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Kansas windscape - 2016 status

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Kansas has played a significant role for the growth of wind energy in the United States. Kansas ranks sixth among states for wind-energy capacity, and is third in the nation for per-capita production of electricity from the wind. Wind farms are sited in topographically high positions on uplands, drainage divides, escarpments, and other rural sites in which there are few or no obstacles to interrupt near-surface wind flow. The best regions of the state include the High Plains, especially in southwestern Kansas, the Blue Hills and Flint Hills, and on the Missouri-Arkansas drainage divide in the Osage Cuestas. Rapid development of wind energy has taken place in these regions during the past few years, except for the Flint Hills, which is an exclusion zone for new wind farms. Bird and bat mortality remains an issue, but with appropriate wildlife mitigation much more wind energy could be developed in Kansas. Aesthetic issues include visibility and noise. Developing safe and renewable energy resources that have minimal environmental impacts is a priority in the twenty-first century. Wind energy from Kansas is part of the solution.

Wind-power overview

At the turn of the twenty-first century, the United States, China, Germany, Spain, and India emerged as the largest producers of electricity from wind energy, and the U.S. was the leading wind-energy country in the world. By 2012, China had surpassed the U.S. with total installed generating capacities of 75 GW and 60 GW respectively (WindPower Countries 2016). Since then, China continues to lead the world in generating capacity (Table 1). However, the United States is the world's leading producer of wind-powered electricity. Although China has a much larger installed generating capacity, the wind resource and actual production of electricity are greater in the U.S. In 2015, the U.S. generated approximately 190 million megawatt-hours (MWh), China 185 million MWh, and Germany 85 million MWh (AWEA 2016). During this period, Kansas has played a significant role for the growth of wind energy in the United States.

The first large wind farm in Kansas was constructed in 2001 on the High Plains near Cimarron. The Gray County Wind Farm has 170 Vestas V47 turbines with a nominal generating capacity of 112 MW (KEIN 2016). By current standards, these turbines have relatively small rotors (47 m diameter), short towers (55 m), and are closely spaced along field boundaries (Fig. 1). The next large wind farm was completed in 2005 in the southern Flint Hills. The Elk River Wind Farm has 100 GE 1.5-MW turbines with a nominal generating capacity of 150 MW (KEIN 2016). Similar GE turbines are erected in many other wind farms of Kansas. They typically have rotor diameters of 100 m and towers 80-96 m tall. Development of wind energy continued apace, until by 2012 Kansas had a dozen large wind farms with a combined generating capacity of approximately 1.33 GW (Aber and Aber 2012), which was more than the generating capacity of the Wolf Creek nuclear power plant (1.16 GW; EIA 2012).

Spurred by tax and financial incentives and governmental mandates, rapid growth has taken place since 2012. Currently installed wind-generating capacity is 3.77 GW, nearly a three-fold increase since 2012, which places Kansas sixth among states for wind-energy capacity (Table 2). Wind power now generates

Figure 1. Gray County Wind Farm was the first large wind-energy development in Kansas in 2001. It contains 170 Vestas V47 turbines with a combined capacity of 112 MW. By current standards, these are relatively small turbines that are closely spaced. Fields with winter wheat (green) alternate with fallow fields (brown) in this spring view. Kite airphoto by SWA and JSA.

nearly one-quarter of electricity needs for Kansas, which ranks the state third in the nation for per-capita wind energy (Table 3). Turbines in Kansas wind farms were manufactured in Denmark, India, Spain, and the United States (KEIN 2016), and Siemens built a turbine manufacturing plant in Hutchinson to supply the rapidly growing midwestern market. By 2017, the number of large wind projects is projected to reach 30, and the total nominal generating capacity is estimated to surpass 4.5 GW (based on data from KEIN 2016).

Table 1. Top 10 countries ranked by installed wind-generating capacity (GW) at the end of 2015 (GWEC 2016).

Country rank	Capacity
1. China	145
2. United States	74
3. Germany	45
4. India	25
5. Spain	23
6. United Kingdom	14
7. Canada	11
8. France	10
9. Italy	9
10. Brazil	9

Table 2. Top 10 wind-energy states ranked by generating capacity. Values given in GW installed capacity, end of 2015. Based on data from WINDExchange (2016).

State Rank	Capacity
1. Texas	17.71
2. Iowa	6.21
3. California	6.12
4. Oklahoma	5.18
5. Illinois	3.84
6. Kansas	3.77
7. Minnesota	3.24
8. Oregon	3.15
9. Washington	3.08
10. Colorado	2.99

Table 3. Top 10 states ranked according to percentage of electricity per capita generated by wind energy during 2015. Based on data from AWEA (2016).

State Rank	%
1. Iowa	31
2. South Dakota	26
3. Kansas	24
4. Oklahoma	18
5. North Dakota	17
6. Minnesota	16
7. Idaho	16
8. Vermont	15
9. Colorado	14
10. Maine	11

Figure 2. New transmission line and substation under construction to serve the wind-energy complex surrounding Spearville near Dodge City, Kansas. This vicinity of the High Plains has the greatest concentration of wind farms in Kansas. Photo by JSA.

The term windscape refers to all those factors related to development of wind energy (Aber et al. 2015). A quick scan of Tables 2 and 3 reveals that windscape conditions in the United States are generally best in the Great Plains and Midwest regions. This is where the best wind resources are found spread across extensive, sparsely populated, rural, mostly prairie or agricultural terrain. This windscape region reaches from western Indiana to eastern Colorado and from Texas to North Dakota. Across vast areas, average wind speed generally exceeds 7 m/sec at 80 m height and in the best locations is greater than 8 m/sec (WINDExchange 2016).

Kansas wind energy

General conditions

Like other Great Plains states, Kansas is well known for wind, but more than wind is necessary for successful siting and operation of wind farms. Essential windscape factors include topography, wind, and electrical transmission lines, as well as environmental and aesthetic aspects. For Kansas, the best wind potential is found in parts of the southwest and north-central portions, where mean annual wind speed at 100 m height exceeds 9 m/sec (KCC 2008). In all cases, wind farms are situated in topographically high positions on uplands, drainage divides, escarpments, and other such sites in which there are few or no obstacles to interrupt near-surface wind flow. Access to existing nearby electrical transmission lines is crucial for developing wind power, as such lines are quite costly to construct or upgrade. In nearly all cases, wind farms also have dedicated electrical substations to connect with the regional grid system (Fig. 2).

Kansas is part of the Eastern Interconnection electrical grid system, which serves most of the eastern United States and central Canada (Combs 2008). Throughout this interconnection, alternating current is synchronized so that

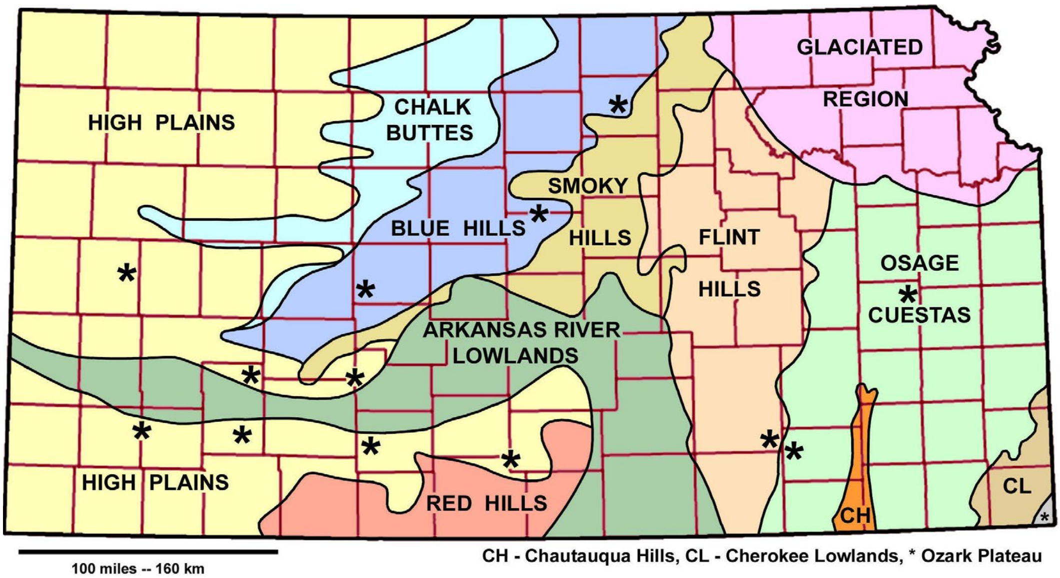

Figure 3. Physiographic regions of Kansas. Asterisks (*) indicate vicinities with large operating wind farms or wind-energy complexes (2015). The High Plains, especially in southwestern Kansas, has the greatest number of wind farms followed by the Blue Hills, Flint Hills, and Osage Cuestas. Adapted from Aber and Aber (2009).

electricity may be produced and consumed anywhere within the system. The Kansas-Colorado border is the boundary with the Western Interconnection. Electricity generated by wind energy in Kansas is sold to local utilities, such as Westar Energy (Topeka, Kansas) and Empire Electric Company (Joplin, Missouri), as well as such distant eastern customers as the Tennessee Valley Authority.

In regards to environmental issues, the Nature Conservancy undertook a statewide analysis of wind-energy impacts on wildlife in Kansas (Obermeyer et al. 2011). They found that with appropriate mitigation for wildlife, wind energy could be developed on more than 10 million hectares (nearly half the state) totaling 478 GW capacity, while still achieving wildlife conservation goals. Compensatory mitigation includes permanent protection of playas, conservation easements for grassland, and fire management for prairie-chicken habitat. This finding suggests that much more wind power could be developed in Kansas without undue impacts on wildlife and related environmental conditions.

Aesthetic issues are more difficult to gauge; some members of the public are adamantly opposed to wind farms as eyesores in the landscape, whereas many are indifferent, neutral, or even find wind farms visually intriguing and attractive features. This raises the concept of thin vs. thick aesthetic considerations (Saito 2004). The thin qualities are seen in a snapshot view that takes in only the immediate windscape; whereas, the thick values include the overall environmental significance of wind energy. Although many people support the environmental benefits of relatively safe, non-polluting energy harvested from the wind, the not-in-my-backyard attitude often applies when wind farms are proposed in their own neighborhoods (Good 2006).

Regional development

Original target regions for wind-power development were the High Plains, Blue Hills, and Flint Hills (Fig. 3; Aber and Aber 2012), which have the best wind-energy potential (>8.0 m/sec average wind speed at 80 m height). During the period 2012-2016, most construction of new wind projects took place

Figure 4. Meridian Way Wind Farm is situated on the Blue Hills escarpment in Cloud County, north-central Kansas. Above – total of 67 Vestas V90 3.0-MW turbines have a nominal generating capacity of 201 MW. Meteorologic tower to left records wind and other weather factors for analysis of turbine performance. Kite airphoto by SWA and JSA. Below – International character of the wind industry in Kansas. Vestas, the world's largest maker of wind turbines, is based in Denmark, and EDPR, among the largest operators of wind farms, is based in Spain. Photo by JSA.

in the High Plains and Blue Hills (Fig. 4). Existing wind farms were expanded and many new wind farms developed in these regions. Among the newest projects in western Kansas is the Alexander Wind Farm completed in 2015 in the Blue Hills region (KEIN 2016). It has 33 Siemens turbines with a nominal generating capacity of 48 MW (Fig. 5). Originally developed by OwnEnergy, it was acquired by New Jersey Resources. The Kansas City Board of Public Utilities bought 25 MW and Yahoo Inc. purchased the remaining production.

Further wind-energy growth has been curtailed in the Flint Hills, however, because of the Heart of the Flint Hills Area exclusion zone, first proposed by Governor Sebelius in 2004 (Aber et al. 2015). This moratorium area was relatively restricted in geographic coverage to that portion of the Flint Hills that preserved the most intact tallgrass prairie habitat, was least altered by human activities, and had the greatest scenic beauty. Elk River and Caney River wind farms are situated to the south in Butler and Elk counties respectively, outside the original Heart of the Flint Hills Area, but nonetheless exhibit typical Flint Hills conditions (Fig. 6).

In 2011 Governor Brownback more than doubled the extent of the exclusion zone (Brownback 2011). Elk River and Caney River wind farms were allowed to continue, and construction of new transmission lines across the Flint Hills is also allowed in order to transport wind-generated electricity from numerous large wind projects in central and western Kansas. In the meantime, the U.S. Fish and Wildlife Service moved toward preserving more than one million acres (>400,000 ha) within the Flint Hills for wildlife habitat (USFWS 2010). The targeted region corresponds closely with Sebelius's original moratorium area.

Farther east, the Osage Cuestas has seen recent construction of a large wind farm on the drainage divide between the Missouri and Arkansas basins, which has the best wind-energy potential in the eastern portion of the state (7.5 m/sec

Figure 5. Siemens turbines in a portion of the Alexander Wind Farm, Rush County. Components of these turbines were manufactured presumably at the Siemens factory in Hutchinson. Siemens is a descendent of Danregn and Bonus, both early Danish makers of wind turbines in the 1980s. Photo by JSA.

average wind speed at 80 m height). The Ad Astra Wind Farm is the first large wind project east of the Flint Hills in the state (Fig. 7). The wind-power industry in Kansas has reached a mature status in which large wind projects are populated by scores of turbines with more-or-less standard design features and dimensions, as the previous examples demonstrate. In addition to this wind-power infrastructure, Kansas consumers now have the option to purchase all or part of their electricity from renewable (wind or solar) sources for a small surcharge. Westar Energy, for instance, predicts that by the end of 2017, one-third of its retail energy would come from the wind (Westar 2016).

Environmental issues

Concerns about visibility, noise, and wildlife are among the most common voiced by the public (Wind Energy EIS 2016). Regarding visibility, wind turbines have a similar profile to other tall man-made objects such as radio and cell-phone communication towers. The primary difference in appearance is the fact that wind turbines move, and human vision has excellent motion perception (e.g. Smith and Ledgeway 2001).

Wind farms situated along US highway 50 near Spearville and either side of I-70 west of Salina are particularly visible to the public. For example the 2015 average annual daily traffic count on I-70 in vicinity of the Smoky Hills Wind Farm was 12,500 vehicles, and US 50 at Spearville recorded 4500 vehicles (KDOT 2016). At night, for instance, wind farms have blinking red lights on selected turbines to warn approaching aircraft. The lights throughout a wind farm are supposed to blink in unison according to FAA regulations (Kalinowski 2007). In our experience, however, this is not always the case within certain wind farms or between adjacent wind farms.

Figure 6. Caney River Wind Farm is situated on a prominent escarpment of the Americus Limestone in western Elk County. The Flint Hills crest is visible on the western horizon. Vestas V90 turbines; the towers are 80 tall, and the blades are 44 m long. The fin on the nacelle is for cooling purposes. This wind farm includes 111 turbines with a nominal generating capacity of 200 MW. Kite airphoto by JSA and J. Schubert.

Much research has been conducted on turbine noise, and regulations for wind farms exist particularly in Europe. The U.S. Occupational Safety and Health Administration has established limits for sound in the workplace (OSHA 2016). Field testing has shown that most turbines generate sound in the ~300-1250 Hz range (Oerlemans 2011), which is well below the high frequency that poses greatest danger for human hearing. Most of the noise from turbines is generated by the trailing edge of the blade. Methods to reduce trailing-edge noise include optimized airfoil shape, swept blades, and serrations or brushes along the trailing edge of the blade (Fig. 8).

The wind generates natural background sounds that many people find pleasing, and at increasing wind speed background sound may mask turbine noise. According to Manolev et al. (2016), turbine *noise is a minor problem today*. In the authors' experience, noise from large, modern turbines barely rises above background noise levels of wind blowing across the Kansas windscape. Ultimately, visibility and noise are matters of individual perception, which vary widely from person to person.

The greatest wildlife hazard posed by wind turbines is for flying animals, namely birds and bats, as well as habitat loss and fragmentation. Ground-based wildlife is generally less affected by turbines and wind farms. In fact, deer and other animals take advantage of turbine shadows to find a spot of relief from the sun during hot summer weather in some Kansas wind farms (Aber et al. 2015). Certain older wind farms in California are well-known for high bird mortality (e.g. Thelander et al. 2003); however, modern turbines are taller and rotate slower and, so, represent less risk for birds. For example, remediation and modernization of the Altamont Pass, California wind-energy complex between 2005 and 2010 reduced bird deaths by approximately half (Lynes 2013).

Figure 7. Ad Astra Wind Farm in the Osage Cuestas near Waverly, Kansas. New Gamesa G114 2.0-MW turbines from Spain. A total of 95 turbines would provide a nominal generating capacity of 190 MW. Turbines were assembled but not yet operating in this view. The traditional barn provides a striking contrast with modern turbines. This wind farm is operated by EDP Renewables, also from Spain. Photo by JSA.

Species of particular concern in Kansas include greater and lesser prairie-chickens (*Tympanuchus cupido* and *T. pallidicinctus* respectively). Optimal prairie-chicken habitat consists of intact tallgrass prairie free of woody encroachment with prescribed burning roughly once every third year (Obermeyer et al. 2011). Since pre-settlement time, prairie-chicken populations have declined substantially as a result of habitat loss and changes in land use. In 2014 the U.S. Fish and Wildlife Service listed lesser prairie-chicken as an endangered species (USFWS 2014). However, the lesser prairie-chicken was removed from the list officially in 2016 following a 2015 court order in Texas (USFWS 2016). Multi-year investigation has shown surprisingly that prairie-chickens are not adversely affected by wind farms; in fact, female survival rates increased after wind turbines were installed at the Meridian Way Wind Power Facility in north-central Kansas (Sandercock 2013).

Bird mortality at wind farms has gained considerable public attention in recent years, but the plight of bats is less appreciated (Aber et al. 2015). Migratory tree bats have the greatest risk for wind-turbine mortality, particularly the hoary bat (*Lasiurus cinereus*), eastern red bat (*Lasiurus borealis*), and silver-haired bat (*Lasionycteris noctivagans*), all of which reside in or migrate across Kansas (Sparks et al. 2011). The Red Hills is especially important for many bat species. This region has numerous caves and is among the most significant in the United States for bat biodiversity. Bat mortality has been noted especially at the Smoky Hills Wind Farm (J. Choate, pers. com. 2008). Wooded valleys run along the base of the Blue Hills escarpment on which the wind farm is situated. However, little is known about bat mortality at other Kansas wind farms (e.g. Hays 2013).

Figure 8. Serrated edges on blade tips for GE turbines. Seen here in the BNFS Railway storage depot at Garden City, Kansas. To the authors' knowledge, few blades of this type are deployed in Kansas wind farms. Photo by JSA.

Rapid increase of atmospheric CO_2 and its potential global warming impact are major environmental issues of general concern worldwide. From a pre-industrial level of ~280 ppm, global mean atmospheric CO_2 concentration exceeded 400 ppm in 2015 and continues to increase (NOAA 2016). This level already has surpassed the presumed tipping point of 350 ppm, beyond which uncertain or irreversible environmental consequences may take place (Foley 2010). Developing safe and renewable energy resources that have minimal environmental impacts is a priority for humanity in the twenty-first century (Aber et al. 2015). Wind energy from Kansas is part of the solution; diverse energy sources must be integrated into a production and delivery system in which the strengths of each type offset weaknesses for other types.

Conclusions

Kansas has played a significant role for rapid growth of wind energy during the early twenty-first century in the United States, which is the world's leading producer of wind-generated electricity. The windscape of Kansas is especially well suited for this purpose, and with appropriate mitigation for wildlife much more wind energy could be developed. Best regions are the High Plains and Blue Hills as well as other prominent upland sites. Wind power now generates nearly one-quarter of electricity needs for Kansas, and it is likely to expect this portion would increase within the next few years. Much more energy of all types is necessary to support growing human population and increasing living standards in the twenty-first century; wind energy from Kansas is part of the solution.

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