

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

James D. McCalley

Professor of Electrical and Computer Engineering  
Iowa State University Ames, IA

# 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

Direction of gas flows before 2005

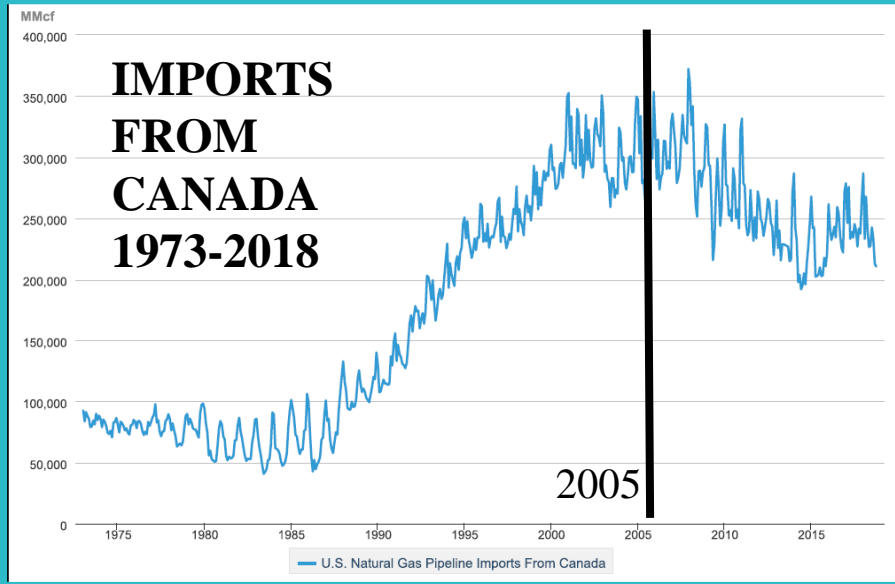


2005

Source: American Petroleum Institute

OHIO BUSINESS ROUNDTABLE

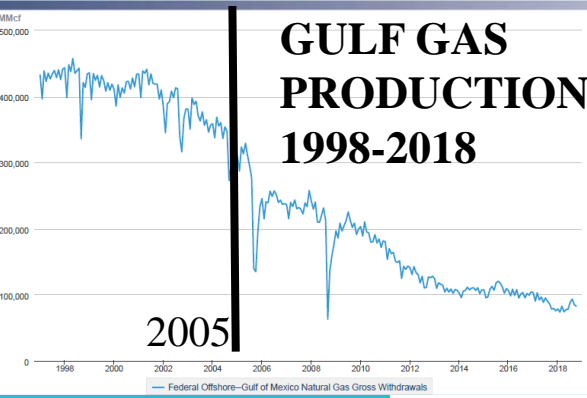
A23



IMPORTS FROM CANADA 1973-2018

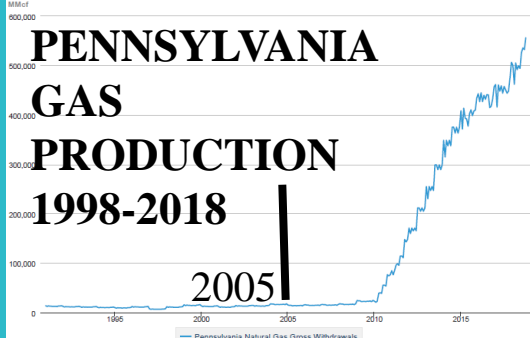
2005

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



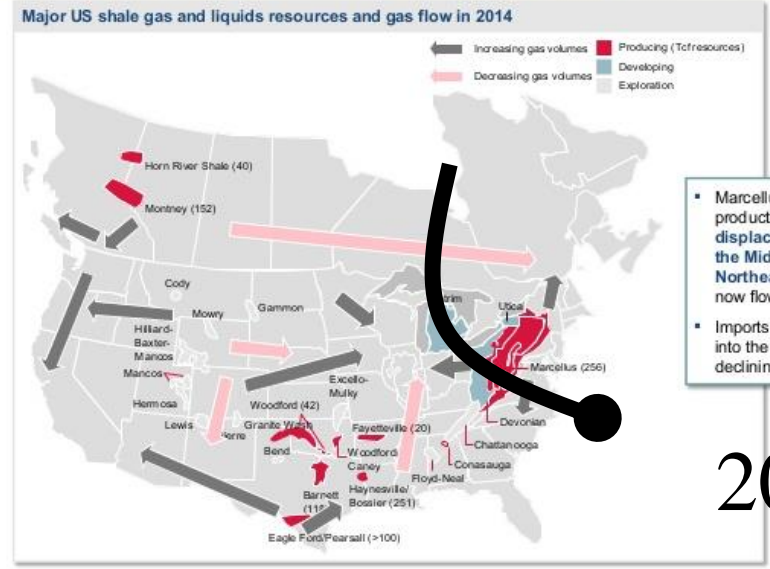
GULF GAS PRODUCTION 1998-2018

2005



PENNSYLVANIA GAS PRODUCTION 1998-2018

2005



Major US shale gas and liquids resources and gas flow in 2014

- Marcellus gas production is displacing inflows to the Mid-Atlantic and Northeast markets and now flows are reversing
- Imports from Canada into the US have been declining

2014

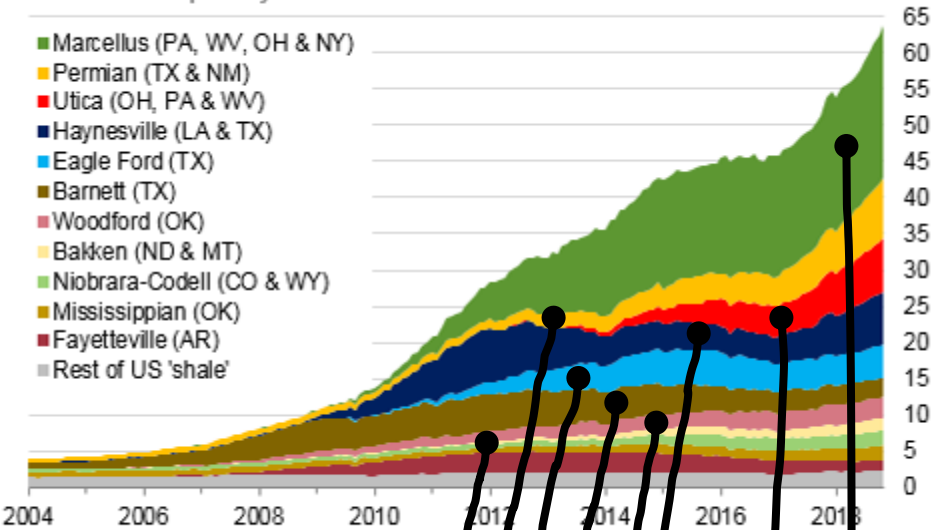
Source: Wood Mackenzie

OHIO BUSINESS ROUNDTABLE

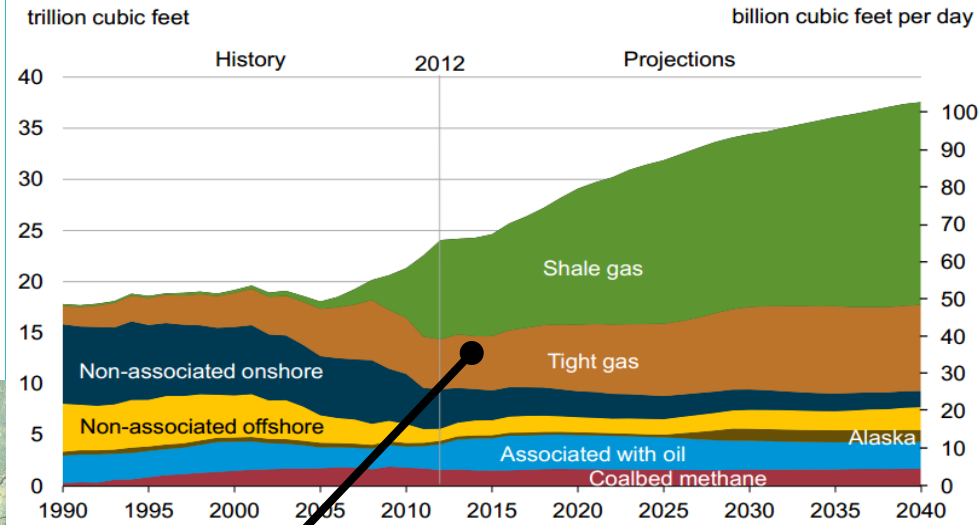
A24

# Shale gas growth

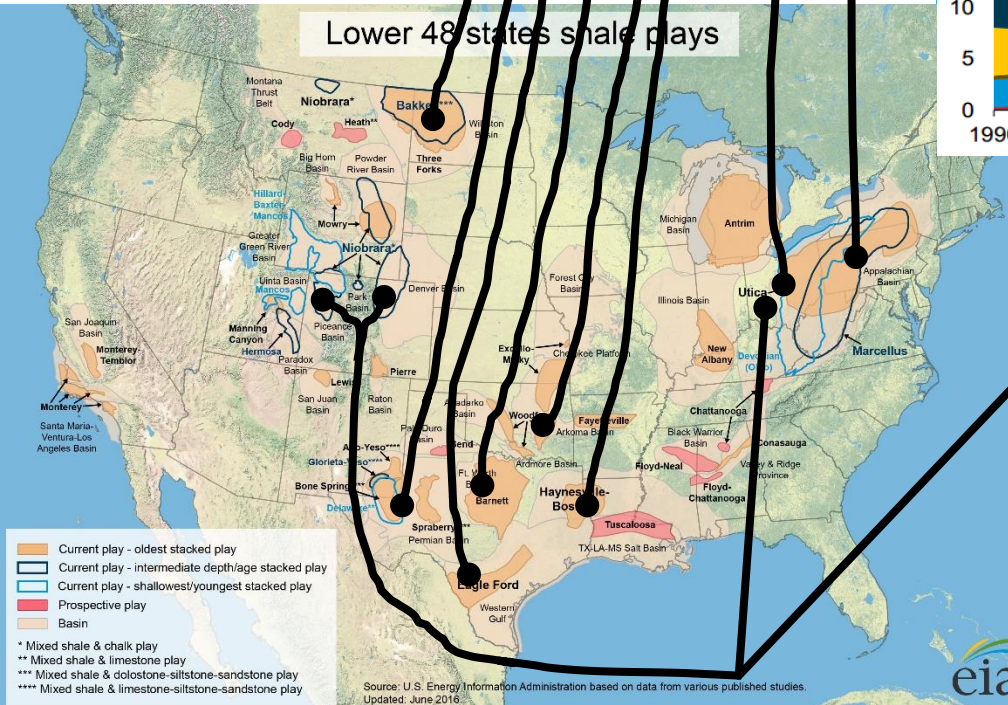
Monthly dry shale gas production  
billion cubic feet per day



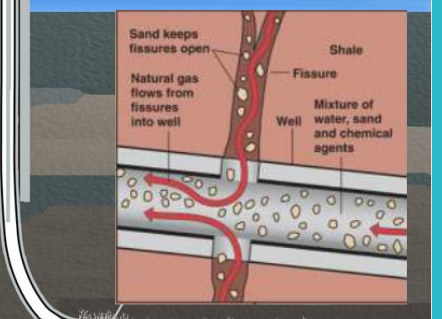
U.S. dry natural gas production  
trillion cubic feet



Lower 48 states shale plays



## Hydraulic fracturing



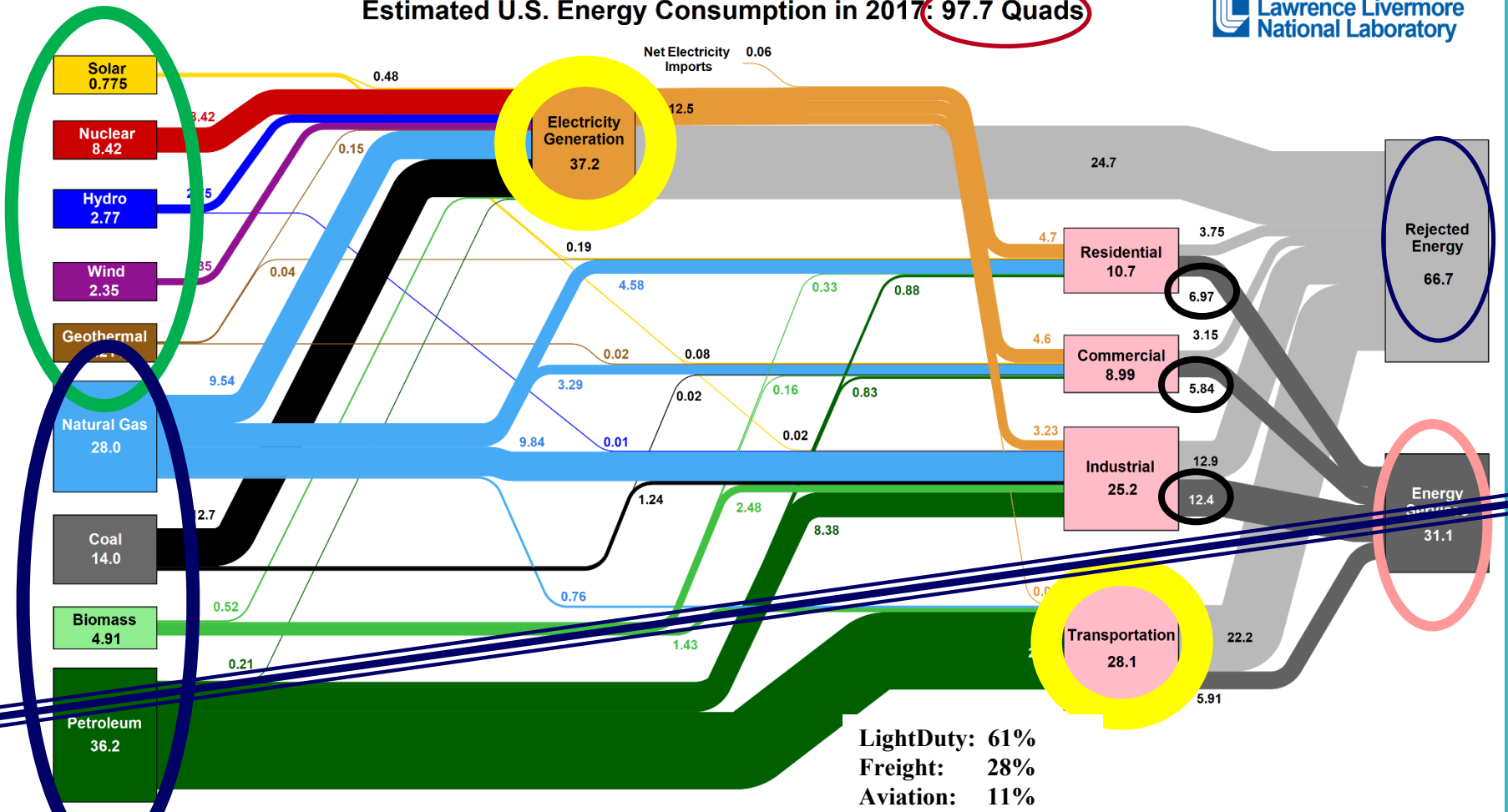
Source: U.S. Energy Information Administration based on data from various published studies. Updated: June 2016.



# The Big Picture!

Estimated U.S. Energy Consumption in 2017: 97.7 Quads

Lawrence Livermore National Laboratory



Source: LLNL April, 2018. Data is based on DOE/EIA MMR (2017). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. This chart was revised in 2017 to reflect changes made in mid-2016 to the Energy Information Administration's analysis methodology and reporting. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector, and 49% for the industrial sector which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

## US Energy View: 2017

<https://flowcharts.llnl.gov/>

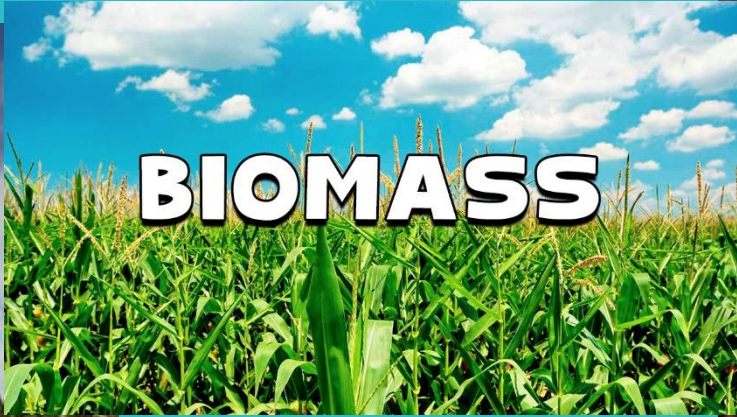
# Renewable Energy

# Geothermal

**Solar**



**BIOMASS**



Pacific Gas & Electric

It's Just Steam!

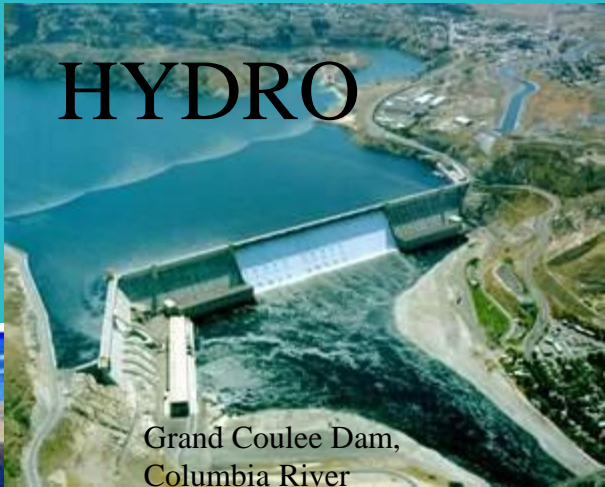
**WIND**



**Tidal**



**HYDRO**

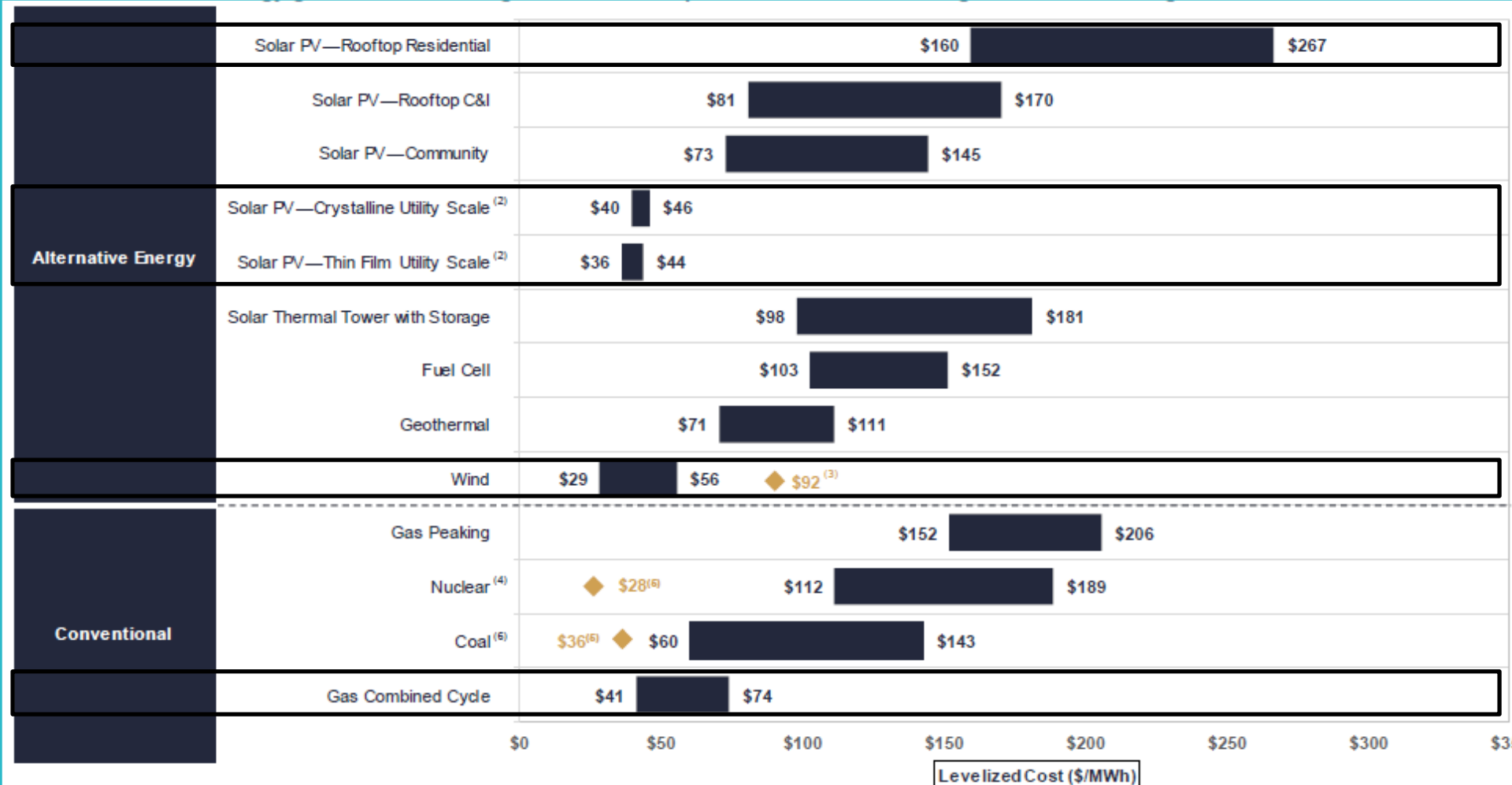


Grand Coulee Dam,  
Columbia River

# LCOEs from Lazard's (unsubsidized, 2018)

<https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-v-final.pdf>

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





NEWS ▾

SHOWS ▾

LIVE ▾



# It's now cheaper to build a new wind farm than to keep a coal plant running

BY IRINA IVANOVA

UPDATED ON: NOVEMBER 16, 2018 / 8:31 AM / MONEYWATCH



A Wood Mackenzie Business

news

research

squared

events

sign up

log in



Solar

Grid Edge

Storage

Wind

More

Trending

Podcasts

Resources



UTILITIES

## Xcel Resource Planning Executive: We Can Buy New Renewables Cheaper Than Existing Fossil Fuels

Jonathan Adelman discusses how the utility is setting an example in decarbonization ahead of his participation at the Power & Renewables Summit 2018.

JUAN MONGE | SEPTEMBER 11, 2018

16



[www.greentechmedia.com/articles/read/an-interview-with-xcels-avp-for-strategic-resource-business-planning-the-re#gs.M9DtFWIZ](https://www.greentechmedia.com/articles/read/an-interview-with-xcels-avp-for-strategic-resource-business-planning-the-re#gs.M9DtFWIZ)

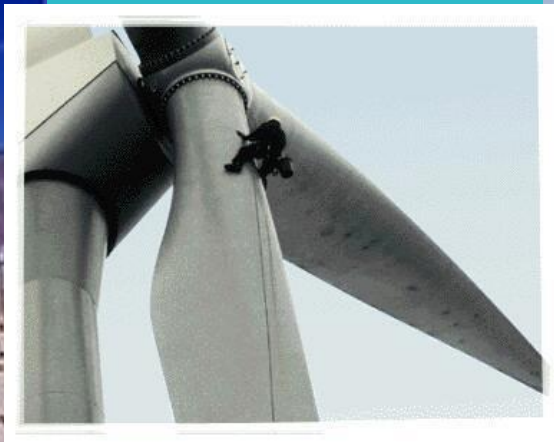
Want th  
Waiting for sync-tm.everestech.net...

gshuo.pdf Show all





Wind



# Where are US wind turbines today?

Source: US DOE, 2017 Wind technologies market report,

<https://www.energy.gov/eere/wind/downloads/2017-wind-technologies-market-report>

- 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

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%
<b>TOTAL</b>	<b>7,017</b>	<b>TOTAL</b>	<b>88,973</b>	<b>TOTAL</b>	<b>6.3%</b>

# The future: US wind potential by state



Annual wind energy potential (10<sup>12</sup> w-hrs)



Annual wind energy potential

$$R = \frac{\text{Annual wind energy potential}}{\text{2006 state annual retail sales}}$$

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.

# The future: US wind potential

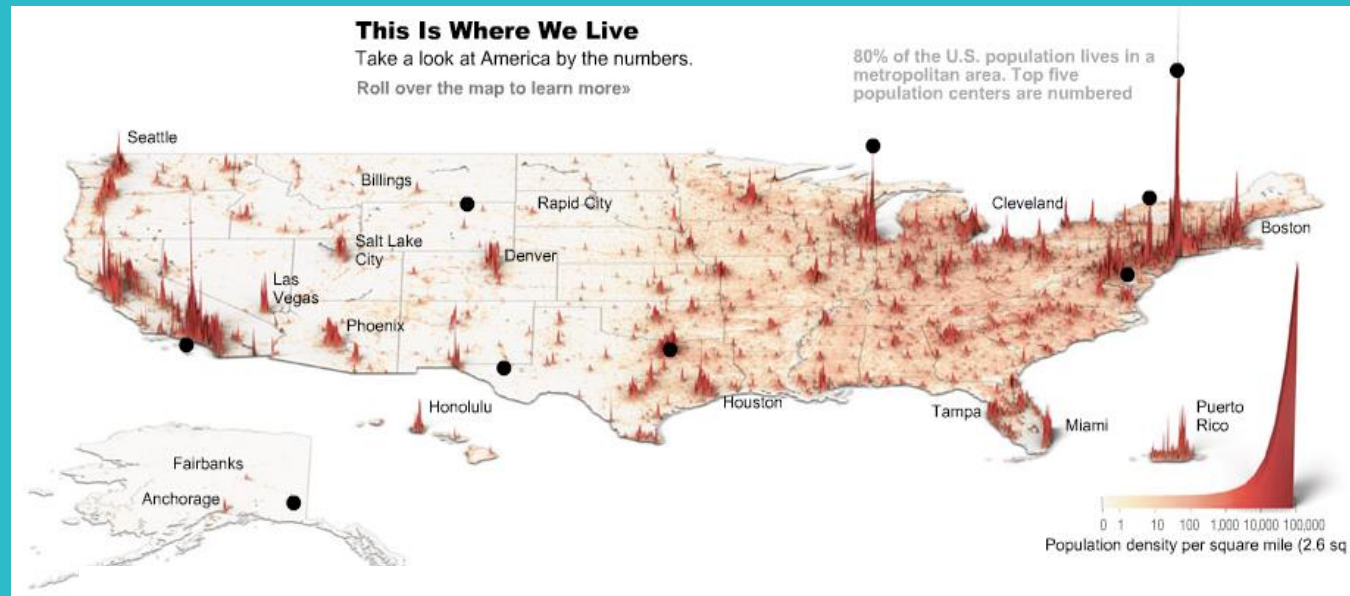
Contiguous US annual wind energy potential , 10 <sup>15</sup> wh		Multiples of Total US Energy Consumption*
Onshore	62	2.12
Offshore, 0-20 meter	1.2	.041
Offshore, 20-50 m	2.1	.072
Offshore, 50-200 m	2.2	.075
Total	68	2.321

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

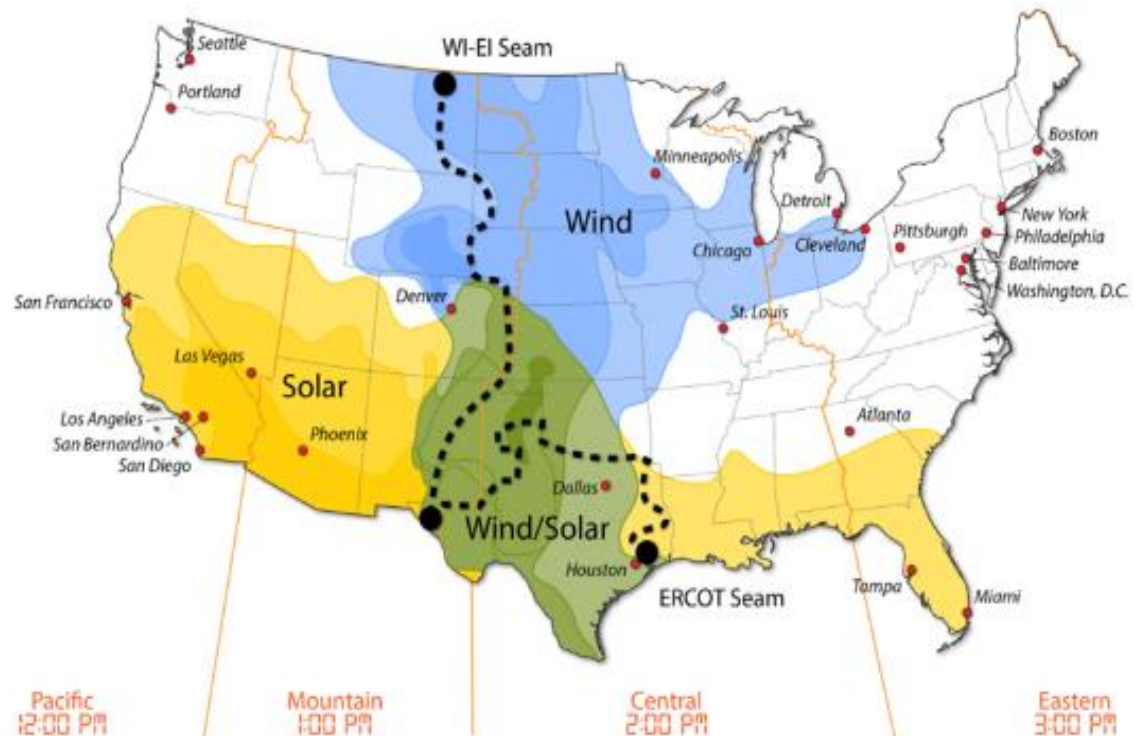
$$100Q \times \frac{1E15BTU}{Q} \times \frac{kwh}{3413BTU} \times \frac{1000wh}{kwh} = 29.3E15wh$$

Source: Xi Lua, M. McElroya, and J. Kiviluomac, "Global potential for wind-generated electricity," Proc. of the National Academy of Sciences, 2009, [www.pnas.org/cgi/doi/10.1073/pnas.0909101106](http://www.pnas.org/cgi/doi/10.1073/pnas.0909101106).

Where do we live in the US?

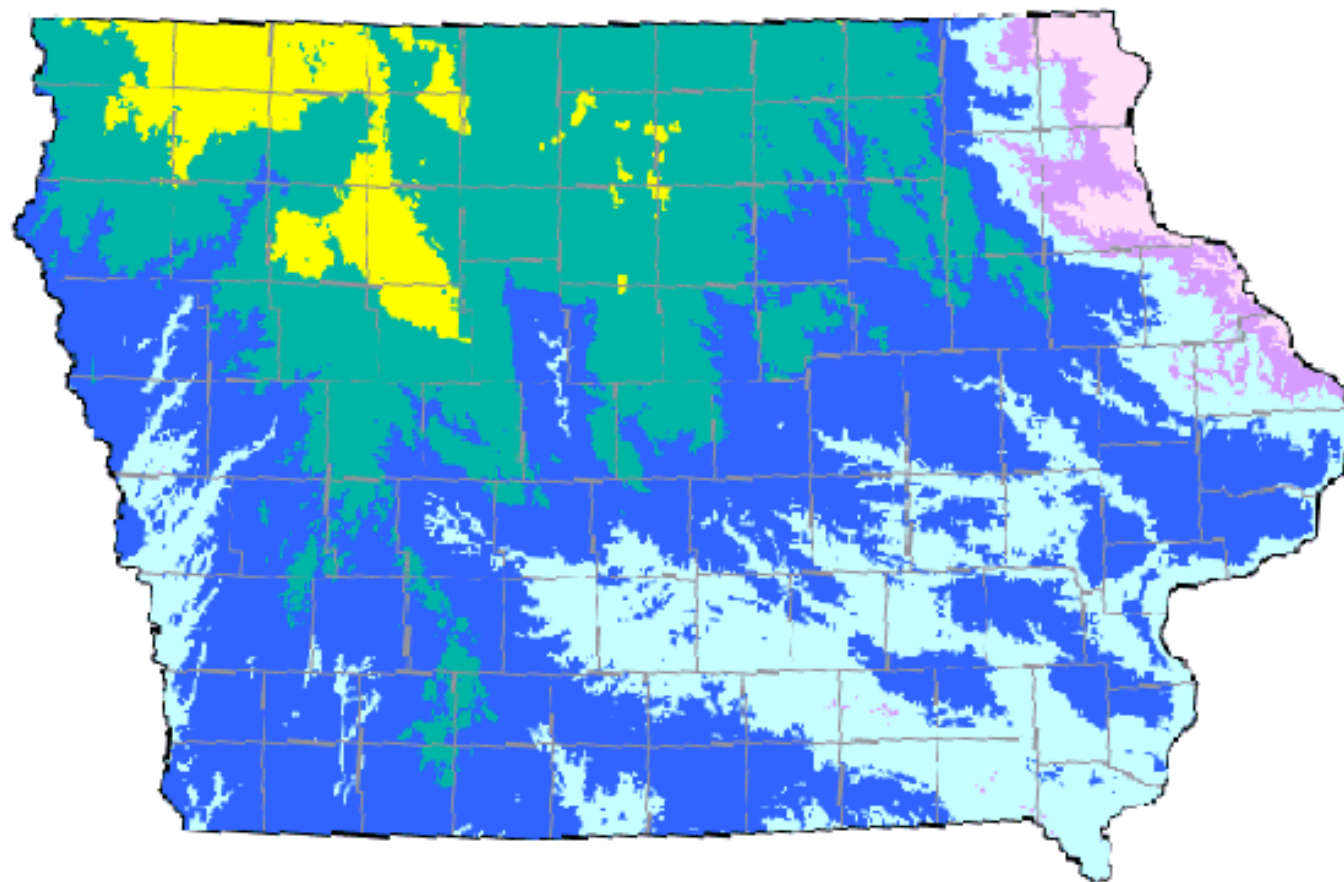


Where in the US are the economically most attractive electric resources?



## 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 Brover & Company, Andover, MA.

Copyright © 1997, Iowa Energy Center. All rights reserved. This map may not be republished without the written consent of the Iowa Energy Center.

# 100% Renewable?

News Article: Wind XII project po x Distributed generation vs central: x +

https://www.midamericanenergy.com/news-article.aspx?story=858

**MIDAMERICAN ENERGY COMPANY**  
Obsessively. Relentlessly. At Your Service™

888-427-5632 About Us Newsroom Careers Contact Us Customer Login

What can we help you find?

My Account Customer Service Rebates | Energy Savings Outages | Storms Safety Renewables

NEWS

Beware of Scams  
Fact Sheets  
Media Contacts  
Multimedia Gallery  
Get News Updates

## MidAmerican Energy News

### Wind XII project positions MidAmerican Energy to hit 100 percent renewable goal

DES MOINES, Iowa - (May 30, 2018) - MidAmerican Energy Company will be the first investor-owned electric utility in the country to generate renewable energy equal to 100 percent of its customers' usage on an annual basis, upon completing its newest proposed wind energy project.

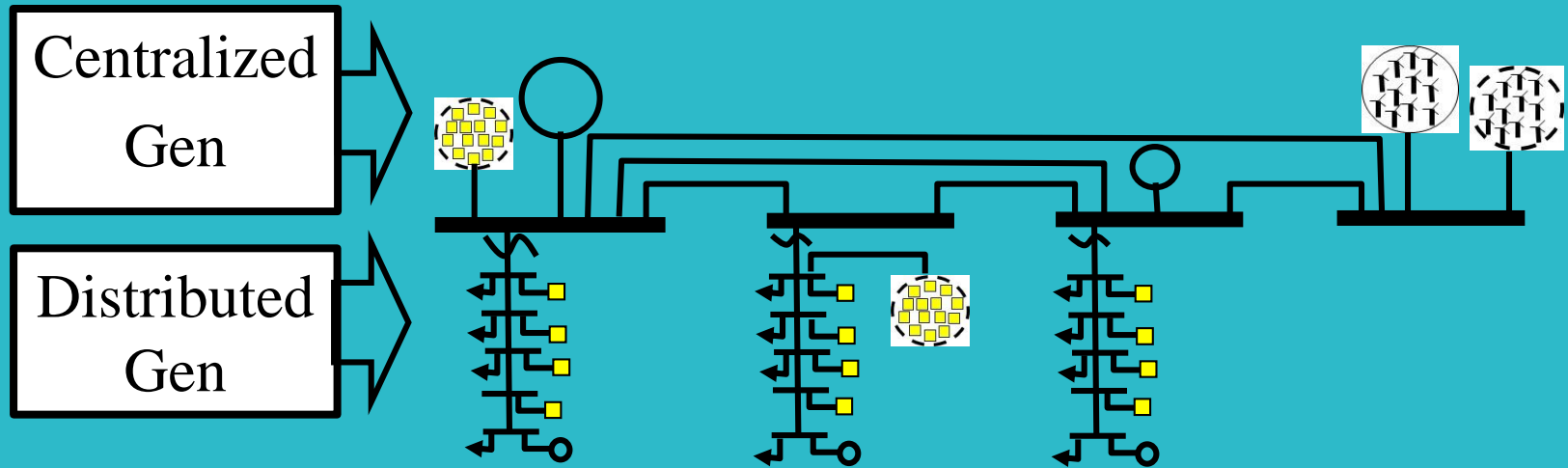
MidAmerican Energy proposed an additional investment of \$922 million with the announcement of its Wind XII project that will be formally filed with the Iowa Utilities Board later today. The project, if approved, is expected to be completed in late 2020. Over the past three years, MidAmerican Energy has moved forward with its previously announced Wind XI and repowering projects, that when combined with Wind XII, will provide customers with 100 percent renewable energy on an annual basis. And, like MidAmerican's previous wind projects, Wind XII will be accomplished without the need to ask for an increase in customers' rates.

UniAberdeen\_Frac...pdf ^ Show all x

Type here to search

10:38 AM 1/17/2019

# Distributed Generation



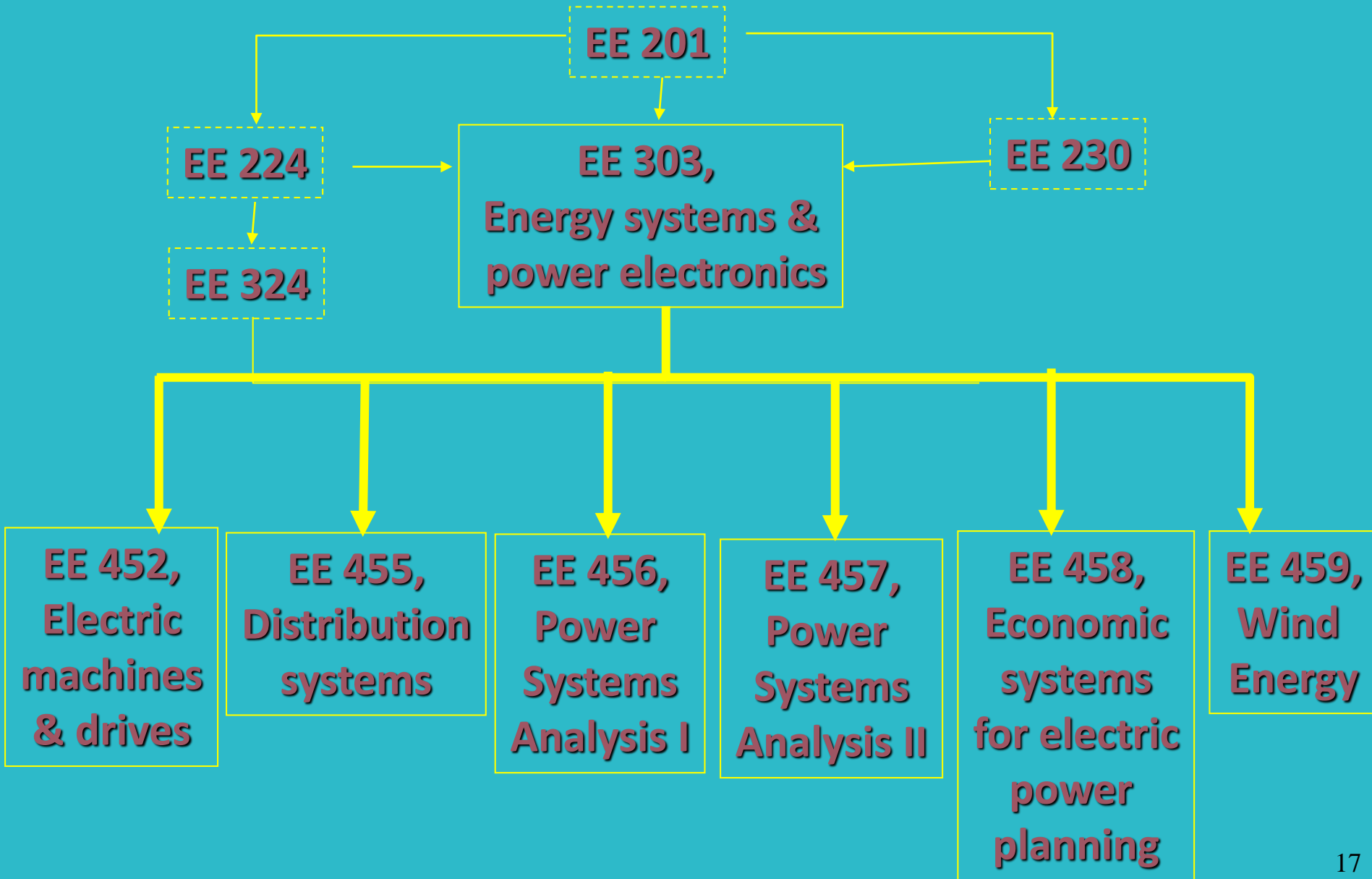
- PV: Solar photovoltaic.
- Microturbines: Gas-fueled small-sized generation, normally CTs.
- Rooftop PV: PV located on roofs of residential, commercial, industrial bldgs.
- Groundmounted PV: PV located on the ground.
- Utility-scale PV: A large-size PV plant, typically  $\gg 1\text{MW}$ , usually ground-mounted
- Community solar: A small, utility-scale PV plant financed by a local customer group.
- DG: Generation connected at the distribution system ( $\leq 34.5\text{ kV}$ ). 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?



The Electric Power + Energy Systems Group has excellent series of courses to prepare you for an exciting career....



## 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, ...