Climate Change and the Electric Grid

Ward Jewell
Wichita State University
Power Systems Engineering Research Center
Electric Power Generation
Electric Power Generation
Electric Power Generation
Electric Power Generation
Electric Generation
Bowersock Mills and Power Company
Lawrence, Kansas

1874, 2.5 MW

www.bowersockpower.com
Electric generation in Kansas

Energy Information Administration
www.eia.gov/state/?sid=ks
Operating and Proposed Wind Farms in Kansas

July 2013

Legend
Status
△ Operating
■ Under Construction
△ Proposed
◯ Status Unknown
△ No longer operating

For more information on individual wind projects, go to the Kansas Energy Information Network - Wind Projects page: www.KansasEnergy.org/wind_projects.htm
Energy vs. Power

$kWh$ and $kW$

Electric Power Monthly, Energy Information Administration
www.eia.gov/electricity/monthly/index.cfm (Energy)
www.eia.gov/electricity/state/kansas/index.cfm (Power)
Transmission
US Electric Transmission Grid

Global Energy Network Institute,
Environmental Challenges for the Electric Energy Industry

1. Mitigation of greenhouse gases
2. Adapting to changing climate
3. Availability of water
US CO₂ emissions

Coal: 205-225 lb CO₂/MMBtu
Oil: 156-174 lb CO₂/MMBtu
Gas: 117-139 lb CO₂/MMBtu

Energy Information Administration, US Department of Energy,
www.eia.doe.gov/environment/emissions/ghg_report/ghg_overview.cfm
Technologies to limit greenhouse gas emissions

**fuel switching: coal to natural gas**

Questions about hydraulic fracturing for natural gas production.

Shawnee, Oklahoma, earthquake 2011
St. Gregory's University
Nuclear Generation
Renewable Generators

Geothermal

Small Hydro

Biomass
Wind and electricity use

Solar energy and electricity use

20-year planning for western grid

- Cost estimates from DOE EIA
- Load price elasticity -0.8
  1% price increase causes 0.8% drop in use
- Average load growth 1.3%
  Varies significantly by state
- Generation types considered:
  dual unit advanced pulverized coal
  advanced natural gas combined cycle
  dual unit nuclear
  onshore wind
  onshore solar.

# Emissions regulations scenarios

## Natural gas prices:

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2022</th>
<th>2032</th>
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<tbody>
<tr>
<td><strong>$/MMBtu</strong></td>
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<tr>
<td>High Gas Prices (HG)</td>
<td>2.5</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Low Gas Prices (LG)</td>
<td>2.5</td>
<td>4.77</td>
<td>5.86</td>
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Emissions regulations scenarios

• Base:
  No new environmental policies
  No renewable incentives

• Cap and Trade (C&T)
  36.94 $/ton in 2022, 60.18 $/ton in 2032
  Renewables incentives 22 $/MWh

• EPA CO$_2$ regulation
  1000 lb/MWh CO$_2$ limit for new plants (no coal)
  Renewables incentives 22 $/MWh
WECC results
Zhouxing Hu, Wichita State

Retirements

Natural Gas
2022 2032
GW
-40.0
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0

Coal
2022 2032
GW
-40.0
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0

Base HG
Base LG
C&T HG
C&T LG
EPA HG
EPA LG
WECC results
New generation

800 MW Nuclear in 2032

**Wind Built in WECC**

- Base HG
- Base LG
- C&T HG
- C&T LG
- EPA HG
- EPA LG

**Solar Built in WECC**

- Base HG
- Base LG
- C&T HG
- C&T LG
- EPA HG
- EPA LG

800 MW Nuclear in 2032
Energy generated in WECC

- 2012
- 2022
- 2032

TWh

- Base HG
- Base LG
- C&T HG
- C&T LG
- EPA HG
- EPA LG

PSERC
Average Wholesale Prices in WECC

$/MWh

2012  2022  2032

Base HG  Base LG  C&T HG  C&T LG  EPA HG  EPA LG
CO₂ Emissions in WECC
Bulk Energy Storage
Battery storage technologies

Lead Acid

Vanadium Redox

Sodium Sulphur

Zinc Bromine
Western grid results with electric energy storage

Zhouxing Hu, Wichita State

- A more detailed planning model that included these storage technologies that were found to be economical in some scenarios:
  - Compressed air
  - Pumped hydroelectric
  - Vanadium redox batteries

- And these technologies that were not:
  - Sodium sulphur batteries
  - Lithium Ion batteries

WECC results with Electric Energy Storage
Simulation Results

- In HG cases, the average production costs drop significantly from 2022 to 2032 because fuel consumption shifts from natural gas to coal, nuclear, wind or solar generation.
- Base Cases have the highest average production cost because of the prevailing natural gas generation.
- C&T policy is the most effective way to reduce CO₂ emission regardless of natural gas price.
- CO₂ emissions in EPA cases are sensitive to natural gas price.
$60B: $0.0024 $/kWh if spread over all US kWh

American Electric Power, Interstate Transmission Vision for Wind Integration,
www.aep.com/about/1765project/docs/WindTransmissionVisionWhitePaper.pdf
1.34 lb CO_2/kWh x 250 x 10^9 kWh = 335 x 10^9 lb CO_2

152 MMT out of 2375 MMT produced by the industry in 2005 = 6.4%

Energy Information Administration, eia.doe.gov.
Demand Response

http://www.eia.gov/todayinenergy/detail.cfm?id=130
Carbon Sequestration

(Source: Geological Survey of Canada)
Residential rooftop solar

- Depends on:
  - Net metering
  - Incentives
  - Cost of PV cells

- Changes the electric distribution business significantly.
The electric energy system of the future will be substantially different from the system of today.

The electric energy business will change significantly.
Thanks to
Power Systems Engineering Research Center
pserc.org

ABB
American Electric Power
American Transmission Company
AREVA T&D
Arizona Public Service
Bonneville Power Administration
British Columbia Transmission Co.
California Independent System Operator
CenterPoint Energy
Duke Energy
Entergy
EPRI
Exelon
FirstEnergy Corporation
GE Energy
Institut de Recherche d'Hydro-Québec
ISO New England
ITC Holdings

MidAmerican Energy
Midwest Independent System Operator
National Grid USA
National Rural Electric Cooperative Association
New York Independent System Operator
New York Power Authority
Pacific Gas and Electric Company
PJM Interconnection
PowerWorld Corporation
Quanta Technology
Salt River Project
Southern California Edison
Southern Company
Tennessee Valley Authority
Tri-State Generation and Transmission
U.S. Department of Energy
Western Area Power Administration

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