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Chapter 2

Texas Climate

Introduction

Texas has more diverse weather on a typical day than any other state within the union—with the possible exception of California. The assortment of weather elements that characterizes Texas' climate is due not merely to its inordinate size, but also to its strategic position on the North American continent. Its proximity to the relatively warm waters of the Gulf of Mexico, as well as its susceptibility to wind flow from the eastern North Pacific, ensure that the Texas atmosphere will be amply fed with enough energy to keep its weather in an almost constant state of flux. Moreover, during much of the year Texas is within reach of the migration of cool air from Canada, and the inevitable interaction of air masses of varying densities impacts the quality and variety of renewable energy resources available to Texans on a daily basis.

For example, the coupling of Texas' location in the mid latitudes of the northern hemisphere with its predominantly flat or gently-rolling terrain contributes to an almost incessant flow of air at Earth's surface in all seasons of the year. In much of the northern and western sectors of the state, where the topography consists largely of vast open spaces with minimal forested areas, wind flow is particularly substantial. The state's climate is sufficiently subtropical to ensure that even when the lower atmosphere is quite moist the sun shines the majority of the time, thereby furnishing a generous supply of solar radiation (insolation). The subtropical nature of the atmosphere also ensures a hefty amount of precipitable water (at least one inch) is present much of the time. This cloud water, within convective towers that form when a "trigger" is present (such as a frontal boundary), gets converted into rainwater, which upon reaching the ground may translate into increases in hydroelectric generation.

Fundamental to any understanding of available and renewable energy resources is the realization that energy is transferred from one place to another through radiation, convection, or conduction. Obviously, a superabundance of energy is propagated throughout the Texas atmosphere on a daily basis by means of radiation. In every season, but particularly in spring, summer, and autumn, the process of convection plays an integral role in the free exchange of energy as well, much of which is renewable. Whereas radiation transfer occurs with the speed of light and can happen without the presence of matter between the object radiating and the object receiving the energy, the other two avenues of transfer require the presence of some intermediate substance such as air. The lower atmosphere of Texas, with its deep boundary layer of heat and moisture, is well suited for the expeditious processing of reradiated energy through the mechanism of convection.

Extremes in the Weather

Any attempt to assess the weather's role in sustaining the renewable energy resources of Texas must begin with the recognition that the incoming supply of energy and moisture varies widely over both space and time. This huge disparity in available energy and moisture is responsible for the existence of both deserts and rain forest-type conditions in the Lone Star State. The dissimilarities that typify Texas weather are evidenced by a wide range of extremes in temperature and precipitation across the state (**Exhibit 2-1**).

Exhibit 2-1 Extremes in Texas Weather[1]

Category	Record	Location	Date
TEMPERATURE			
Coldest °F	-23°	Tulia Seminole	February 12, 1899 February 8, 1933
Hottest °F	120°	Seymour Monahans	August 12, 1936 June 27, 1994
RAINFALL			
Greatest in 24 hours	29.05 inches	Albany	August 4, 1978
Greatest in 1 month	35.70 inches	Alvin	July, 1979
Greatest in 1 year	109.38 inches	Clarksville	1873
SNOWFALL			
Greatest in 24 hours	24.0 inches	Plainview	February 3, 1956
Greatest in single storm	61.0 inches	Vega	February, 1956
Greatest in one season	65.0 inches	Romero	1923-1924
WIND			
Highest sustained speed	145 mph	Matagorda Port Lavaca	September 11, 1961 September 11, 1961
Highest peak gust	180 mph	Aransas Pass Robstown	August 3, 1970 August 3, 1970

The state's weather history illustrates how a wide array of weather—from an epic drought to devastating floods and catastrophic Arctic cold waves to relentless, killer heat—has been endured by Texans in every decade. It is the extremes in the weather that distinguish the state as a land of contrast and emphasize the degree to which Texas has at its disposal an immense atmospheric reservoir of renewable energy resources. An accurate characterization of Texas weather could not be made without due recognition of the extent to which the weather oscillates from one atypical level to another.

Average Weather as Indicator of Available Resources

Yet, it is not the extremes that provide clues as to how much renewable energy is available in Texas for consumption and preservation. Rather, it is the mean, or average, set of climatic conditions that best quantifies the extent to which Texas has been endowed with multiple and replenishable natural assets. For sure, several elements of the weather are particularly influential in the realm of renewable energy resources. These elements exert much more than mere nuisance value on a host of operations, and even on whole industries. For example, high humidity can lead to deterioration, mildew, and rotting of raw materials, or corrosion of metals. Poor visibility (due to fog, smoke, or dust) may impair the movement of workers and materials, though the restrictions imposed may be short-lived. Electrical storms with lightning and heavy rainfall or a strong, straight-line thunderstorm wind (downburst) can contribute to a significant curtailment of industrial operations.

Thus, it is imperative that a concerted effort be made to measure and quantify the whole array of climatic parameters that defines the state's renewable energy resources. Some parameters, most notably temperature and precipitation, have been well documented by a network of weather offices and volunteer weather stations maintained by the National Weather Service and its predecessor, the U. S. Weather Bureau. But many of the parameters (such as measures of wind speed and incoming solar radiation) that are critical to an accurate assessment of renewable resources have been poorly and inconsistently quantified until rather recently. For solar radiation, the instrumentation deployed has been shown to be only marginally helpful in characterizing how much energy is available, especially in sparsely-populated areas of the state. Wind data are considerably more plentiful, particularly for the period of the past two decades. Still, the bulk of the most reliable weather-observing equipment (such as anemometers and pyrheliometers with digital recording capability) continue to be predominantly cloistered around airports in the state's most heavily populated areas, where only a modest fraction of the total amount of renewable energy resources is distributed. Moreover, there is no centralized facility where these data are routinely collected, examined for quality-control purposes, and archived for ready accessibility. In those parts of Texas where such resources as solar radiation and wind flow are particularly ample, the sensors that detect them have been sparse and poorly positioned, or they have not been in operation for a long enough period to quantify what is considered to be "normal" weather. Over the years, existing networks of weather observations have been geared primarily to serve the interests of aviation and not those of energy capture, distribution, and consumption.

Precipitation

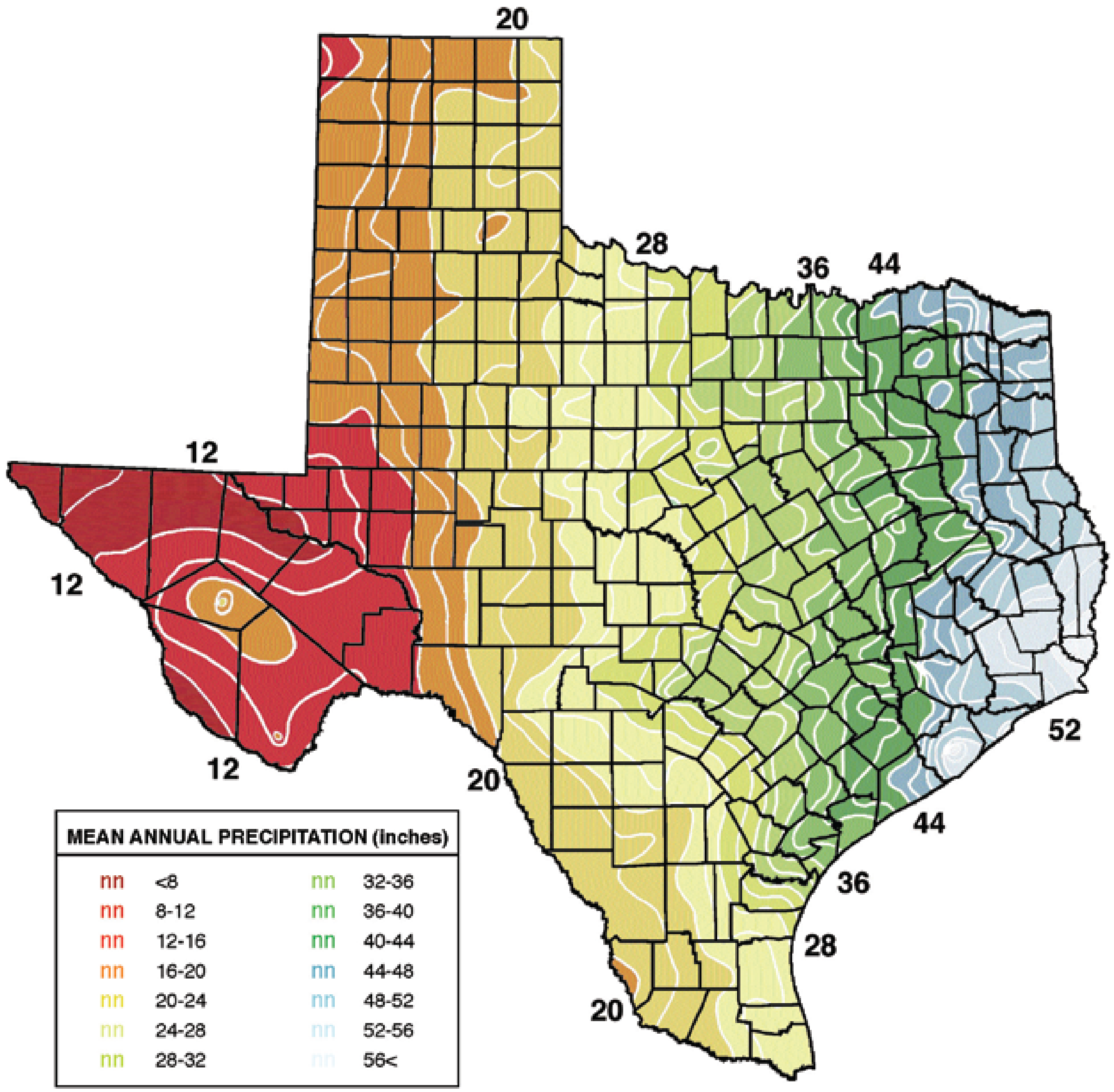
Nevertheless, enough data have been collected for long enough periods to allow a reasonable characterization of renewable climatic resources. The best-documented climatic resource, without a doubt, is precipitation, the bulk of which occurs in liquid form as rainfall. In a typical year, over half of Texas collects less than 30 inches of precipitation (**Exhibit 2-3**). The mean annual rainfall distribution is so diverse and disparate that the extreme western tip of Texas gathers a mere 8 inches while the easternmost edge along the Sabine River garners over 62 inches in a year. A rule of thumb is that precipitation, on an annual basis, decreases about 1 inch for each 15-mile displacement from east to west across Texas. So the Trans-Pecos region, with an average annual region-wide precipitation of under 12 inches, perennially is the driest climatic division of the state. By contrast, the eastern portion of the Upper Coast is the wettest region of the state, with a mean annual precipitation total of 55 to 60 inches.

Precipitation in a typical year is seldom spread even remotely uniformly across Texas. Virtually every region of the state has its "dry" and "wet" seasons (**Exhibit 2-2**). Spring is the wettest season of the year in most of Texas, with precipitation in the month of May somewhat more bountiful than in April. The exception is the western third of Texas (High Plains and Trans Pecos), where summer and early autumn furnish the bulk of the year's average rainfall. Thunderstorms, a sizeable number of which are nocturnal, are responsible for the bulk of rainfall in these regions.

Exhibit 2-2 Average Seasonal Precipitation (inches)

Location	Winter	Spring	Summer	Autumn	Annual
Abilene	3.37	5.91	7.39	7.11	23.78
Amarillo	1.79	4.96	8.90	4.06	19.71
Austin	6.32	9.68	8.09	9.56	33.65
Brownsville	3.65	5.37	7.69	10.84	27.55
Corpus Christi	5.21	7.27	9.07	10.71	32.26
Dallas-Ft Worth	6.84	11.41	7.38	9.10	34.73
El Paso	1.61	.87	4.11	2.84	9.43
Fort Stockton	1.57	2.69	4.99	4.81	14.06
Galveston	10.22	9.02	11.71	12.89	43.84
Houston	10.35	12.11	12.36	13.02	47.84
Laredo	2.55	5.20	7.20	6.58	21.53
Lubbock	1.88	4.36	7.47	4.98	18.69
Lufkin	12.06	11.95	9.86	12.75	46.62
Midland-Odessa	1.76	2.94	5.37	4.73	14.80
Port Arthur	14.29	13.42	16.66	15.52	59.89
San Angelo	2.94	5.68	5.67	6.62	20.91
San Antonio	5.37	9.21	8.90	9.44	32.92
Texarkana	12.66	13.66	10.85	14.07	51.24
Victoria	6.95	10.34	10.91	11.90	40.10
Waco	7.09	9.93	7.16	9.16	33.34
Wichita Falls	4.38	8.81	7.66	7.98	28.83

Exhibit 2-3 Average Annual Precipitation



Note: Based on 1961-1990 precipitation data from the cooperative weather observing network of the National Weather Service.[2] Intermediate contours (white lines) are indicated at 2 inch intervals. Throughout the data-sparse Trans-Pecos region, countours reflect higher uncertainty than in other parts of the state.

Exhibit 2-4 Average Monthly Minimum and Maximum Temperatures (°F)

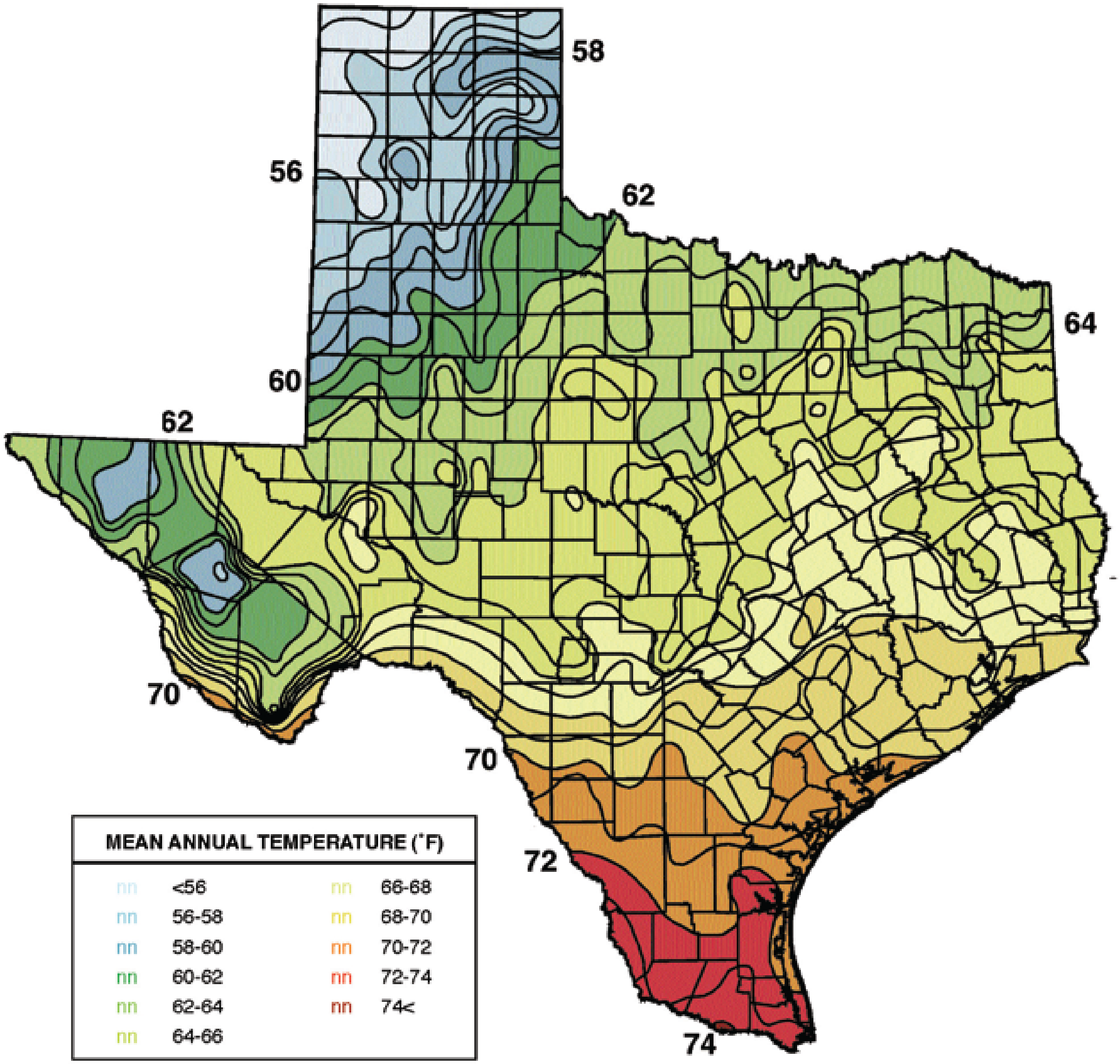
Location	January		April		July		October	
Abilene	32	55	52	77	72	95	54	78
Amarillo	23	49	42	71	65	91	45	72
Austin	40	60	58	79	65	91	45	72
Brownsville	51	69	65	82	75	92	66	84
Corpus Christi	46	66	62	81	74	93	64	84
Dallas-Ft Worth	34	54	54	76	75	95	56	78
Del Rio	40	63	59	83	74	96	61	82
El Paso	33	57	51	78	72	95	50	78
Houston	41	62	58	79	74	94	59	82
Laredo	44	68	63	89	75	102	63	87
Lubbock	24	52	45	75	68	92	47	74
Midland-Odessa	30	57	49	79	69	94	51	77
Port Arthur	43	62	59	78	74	92	60	81
San Angelo	32	58	51	79	70	94	53	84
San Antonio	39	62	57	80	74	95	62	83
Texarkana	36	53	54	75	73	93	55	77
Victoria	44	63	60	79	75	93	62	83
Waco	35	57	54	78	74	97	57	80
Wichita Falls	29	52	49	76	72	97	52	77

Temperature

An assessment of the state's renewable energy resources must also take into account how energy in the form of heat is expressed as air temperature, the distribution of which is influenced to a very large degree by the amount of solar radiation reaching the surface. This quantity of energy is of no small value owing to the fact that Texas covers a broad range of latitude (26˚N in the extreme south to 36˚N in the northern fringe) and, hence, is on the equatorial side of the mid-latitude regions. But its subtropical latitude is only one of the controlling factors related to the way solar radiation is used. Another is the influence of the Gulf of Mexico, which is best evidenced by the prevailing winds that blow from the sea surface inland for much of the year. Cold-air outbreaks in winter are quickly moderated once they reach Texas because they are readily mixed with air previously supplied from the Gulf.

Unlike mean annual precipitation, mean annual temperature varies not so much from east to west as, quite consistently, from north to south (latitudinally). The coldest temperatures anywhere in Texas are observed in the extreme northern sector of the High Plains, which also features the lowest mean annual temperatures anywhere in the state (**Exhibit 2-5**). Conversely, the highest (warmest) mean annual temperatures occur in Southern Texas along the Rio Grande, from Eagle Pass to Falcon Reservoir. In some years, the hottest temperatures of summer are observed in this region. (Average maximum daily temperature is shown in **Exhibit 2-6**; minimum average daily temperature appears in **Exhibit 2-7**.) In winter (January), the coldest mean minimum temperatures (in the low 20s), are observed in the High Plains (at Amarillo, for example), while in the summer (July), hottest mean daytime readings (in the upper 90s), are measured in the area along the Red River (at locations such as Dallas and Wichita Falls) (**Exhibit 2-4**).

Exhibit 2-5 Average Annual Temperature



Note: Based on 1961-1990 data from the cooperative weather observers network of the National Weather Service.[2] Intermediate contours (black lines) are generally indicated at 1 degree intervals. Throughout the data-sparse Trans-Pecos region, countours reflect higher uncertainty than in other parts of the state.

Exhibit 2-6 Average Daily Maximum Temperature

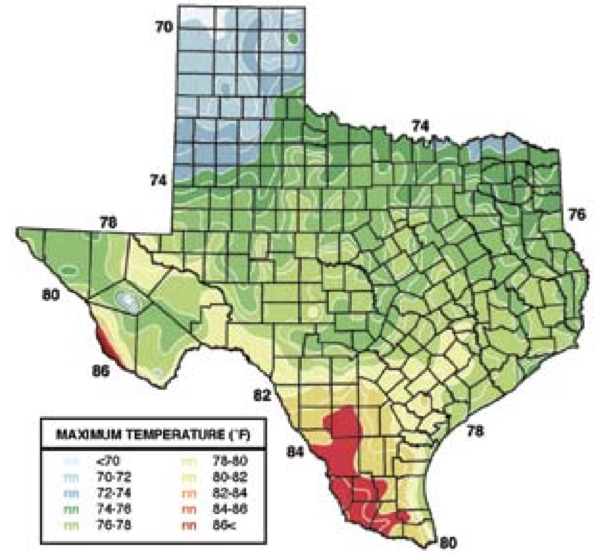


Exhibit 2-7 Average Daily Minimum Temperature

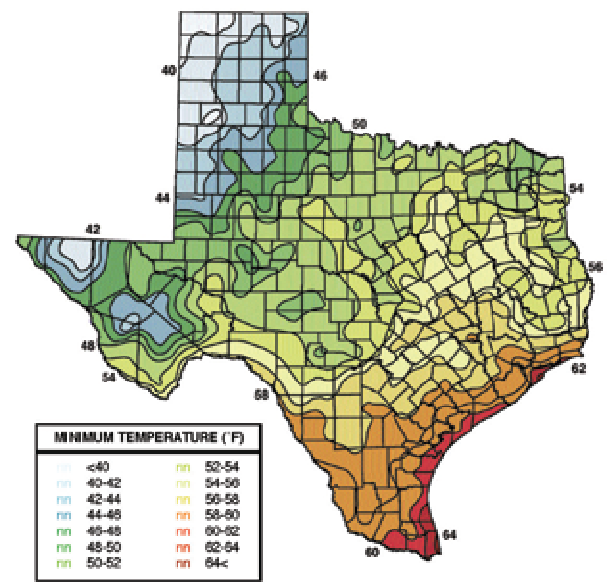


Exhibit 2-8 Average Wind Direction and Speed (mph) for the Mid Month of Each Season*

Location	January	April	July	October
Abilene	S 11.7	S 13.8	S 10.8	S 11.0
Amarillo	SW 12.8	SW 15.2	S 12.7	SW 12.8
Austin	S 9.3	S 10.1	S 8.3	S 7.9
Brownsville	S 11.1	SE 13.6	SE 11.3	SE 9.4
Corpus Christi	S 12.0	SE 14.3	SE 11.5	S 10.4
Dallas-Fort Worth	S 11.0	S 12.4	S 9.8	S 9.7
El Paso	NW 8.3	W 11.0	SE 8.3	SW 7.5
Houston	S 8.1	SE 9.0	SE 6.7	S 6.9
Lubbock	SW 12.0	SW 14.7	S 11.4	S 11.2
Midland-Odessa	S 10.4	SW 12.5	SW 10.8	S 10.1
Port Arthur	S 10.7	S 11.5	S 7.4	S 8.8
San Angelo	SW 10.2	S 12.1	S 9.8	S 9.3
San Antonio	S 8.8	S 10.1	S 9.1	S 8.3
Waco	S 11.3	S 12.6	S 10.7	S 10.0
Wichita Falls	N 11.3	S 13.1	S 11.1	S 10.7

*Typically measured at heights of 7 to 10 meters above the ground.

In spite of Texas' proximity to the Gulf of Mexico, day-to-night (diurnal) variations in temperature across the state are appreciable in all but parts of the state's coastal plain. On most days the moisture content of the lower atmosphere is sufficiently dry that, with the setting of the sun, air temperatures drop steadily. Mean annual diurnal temperature variations of 30˚F or more are observed in much of Texas west of the Pecos River where the air is exceptionally dry, while along the upper Texas coastline (most notably, Galveston Island) more than ample moisture much of the time keeps extreme minimum and maximum temperatures from varying more than 15˚F (**Exhibit 2-8**).

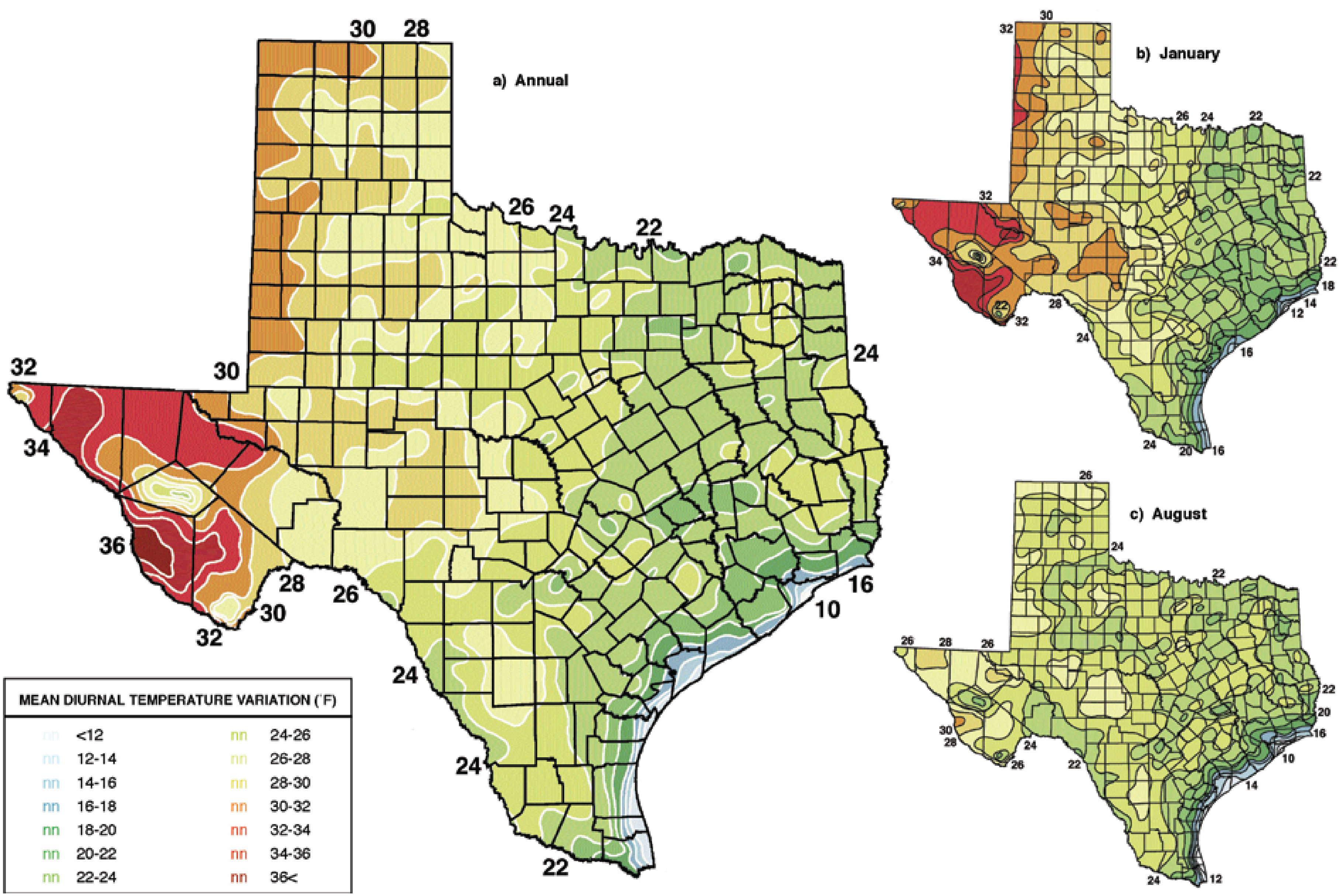
Occasionally, and particularly in winter, the air may be so laden with moisture that the diurnal range in temperature is only a few degrees. A blanket of clouds excludes much of the incoming solar radiation, thereby preventing the temperature from rising substantially above morning minimum values, and the same cloud cover can restrict outgoing heat energy at night so that minimum temperatures do not fall appreciably. The preponderance of cloud cover explains why, in a typical winter month, the range in diurnal temperature readings in the coastal plain is markedly less than that in the higher elevations in West Texas, where the air is much drier and the sky is usually cloud-free (**Figure 2-5b**). While the average diurnal variation is as little as 15-20˚ in that strip of coastal terrain within 20-30 miles of the coastline, the variation can be as little as 5˚ or less on as many as a half-dozen days in each of the months of December, January, and February. In the summer, because the air is warmer (and hence capable of holding more moisture), the diurnal temperature variation is not quite so small in the coastal plain (**Figure 2-5c**).

Wind Energy

The product of differences in atmospheric pressure between locations (pressure gradient), the strength and ubiquitous nature of the wind offers substantial promise as a source of renewable energy. While the wind is not merely a horizontal flow of air (its myriad of circular-moving eddies provides both upward and downward-moving pulses of energy), it is the lateral component of air motion that is of primary interest to energy providers and consumers. Though it has been poorly documented, the action of these individual eddies and the sum total of the vertical movement of the air at a particular place over a period of time may prove to be an additional and appreciable source of energy.

A southerly wind—or some component of it (southwesterly or southeasterly)—is the predominant wind condition in Texas for much of the year. In most sections of the state, the average wind speed varies between 7 and 15 miles per hour (**Exhibit 2-8**). A southerly wind is especially dominant in summer, when wind shifts induced by advancing cool fronts are much less common. In the southern half of Texas, where cool fronts often do not extend, a southerly wind is present some 90 percent of the time. In the north, northerly winds do blow on occasion, but southerly winds are observed at least 80 percent of the time. By contrast, the frequent intrusion of polar air in winter ensures a northerly wind about half of the time in much of Texas. Northerly winds are far from uncommon in both spring and autumn, though southerly flow remains dominant during those two seasons.

EXHIBIT 2-9 Mean Diurnal Temperature Variation (°F): a) Annual, b) January, and c) August. All three maps use the legend located at the bottom left of the page.[2]



Note: Throughout the data-sparse Trans-Pecos region, countours reflect higher uncertainty than in other parts of the state.

Exhibit 2-10 Average Number of Days with Various Sky Conditions

Location	January			April			July			October		
	CR	PC	CD	CR	PC	CD	CR	PC	CD	CR	PC	CD
Abilene	11	6	14	12	8	11	14	10	7	15	7	9
Amarillo	13	7	11	12	9	9	13	12	5	17	7	8
Austin	9	6	16	8	8	15	12	13	6	12	9	9
Brownsville	6	7	18	5	10	15	11	14	6	11	12	7
Corpus Christi	7	7	17	6	9	15	11	14	6	12	10	8
Dallas-FtWorth	10	6	16	9	8	13	15	10	6	14	7	10
El Paso	14	7	10	17	8	5	12	13	5	19	7	5
Houston	7	5	18	7	7	16	7	16	8	11	9	11
Lubbock	12	6	12	12	9	9	14	11	6	17	7	8
Midland	12	6	12	13	8	9	13	11	7	17	6	8
Port Arthur	7	6	18	6	8	16	7	15	9	12	10	9
San Angelo	12	6	13	11	8	11	15	10	7	15	7	8
San Antonio	9	6	16	7	8	15	9	15	7	11	10	9
Waco	9	6	16	9	7	14	14	10	6	13	8	9
Wichita Falls	11	6	14	11	8	11	15	9	7	15	7	9

CR = clear; PC = partly cloudy; CD = cloudy

For the year as a whole, the vast tableland known as the High Plains is the windiest region in the state, though some coastal locations also benefit from vigorous wind movement much of the time. In fact, with winds in the spring averaging from 13 to 17 miles per hour, the High Plains of northwestern Texas is one of the windier sectors of the North American continent. On many days during spring, and not infrequently in other seasons, the wind habitually gusts to a velocity two or three times as much as the daily average wind speed. Gusts in the vicinity of thunderstorms may exceed 60 miles per hour several times in any one season. The winter in the High Plains is almost as windy, however, as frequent invasions of polar or Arctic air sometimes make outdoor activity hazardous for human beings and livestock.

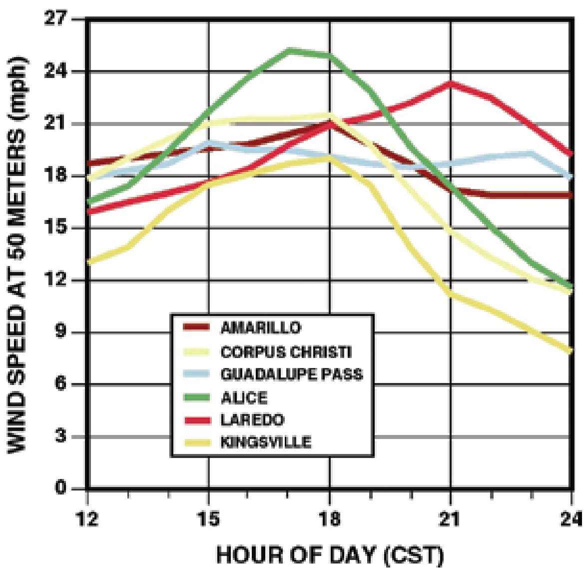
Wind speeds vary in relation to time of day. As a general rule, and in the absence of a “forcing mechanism” such as an approaching frontal system or thunderstorm, the wind attains a maximum velocity from midday through the late afternoon, in response to the peak flow of incoming solar energy (warmth). This is especially true during the warmest season of the year, when the demand for electric power for cooling also is maximized during the hottest portion of the day. Yet, as **Exhibit 2-11** illustrates, even at locations near one another and within the same climatic region, wind speeds can vary dramatically. The peak wind of 20 miles per hour or greater at some coastal sites suggests the influence of the sea breeze, while locations more distant from the coastline may feel less effect from that phenomenon and, hence, sustain lower maximum wind speeds.

The intensity and timing of maximum winds may also depend upon a community's proximity to marked topographic features, such as mountain ranges and basins. In more arid climes (such as the Guadalupe Mountains), where the dry air allows the temperature to reach a maximum earlier in the afternoon, the peak wind occurs not much beyond midday. Some locales within reach of the sea breeze (such as Corpus Christi) experience highest winds in concert with the migration of the breeze inland, or some four to five hours after high noon. Cities far removed from the effect of the sea breeze (such as Laredo), but in the path of outflow from a desert, may not experience fastest winds until nearly sunset, or when the gust from hot air radiating from the desert reaches the city.

Insolation and Cloud Cover

The availability of insolation as an abundant renewable energy resource is evidenced in a number of ways. One means of quantifying the resource is by the number of days characterized by cloudy or cloud-free skies (**Exhibit 2-10**). A clear sky, or the equivalent of a maximum of incoming solar energy, is most common in the western sector of Texas, particularly during the colder half of the year. In much of the Trans-Pecos, for instance, the sky is cloud-free on an average of two of every three days during both the autumn and winter. Even in the warmer half of the year, the sky in this region is overcast on only one day of every six. By contrast, over half of the days in winter and spring are overcast in southeastern Texas, and only one in four days during these seasons is free of cloud cover. In that part of Texas east of the 100th meridian, the least likelihood of overcast skies occurs during the summer, even though partial cloud cover is more prevalent in this season than in any other.

Exhibit 2-11 Average Summer Afternoon Wind Speed at 50 Meters Above the Ground.



Note: Estimated from measurements taken closer to the ground, typically at 7-10 meters.

Exhibit 2-12 Average Amount of Sunshine (as Percent of the Total Possible)

	Winter			Spring			Summer			Autumn		
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Abilene	62	62	64	70	72	70	78	80	78	71	72	67
Amarillo	67	69	68	72	74	71	78	79	77	73	75	72
Austin	49	49	51	55	54	56	69	75	75	66	64	54
Brownsville	42	41	48	53	58	63	73	80	76	68	65	51
Corpus Christi	43	44	49	54	56	59	72	79	76	68	67	54
Dal-Ft Worth	52	52	54	58	61	57	67	75	73	67	63	57
El Paso	77	78	82	86	89	90	90	82	81	83	84	83
Houston	51	45	50	54	58	62	68	70	68	66	64	52
Lubbock	65	65	66	73	74	71	76	77	76	71	75	69
Midland	65	66	69	73	78	78	81	81	77	77	72	74
Pt Arthur	47	42	52	52	52	64	69	65	63	62	67	57
San Antonio	48	47	50	57	56	56	67	74	74	67	64	54

Obviously, the time of day when cloud cover is most likely to occur has an appreciable impact on available solar energy. In winter, for instance, an opaque cloud layer has a peak occurrence in the few hours following sunrise (**Exhibit 2-13**); it is least likely during the mid-afternoon hours, or just after the peak period of incoming solar insolation. This pattern of maximum cloud cover at mid-morning and minimum cloud cover in mid-afternoon is observed in most of Texas. It is most pronounced in the coastal plain (at locations such as Houston, Corpus Christi, and Brownsville). Only in the area west of the Pecos River (for example, El Paso) is the frequency of occurrence of opaque cloud cover spread almost uniformly throughout the day.

During the peak heating season, however, when solar insolation is at a maximum, the pattern of opaque cloud cover is not nearly so uniform statewide. In semi-arid West Texas, where the bulk of the year's substantive rainfall is produced by deep convective cloud formations, opaque cloud cover reaches a maximum at midday or in the early afternoon hours, when thunderstorms have matured and spread a shield of far-reaching cirrus clouds across the sky (**Exhibit 2-14**). The near-surface layer of air is hardly moist enough to allow a morning overcast to develop, hence the frequency of occurrence of opaque cloud cover is quite small (less than 35 percent of the time). The pattern is almost reversed in lower elevations, however. A thick near-surface layer of moist Gulf air foments the formation of a deck of stratus clouds on nearly half of the mornings in the month of August. The rising sun usually dissipates the stratus by late morning. A secondary peak of opaque cloud cover results from the eruption of scattered deep convection (thunderstorms) during the peak heating period of the day.

An even better indicator of available solar energy for specific sites in Texas is the measure of sunshine, usually expressed as the percent of the total possible for the given location (**Exhibit 2-12**). As a general rule, sunshine is more abundant in the higher elevations of western Texas, no matter the season of the year. The region where sunshine is superabundant almost year-round is the area west of the Pecos River, particularly in the vicinity of the Rio Grande. There, from mid-winter until mid-summer, uninhibited sunshine is available more than 90 percent of the time during daylight hours. On the other hand, sunshine is most scarce in the coastal plain during the three coldest months of the year (December through February). In this region of low elevation, sunshine is most plentiful (at least two-thirds of the time) during the summer.

EXHIBIT 2-13 Average Opaque Cloud Cover for January

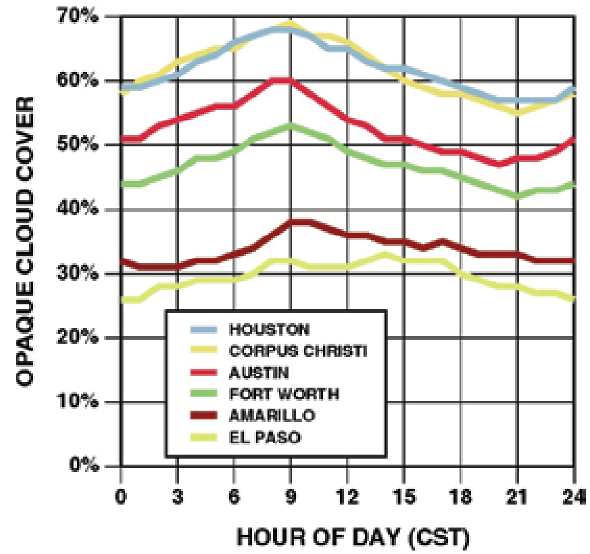
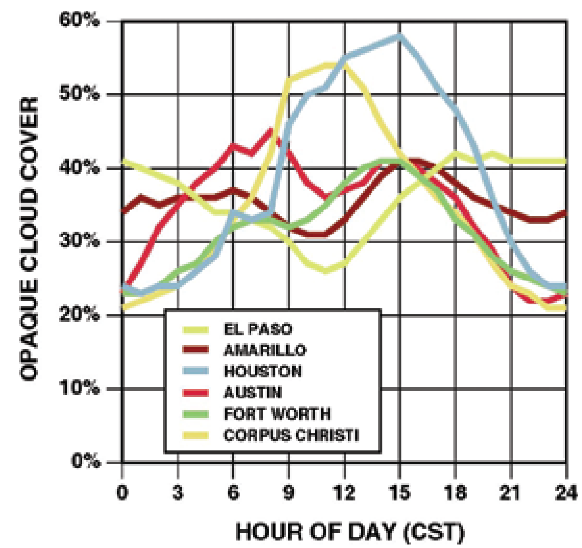


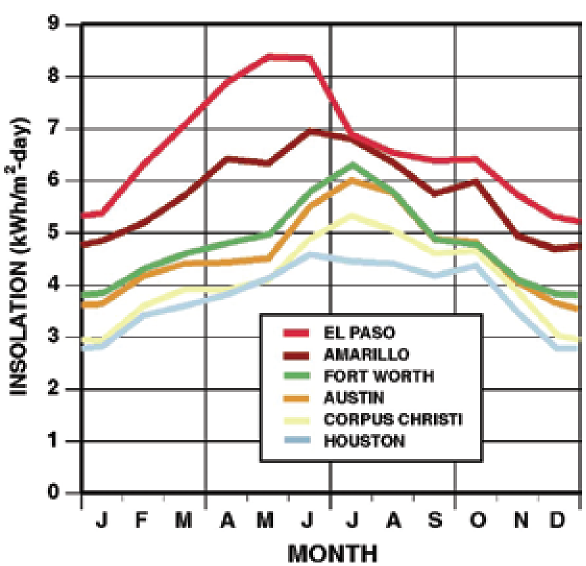
EXHIBIT 2-14 Average Opaque Cloud Cover for August



Direct measurements of incoming solar energy reflect a maximum in semi-arid West Texas that is coincident with the occurrence of the summer solstice (June 21) (**Exhibit 2-15**). The rainy season west of the Pecos River usually does not get underway until some weeks after the solstice, and the onset of an almost daily occurrence of significant thunderstorm development sometime in July brings about a rather sharp diminution of normal insolation.

In the east, especially in the coastal plain, a seasonal rainfall maximum in the late spring coincides with a relative minimum in normal insolation at locations such as Houston, Corpus Christi, and Brownsville. This is followed by a respite in thunderstorm frequency in early summer, when normal insolation increases appreciably. However, insolation drops proportionally in late July or early August with a tropical-cyclone season increasing the frequency of daytime showers and thunderstorms along the coastline and tens of miles inland.

Exhibit 2-15 Average Direct Solar Radiation by Month



Regrettably, while it is a key element in the spectrum of renewable energy resources in Texas, solar radiation may be the most poorly quantified, and hence least understood. This is due to the lack of an extensive observation network in Texas that detects sunshine. Where sensors are deployed, most have operating characteristics that are hardly uniform from one location to another. Solar energy is a resource marked by great variability over short distances, owing to cloud or turbidity conditions that are highly erratic. For the most part, reliable sunshine data are available for only a few of the largest metropolitan areas of the state. This means that vast areas of the High Plains, Low Rolling Plains, Edwards Plateau, Trans-Pecos, and Southern Texas are not well represented by existing data on sunshine availability. Even the more densely populated regions of northeastern and East Texas are lacking in good-quality sunshine data. That is all the more reason why the need for expanded coverage of radiation sensors and better standardization of instrument usage should be recognized and addressed. Nonetheless, the reliable data that do exist corroborate the fact that Texas is well endowed with this resource.

Summary

Texas, by virtue of its proximity to a surface energy source (the Gulf of Mexico) and its strategic position beneath a potent stream of energy aloft in the atmosphere (the subtropical and polar jets), is rich in renewable energy resources. The degree of abundance of each climate-related resource can be attributed to the intensity of solar insolation and by the gradient of that insolation from place to place across the state. After all, it is the disparity in incoming solar energy, from season to season and from locale to locale, that dictates the temperature gradients observed from west to east and from north to south across the Lone Star State. These temperature gradients ultimately determine the pressure gradients and the fluctuations in wind associated with them. The differential in pressure, in turn, determines the origin of air masses that migrate into and out of Texas with a striking degree of regularity throughout much of the year. How the weather behaves from year to year, in relation to this intricate energy budget, provides us with some measure of just how energy-rich the state really is.

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