"Energy Systems"
A Critical National Infrastructure
Slide Deck #2

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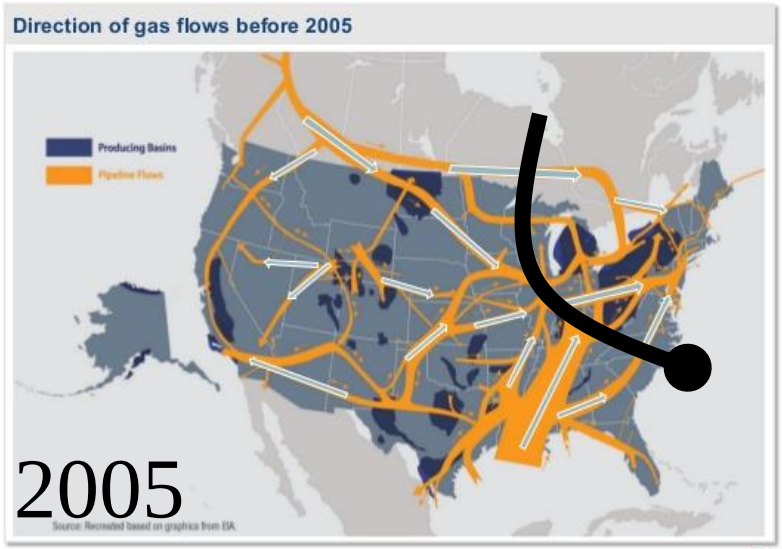
The Future of Energy

- Shale gas growth
- Big picture!
- Renewables
- Distributed generation

A1b. OIL & GAS: HISTORICAL FACT BASE – NATURAL GAS

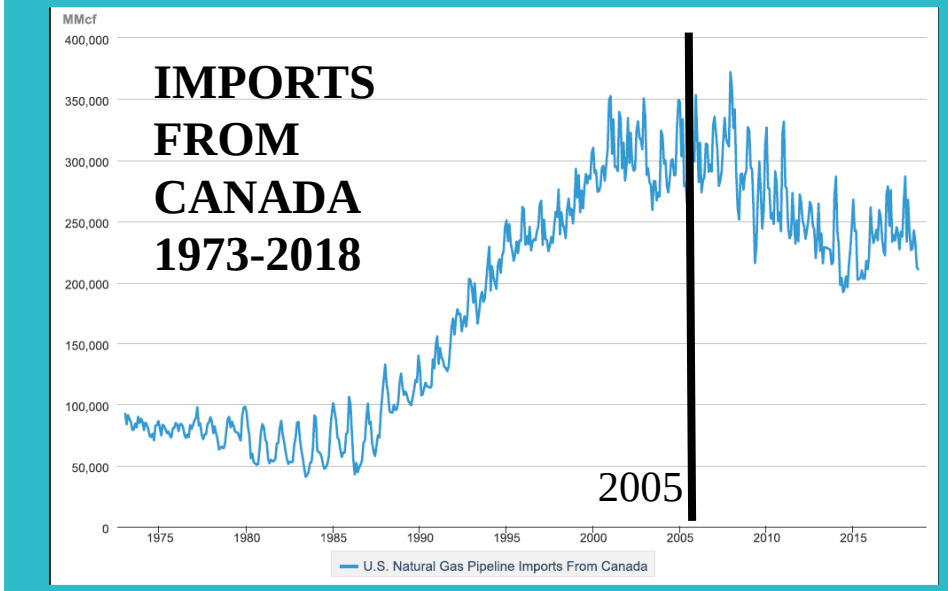
Historically, gas flowed from the Gulf, Midcontinent and Rockies supply regions to the eastern markets through Ohio

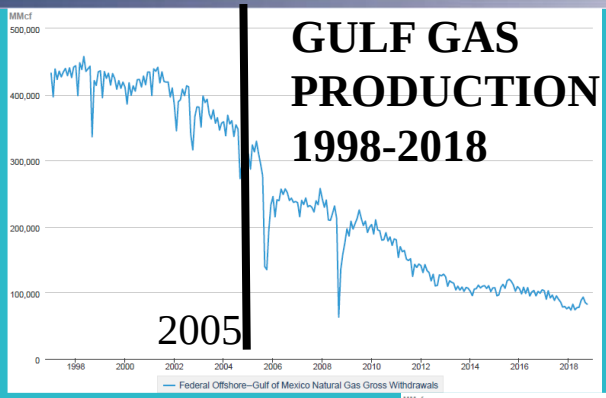


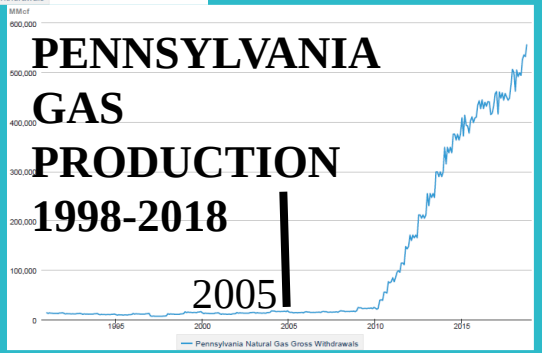
Source: American Petroleum Institute

OHIO BUSINESS ROUNDTABLE

A23

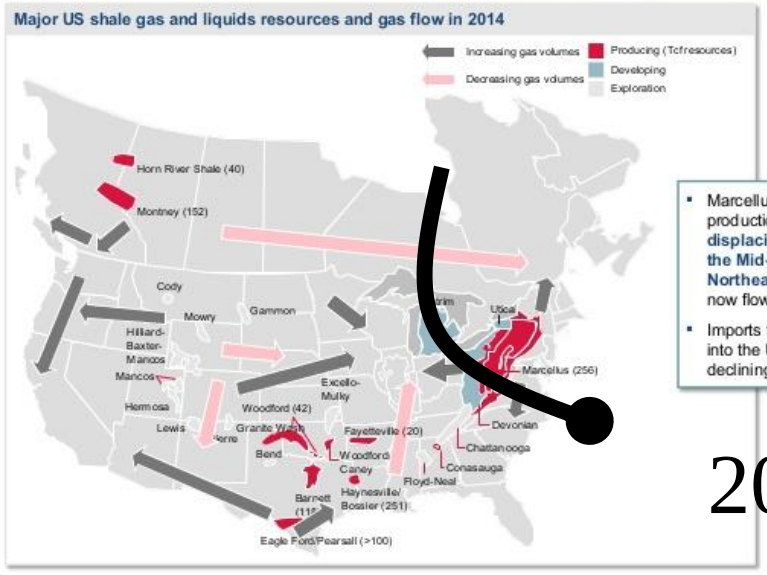






A1b. OIL & GAS: HISTORICAL FACT BASE – NATURAL GAS

Recent changes in North American natural gas flows have occurred as Marcellus and Utica production volumes increased



Source: Wood Mackenzie

OHIO BUSINESS ROUNDTABLE

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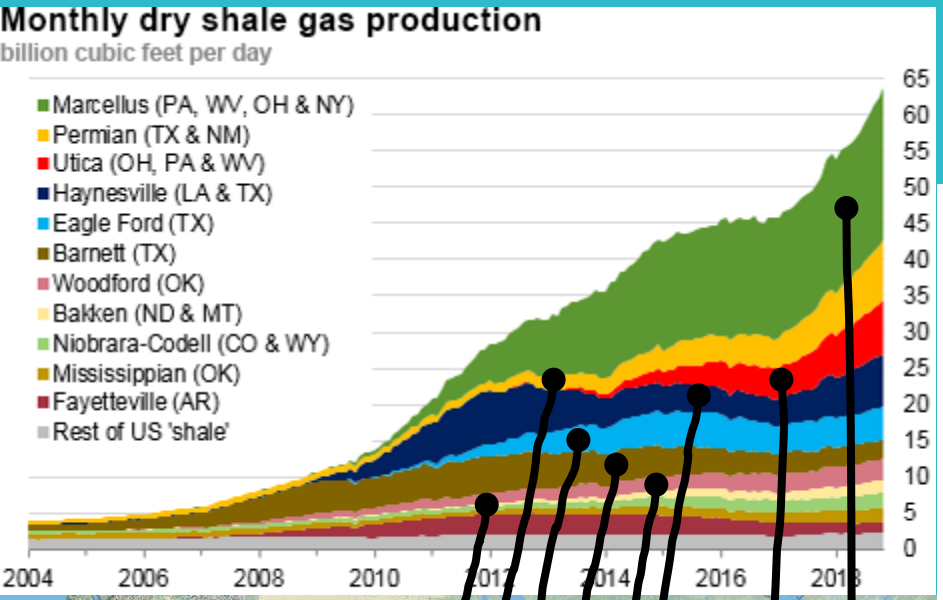
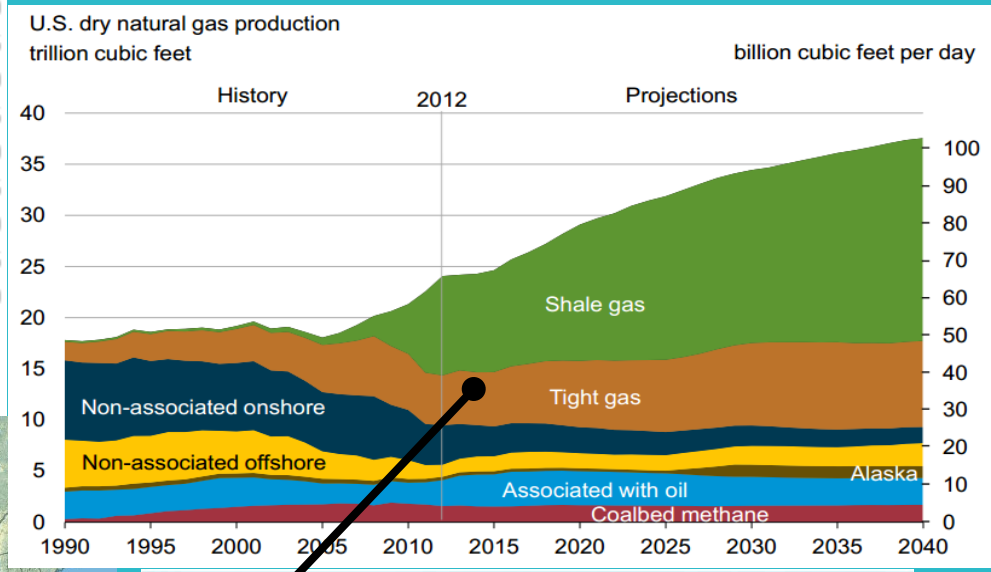
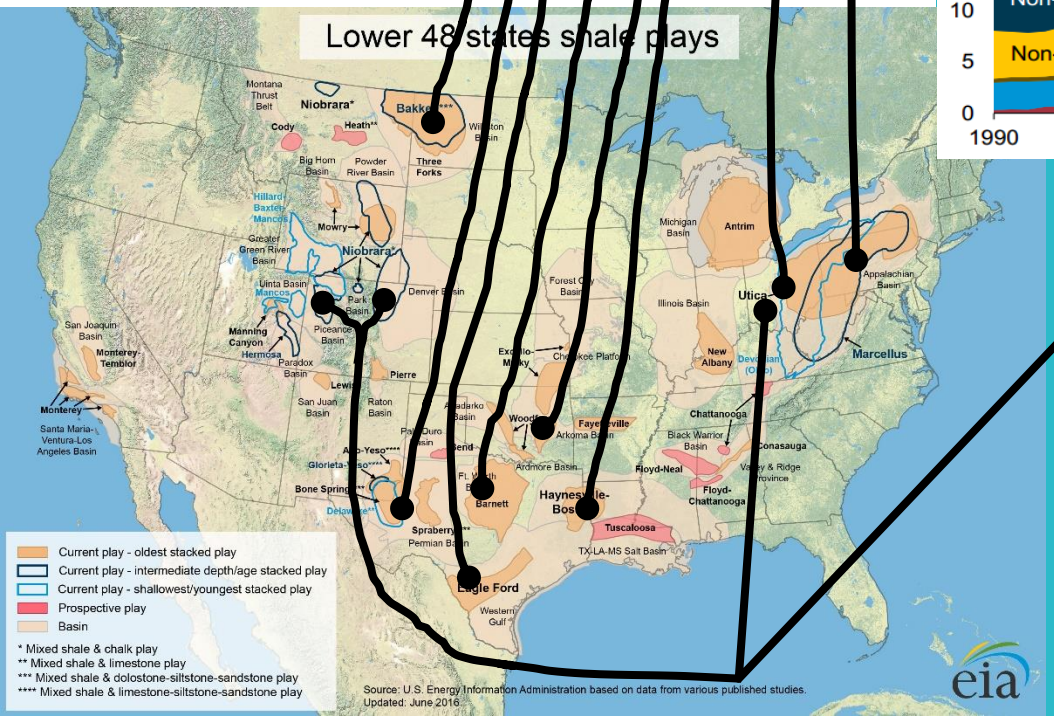
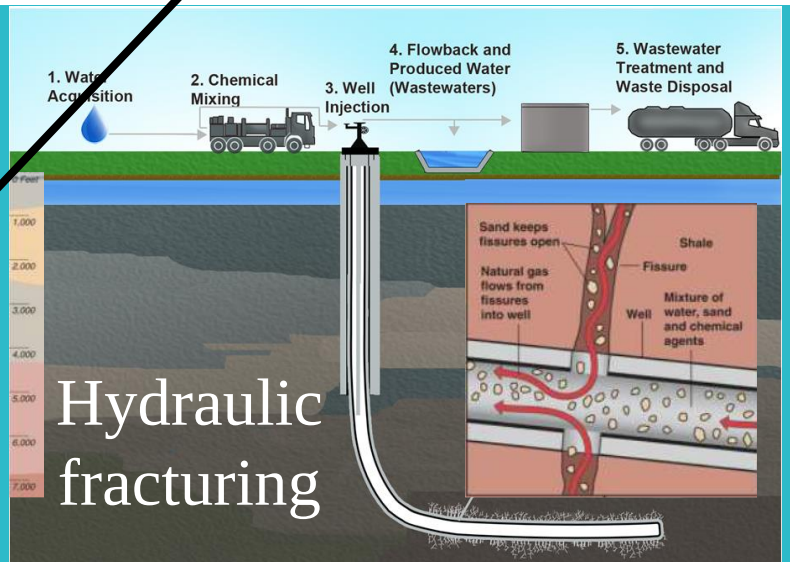
Shale gas growth

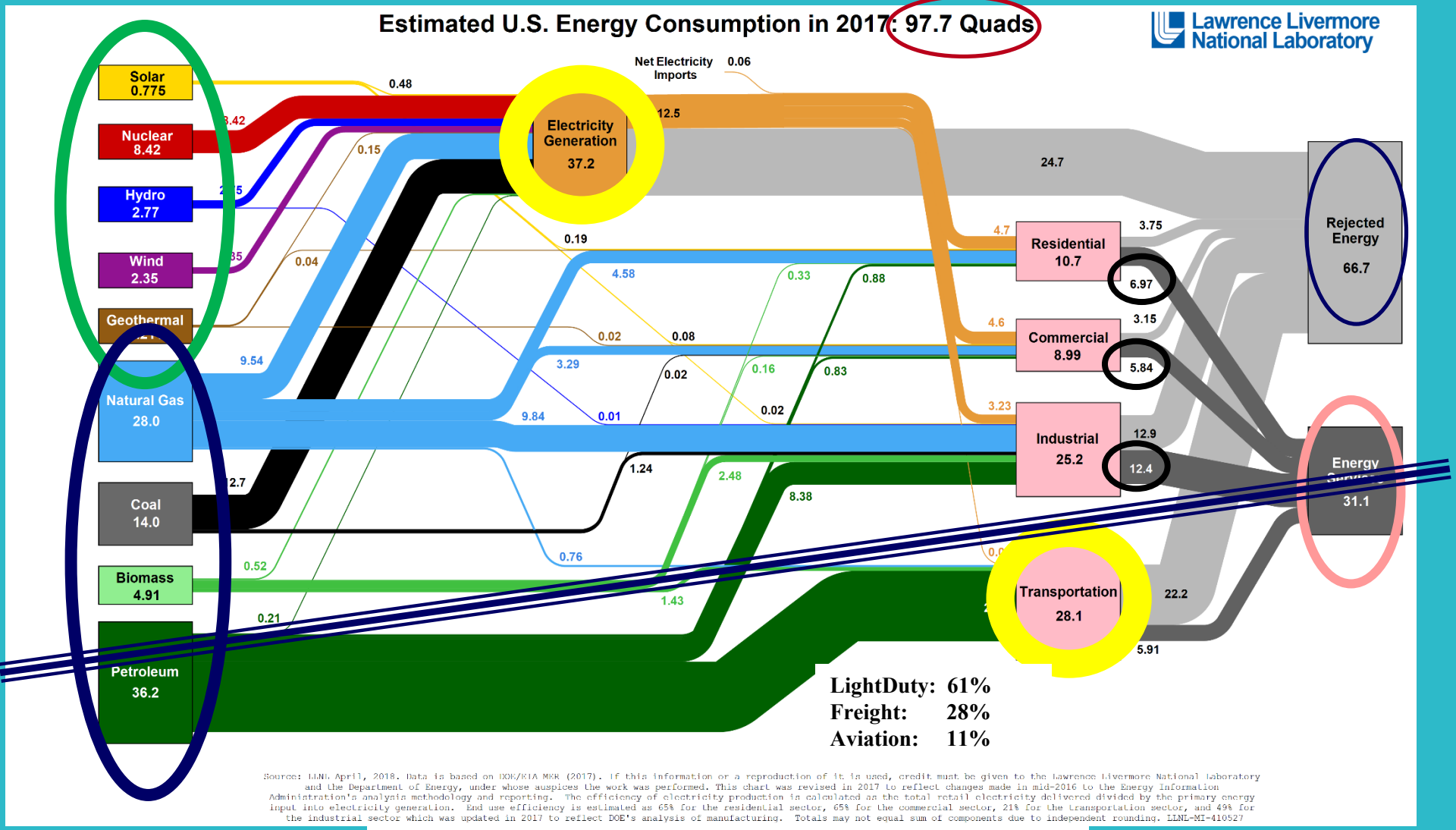








The Big Picture!

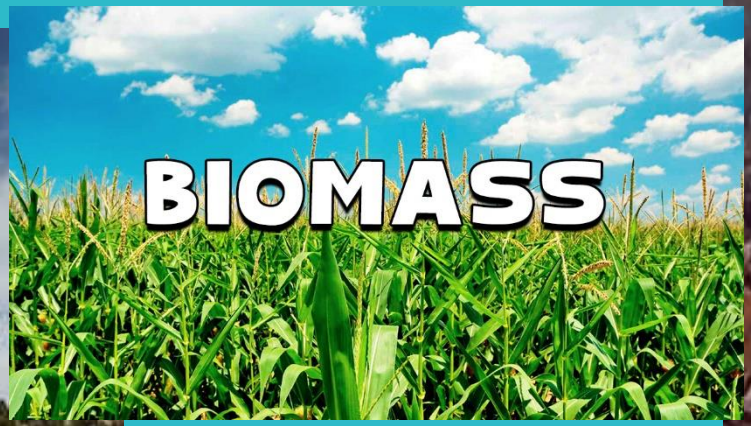


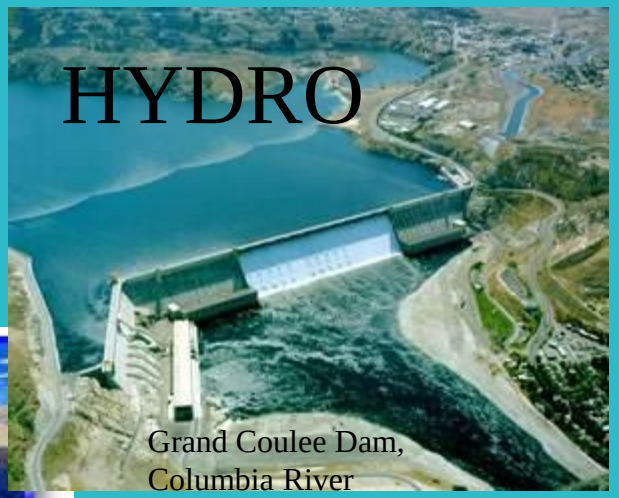
US Energy View: 2017

https://flowcharts.llnl.gov/

Renewable Energy

Geothermal

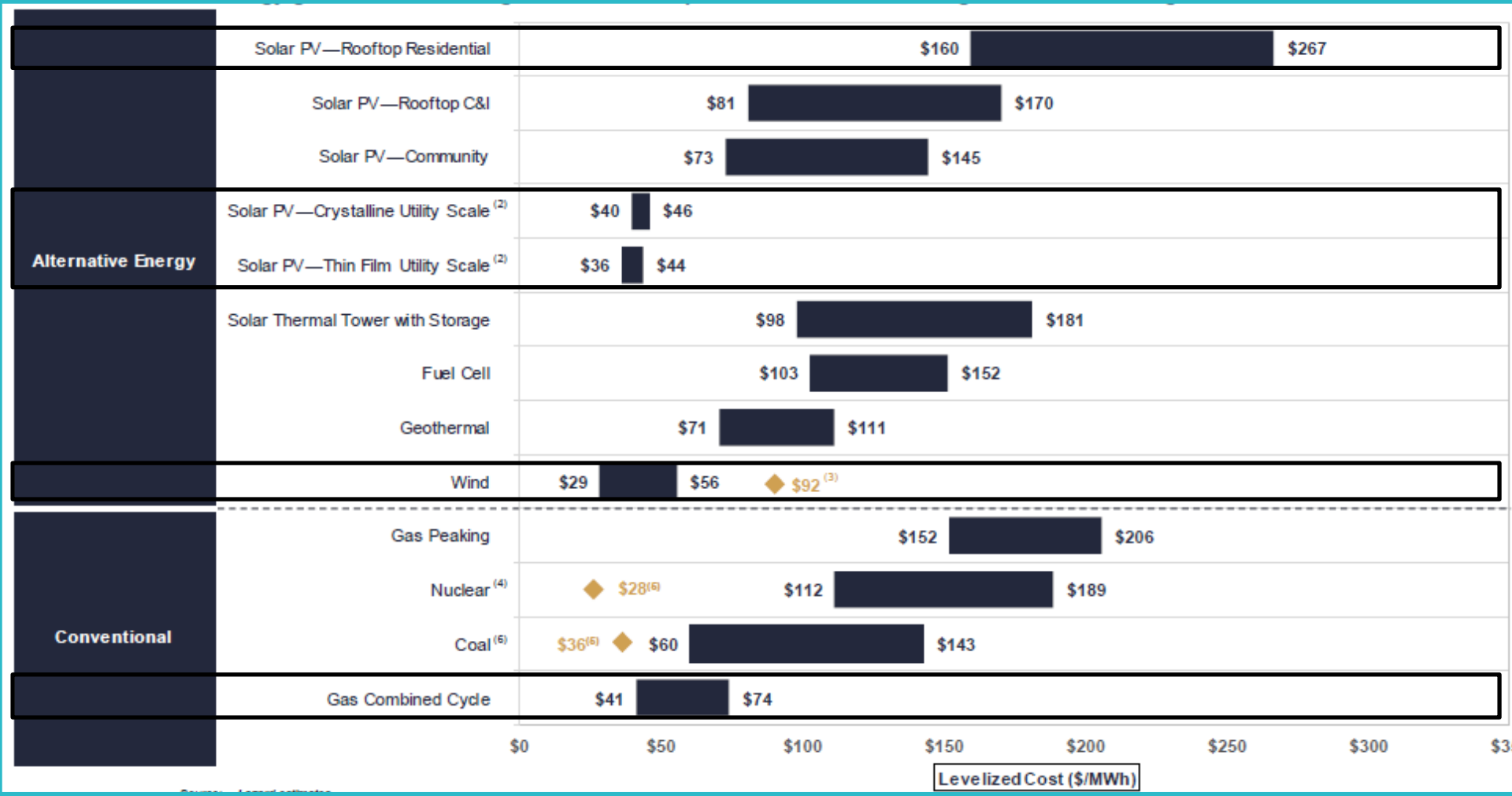




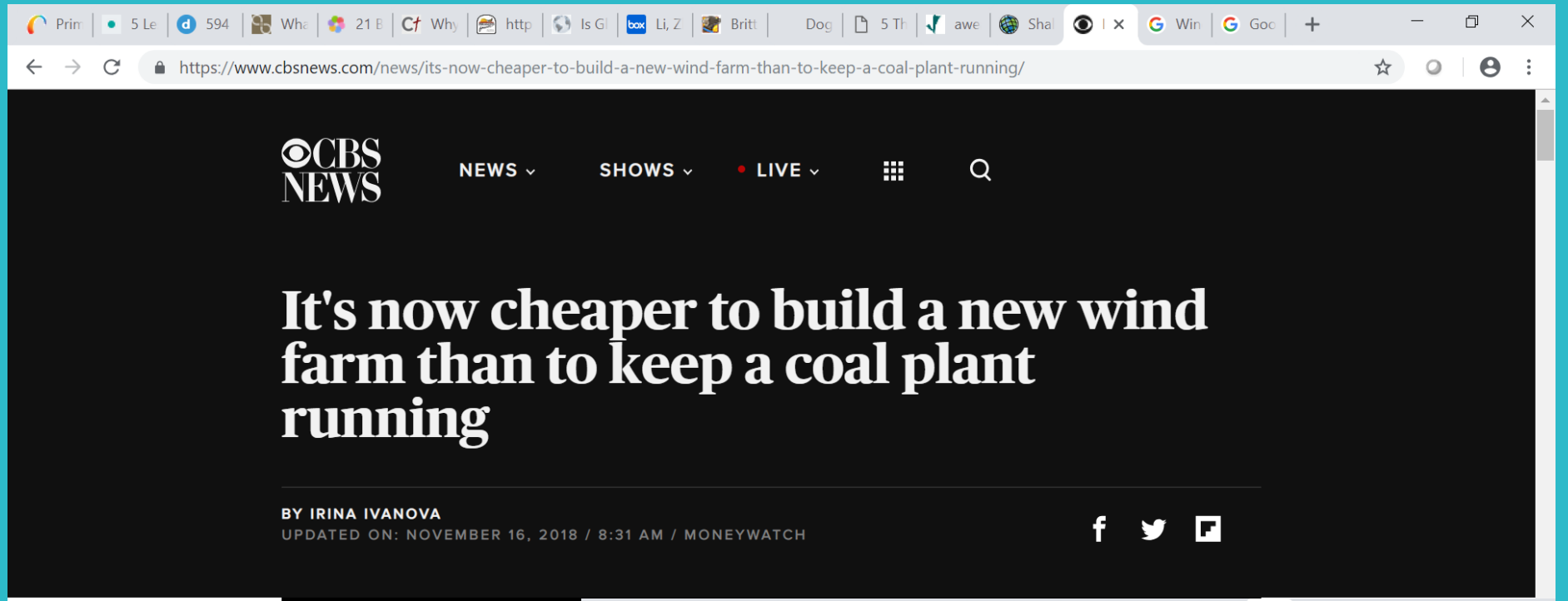
LCOEs from Lazard's (unsubsidized, 2018)

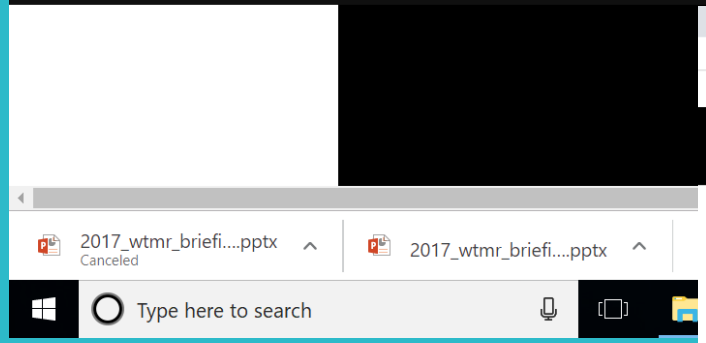
https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf

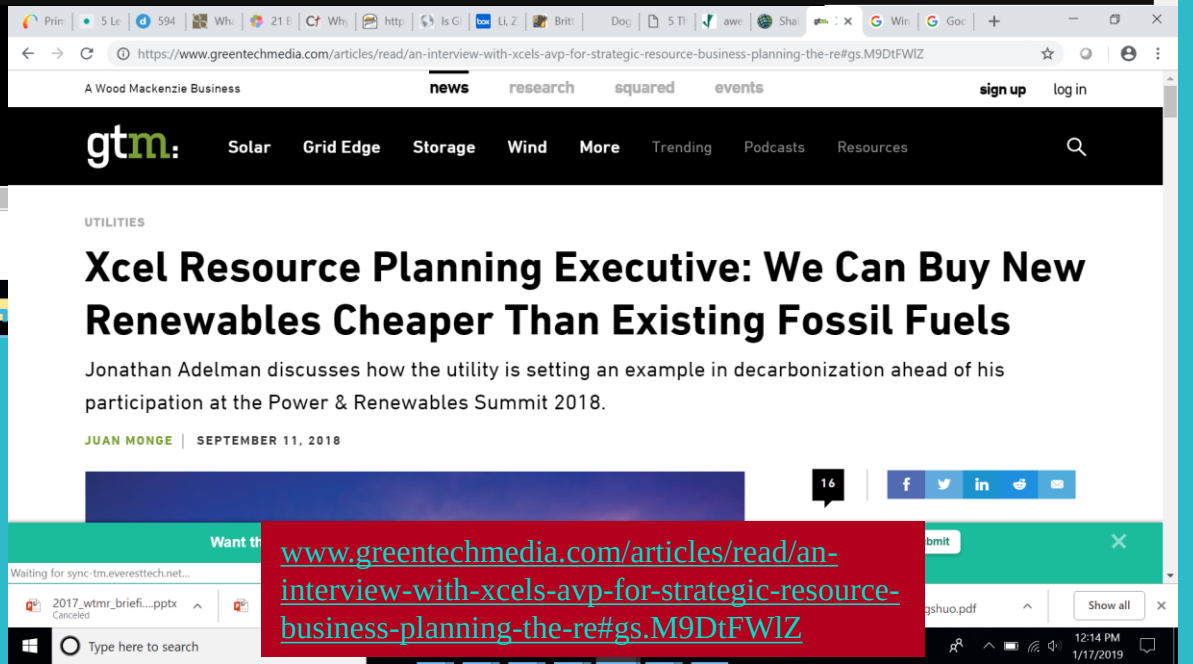
Levelized Cost of Energy ($/MWhr) = $\frac{\text{Annualized Total Cost (Invest+O\&M)}}{\text{Average Annual Energy Production (MWhrs)}}$



https://www.cbsnews.com/news/its-now-cheaper-to-build-a-new-wind-farm-than-to-keep-a-coal-plant-running








Wind

Where are US wind turbines today?

- 14 of top 20 are in the interior of the nation.
- Top 3 coastal states are West.
- East coast is light on wind but heavy on load.
- Implication?

➔3 options for East coast use of wind:

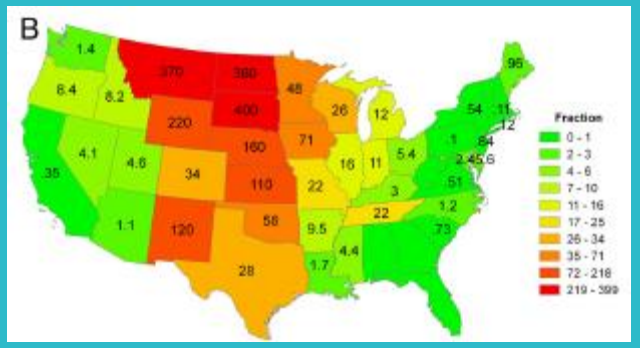
  - Build high cost inland wind,
  - go offshore, or
  - use transmission to move it from Midwest

Source: US DOE, **2017 Wind technologies market report,** https://www.energy.gov/eere/wind/downloads/2017-wind-technologies-market-report

Installed Capacity (MW)				2017 Wind Gen (MWhr) as % of In-state Gen	
Annual (2017)		Cumulative (end of 2017)			
Texas	2,305	Texas	22,599	Iowa	36.9%
Oklahoma	851	Oklahoma	7,495	Kansas	36.0%
Kansas	659	Iowa	7,308	Oklahoma	31.9%
New Mexico	570	California	5,555	South Dakota	30.1%
Iowa	397	Kansas	5,110	North Dakota	26.8%
Illinois	306	Illinois	4,332	Maine	19.9%
Missouri	300	Minnesota	3,699	Minnesota	18.2%
North Dakota	249	Oregon	3,213	Colorado	17.6%
Michigan	249	Colorado	3,106	Idaho	15.4%
Indiana	220	Washington	3,075	Texas	14.8%
North Carolina	208	North Dakota	2,996	Nebraska	14.6%
Minnesota	200	Indiana	2,117	New Mexico	13.5%
Nebraska	99	Michigan	1,860	Vermont	13.4%
Wisconsin	98	New York	1,829	Oregon	11.1%
Colorado	75	New Mexico	1,682	Wyoming	9.4%
Ohio	72	Wyoming	1,489	Montana	7.6%
Oregon	50	Nebraska	1,415	California	6.8%
California	50	Pennsylvania	1,369	Hawaii	6.5%
Vermont	30	South Dakota	977	Washington	6.5%
Maine	23	Idaho	973	Illinois	6.2%
Rest of U.S.	7	*Rest of U.S.*	6,774	*Rest of U.S.*	1.1%
TOTAL	7,017	TOTAL	88,973	TOTAL	6.3%

The future: US wind potential by state

Annual wind energy potential (10^{12} w-hrs)



R= Annual wind energy potential / 2006 state annual retail sales

States with high production and R-ratio have high export potential (Montana, Dakotas, Wyoming, Nebraska, Kansas)

Analysis assumes (a) only sites having capacity factor > 20% included; (a) loss of 20% and 10% of potential power for onshore and offshore, respectively, caused by interturbine interference, (c) offshore siting distance within 50 nm (92.6 km) of nearest shoreline.

Source: Xi Lua, M. McElroya, and J. Kiviluomac, "Global potential for wind-generated electricity," Proc. of the National Academy of Sciences, 2009, www.pnas.orgcgidoi10.1073pnas.0904101106.

The future: US wind potential

Contiguous US annual wind energy potential , 10^{15} wh		Multiples of Total US Energy Consumption*
Onshore	62	2.12
Offshore, 0-20 meter	1.2	.041
Offshore, 20-50 m	2.1	.072
Offshore, 50-200 m	2.2	.075
Total	68	2.321

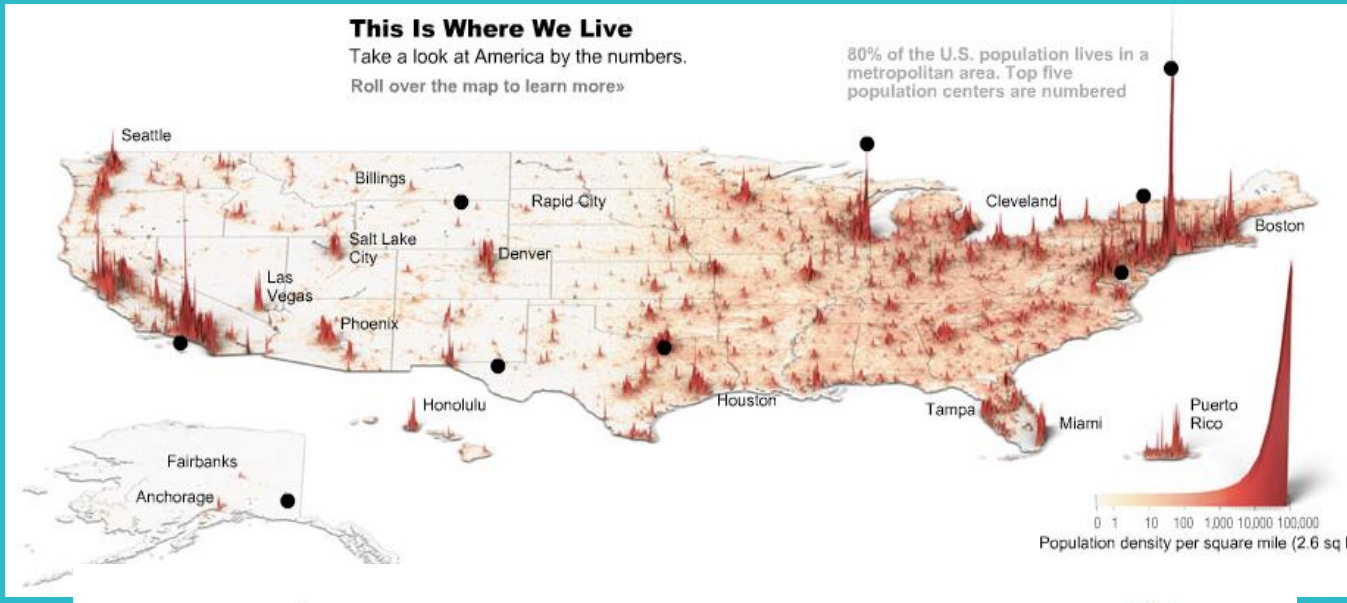
Total US Energy consumption across *all* sectors is 100 Quads:

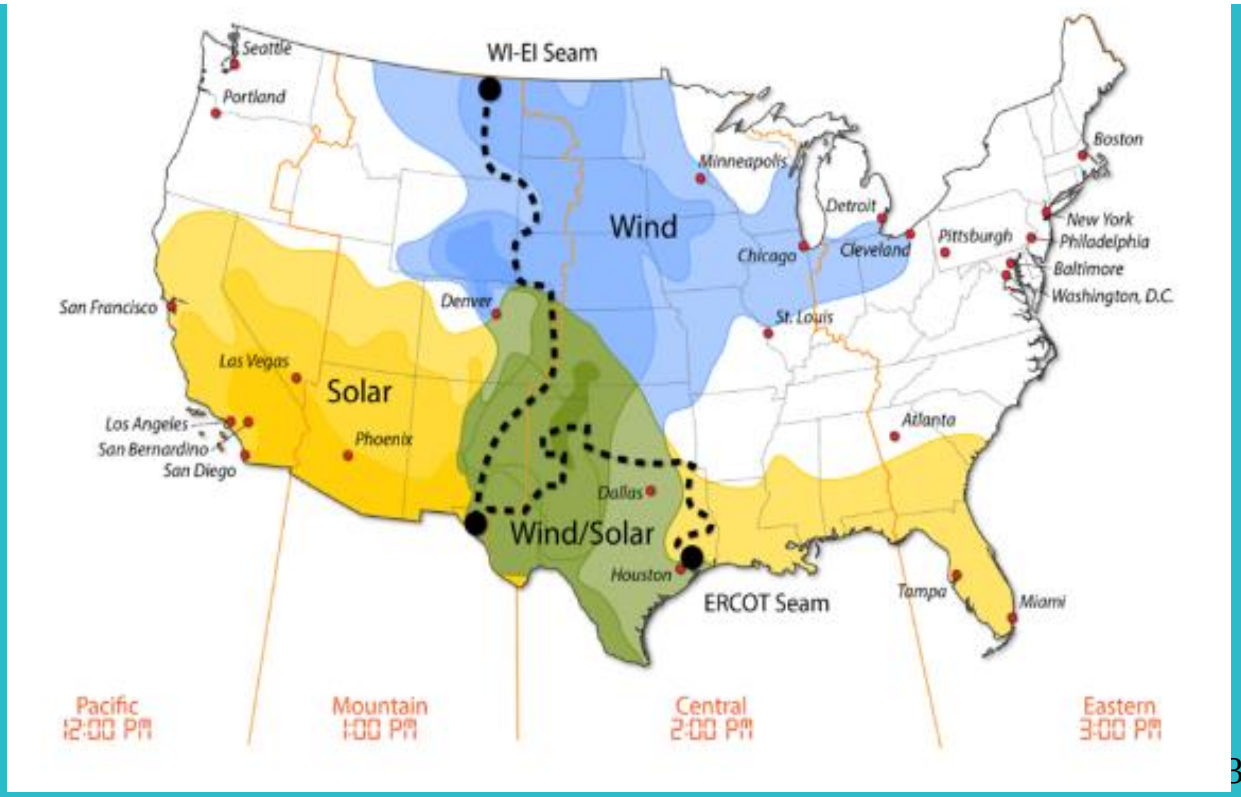
$$100Q \times \frac{1E15BTU}{Q} \times \frac{kwh}{3413BTU} \times \frac{1000wh}{kwh} = 29.3E15wh$$

Source: Xi Lua, M. McElroya, and J. Kiviluomac, "Global potential for wind-generated electricity," Proc. of the National Academy of Sciences, 2009, www.pnas.orgcgidoi10.1073pnas.0904101106.

Where do we live in the US?

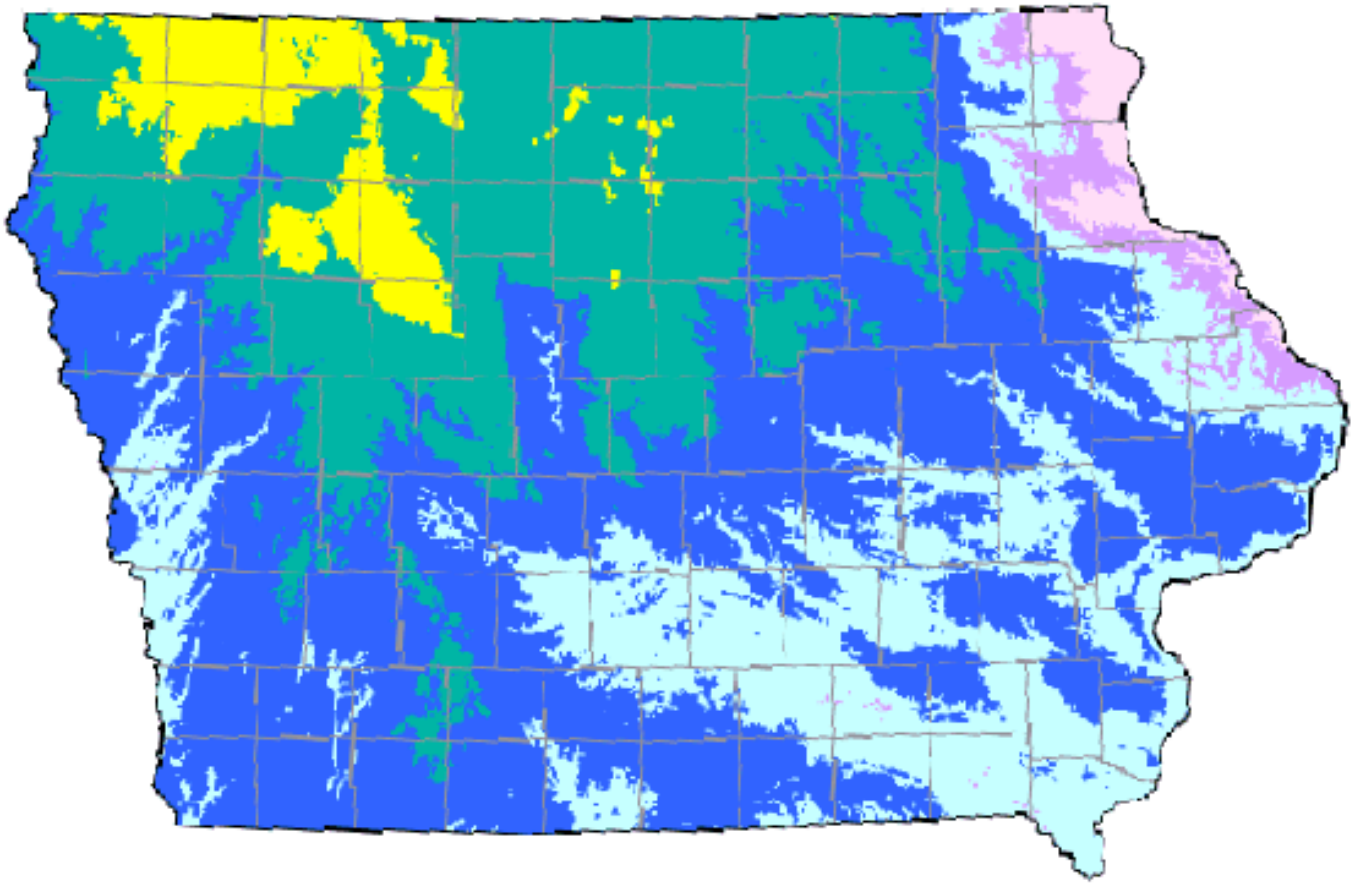
Where in the US are the economically most attractive electric resources?





Estimated Average Annual Wind Speeds

Typical average wind speeds on well exposed sites at 50 m above ground



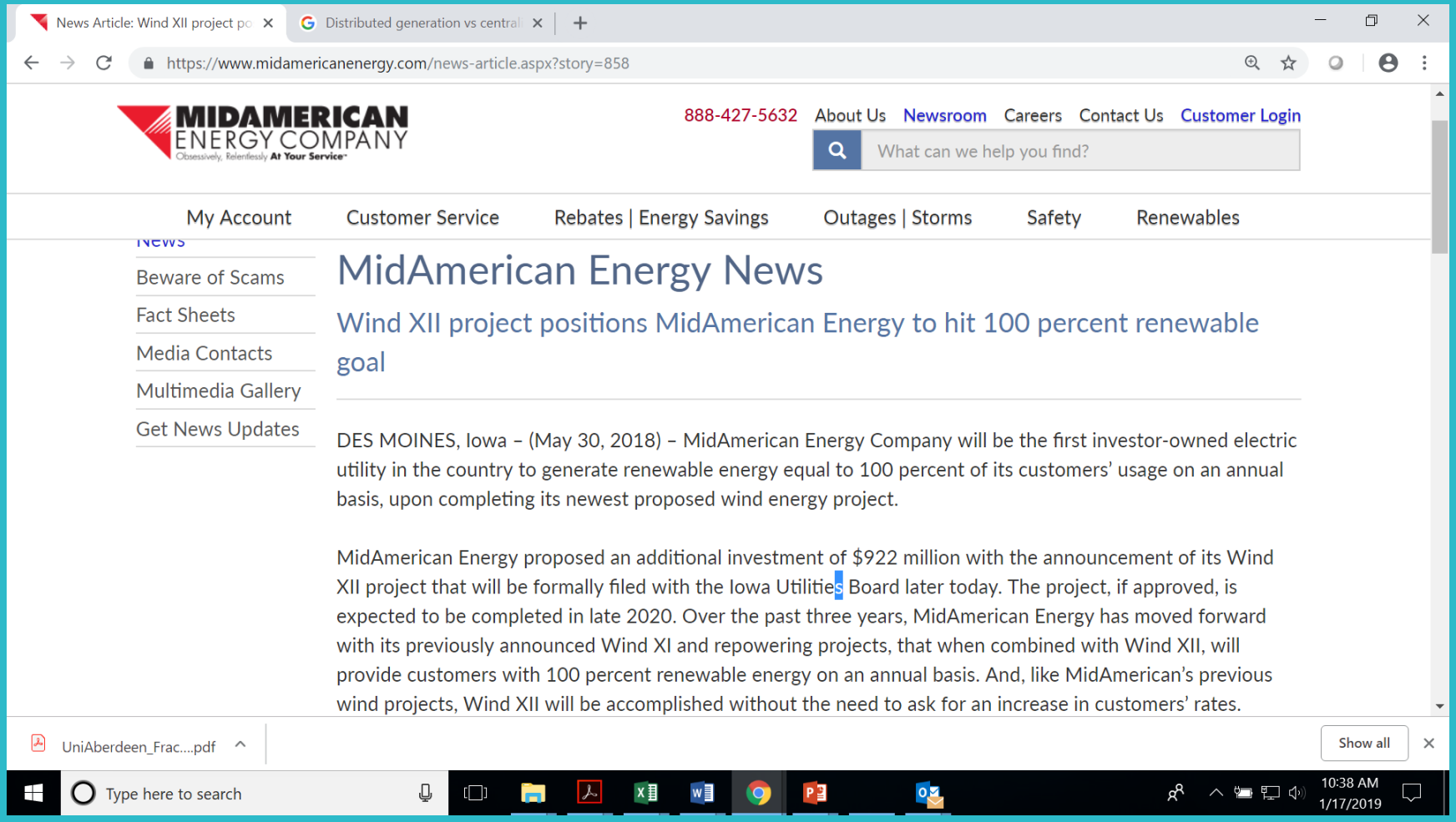
MPH		m/s
>19.0		>8.5
17.9-19.0		8.0-8.5
16.8-17.9		7.5-8.0
15.7-16.8		7.0-7.5
14.5-15.7		6.5-7.0
13.4-14.5		6.0-6.5
12.3-13.4		5.5-6.0
<12.3		<5.5

Iowa Energy Center

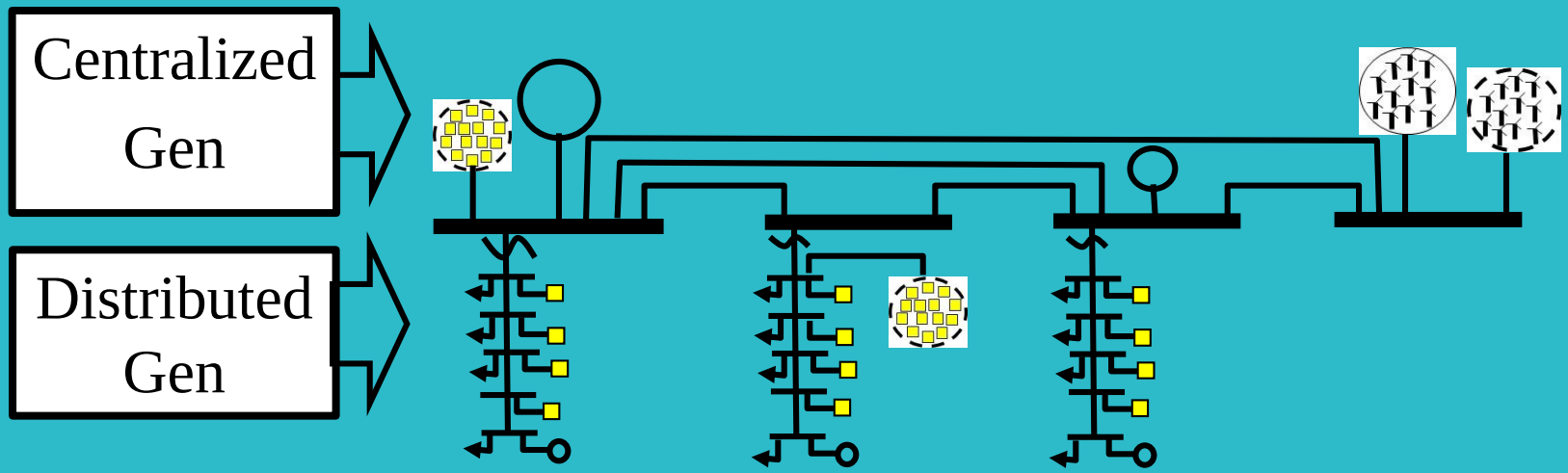
This map was generated from data collected by the Iowa Wind Energy Institute under Iowa Energy Center Grant No. 93-04-02. The map was created using a model developed by Brower & Company, Andover, MA.

Iowa Energy Center, 2521 Elwood Drive, Suite 124, Ames, IA 50010-8263 Phone: (515) 294-8819 Fax: (515) 294-9912

100% Renewable?



Distributed Generation



- PV: Solar photovoltaic.
- Microturbines: Gas-fueled small-sized generation, normally CTs.
- Rooftop PV: PV located on roofs of residential, commercial, industrial bldgs.
- Groundmounted PV: PV located on the ground.
- Utility-scale PV: A large-size PV plant, typically >> 1MW, usually ground-mounted
- Community solar: A small, utility-scale PV plant financed by a local customer group.
- DG: Generation connected at the distribution system (≤34.5 kV). Can be any technology but normally PV or microturbines.
- Microgrids: Portions of the distribution system that can operate in isolation

Questions:

1. Is all PV also DG?
2. Is most rooftop PV also DG?
3. Does all PV have the same LCOE?
4. Does all rooftop PV have same LCOE?
5. Are all dist systems having DG also microgrids?
6. Is all utility-scale PV owned by utilities?
7. Is all DG renewable?
8. Is most wind also DG?

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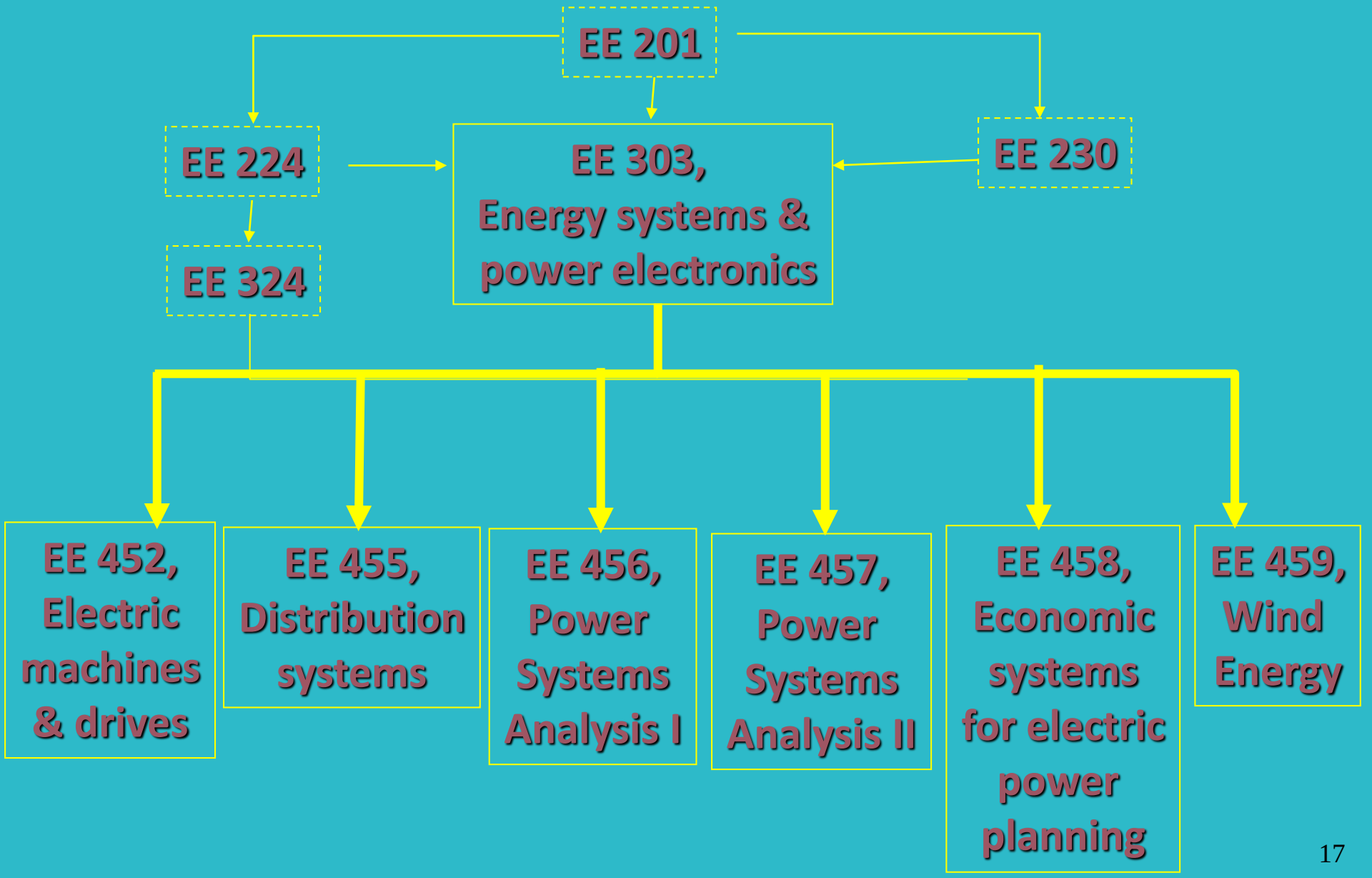

For whom might you work? (below - mainstream comp only)

- Investor-owned utilities: 239 (MEC, Alliant, Xcel, Exelon, …)
- Federally-owned: 10 (TVA, BPA, WAPA, SEPA, APA, SWPA…)
- Public-owned: 2009 (Ames, Cedar Falls, Dairyland, CIPCO…)
- Non-utility power producers: 1934 (Alcoa, DuPont,…)
- Power marketers: 400 (e.g., Cinergy, Mirant, Illinova, Shell Energy, PECO-Power Team, Williams Energy,…)
- Coordination organizations: 10 (ISO-NE, NYISO, PJM, MISO, SPP, ERCOT, CAISO, AESO, NBSO)
- Oversight organizations:
  - Regulatory: 50 state, 1 Fed (FERC)
  - Reliability: 1 National ((NERC), 8 regional entities
- Manufacturers: GE, ABB, Toshiba, Schweitzer, Westinghouse
- Consultants: Black&Veatch, Burns&McDonnell, HD Electric,…
- Vendors: Siemens, Areva, OSI,…
- Govt agencies: DOE, EPA, Labs,…
- Professional & advocacy organizations: IEEE, IWEA, …