TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCE
Vol. 123, no. 3-4
p. 403-413 (2020)

Kansas wind power status

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Wind-generated electricity has grown from a niche enterprise in the late 20th century to become a major energy source globally and nationally, and Kansas has played a significant role. Kansas wind power expanded more than six-fold between 2008 and 2018. Among states, Kansas now ranks fourth for total wind generating capacity (>6 GW) and second for combined wind and solar electricity production as a fraction of electricity consumption (47%). Kansas is virtually tied with Iowa for the highest amount of wind energy as part of the electric grid mix (>41%). From early development in the High Plains, wind farms and energy complexes have expanded into nearly all regions of the state. The drainage divide between the Missouri River and Arkansas River basins is a geographic focus for recent development of wind farms in eastern Kansas.

Generation of electricity in Kansas mirrors overall energy trends in the United States during the past two decades. Coal, petroleum, and nuclear have declined, hydroelectric has been stable, natural gas has grown, and renewable (wind, solar) energy has expanded dramatically. These shifts in energy sources are reflected likewise in significant declines of carbon, sulfur, and nitrogen emissions. Kansas reflects the international character of the wind-energy industry. Installed wind turbines are mainly of Danish, German, and/or Spanish origin with some components manufactured in Kansas and other nearby states.

Keywords: coal, GE Renewable Energy, petroleum, natural gas, Nordex Acciona, nuclear, Siemens Gamesa, solar, Suzlon, turbine, Vestas, wind energy, windscape.

INTRODUCTION

Wind-generated electricity has grown from a niche enterprise in the late 20th century to become a globally significant energy source, which surpassed 600 GW capacity in 2019 (IRENA 2020). China and the United States lead the world, accounting for more than half of total wind-energy capacity. Germany, India, Spain and the United Kingdom are the next major countries for wind energy (Table 1). Between 2009 and 2018, wind-energy production more than tripled in the United States (Sundby, Weissman and Sargent 2019), and the United States achieved 107 GW total capacity by mid-2020 (WindExchange 2020a). In addition, another 24.7 GW were under construction during the first quarter of 2020, and 19.6 GW were in advanced development both on land and offshore (AWEA 2020).

Among states, Texas, Oklahoma, Kansas, Iowa and Illinois led the nation in growth of wind energy for the years 2009 to 2018; Kansas wind power expanded more than six-fold during that period (Sundby, Weissman and Sargent 2019). We have reported previously on the emergence of wind energy in Kansas (Aber and Aber 2012, 2016). Given its continued rapid growth and geographic expansion, an update on the current status of wind-generated electricity in Kansas is appropriate.

KANSAS WINDSCAPE

We adopted the term *windscape* to refer to all factors related to wind-energy development, including natural, physical, technical, environmental, and such human aspects as aesthetics, health, economic development, and

Table 1. Top ten countries for installed wind-energy capacity at the end of 2019. Capacity given in GW; capacity and percentage values rounded; data provided by IRENA (2020).

Country	Capacity	Share (%)
1. China	210	34
2. United States	103	17
3. Germany	61	10
4. India	38	6
5. Spain	26	4
6. United Kingdom	24	4
7. France	16	3
8. Brazil	15	2
9. Canada	13	2
10. Italy	11	2
Rest of world	106	17

public policy (Aber, Aber and Pavri 2015). The windscape of Kansas is particularly suitable for development of wind farms. Much of the state consists of broad, mostly treeless, rural, upland terrain with relatively low human population and excellent to good wind potential. Some places, of course, are not suitable for constructing wind farms for environmental, technical, or aesthetic reasons. Nonetheless, Obermeyer et al. (2011) found that with appropriate mitigation for wildlife nearly half the state would be feasible for development of wind energy. Further analysis by the Nature Conservancy has shown that 36% of the state is suitable for wind-energy development and 21% is low-impact suitable land (TNC 2019).

The Kansas Department of Commerce (KDC 2019) projected that the state could provide up to 7 GW of wind-generated electricity for export to other states by 2030, and a 10-year property tax exemption is offered to encourage development of renewable energy. For the period 1984 through 2015, Dodge City was the windiest city in the contiguous (48) United States with an average wind speed of 5.8 m/s, and Goodland was the fifth windiest at 5.4 m/s (Table 2). It is not surprising that the first large wind farm in Kansas was constructed just 20 miles (~32 km) southwest of Dodge City (Fig. 1).

Table 2. Five windiest cities in the contiguous (48) United States. Near-surface, average wind speed for the period 1984 to 2015 given in meters per second. Based on data from Stockdale (2019).

City	Wind
1. Dodge City, KS	5.8 m/s
2. Amarillo, TX	5.7 m/s
3. Cheyenne, WY	5.5 m/s
4. Rochester, MN	5.4 m/s
5. Goodland, KS	5.4 m/s

Early development took place mainly in the High Plains, Blue Hills and Flint Hills. Wind farms have expanded during the past few years into the Chalk Buttes, Smoky Hills, Arkansas River Lowlands, Osage Cuestas, and glaciated region (Figs. 2 and 3). The Flint Hills, however, is a moratorium area. In 2004, the Heart of the Flint Hills Area exclusion zone was proposed by Governor Sebelius, and Governor Brownback expanded the exclusion zone in 2011. The goal was to preserve intact tallgrass prairie habitat that was least altered by human activities and had the greatest scenic beauty (Aber and Aber 2016).

The divide between the Missouri River and Arkansas River drainage basins is a geographic focus for recent development of wind farms in eastern Kansas. This divide is the highest topographic feature in east-central and southeastern Kansas and, thus, has excellent wind potential, which is greater toward the west and declines eastward. Four wind farms

Figure 1. Gray County Wind Farm, the first large array of wind turbines erected in Kansas in 2001. Vestas V47 turbines are relatively small and closely spaced along field boundaries compared with newer and much larger wind turbines. Kite photograph by the authors.

have been constructed on or near the Missouri-Arkansas drainage divide during the past several years (Table 3; Fig. 4).

On the other hand, a proposed wind-energy project in Reno County, which includes Hutchinson, was blocked by a grass-roots initiative in 2019. Citizens were concerned about the conversion of rural aesthetic values for industrial development. Those opposed to the wind farm had forced a protest petition that required unanimous approval by the county commission (Shorman 2019). When one commissioner voted no, the project was halted; the first wind farm to be rejected in Kansas during the past decade.

Kansas now ranks fourth among states for wind-generated electricity with >6 GW installed capacity (Table 4). Wind energy represents >41% of total Kansas electricity capacity, virtually tied with Iowa for highest in the nation. Wind is the biggest energy source for electricity generated in Kansas,

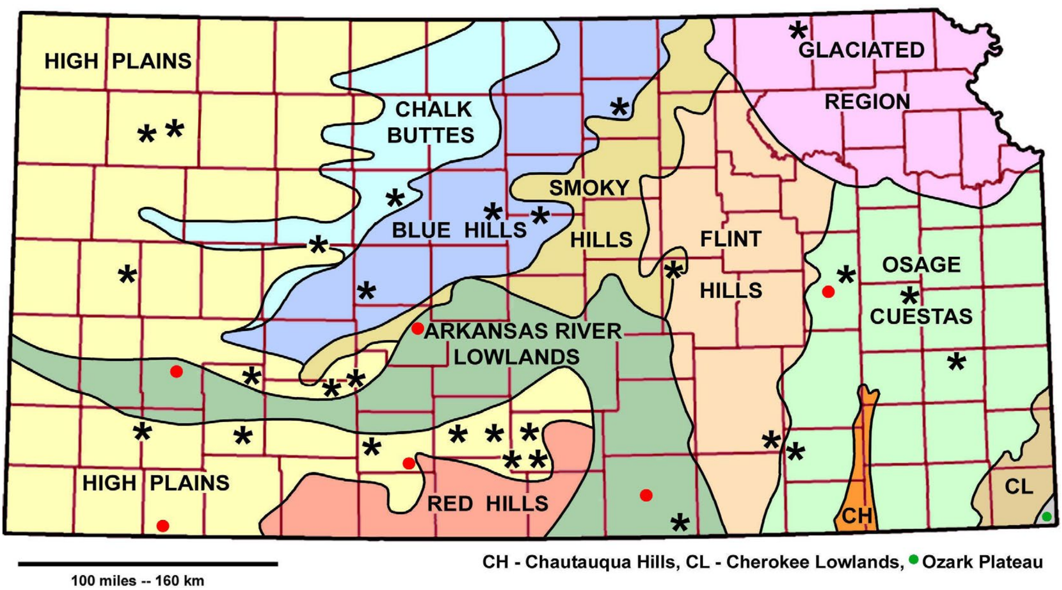

Figure 2. Landscape regions of Kansas. Asterisks (*) indicate approximate locations for large operating wind farms or wind-energy complexes, and red dots show railroad logistics and transportation centers. Adapted and updated from Aber and Aber (2016).

Table 3. Wind farms in eastern Kansas located on or near the Missouri-Arkansas drainage divide, arranged from west to east. Wind speed is average at 100 m height, given in meters per second (KDC 2016). Other data derived from KGS (2019), EDP (2020), and USWTD (2020).

Wind farm	Diamond Vista	Reading	Ad Astra	Prairie Queen
Region	Smoky Hills	Osage Cuestas	Osage Cuestas	Osage Cuestas
County	Marion	Lyon, Osage	Coffey	Allen
Bedrock geology	Kiowa Formation, Cretaceous	Wabaunsee Group, Pennsylvanian	Shawnee Group, Pennsylvanian	Kansas City Group, Pennsylvanian
Turbine type and capacity	Nordex 3.15 MW	Siemens 2.3 MW and Siemens Gamesa 3.4 MW	Gamesa 2.1 MW	Gamesa 3.55 MW and 2.625 MW
Wind speed	8.5-9.0 m/s	8.0-8.5 m/s	8.0-8.5 m/s	7.5-8.0 m/s
Year online	2018	2020	2015	2019

larger than coal plus natural gas combined (WINDExchange 2020b). In fact, Kansas ranks second in the nation in combined wind and solar electricity production as a percentage of electricity consumption within the state (Sundby, Weissman and Sargent 2019). Only North Dakota exceeds Kansas (Table 5).

Rapid growth of wind energy has spurred development of support activities and infrastructure associated with the construction of wind farms. For example, a large transportation and logistics center serves southwestern Kansas from the BNSF Railway depot in Garden City (see Fig. 2). Turbine components are delivered via special railcars, off-loaded for temporary storage, and eventually transported by oversized trucks to

Figure 3. Marshall Wind Energy complex east of Beatite in the glaciated region. Vestas V110, 2.0 MW turbines; towers stand 95 m tall and rotor diameter is 110 m. The turbines are located on a local drainage divide, known as the Summit, between the Roubidoux Creek basin to the west and North Fork Black Vermillion River basin to the east. This wind farm began operation in 2016.

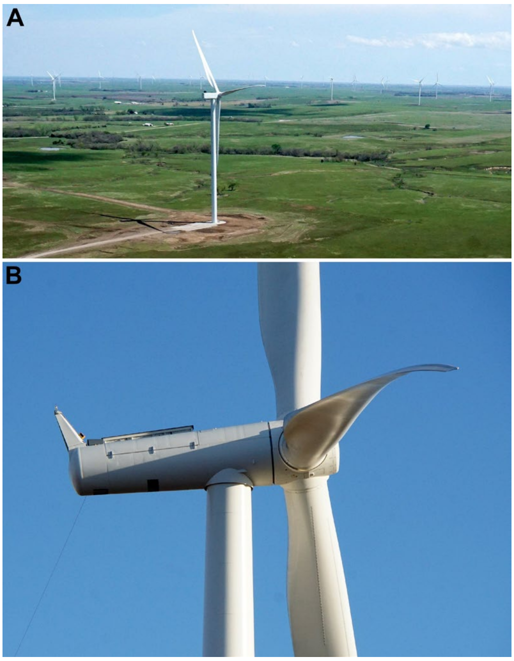

Figure 4. Newly erected, but not yet operational Siemens Gamesa wind turbines in the Reading wind farm in the spring of 2020. Located near the Missouri-Arkansas drainage divide in the Osage Cuestas, Lyon County, east-central Kansas. A – aerial overview, kite photograph by the authors, and B – close-up view showing curved blades and nacelle.

wind-farm construction sites. Other logistics centers have been established by the BNSF Railway, Union Pacific Railroad, and K&O Railroad in southern and eastern Kansas (Fig. 5).

Kansas fuel resources

Coal, petroleum (oil), natural gas, and nuclear (uranium) were primary fuel sources for generating electricity in the 20th century. Kansas was formerly a major source for coal early in the 20th century, particularly from numerous coal beds in Middle Pennsylvanian strata from the Cherokee Lowlands (see Fig. 2). However, most coal mines ceased operating in the mid-20th century. In the early 21st century, coal strip-mining continued in Bourbon and Linn counties near the Missouri border, and these mines supplied coal to nearby electric-generating plants. The last coal mine in Kansas shut down at least temporarily in 2016 (GeoKansas coal 2020).

Table 4. Top ten wind-energy states for installed capacity as of 2019. Capacity given in GW; data from WINDExchange (2020a).

State Rank	Capacity
1. Texas	29.41
2. Iowa	10.66
3. Oklahoma	8.17
4. Kansas	6.13
5. California	5.94
6. Illinois	5.66
7. Minnesota	3.84
8. Colorado	3.76
9. North Dakota	3.64
10. Oregon	3.42
All states total	107.32

The recent role of coal in Kansas electricity generation is illustrated well by events at Holcomb, near Garden City. The current coal-fired electric-generating station at Holcomb was built in the early 1980s. It uses low-sulfur coal from Wyoming's Powder River Basin (Fig. 6) along with advanced technology to limit emissions of sulfur, nitrogen, and mercury gases (Sunflower 2020). Its nameplate capacity was listed at 349 MW in 2019 (EIA 2020). A plan to expand the generating station was proposed in 2007.

The expansion proposal was rejected initially by the Kansas Department of Health and Environment, because of carbon dioxide

Table 5. Ranking of states for combined wind and solar electricity production as a percentage (%) of electricity consumption within the state as of 2019. Data from Sundby, Weissman and Sargent (2019).

State	Consumption
1. North Dakota	54
2. Kansas	47
3. Oklahoma	44
4. Iowa	43
5. New Mexico	32
6. Wyoming	25
7. South Dakota	22
8. Maine	22
9. California	21
10. Colorado	21

emissions and concern about global warming. A revised and downsized plan for an 895-MW plant was finally approved in 2010, whereupon the Sierra Club filed suit to block the project. The state Supreme Court eventually approved expansion of the generating station in 2017, but the Tri-State Generation and Transmission Association declined to pursue the project (Hancock 2017). Early in 2020, Sunflower Electric Power finally abandoned its effort to build the $2.2 billion coal-fired generating station after spending $100 million on the project (Swaim and Shorman 2020).

Since the initial proposal in 2007, new federal regulations and the impact of renewable (wind) energy had made construction of the Holcomb plant less attractive economically. In fact, no new coal-fired electric power stations have been built or brought online in the United States since 2015. Older coal-fired plants have been closed down every year since 2012 with more closures planned in the near future. From a total capacity of nearly 320 GW nationally a decade ago, coal-fired generating capacity is projected to shrink to less than 200 GW by 2025 (DiSavino 2020).

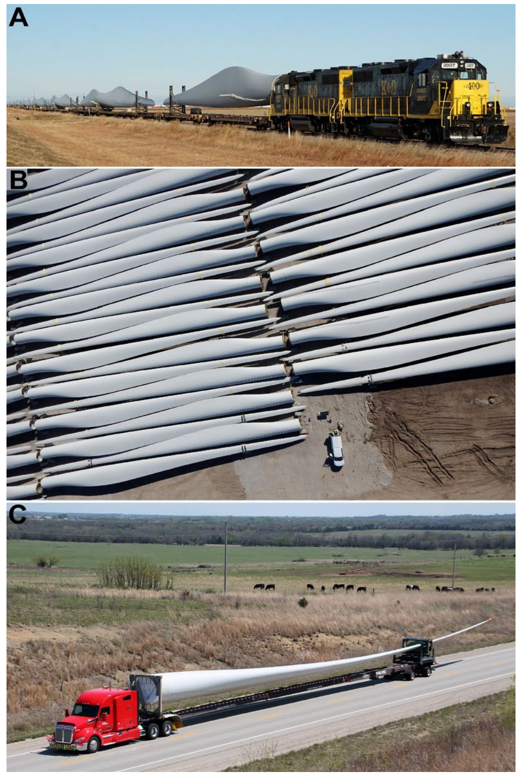

Figure 5. Railroad logistics and truck transportation of turbine blades in Kansas. A – turbine blades on the K&O Railroad wait for unloading at a storage area near Larned. B – vertical view of turbine blades stored in the BNSF Railway depot at Emporia. Service truck provides scale; kite photograph by JSA with D. Leiker. C – turbine blade transported by truck on state highway 99, Elk County. These blades are typically about 50-60 m long.

While coal is declining nationally as a fuel source for generating electricity, natural gas has experienced considerable growth. Numerous sources of natural gas are found in Kansas, including a sizable portion of the huge Hugoton

Figure 6. BNSF Railway coal train at Las Animas in southeastern Colorado heading east toward the coal-fired electric generating station at Holcomb, Kansas, and perhaps beyond.

Field, which is the largest natural gas field in North America and among the largest in the world (KGS Hugoton 2001). As a relatively clean fuel in abundant supply, electric utilities have turned to natural gas. The Emporia Energy Center, for example, is a natural-gas fired generating station designed to operate during high-peak demand periods, such as hot summer days. It was put online in 2008 and had a nameplate capacity of 720 MW in 2019 (EIA 2020).

Nuclear energy underwent rapid development during the mid-20th century with the promise of cheap, clean, and virtually unlimited supply. Kansas has one nuclear power plant, the Wolf Creek Generating Station near Burlington in Coffey County. The station went online in 1985, and is licensed to operate until 2045 (USNRC 2018). Its nameplate capacity was listed at 1268 MW in 2019 (EIA 2020). However, the allure of nuclear energy has faded with concerns about safety, mining, proliferation, and disposal of nuclear wastes (Aber, Aber and Pavri 2015).

Kansas and national energy trends

Kansas trends in power plants and electricity generation mirror those of the United States overall for the past decade (Table 6). For fossil fuels, the number of coal-fired power plants has declined by >40% and petroleum by 8%, but natural-gas power plants have increased by 12%. Small changes are noted for nuclear (9% decline) and hydroelectric (2% increase) power plants. On the other hand, renewable energy power plants (solar, wind) have increased more than three-fold.

Payback for capital investment for conventional fossil-fuel generating plants is typically many years to decades. In contrast, the payback period

Table 6. United States electric industry power plants by predominant energy sources for the period 2008 through 2018. * Renewable includes wind plus solar. Data derived from EIA (2019a, Table 4.1); percentages rounded to whole values.

Year	Coal	Petroleum	Natural gases	Nuclear	Hydro-electric	Renewable*
2008	598	1170	1698	66	1462	1076
2018	336	1087	1900	60	1498	4667
% change	-44	-8	+12	-9	+2	+334

Table 7. United States emissions of CO_2, SO_2, and NO_x from conventional power plants and combined-heat-and-power plants, 2008 through 2018. Data derived from EIA (2019b, Table 9.1); emissions in 1000s of metric tons, percentages rounded to whole values

Year	Carbon dioxide	Sulfur dioxide	Nitrogen oxides
2008	2,484,012	7,830	3,330
2018	1,874,346	1,571	1,485
% change	-25	-80	-55

for a wind farm is only a few years. Haapala and Prempreeda (2014), for example, calculated the cradle-to-grave costs of all materials, manufacturing, transportation, construction, operation, and decommissioning for 2.0 MW turbines of typical mechanical characteristics and 20-year lifespan. They found the financial payback for a single turbine was less than one year. Wind energy, thus, represents a relatively fast return on investment compared with conventional power plants.

Solar-energy power plants have proliferated mainly in the sunny Southwest; whereas, wind energy has grown most in the Great Plains and Midwest regions. These trends likely will continue into the 2020s. Solar, wind, and natural gas will supply increasing shares of total electricity generation in the United States. Construction of new coal-fired or nuclear power plants seems unlikely for the foreseeable future. These shifts in energy sources are reflected likewise in significant declines of carbon, sulfur, and nitrogen emissions into the atmosphere (Table 7).

International connections

Kansas demonstrates the international character of the modern wind industry. Installed wind turbines are mainly of Danish, German, and/or Spanish origin with some components manufactured in Kansas and other nearby states. Siemens Gamesa is a good example (see Fig. 4), which illustrates the trend toward consolidation and international reach of modern wind-power companies (Siemens Gamesa 2020). Gamesa had its start in Spain 1976 as an industrial and technology company, and it entered the wind industry in partnership with Vestas in 1993 (see below). Bonus Energy began manufacturing wind turbines in Denmark in 1980.

Table 8. Top ten companies worldwide for manufacturing wind turbines and wind-energy technology. Market share (%) in 2018 based on sales. Companies with turbines in Kansas are highlighted in color. Data from Statista (2019).

Company	Country	Share
1. Vestas	Denmark	20.3
2. Goldwind	China	13.8
3. Siemens Gamesa	Spain	12.3
4. GE Renewable Energy	United States	10.0
5. Envision	China	8.4
6. Enercon	Germany	5.5
7. Mingyang	China	5.2
8. Nordex Acciona	Germany	5.0
9. Guodian United Power	China	2.5
10. Sewind	China	2.3

Both companies expanded rapidly into international markets in the late 1990s and early 2000s. Siemens (a German company) acquired Bonus Energy in 2004, which was renamed as Siemens Wind Power. In the United States, Siemens opened a turbine-blade factory in Fort Madison, Iowa (2007) and a nacelle assembly plant in Hutchinson, Kansas (2010). Gamesa and Siemens merged in 2017 with headquarters in Spain; as of 2018, Siemens Gamesa Renewable Energy held a one-eighth share of worldwide wind-turbine manufacturing (Table 8).

Nordex was founded in Denmark in 1985, part of the Danish revolution in wind energy (Nielsen 2009), and Nordex moved to Germany in 1992. Acciona Windpower built its first wind farm in Spain in 1994, and since

Figure 7. Vestas wind turbines. A – early, small Vestas turbine in operation on the island of Fejø, southeastern Denmark (1987). Note access door and person at bottom of tower for scale. B – Vestas Tower manufacturing plant south of Pueblo, Colorado. V100, 1.8 MW turbine on right was erected in 2010 and is designed for light-wind and/or high-altitude operation.

expanded rapidly. Nordex and Acciona merged in 2016 (Acciona 2020) and, as of 2018, was the eighth largest wind-energy company with a 5% share of the worldwide market.

Vestas and GE Renewable Energy also continue as major suppliers for wind turbines in Kansas. Vestas was a relatively small Danish company that manufactured agricultural equipment and hydraulic cranes in the 1970s. Vestas acquired the designs and rights for the Herborg Vind Kraft (HVK) machine,

Figure 8. Tackle wind turbines manufactured in Germany and seen here in 1998 at Swarzewo, near Władysławowo, northern Poland. Tackle is the ancestor for modern GE turbines, which are found in many Kansas wind farms.

which was the prototype for all modern wind turbines, and commercial production began in 1979 (Musgrove 2010). Vestas grew rapidly and became the world's largest wind-energy company, a position that it maintains with >20% of the global market. Vestas is headquartered in Denmark and has a tower manufacturing plant in Pueblo, Colorado (Fig. 7).

GE Renewable Energy is the only company with a primary base in the United States; it has a turbine-blade manufacturing facility in North Dakota as well as a components assembly plant in Florida and engineering offices in New York and South Carolina, but no manufacturing plants in Kansas (GE Renewable 2020). GE wind turbines are descendants of the German Tackle turbines of the 1990s (Fig. 8). Tackle went bankrupt in 1997 and was bought by Enron Wind, which was acquired subsequently by General Electric in 2002 (Aber, Aber and Pavri 2015).

Another noteworthy international connection is the small wind farm at Greensburg, which is equipped with 10 Suzlon turbines from India

(USWTD 2020). This wind farm came online in 2010 in response to the devastating tornado that demolished most of Greensburg in 2007. As these companies demonstrate, the wind industry in Kansas is truly international in scope.

Acknowledgments

Several people have assisted us with observations and kite aerial photography of Kansas wind farms over the years including David Leiker, Jim Schubert, Cheryl Unruh, and many students from Emporia State University. We were introduced to early wind turbines in Denmark by Preben Jensen and in Poland by Dariusz Gałązka. We thank two anonymous reviewers who offered comments for improving this article.

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