate program concept originated there in 1981 and now is being used successfully by such major utilities as Pacific Gas & Electric in California. In these programs, utilities help customers pay the cost of

GT-SOLAR MODULE

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Inputs

- PJM load shape
- PJM hourly prices
- Customer load profiles
- Solar production profiles
- Rate design
- SREC prices
- Electricity demand
- NG prices
- Solar installation patterns
- Solar requirements

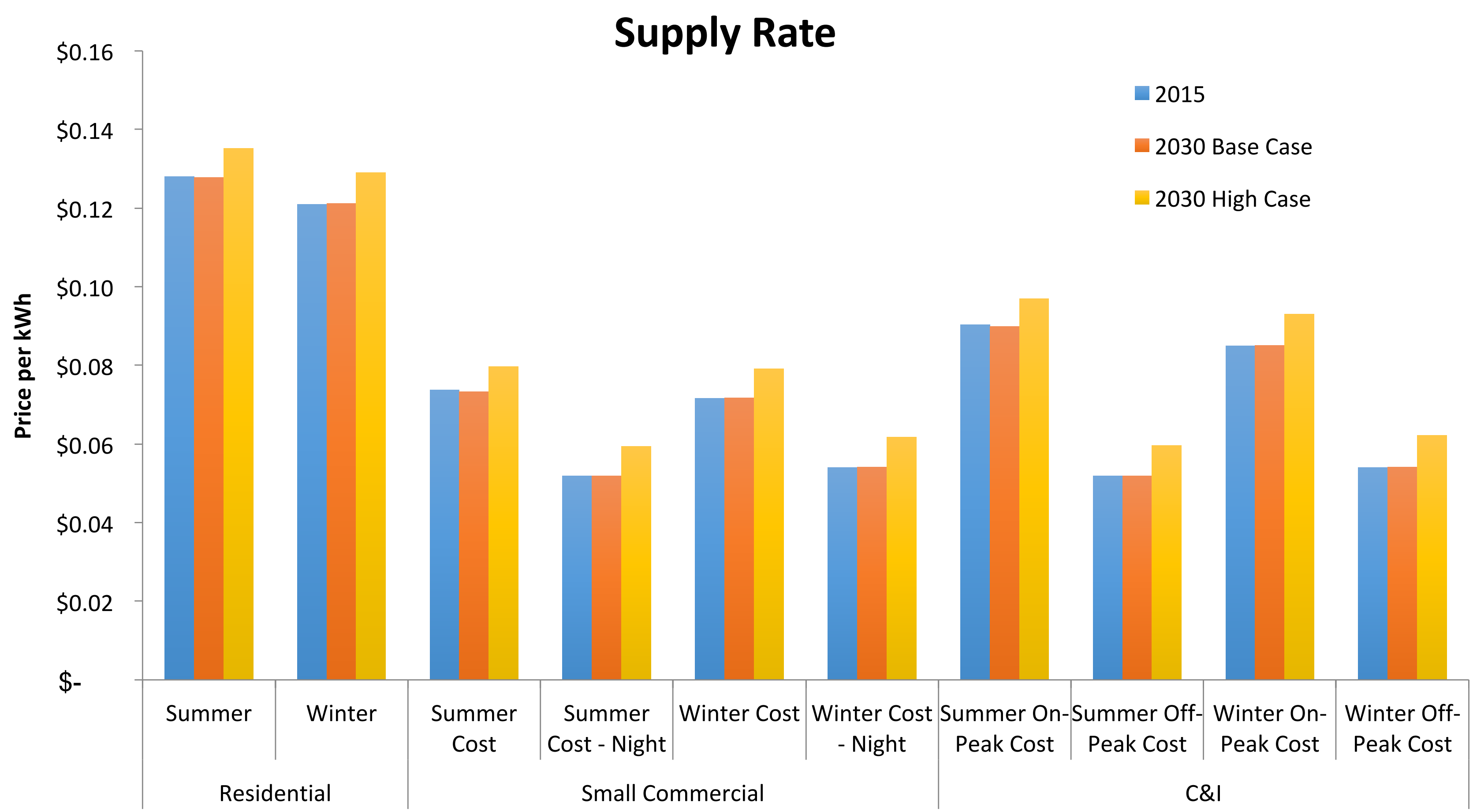
GT SOLAR MODEL

Outputs

- Supply rates
- Distribution rates
- Average bills
- Solar-participant bills
- Solar non-participant bills
- All results by customer class and scenario

RESULTS: IMPACT ON SUPPLY RATES

Result 1. High solar installation increases electricity supply rates: Tradeoff between supply curve shift and SREC costs



Source: Johnson, E. et al. (2017). Peak Shifting and Cross-Class Subsidization: The Impacts of Solar PV on Changes in Electricity Costs., *Energy Policy,* Forthcoming.

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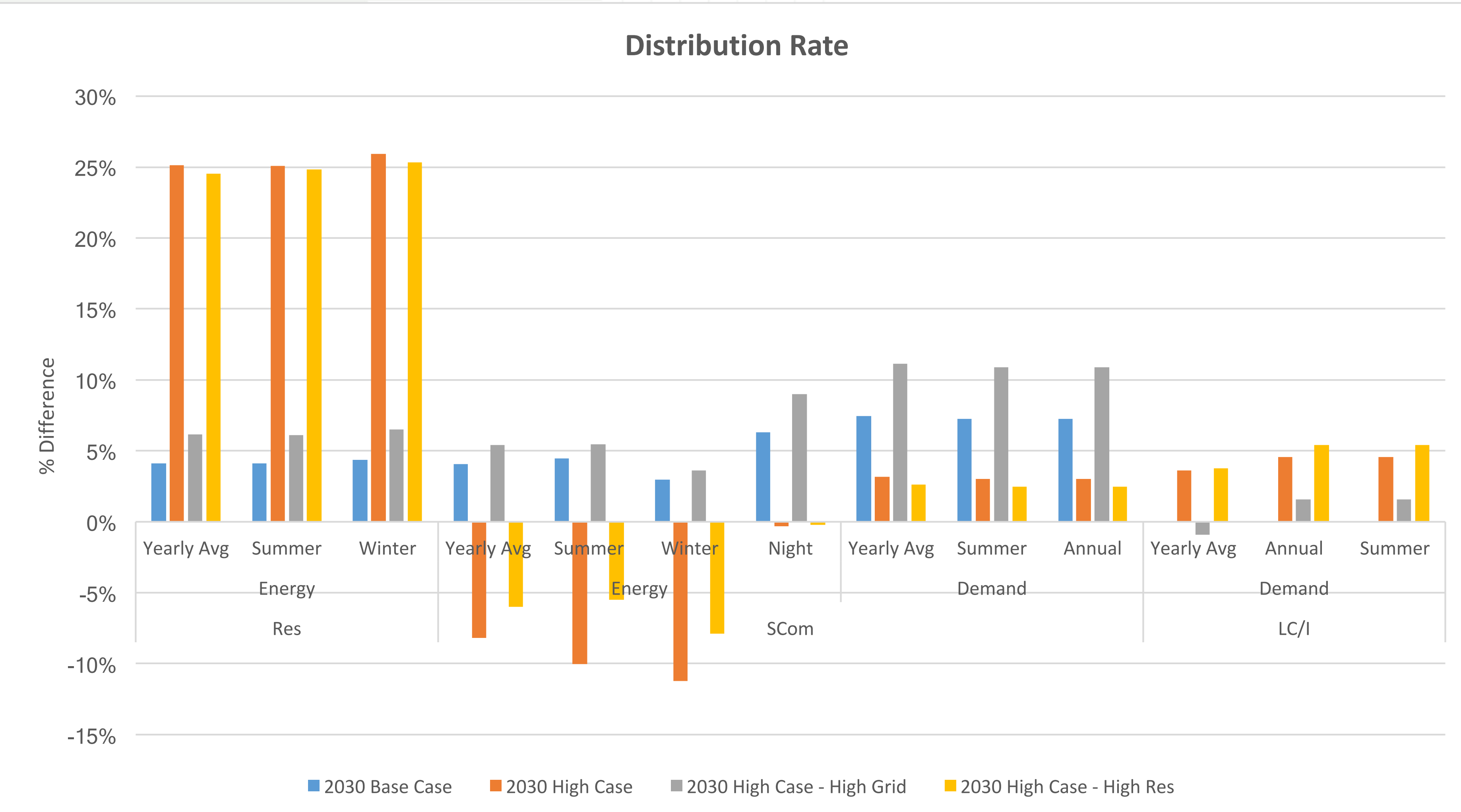
RESULTS: HIGH SOLAR INCREASES RESIDENTIAL DISTRIBUTION RATES

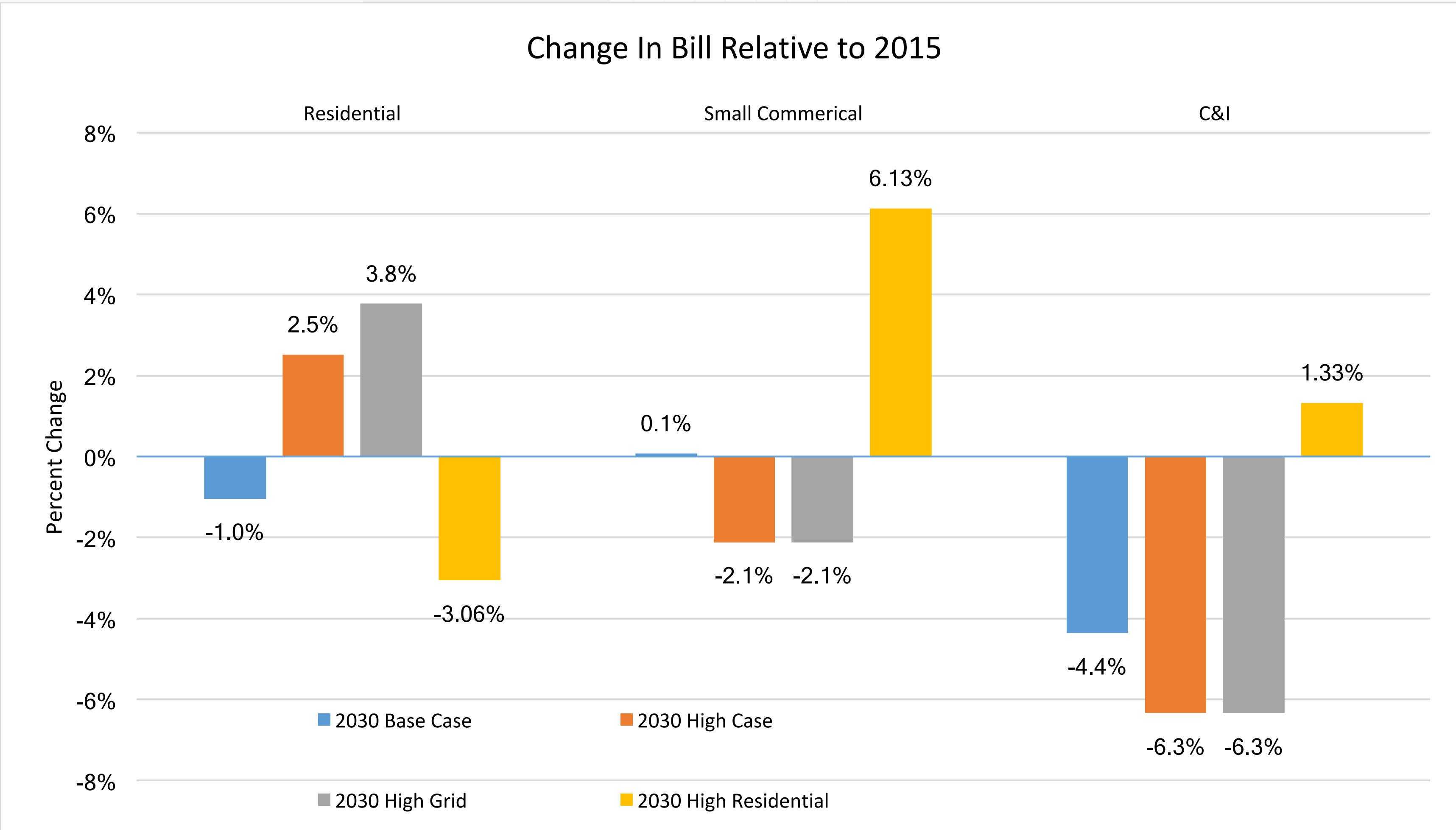
Result 2. Distribution costs rise as much as 30%; results depend on installation patterns and rate design



Source: Johnson, E. et al. (2017). Peak Shifting and Cross-Class Subsidization: The Impacts of Solar PV on Changes in Electricity Costs., *Energy Policy*, Forthcoming.

RESULTS – AVERAGE BILLS

Result 3. Changes in bills depends on who installs solar; rate design.
- Results highlight shifting in cost allocation



Source: Johnson, E. et al. (2017). Peak Shifting and Cross-Class Subsidization: The Impacts of Solar PV on Changes in Electricity Costs., *Energy Policy*, Forthcoming.

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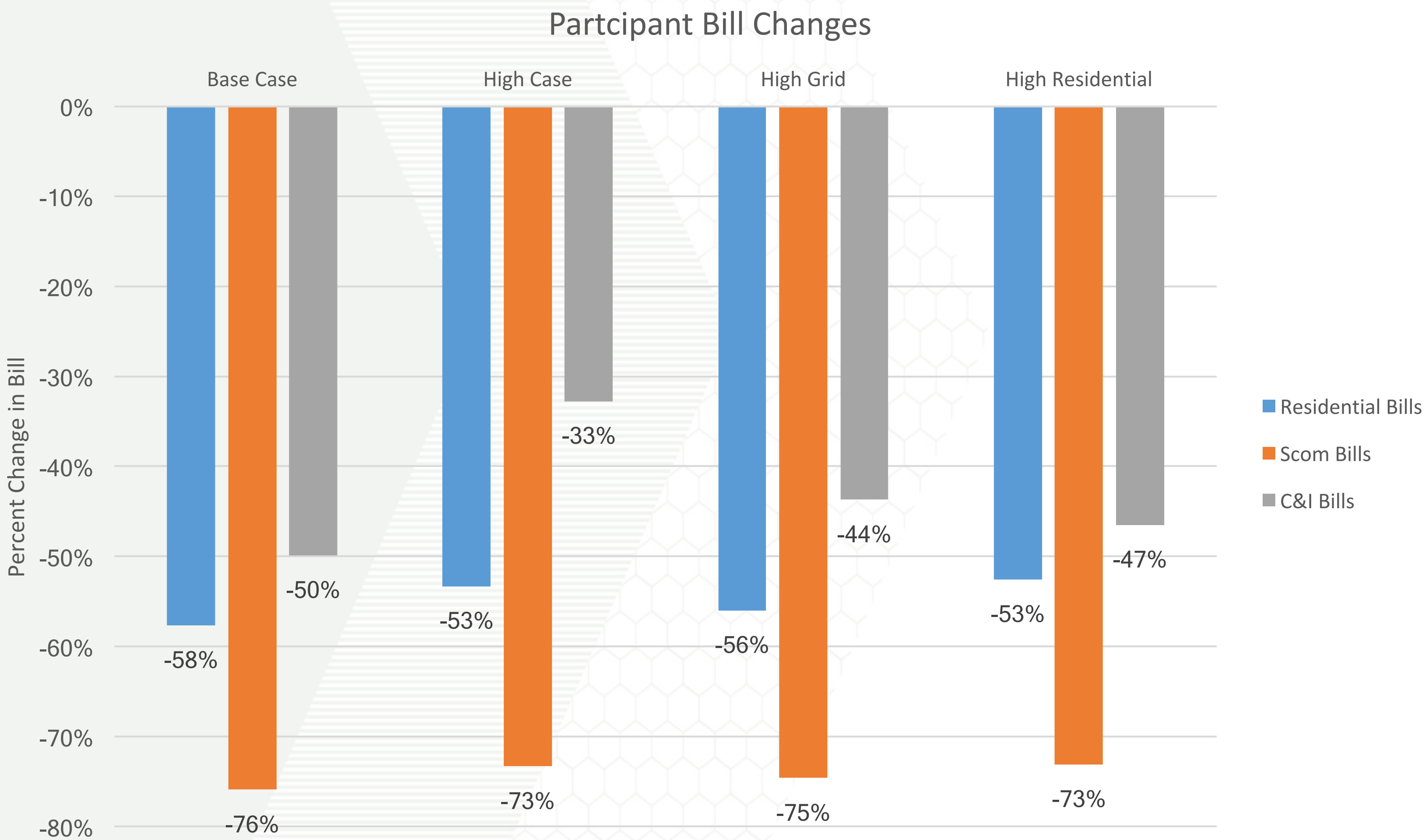
RESULTS –PARTICIPANT BILLS

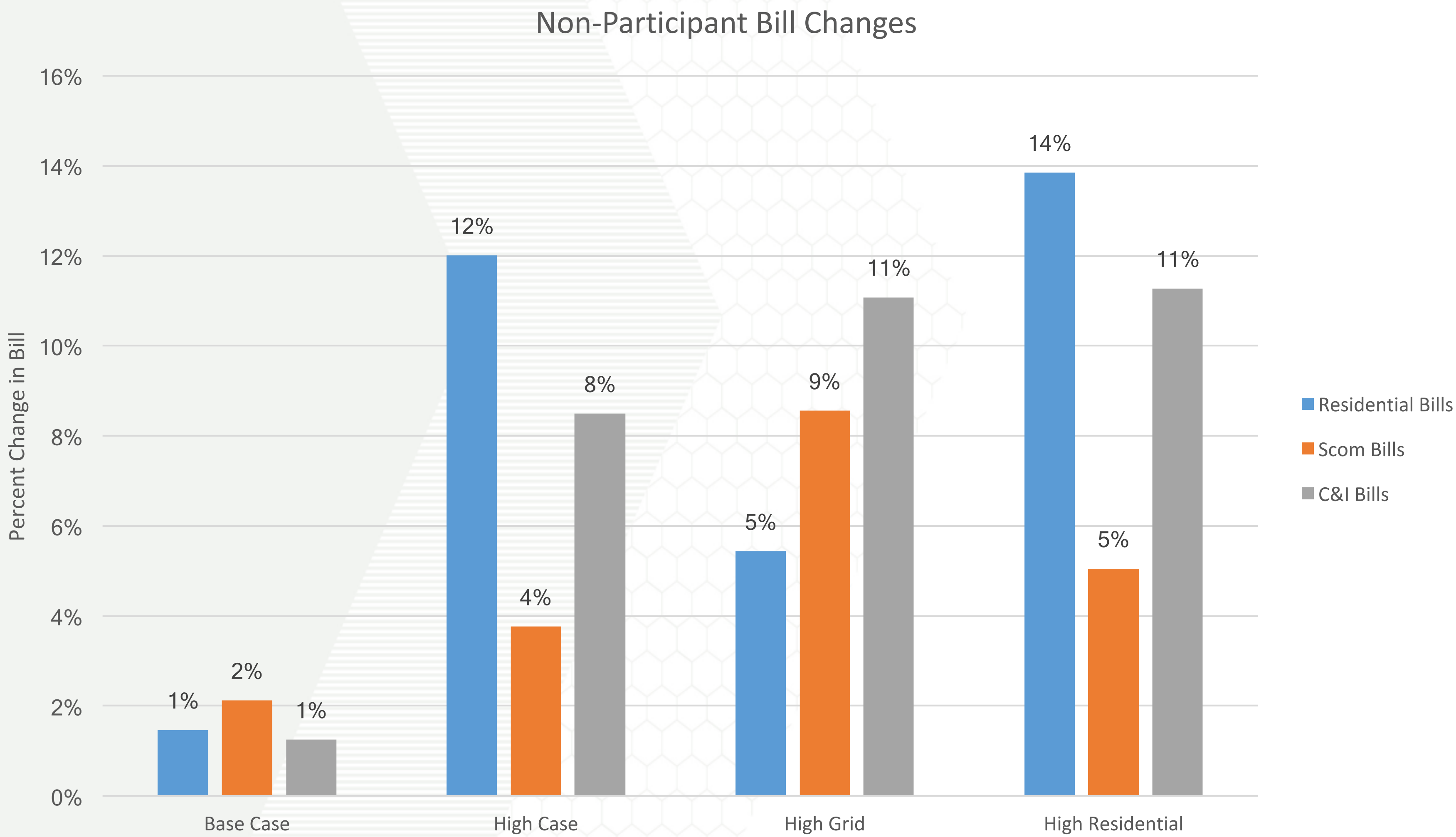
Result 4. Net Metering Participants Reduce Electricity Bills; Avoid Costs
- Results depend on rate design and installation patterns



Source: Johnson, E. et al. (2017). Peak Shifting and Cross-Class Subsidization: The Impacts of Solar PV on Changes in Electricity Costs., *Energy Policy,* Forthcoming.

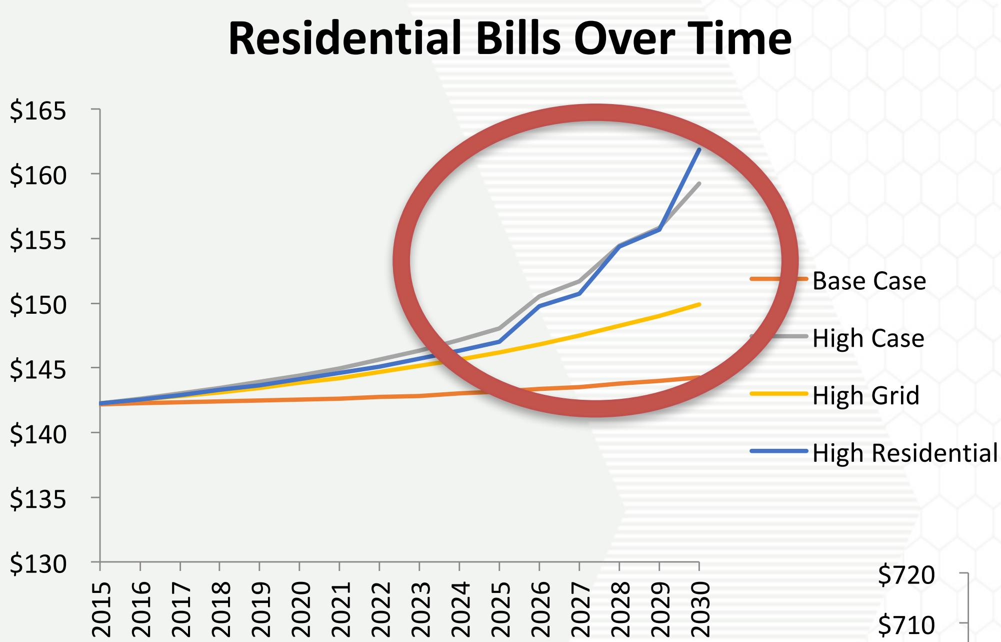
RESULTS – NON PARTICIPANT BILLS

Result 5. Non-participants absorb cost increases. Cost increases depend on quantity of solar, installation patterns, and rate design.

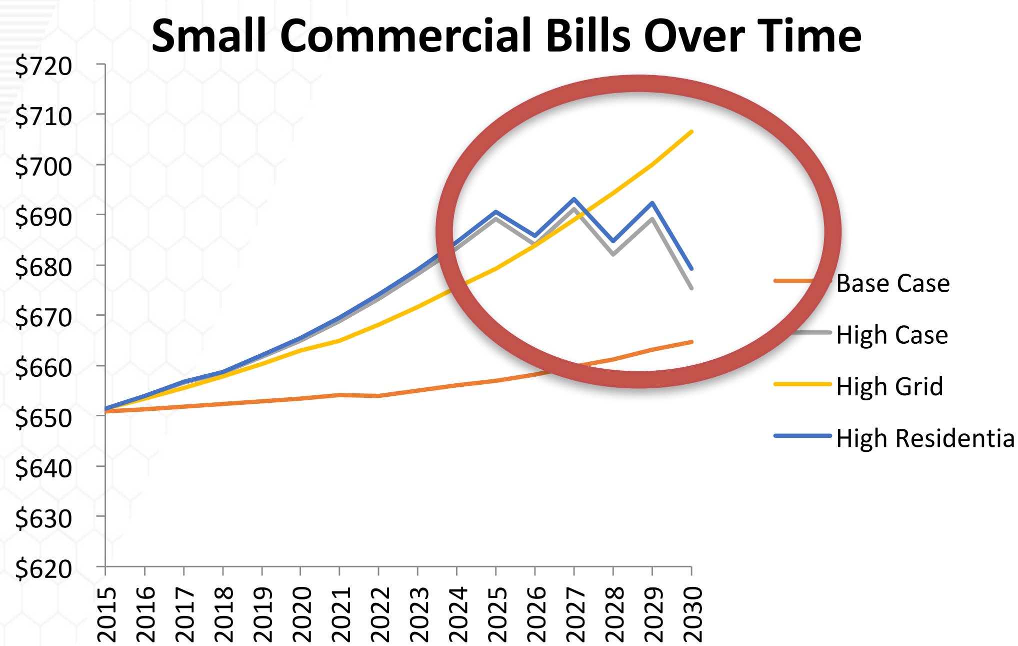


Source: Johnson, E. et al. (2017). Peak Shifting and Cross-Class Subsidization: The Impacts of Solar PV on Changes in Electricity Costs., *Energy Policy*, Forthcoming.

RESULTS – BILLS OVER TIME



- Kink points represent changes in peak hour of grid demand
- Shifts from 4pm to 8pm
- Demand charges and distribution charges change accordingly



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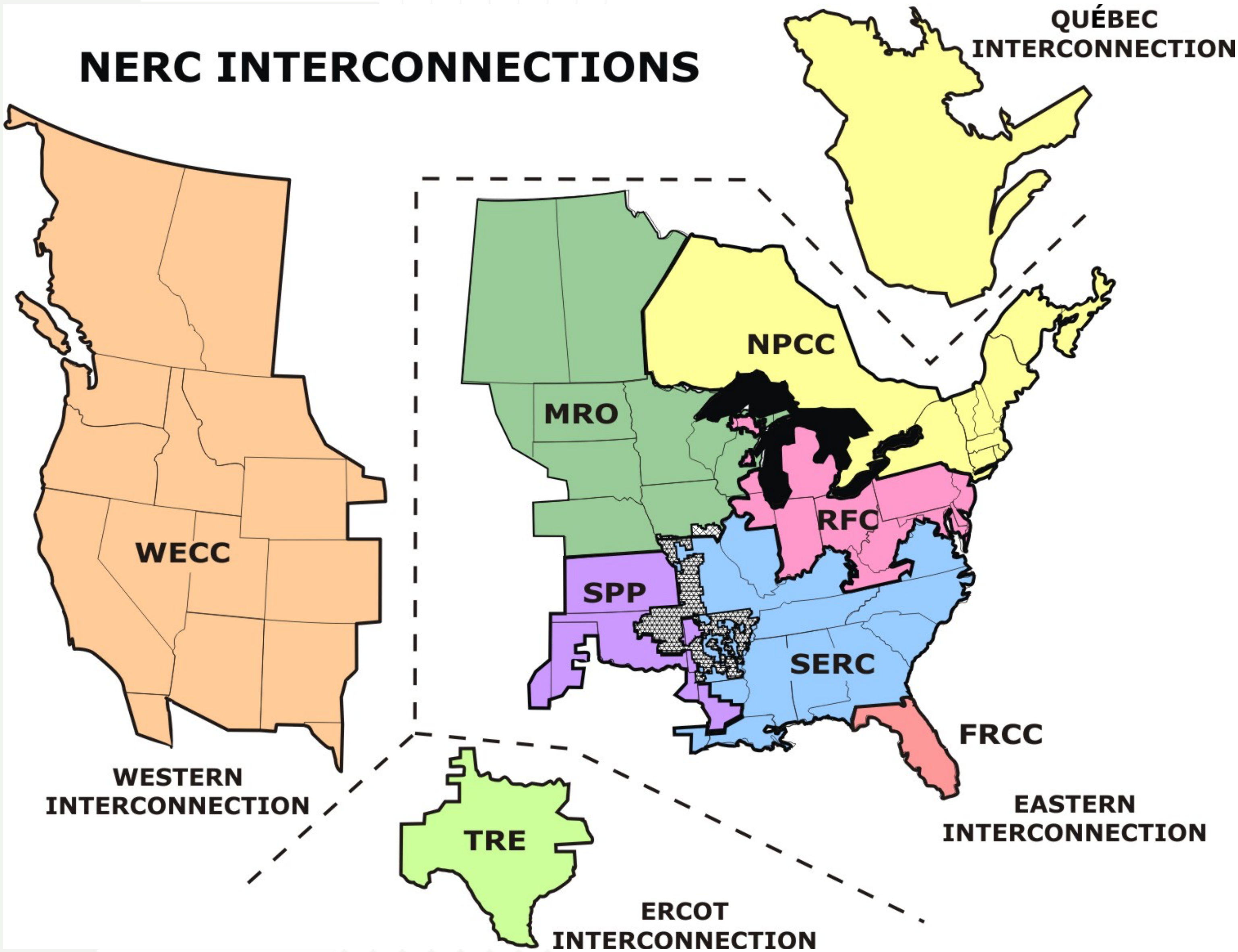
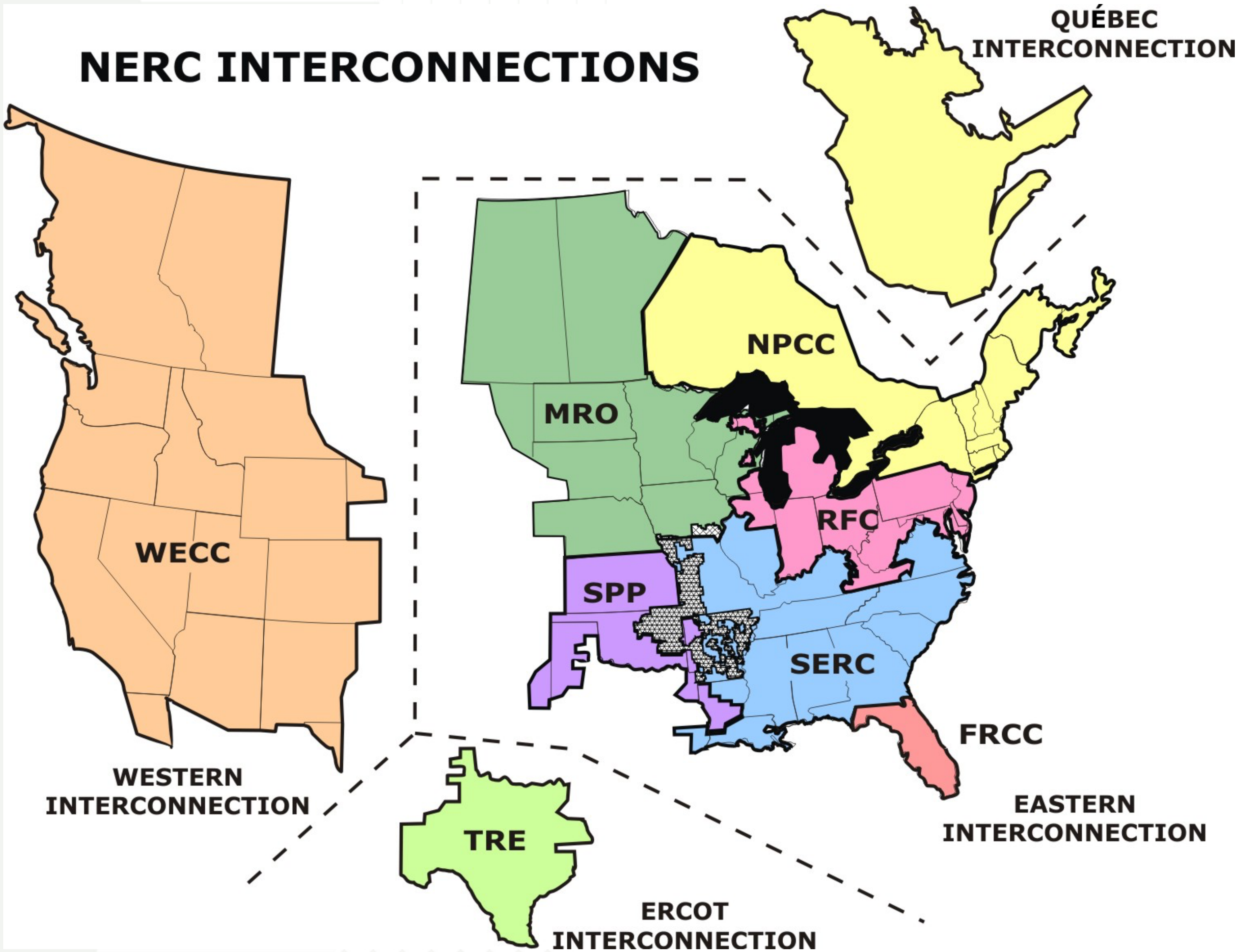
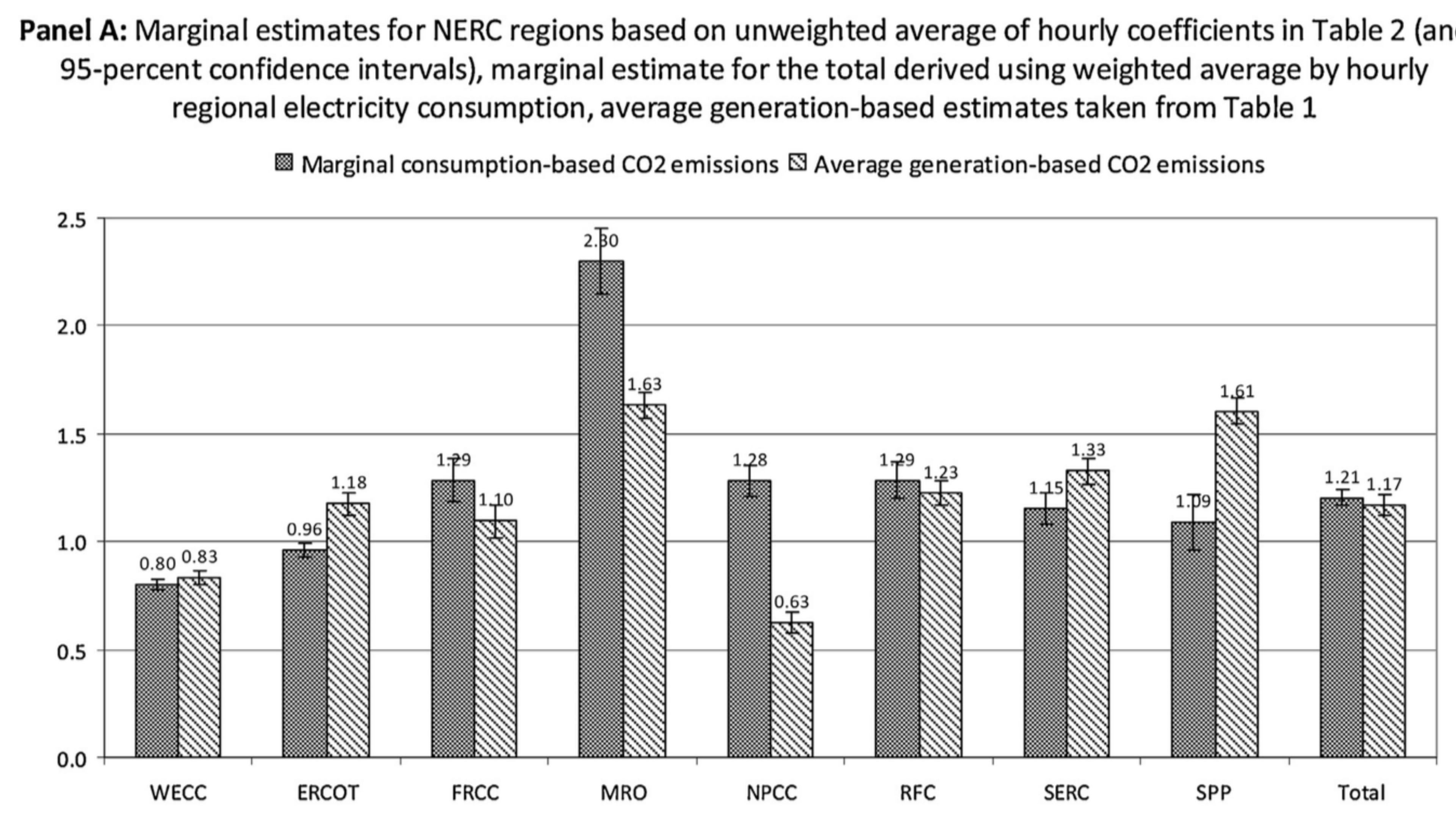
ENVIRONMENTAL IMPACTS OF ELECTRICITY GENERATION



ENVIRONMENTAL IMPACTS OF ELECTRICITY GENERATION

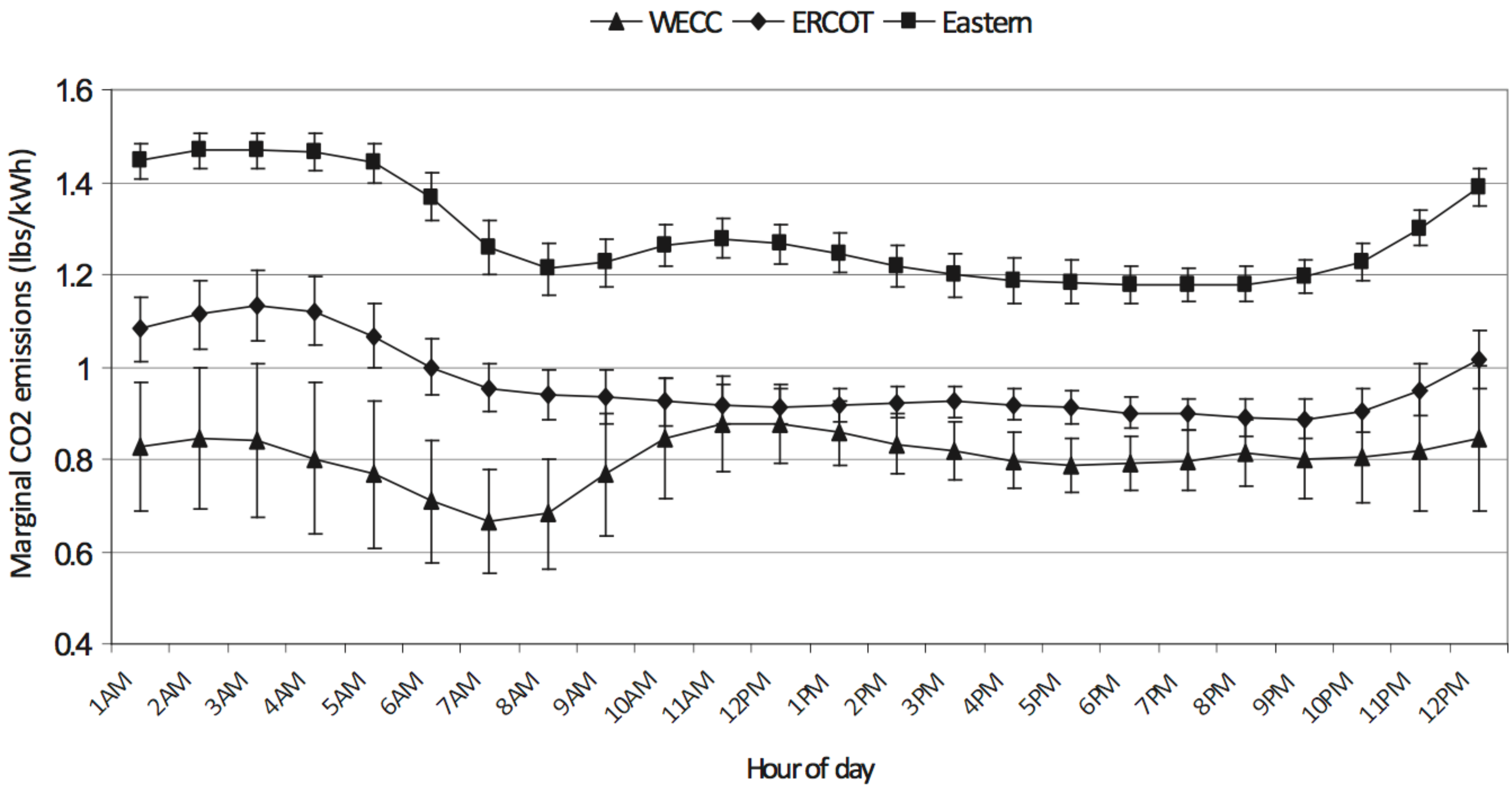


AVERAGE EMISSIONS VS MARGINAL EMISSIONS



Source: Graff Zivin, J. S., Kotchen, M. J., & Mansur, E. T. (2014). Spatial and temporal heterogeneity of marginal emissions: Implications for electric cars and other electricity-shifting policies. *Journal of Economic Behavior & Organization*, *107*, 248–268.

HOURLY MARGINAL EMISSIONS



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Thank You

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