ELECTRICITY REPORT CARDS FOR THE FIFTY STATES

Overview of Electricity Grades from GridClue.com

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Critical Issues

Electricity generation in the United State presents an acute, three-pronged challenge. First—supply sufficient to consistently meet consumers' needs. Many energy systems are unreliable, costly for consumers, and lack resilience to grid disturbances, natural disasters, and deliberate attacks. Second— environmental concerns. Resources that generate electricity are often carbon-intensive and have other emissions or waste products. Third —growing demand for electricity and resulting capacity shortfalls. This last concern is increasingly relevant as the United States strives for widespread adoption of electric vehicles and electric heating.

To provide a public communication platform around these issues, GridClue.com presents two automated tools to analyze the electricity resources of each state:

- The **Electricity Report Card** communicates a state's ability to serve its ratepayers
- The **Policy Scenario** explores ways of enhancing a state's electricity performance

With these tools, users — policymakers, analysts, and concerned citizens — can gain critical insights, make informed decisions, identify priorities, and improve regulation of electricity generation.

For decades, government leaders have championed policies that emphasize cheap energy and decarbonization. Often absent from their consideration has been reliability and resilience of energy systems. Authoritative facts and quantified analysis are often not publicly disclosed or not fully analyzed. As a result, poor policies have increased the risk of long-term, wide-area blackouts when dispatchable resources lack capacity and renewables are intermittent.

Electric grids are increasingly at risk of collapse after a deliberate attack, natural disaster, or accidental disruption. For some regions, prompt electricity restoration is uncertain. The challenge is complex. Electric grids are interconnected and, therefore, susceptible to cascading collapse, a vulnerability resulting from grid design and the physics principle, "electricity supply must precisely equal demand." When an unexpected event occurs—e.g., loss of a transmission line to a large metropolitan area—the grid is challenged to balance supply with demand. If balancing attempts are unsuccessful, relays trip, causing power backups. This, in turn, forces more relays to trip, prompting a cascading collapse that can affect millions of people.

Why is public information on electricity policy so important? The electric grid currently delivers forty percent of the total energy consumed in the U.S., with demand expected to grow exponentially. To manage this critical resource for energy delivery, grid systems must be designed for clean and affordable daily operation and enhanced for reliability and resilience. Greater demands on electric grids and worsening vulnerabilities argue for prompt public attention, before a disaster occurs.

The remainder of this whitepaper documents how GridClue scores are calculated, and how the fifty states are graded. We present GridClue data for several states as case studies.

Grading Methodology

To analyze performance of electric grids at the state and regional levels, GridClue.com leverages public data released by agencies such as the U.S. Energy Information Administration (EIA), Environmental Protection Agency (EPA), the Census Bureau, U.S. Department of Transportation (DOT), and the Federal Energy Regulatory Commission (FERC).

GridClue.com applies this data to four categories of graded performance:

- Resilience against a long-term outage
- Carbon Intensity of in-state generation resources
- Reliability as measured by the record of ratepayer outages
- Cost as tracked by average price per kilowatt-hour billed to consumers

GridClue scores states in these four categories to produce an "Electricity Report Card," using the U.S. model for grade point average: "A" is 100% to 90%, "B" is 89% to 80%, "C" is 79% to 70%, "D" is 69% to 60%, and "F" is 59% and lower. These scores are then aggregated, allowing users to understand which states are performing well, in which categories, and what adjustments might be needed to improve.

Letter	Grade	GPA
A+	97	4.3
A	93	4.0
A-	90	3.7
B+	87	3.3
B	83	3.0
B-	80	2.7
C+	77	2.3
C	73	2.0
C-	70	1.7
D+	67	1.3
D	63	1.0
D-	60	0.7
F	50	0.0

Grades for electric grids often exhibit tradeoffs between two or more metrics. For example, a state may have invested in dispatchable resources (e.g., coal, natural gas, or petroleum). However, this focus on resilient generation would depress the grade for Carbon Intensity, as burning of fossil fuels releases carbon dioxide. Also, some states' metrics are influenced –

positively or negatively – by their unique circumstances, e.g., climate and geography; availability of rivers for hydroelectric dams; and extreme weather patterns.

Resilience

To determine the grade for Resilience, GridClue.com uses a ratio comparing resilient capacity to average electricity demand. The following resources comprise resilient capacity:

1. Natural gas-fired plants that can switch to fuel oil backup (dual-fuel)
2. Natural gas-fired plants connected to more than one pipeline
3. Nuclear power plants
4. Hydroelectric and pumped storage plants
5. Geothermal plants
6. Petroleum-fired plants
7. Coal-fired plants

A high score signifies a high ratio of capacity to average electricity consumption. For example, a state that earns a 100% in Resilience has a large capacity of dispatchable resources with on-site fuel; its resources well exceed average demand. Within this paradigm, the states of Wyoming and West Virginia are the “curve-breakers.” Their supply and demand factors combine to create an exceptionally high capacity-to-consumption ratio.

- Supply: Each state uses its large coal reserves to fuel dispatchable coal plants. Wyoming, 94.3% of its resilient capacity comes from coal, with 94.5% for West Virginia.
- Demand: Wyoming and West Virginia only consume 38.2% and 50.6% of their electricity generation, respectively.

Table 1 presents the top 10 states in the category of Resilience.

Resilience Rank	State	Resilience Grade	Resilient Natural Gas	Nuclear	Hydro	Pumped Storage	Geothermal	Petroleum	Coal	Resilient Capacity (MW)	Avg. Hourly Consumption (MW)	Capacity to Consumption Ratio ▼
1	Wyoming	A+	144	0	303	0	0	6	7,539	7,992	1,809	4.42
2	West Virginia	A-	378	0	371	0	0	18	13,072	13,838	3,739	3.70
3	Montana	B-	310	0	2,649	0	0	68	1,865	4,892	1,701	2.88
4	Alaska	B-	322	0	481	0	0	839	192	1,835	679	2.70
5	New Hampshire	C+	785	1,242	519	0	0	107	559	3,212	1,240	2.59
6	Washington	C+	1,236	1,200	21,299	314	0	16	730	24,794	10,000	2.48
7	Hawaii	C+	0	0	34	0	51	2,172	203	2,459	1,019	2.41
8	South Carolina	C+	5,203	6,875	1,365	2,753	0	627	5,082	21,904	9,150	2.39
9	Connecticut	C	2,475	2,163	115	31	0	2,282	400	7,466	3,152	2.37
10	Delaware	C	2,443	0	0	0	0	122	446	3,010	1,310	2.30

Table 1. Top 10 States in the Resilience Category

A low score signifies a low ratio of resilient capacity in comparison to demand. For example, a state earning a 50 in Resilience would possess no dispatchable, energy-secure resources and, therefore, could not reliably meet demand or conduct grid restoration. Imported power for a state also lowers its Resilience score.

- Vermont scores the worst for these very reasons. In 2013, the Vermont Yankee Nuclear Power Plant generated 70% of the state's electricity, giving the state a Resilience ratio of 1.59, signifying its capacity would theoretically satisfy all the state's demand in a time of crisis and with a 59% surplus. However, Vermont closed its nuclear power plant in 2014. As a result, Vermont's resilience ratio decreased to 0.81 in 2021. If all of the state's hydroelectricity and petroleum generation operated at 100% capacity, Vermont still could not satisfy its average demand.

Table 2 presents the bottom 10 states in the Resilience category.

Resilience Rank ▼	State	Resilience Grade	Resilient Natural Gas	Nuclear	Hydro	Pumped Storage	Geothermal	Petroleum	Coal	Resilient Capacity (MW)	Avg. Hourly Consumption (MW)	Capacity to Consumption Ratio
50	Vermont	F	0	0	329	0	0	171	0	500	618	0.81
49	California	F	5,156	2,323	10,066	3,746	2,824	505	62	24,682	28,054	0.88
48	Idaho	D-	18	0	2,693	0	18	5	6	2,740	2,874	0.95
47	Nevada	D-	1,382	0	1,052	0	857	6	1,051	4,348	4,476	0.97
46	Colorado	D-	1,404	0	686	508	0	182	4,656	7,436	6,490	1.15
45	Mississippi	D	3,306	1,440	0	0	0	9	1,610	6,365	5,507	1.16
44	Oklahoma	D	3,955	0	824	259	0	87	3,573	8,699	7,394	1.18
43	Ohio	D	7,399	2,237	129	0	0	730	10,622	21,116	16,924	1.25
42	Rhode Island	D	1,050	0	3	0	0	7	0	1,060	840	1.26
41	Virginia	D	7,338	3,654	822	3,109	0	984	2,872	18,780	14,131	1.33

Table 2. Bottom 10 States in the Resilience Category

Carbon Intensity

The Carbon Intensity score is calculated by adding the annual carbon dioxide emissions from generation plants operating in the state, then dividing that sum by the kilowatt-hours of electricity the state generates over the same annual period. This yields a figure in tons/kilowatt-hour.

A state earning a 100% score in Carbon Intensity generates all electricity without carbon dioxide emissions. A state earning a 50% score in this category pollutes the most amount of carbon per kWh of electricity compared to all other states.

Top performers for Carbon Intensity earn high marks for two reasons. First, some states import substantial portions of their electricity that does not count toward their in-state carbon emissions. Second, their in-state generation is almost solely based on renewables or carbon-neutral sources. Vermont exemplifies a state that relies on imports for a large portion of its power. The remaining energy sources are hydroelectric, biomass, wind, and solar (listed in order of the amount of power generated). The EIA and EPA consider biomass to be carbon-neutral; therefore, Vermont's biomass plants do not count toward its Carbon Intensity score. This combines for a near-perfect Carbon Intensity score contrasted with Vermont's fiftieth-place score in Resilience.

Table 3 shows the states with the top ten scores for Carbon Intensity.

Carbon Rank ▲	State	Carbon Intensity Grade	In-State Carbon Emissions (Tons)	In-State Generation (MWh)	Carbon Intensity (Lbs/kWh)
1	Vermont	A+	41,937	2,106,893	0.04
2	Washington	A	10,889,949	110,004,096	0.20
3	Maine	A	1,314,890	10,070,403	0.26
4	Idaho	A-	2,292,217	16,698,624	0.27
5	New Hampshire	A-	2,355,610	17,023,958	0.28
6	South Dakota	A-	2,551,795	17,402,545	0.29
7	Oregon	A-	9,212,580	60,861,641	0.30
8	New York	B+	26,188,386	120,692,246	0.43
9	California	B+	43,023,713	195,098,722	0.44
10	New Jersey	B+	13,732,811	60,325,866	0.46

Table 3. Top 10 States in the Carbon Intensity Category

Use of natural resources high in carbon (e.g., coal) for electricity generation, is a driving factor for states receiving the lowest scores in Carbon Intensity.

- West Virginia receives the lowest score. With a long history of coal mining, this fuel source generates 90.4% of the state's electricity. The remaining generation technologies are natural gas at 3.9%, hydroelectric at 2.6%, and wind at 2.5%.

- Hawaii is an outlier in the bottom 10 due to its geographic separation from the contiguous United States. The state obtains its fuel supply solely though shipped fossil fuels. Accordingly, 67.9% of Hawaii's capacity comes from petroleum generation. The remaining generation uses coal, solar, and wind as energy sources, with the renewables counteracting some of coal's high carbon intensity. This combination results in a carbon intensity of 1.56 Lbs./kWh.

Table 4 shows the states with the bottom ten scores for Carbon Intensity.

Carbon Rank ▼	State	Carbon Intensity Grade	In-State Carbon Emissions (Tons)	In-State Generation (MWh)	Carbon Intensity (Lbs/kWh)
50	West Virginia	F	62,953,804	64,753,696	1.94
49	Wyoming	F	36,588,805	41,528,852	1.76
48	Kentucky	F	54,777,824	63,255,066	1.73
47	Missouri	F	62,917,972	73,828,569	1.70
46	Indiana	F	72,912,502	88,974,140	1.64
45	Hawaii	F	6,566,981	8,395,615	1.56
44	Utah	D-	31,358,649	41,200,051	1.52
43	North Dakota	D	27,418,010	41,387,275	1.32
42	Nebraska	D+	22,633,873	37,796,280	1.20
41	Colorado	D+	33,728,277	56,391,109	1.20

Table 4. Bottom 10 States in the Carbon Intensity Category

Reliability

The electric utility industry has developed multiple metrics to reflect reliability. The System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) are two of the most common. The EIA publicly reports both metrics.

GridClue.com uses the SAIDI metric, which includes major event days (MED) and loss of supply (LOS). This means that every outage is included in the final metric, regardless of cause. Thus, a state earning a 100% in Reliability has zero minutes of outages over the entire year. A state earning a 50% has the highest average minutes of customer outage with its residents experiencing more minutes of outages than those in any other state.

States in the top 10 earned their scores by minimizing outages. This can result from being in a region characterized by a mild climate in which extreme weather is rare or, alternatively, by being prepared for extreme weather by investing in electricity generation, transmission, and distribution to prevent sustained blackouts.

Table 5 shows the states with the bottom ten scores for Reliability.

Reliability Rank ▲	State	Reliability Grade	Total Outages (Minutes)	Customers Reporting Outage During Year	Average Outage Per Customer (Minutes)
1	Delaware	A+	28,770,888	447,196	64.34
2	Florida	A+	897,386,141	11,188,260	80.21
3	North Dakota	A+	34,459,888	403,628	85.38
4	Nevada	A+	149,821,679	1,462,887	102.42
5	South Dakota	A+	37,807,426	358,002	105.61
6	Arizona	A+	338,323,232	3,186,443	106.18
7	Utah	A+	141,068,156	1,216,578	115.95
8	Minnesota	A+	297,222,433	2,478,402	119.93
9	South Carolina	A+	325,429,817	2,692,336	120.87
10	Illinois	A+	741,992,988	5,841,585	127.02

Table 5. Top 10 States in the Reliability Category

The bottom 10 states have the highest average outage minutes in the country. This is often attributed to major event days that far exceed the average rate of daily outages. Many states that performed poorly have experienced natural disasters (e.g., winter storms, hurricanes, and wildfires).

Table 6 shows the states with the bottom ten scores for Reliability.

Reliability Rank ▼	State	Reliability Grade	Total Outages (Minutes)	Customers Reporting Outage During Year	Average Outage Per Customer (Minutes)
50	Louisiana	F	11,209,018,093	2,329,839	4811.07
49	Oregon	B	2,884,706,796	1,937,129	1489.17
48	Texas	B+	15,205,372,703	12,937,516	1175.29
47	Mississippi	B+	1,504,089,236	1,325,891	1134.40
46	West Virginia	B+	1,119,476,073	1,002,081	1117.15
45	Michigan	A-	4,254,733,716	4,872,176	873.27
44	Kentucky	A-	1,607,395,340	2,271,123	707.75
43	Washington	A	1,829,464,395	3,469,555	527.29
42	Massachusetts	A	1,586,965,908	3,059,740	518.66
41	Nebraska	A	408,296,539	791,260	516.01

Table 6. Bottom 10 States in the Reliability Category

Cost

The top 10 states for electricity cost have the lowest average retail price. Cost of electricity is determined using the state's average retail price/per kilowatt hour. Electricity imported and then sold within a state is included in this calculation. Electricity generated within a state and then exported to other states is *not* included in the Cost score.

A state that earns a 100% score in Cost has the lowest average electricity price, while the state that earns a 50% has the highest score.

Many states have abundant natural resources (e.g., hydroelectricity, coal, or natural gas), allowing inexpensive generation and, therefore, low cost for consumers.

Table 7 reflects the states with the top ten scores for Cost.

Electricity Cost Rank ▲	State	Electricity Cost Grade	Population	Residential Price (Cents/kWh)	Commercial Price (Cents/kWh)	Industrial Price (Cents/kWh)	Average Retail Price (Cents/kWh)
1	Idaho	A+	1,848,000	10.18	7.90	6.39	8.17
2	Wyoming	A+	577,000	11.20	9.67	6.83	8.25
3	Utah	A+	3,282,000	10.50	8.14	6.26	8.39
4	North Dakota	A+	779,000	10.83	9.17	7.01	8.47
5	Nevada	A+	3,114,000	11.50	7.77	6.14	8.64
6	Washington	A+	7,719,000	10.09	9.23	5.81	8.78
7	Louisiana	A+	4,651,000	11.04	10.28	6.18	8.82
8	Oklahoma	A+	3,962,000	12.27	8.51	5.31	8.83
9	West Virginia	A+	1,790,000	12.16	9.50	6.12	8.89
10	Nebraska	A+	1,961,000	10.85	8.85	7.37	8.93

Table 7. Top 10 States in the Cost Category

The bottom 10 states had the highest average retail price, which could result from participation in inefficient Regional Transmission Organizations (RTO) or Independent System Operators (ISO) markets, reliance on limited availability of pipelines for natural gas, or inflated costs for local labor and supplies.

- California and the Northeastern U.S. consistently have high rates for electricity because of policy choices, especially restricted permitting for energy infrastructure.
- Hawaii and Alaska consistently have high rates because of reliance on shipped petroleum for generation.

The Cost category considers electricity sales to residential, commercial, and industrial sectors averaged together. In some states, commercial and industrial enterprises are able to negotiate lower rates than residential consumers.

Table 8 shows the states with the bottom ten scores for Cost.

Electricity Cost Rank ▼	State	Electricity Cost Grade	Population	Residential Price (Cents/kWh)	Commercial Price (Cents/kWh)	Industrial Price (Cents/kWh)	Average Retail Price (Cents/kWh)
50	Hawaii	F	1,452,000	33.30	31.16	27.14	30.35
49	Alaska	C	732,000	22.58	19.59	17.00	20.05
48	California	C	39,500,000	22.85	19.21	15.14	19.76
47	Massachusetts	C	7,022,000	22.91	17.16	15.31	19.17
46	Connecticut	C	3,600,000	21.86	16.71	13.24	18.78
45	Rhode Island	C	1,096,000	22.30	15.62	16.10	18.52
44	New Hampshire	C+	1,378,000	19.86	16.23	13.84	17.42
43	Vermont	B-	642,000	19.27	16.62	11.41	16.37
42	New York	B-	20,155,000	19.44	16.14	6.33	16.14
41	New Jersey	B	9,280,000	16.37	12.81	10.79	14.10

Table 8. Bottom 10 States in the Cost Category

Grade Distribution from Electricity Report Cards

Figure 1 shows a distribution of overall grades for 2021 data. Grades were mostly evenly distributed but with a handful of outliers. Proceeding from left to right:

- Washington earned the highest score – a ”B+” with a 3.65 GPA. In addition to the Resilience category, the state excelled by running a low-carbon, reliable, and low-cost grid. Four other states also got a “B+.”
- The most common grade for 2021 was a flat “B,” earned by 20 of the states.
- Only two states got a flat “C” or “D+.”
- No state got an overall failing grade of “F.”

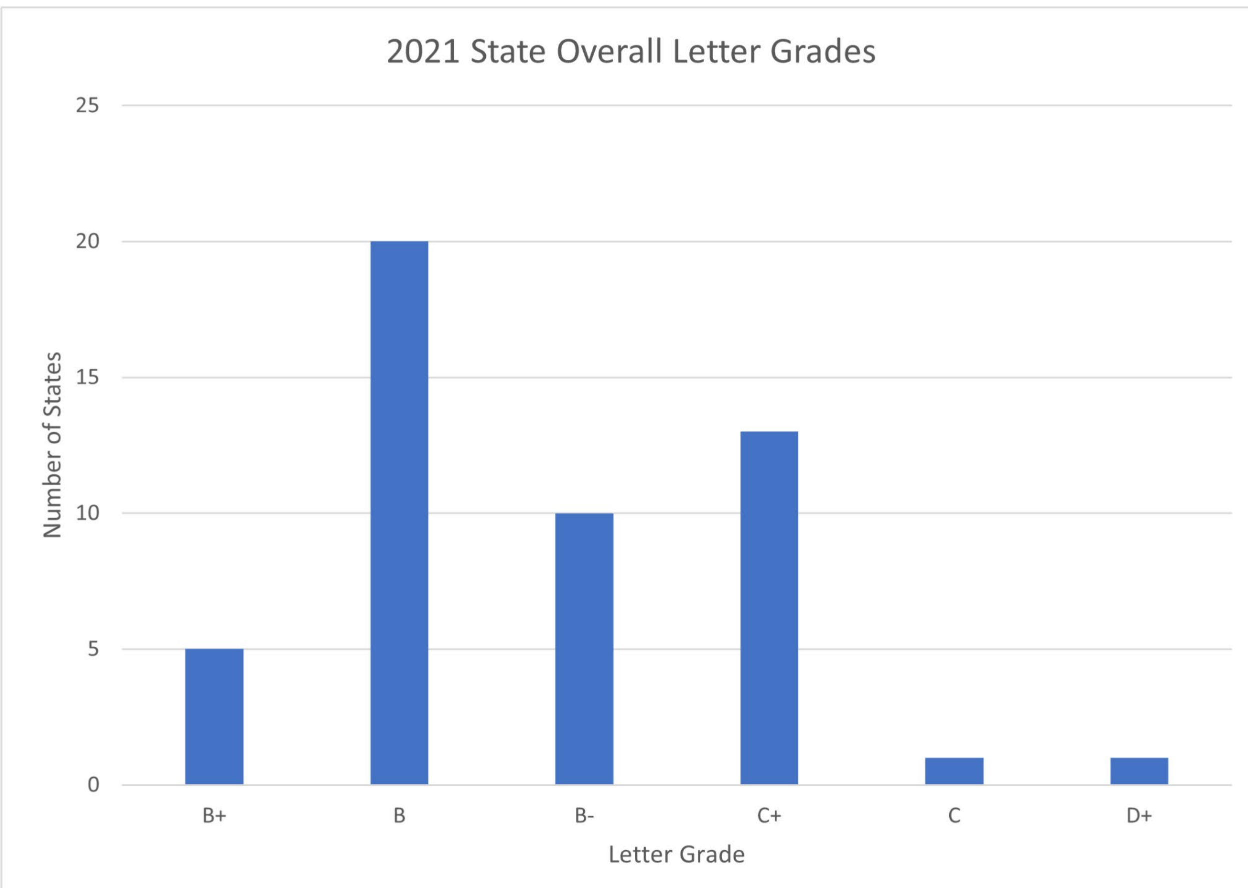
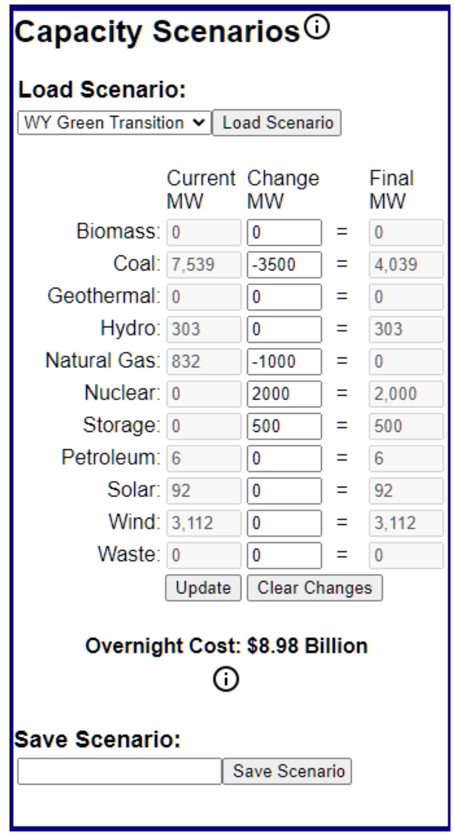


Figure 1. State Overall Letter Grades

Policy Scenarios Feature

The Policy Scenarios feature is a data-driven, analytical platform built on the foundation of the Electricity Report Card. It enables policymakers, analysts, and concerned citizens to add, reduce, or entirely delete elements of a state's electricity generating capacity and determine the best way to transition to cleaner, cheaper, and more reliable and resilient sources.



After selecting the year and state, users can see the current capacities for each category of generation resource. To the right of each figure is a text box in which changes in megawatts (MW) can either be typed or adjusted using arrows within the text box. The rightmost column shows the adjusted final capacity for the state. If a user tries to remove more of a source than the state possesses, that source's capacity will just be zero, as shown. Users with an account on GridClue.com have the option to load and save scenarios for future use.

Grades are adjusted per the methodology below:

- <u>Resilience</u>: Users can change the capacities of resilient energy resources (i.e., nuclear, hydroelectricity, pumped storage, geothermal, petroleum, coal, and natural gas). Increases in capacity for any of these resources will increase the state's resilient capacity-to-consumption ratio. Reductions will lower the ratio. The resulting ratio is then compared with the other 49 states and a new grade is given.
- <u>Carbon Intensity</u>: Using EIA data, GridClue estimates generation and emission figures for each energy resource in each state. Carbon emissions are calculated by estimating an energy resource's emissions-per-megawatt capacity. States' carbon grades can be improved by:
    - Reducing or removing capacity of carbon-emitting sources like coal, petroleum, and natural gas
    - Transitioning their capacity to a cleaner source (e.g., natural gas is cleaner than coal)
    - Adding renewables or carbon-neutral sources to the state's resource base.

Changes to generation are calculated using the state's average generation-per-megawatt for the energy resource. This accounts for certain resources being more efficient in one state than another.

For example, solar power in Arizona operates at a capacity factor of 27%, while solar power in Wisconsin operates at only 8%. Thus, additions of solar power are more effective in changing grades in a sunnier state.

- Reliability: Reliability scores are based on reported experience of utilities, not on calculations. Therefore, while added generation resources may decrease average outage minutes per for future years, the Reliability score is not changed in the Electricity Report Cards.
- Cost: This score helps users determine ways to increase a state's grade. Labeled as the "Overnight Cost" beneath the capacity controls, this metric approximates the cost of suggested changes for generation resources based on adjustments to megawatt capacities.[1]

Policy Scenarios Tool – Demonstration

Wyoming is presented here to demonstrate capabilities of the Policy Scenario tool.

Electricity Report Card for 2021:

- Resilience: Wyoming earns an "A+," placing it at #1 of the 50 states, due to its large coal sector providing much of the state's electricity.
- Carbon Intensity: Wyoming earns an "F," placing it as #49 of the 50 states.
- Reliability: "A+" (#17 of 50)
- Cost: "A+" (#2 of 50)

Adjustments: Users can modify Wyoming's generation resources with the steps below, thereby improving the state's total score:

- Increasing wind generation by adding a gigawatt of capacity. Wyoming has one of the highest potentials for wind energy and has already begun to capitalize on that resource.
- Expanding storage capacity of wind energy for use during peak demand. This could also reduce intermittency of renewables and improve system reliability in future years.
- Building a nuclear plant or small modular reactors. Nuclear power, potentially cleaner than carbon-based resources, is a resilient, reliable generation technology
- Retiring aging coal plants, which would improve the score for Carbon Intensity

These adjustments would improve Wyoming's scores by: (1) elevating the Carbon Intensity score from an "F" to a "C+," advancing it 16 places to #33 in this category; (2) increasing the state's aggregate grade from a "B" (3.23) to an "A-" (3.8) and advancing it from #6 to #1 of all fifty states. Figure 2 depicts the Wyoming scenario, presenting information for both the baseline Electricity Report Card and modifications made with the Policy Scenarios tool.

[1] Overnight Cost is based on EIA and IPCC estimates which may not equate to the actual construction costs.

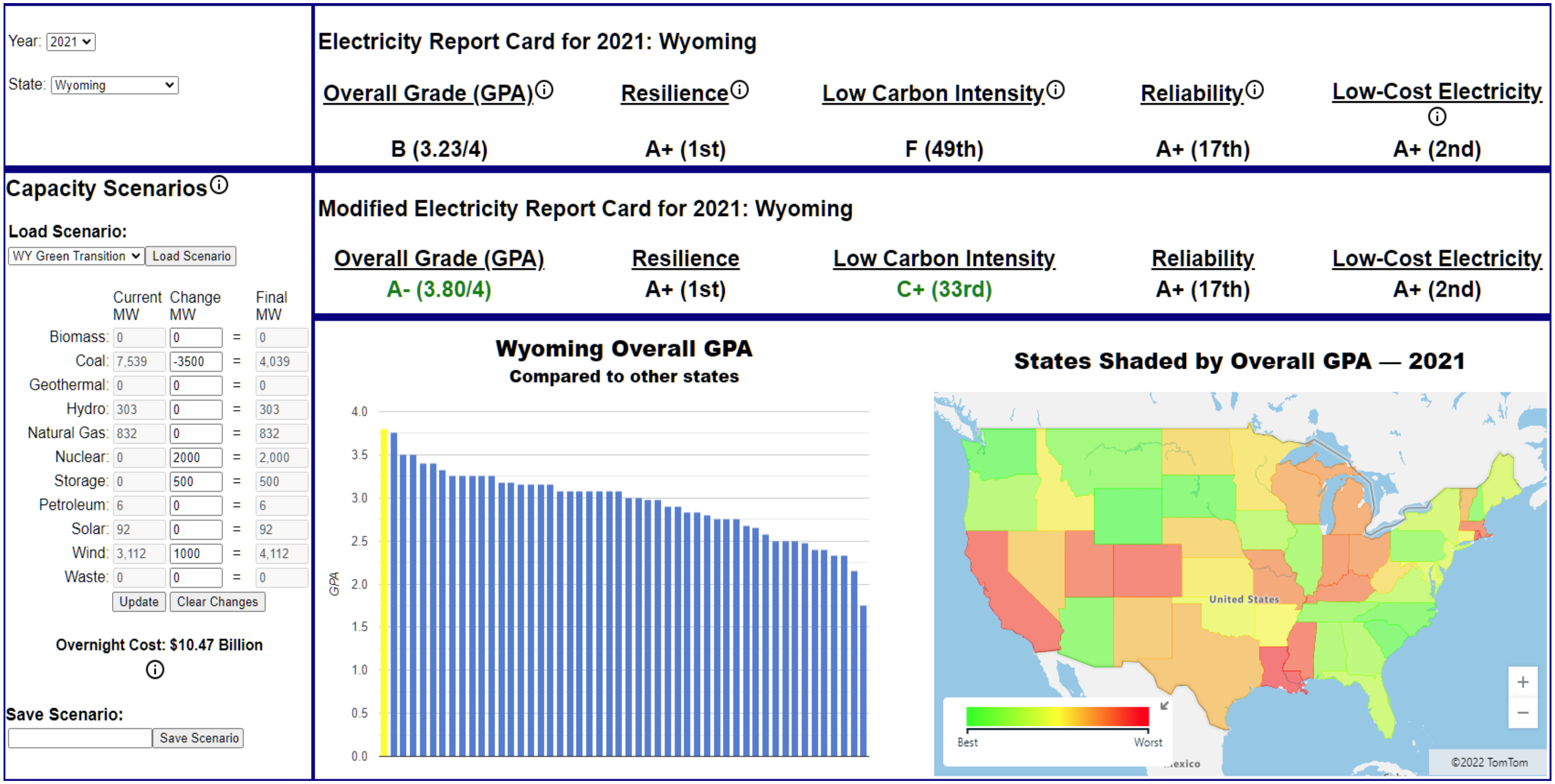


Figure 2. Wyoming Policy Scenario

Conclusions and Next Steps

GridClue.com's grading system for electricity report cards is designed to facilitate transparent, fact-based discussions regarding each state's ability to reliably meet ratepayers' daily needs and promote resilience to grid disturbances. The grading system aims to be intuitive for American-educated students familiar with the "A to F" paradigm. While some states have natural advantages in their grading, such advantages are also present in human classrooms. With each category of electricity grades, there are several takeaways, as well as potential next steps.

When grading Resilience, natural resources and geography play significant roles in a state's grade. States with large coal, natural gas, and hydroelectricity potentials consistently score higher in Resilience. States that are net exporters of electricity often score higher in Resilience because they have slack capacity. On the opposite end, states that are net importers have a lower Resilience score. Grades can be nuanced for states integrated into a larger system. For example, Vermont scores poorly because of the lack of in-state generation, but it exists as part of ISO-New England and does not really operate independently as the Resilience metric implicitly assumes.

Natural resources play as much of a role when measuring Carbon Intensity as they do for Resilience. A state's solar, wind, and hydroelectricity potential will affect how low its Carbon Intensity is. The second piece of the puzzle is how much is invested in renewables. There are several examples of states with similar renewable potential, but a difference in their development puts them at opposite ends of the Carbon Intensity grade. It is also important to note that Resilience and Carbon Intensity tend to be a tradeoff. Most resilient energy sources rely on coal, natural gas, or petroleum for generation, which negatively affects the Carbon Intensity of the state (e.g., West Virginia). On the opposite side, states that invest heavily in renewables, lowering the Carbon Intensity, often lack dispatchable power sources and are at greater risk of blackouts (e.g., California). States with high shares of hydroelectric, nuclear, and/or geothermal resources have advantaged Resilience scores; all of these technologies provide dispatchable power with no carbon emissions.

The SAIDI index reflects reliability impacts on ratepayers but can be an incomplete metric. When measuring Reliability using the SAIDI, we have found that the grades can be skewed. Because of infrequent and localized natural disasters, there is generally a single state with a significantly higher SAIDI than all the others for the year graded. The state with the highest SAIDI sets the worst performance for Reliability grades; all other states are elevated to higher grades. For example, in the year 2021, forty-five states received an A- or higher in Reliability because of Louisiana's high outage rate after Hurricanes Claudette and Ida. A potential solution to this grade skewing would be to use the SAIDI while excluding major event days (MED). Grades would represent "normal curve" outages. The Reliability grades would be more representative of day-to-day operation and more consistent year-to-year. However, it would let states "off the hook" for not being prepared for expected major events (hurricanes, winter storms, etc.). Another option would be to log-normalize the SAIDI to smooth out the distribution. This could work since there are a handful of states with low SAIDIs, and a few extreme outliers with high SAIDIs. However, log-normal distributions would be less intuitive for the average user, and prudent states would lose part of their grade advantage over the poorly performing outliers.

The electricity Cost grades are perhaps the simplest way to compare the states. With Cost scoring, users can easily see the regionality of electricity rates. The New England states consistently have higher electricity rates, as well as the state of California. Higher rates are caused by participation in inefficient electricity markets, reliance on limited natural gas pipeline capacity, and inflated regional costs for labor and supplies. To remedy the issue of unequal costs for regional inputs, we have attempted grading states by their average residential electricity bill compared to median income. This would adjust for regional costs, but it would not take into account the low commercial electricity rates that some states pride themselves on. Outliers for the Cost score can skew the grades for multiple states. For example, Hawaii's high electricity rates elevate the relative Cost scores for other states.

Each grading category has its natural constituency. The grid security community is likely to be a strong consumer of the Resilience and Reliability grades. The environmental advocacy community can understand which states have fossil fuel consuming electricity sectors, as well as which specific resources contribute to the Carbon Intensity score. Consumer advocates can see which states charge consumers the highest rates for electricity, and how well that money is used to make grids clean, reliable, and resilient.

GridClue's Electricity Reports Cards are a work in progress. We look forward to continuing to update the report cards each year with new data from the U.S. Energy Information Administration. We also look forward to getting feedback from users and finding ways to improve the grading methodology.

Appendix A: Case Studies

This appendix is designed to help users – policy makers, analysts, and the general public – understand analytical capabilities of GridClue.com and the Electricity Report Cards. Using data from 2021, three case studies examine large states that have each made policy decisions regarding electricity generation with varying levels of success:

- Washington State being an early success story for renewable energy.
- California showing where it succeeds and falls short with its energy transition goals.
- Texas addressing consequences the state's policies have had on reliability and resilience.

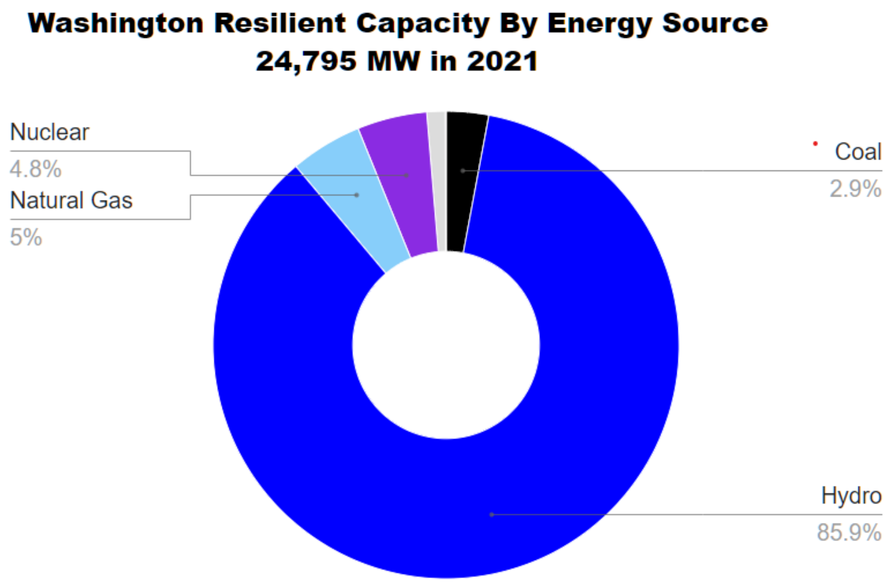
Washington State

Electricity Report Card for 2021: Washington

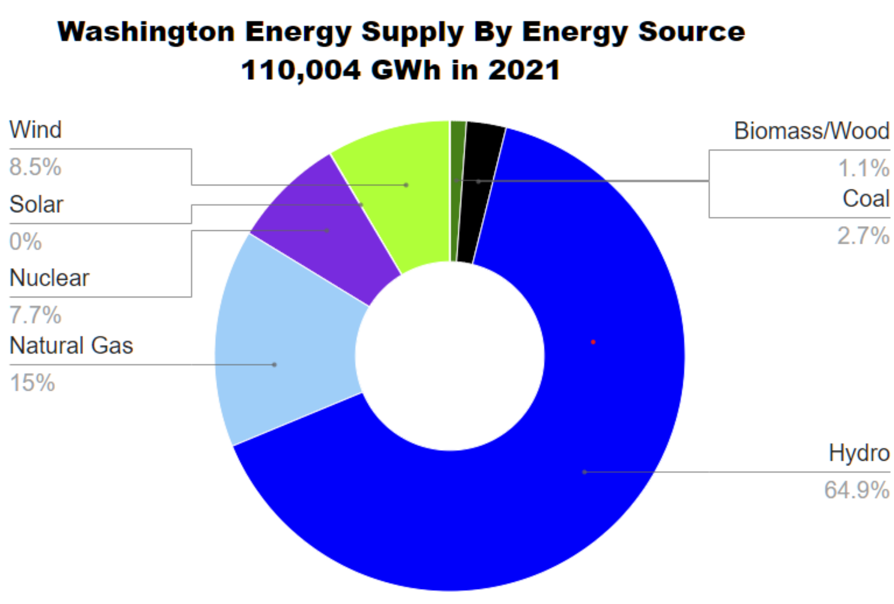
Overall Grade (GPA) ⓘ	Resilience ⓘ	Low Carbon Intensity ⓘ	Reliability ⓘ	Low-Cost Electricity ⓘ
B+ (3.65/4)	C+ (6th)	A (2nd)	A (44th)	A+ (6th)

Overview: Washington tops the Electricity Report Cards year after year, primarily due to its plentiful hydroelectric resources and advantageous weather that minimizes use of air conditioning. A plethora of rivers flow through the Pacific Northwest, powering Washington's hydroelectric dams. The Columbia Basin in the southern part of the state has a high potential for wind energy, which the state exploits via several projects. The region enjoys a consistently mild climate free of hurricanes and most other severe weather. Other than a growing risk of wildfires, Washington does not face the level of natural disasters that confront other states. These factors combine to give Washington favorable performance. Below is an explanation for each grade, and how Washington achieved it

Resilience: Hydroelectricity resources are the main factor in Washington's favorable Resilience grade. While the state places sixth, it earns a "C+" only because Wyoming and West Virginia excel in Resilience. Washington's resilient capacity-to-consumption ratio is 2.48, well above the national average of 1.69. Of Washington's resilient capacity, 86% comes from hydroelectricity, with the remaining from nuclear and natural gas.

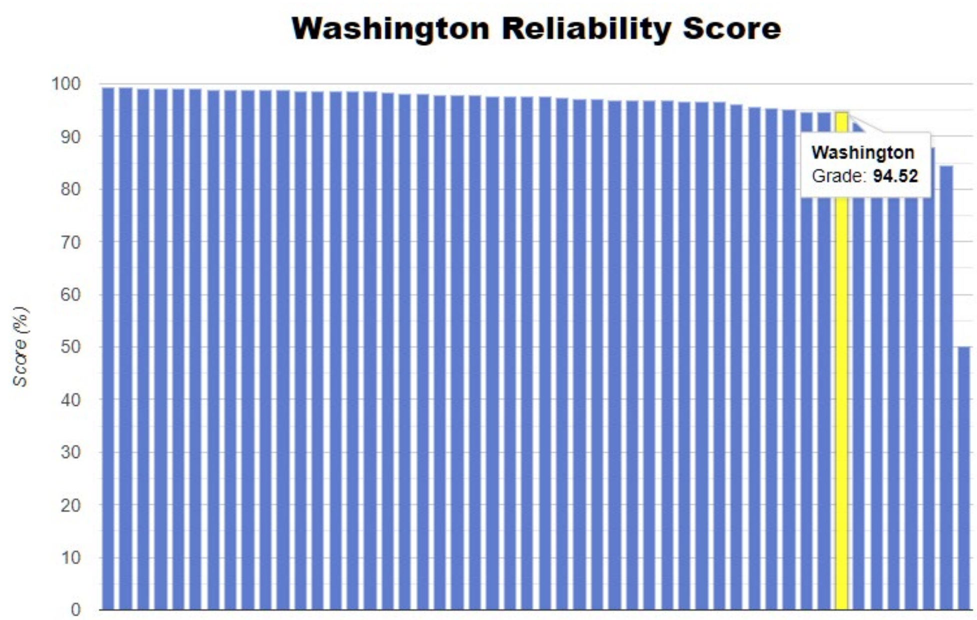


Carbon Intensity: Washington earns second place in Carbon Intensity due to hydroelectricity producing 65% of the state's generation. The Columbia Generating Station leverages wind in the Columbia Basin to provide the state 8,500 GWh of electricity (8.5% of Washington's generation), yielding much zero-carbon energy and increasing the score. Most of the state's carbon emissions result from natural gas generation, which has a relatively low carbon intensity compared to coal-fired generation. These factors combine for Washington's statewide Carbon Intensity of 0.20 Lbs./kWh, second only to Vermont.



Reliability: Washington placed 44th while also receiving an "A." Why? States such as Louisiana are "breaking the curve" by performing poorly and elevating the grades of the other states. In

In 2021, two natural disasters depressed Washington's Reliability score. First, the state experienced multiple wildfires during the summer. Second, the state experienced heavy flooding at year's end, causing the governor to declare a state of emergency. As a result, the average customer experienced 8.7 hours of outages. [2] Washington still had an above-average SAIDI at 527 minutes.



Cost: Washington does well on cost for ratepayers, too, because of the ample hydroelectric resources in the state. A mild climate helps the state to minimize costs for grid equipment. Finally, Washington benefits from the inexpensive natural gas from British Columbia and Alberta, Canada. According to the Washington Department of Commerce, "In Washington, additional sources of natural gas are also being explored, as is the ability to manage our power grid for maximum efficiency, stability, and reliability, allowing seamless load balancing to ensure uninterrupted and consistent flows of energy."[3] These factors combine to create residential, commercial, and industrial rates lower than the national average.

California

Electricity Report Card for 2021: California

Overall Grade (GPA)	Resilience	Low Carbon Intensity	Reliability	Low-Cost Electricity
C+ (2.33/4)	F (49th)	B+ (9th)	A (35th)	C (49th)

Overview: California is a state needing improvement of its generation resources. While it earned a "C+," this is the 4th lowest in state rankings. California has long emphasized a

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[2] https://www.fema.gov/locations/washington

[3] http://choosewashingtonstate.com/why-washington/our-strengths/low-cost-energy/

preeminent policy goal of reducing pollution from electricity generation. It decommissioned coal- and petroleum-fired plants starting in the 1990s, replacing them with cleaner gas-fired plants and power imported from neighboring states. In 2013, California closed the San Onofre nuclear plant, leaving a single nuclear plant remaining. California passed a law in 2018 requiring renewable and zero-carbon generation to supply 100 percent of the state's electricity by 2045. Operators of the remaining gas-fired, thermal plants have little incentive to replace or refurbish aging infrastructures, making forced outages common occurrences. Due to financial incentives, intermittent solar power has grown to comprise a substantial proportion of electricity consumed in California—nearly 100% in the middle of some sunny days. These factors combine to create a precarious electric grid.

Resilience: California has the second lowest score in this category. While reliance on renewable energy is commendable, it prompts a concern about resilience. Based on GridClue.com's definition of Resilience, only 28.3% of California's nameplate capacity[4] is resilient. This percentage might be considered optimistic, as 40.8% of the resilient capacity is hydroelectric and California has experienced years of drought. Another issue is baseload generation relying on natural gas. Out of the 41GW of natural gas capacity, only 5GW has pipeline redundancy or a second fuel source. This risky arrangement makes many plants susceptible to natural gas supply issues. These factors combine to give California a resilient capacity-to-consumption ratio of 0.88, approximately half the national average. Furthermore, if every resilient resource in California operated at full capacity, only 88% of the average electricity demand would be satisfied.

Carbon Intensity: California excels in this category. In 2021, renewables comprised 30.9% of the state's energy supply. Half of the renewable generation came from solar, with the remaining split between nuclear, wind, hydro, and geothermal (listed in order of significance). Natural gas-fired generation is the dominant source of carbon dioxide emissions in the state. Since California's natural gas plants only pollute at a rate of 0.87 Lbs./kWh, the overall carbon intensity of the state is low (0.44 Lbs./kWh).

Reliability: California's scores near the middle of the fifty states. While the state did not experience any state-wide disasters as did Texas or Louisiana, it experienced several wildfires throughout the year that disrupted power delivery. This and other minor service disruptions earned them a SAIDI of 325.

Cost: California placed 48th of the states, earning a "C," ahead of only Hawaii and Alaska. Thus, California is the most expensive state for electricity in the contiguous United States, with residential rates of 22.85 cents/kWh in 2021. California is a summer peaking system. To meet peak demand days, system operators must balance intermittent solar and wind resources with dispatchable natural gas resources. When that combination is insufficient, California relies on

[4] "Nameplate capacity" is the designed capacity of generation units, often designated by a brass nameplate fixed to the equipment.

imports from Arizona, Nevada, and the Pacific Northwest. This reliance on imports and natural gas generation to cover last-minute renewable drop-offs results in Californians paying more for generation than the average U.S. ratepayer.

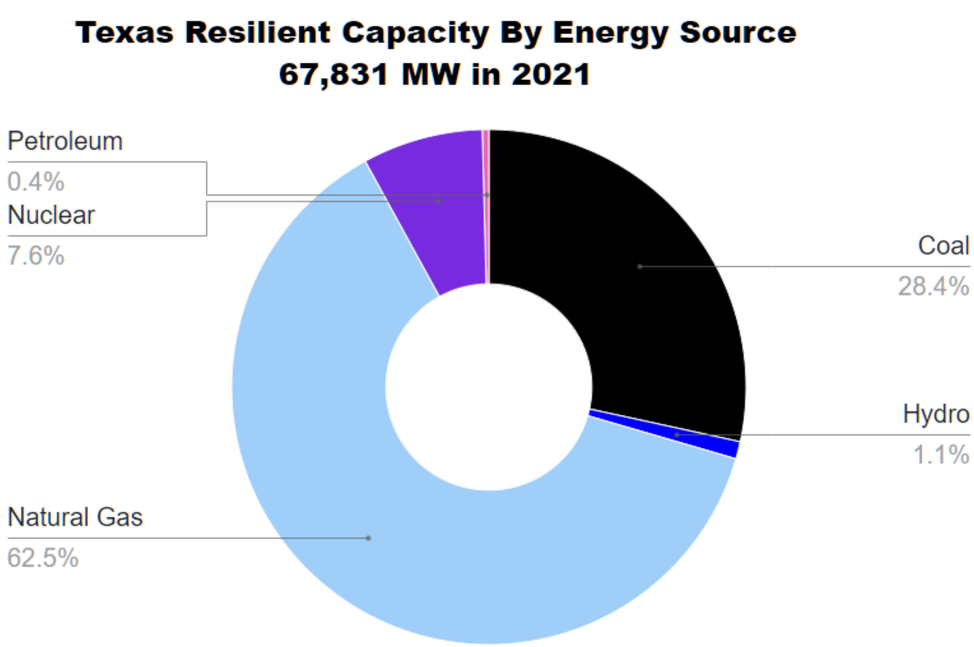
Texas

Electricity Report Card for 2021: Texas

Overall Grade (GPA)	Resilience	Low Carbon Intensity	Reliability	Low-Cost Electricity
B- (2.73/4)	D (39th)	C+ (31st)	B+ (49th)	A+ (16th)

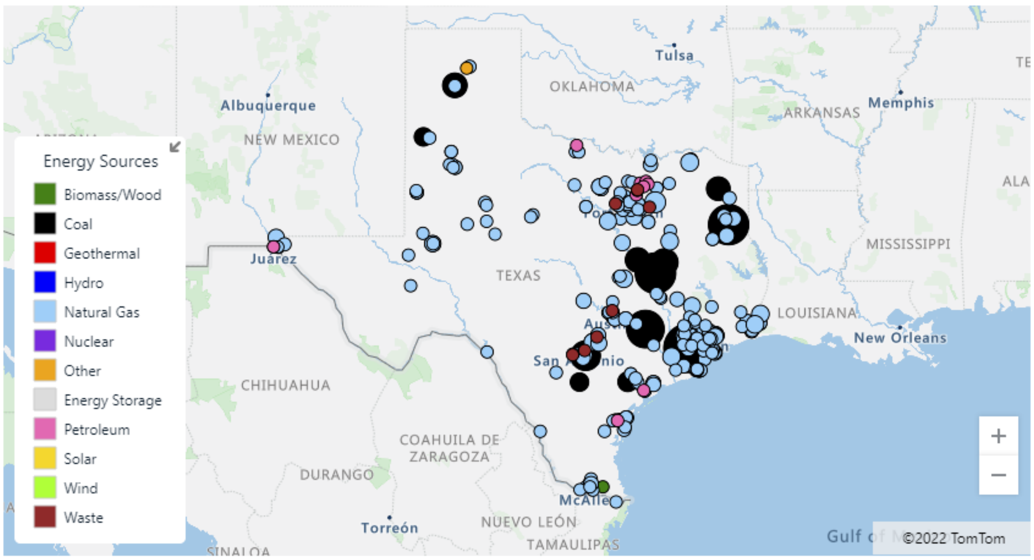
Overview: Texas takes pride in its favorable business environment and considers its low cost of electricity a significant incentive for businesses to operate in the state. Tesla, Hewlett-Packard Enterprise, Oracle, and Charles Schwab agree, having recently relocated corporate headquarters from California to Texas. The ERCOT electricity market provides cheap electricity by paying for energy delivered but not reserve capacity. Such reserve capacity is essential to ensure resilience against extreme weather; hurricanes; deliberate attacks; and other disasters.

Resilience: Texas scores a "D" as only 45% of its 151GW of capacity is considered resilient under the GridClue paradigm. The state's continuous investment in wind reduces carbon emissions, but this non-dispatchable resource cannot be counted on in a crisis, as proven during Winter Storm Uri in February 2021. While Texas has abundant natural gas, many plants lack redundant pipelines to transport that supply. Thus, 47% of gas generation capacity is not considered resilient under the grading paradigm. Texas' resilient capacity-to-consumption ratio is 1.39. This puts Texas at risk during times when cold weather spikes demand and compromises natural gas supply.



Carbon Intensity: Texas earns a “C+” due to its reliance on natural gas and large coal-fired generators. Natural gas-fired electricity is less carbon intensive at 0.88 Lbs./kWh. Natural gas generates 49% of the state's electric energy. Coal, which releases carbon at a rate of 2.31 Lbs./kWh, generates 18% of the state's electric energy. Wind farms in west Texas and the state’s two nuclear facilities reduce the total carbon intensity to 0.84 Lbs./kWh.

Texas Plants Scaled by CO_2 Emissions — 2021



Reliability: In 2021, Texas scored 49th in reliability, predominantly due to Winter Storm Uri in February 2021. Devastation wrought by this extreme weather caused the near total collapse of the ERCOT electric grid – a dramatic demonstration of why electricity markets should value resilient generation capacity. Extreme cold weather hit Texas on February 14th. Early the next morning, coal-fired and gas-fired plants tripped offline due to the freeze. Wind turbine generation declined as ice accumulated on the blades. Starting at 1:20 a.m. on February 15, ERCOT ordered a series of rolling blackouts. Hours later, electricity demand exceeded planned capacity by nearly 10 gigawatts for a system with 83 gigawatts of winter capacity. By that evening, almost 4.5 of 12.5 million ratepayers were in blackout. It took four days to restore power for most regions of Texas. As would be expected, Winter Storm Uri dramatically increased the average customer outage metric (SAIDI) in Texas for 2021.

Cost: In 2021, Texas scored an “A+” for cost of electricity and ranked 12th in the nation, with an average, retail price of 9.31 cents/kWh. This state offers low-cost electricity through ERCOT’s laissez-faire electricity market. With few incentives to increase reliability, winterize, or procure redundant fuel supplies, the whole system runs leanly and inexpensively. Commercial ratepayers enjoy an average price of 8.89 cents/kWh; industrial ratepayers pay only 6.27 cents. Low-cost electricity is inviting for big tech companies, especially those relocating from states with expensive reserve capacity incentives in their electricity markets.

However, the state's growing risk of outages and resulting service disruptions and production delays can handicap businesses. In the aftermath of Winter Storm Uri, the Texas Comptroller reported, "… devastation continues to be tallied, early estimates of the storm's economic toll, as mentioned, ranges from $80 billion to $130 billion — the result of power loss, physical infrastructure damage, and forgone economic opportunities."[5]

[5] Jess Donald. "Winter Storm Uri 2021 The Economic Impact of the Storm." Fiscal Notes; A Review of the Texas Economy. Texas State Comptroller. October 2021. Available at: https://comptroller.texas.gov/economy/fiscal-notes/2021/oct/winter-storm-impact.php

Appendix B: Scoring Methodologies

This appendix contains screenshot descriptions of the scoring methodologies for each of the grade categories in the Electricity Report Cards.

Resilience

Resilience against Long-Term Outage as determined by the Ratio of **Resilient Nameplate Capacity** to **State Consumption.**

Resilient Nameplate Capacity: The sum of dispatchable resources and resources with sufficient on-site fuel storage. Natural gas plants are only included in this total if they have 2+ pipeline connections, or if they have an alternative energy source they can switch to.

State Consumption: The sum of electricity sales by utilities for the selected year.

$$\frac{Resilient\ Natural\ Gas + Nuclear + Hydro + Pumped\ Storage + Geothermal + Petroleum + Coal}{State\ Electricity\ Consumption}$$

Carbon Intensity

Carbon Intensity of generation plants, which is the **Sum of Carbon Emissions** divided by the **Electricity Generation.**

Carbon Intensity: Determined by multiplying fuel-specific carbon emissions per mmBTU and the thermal output associated with that fuel.

$$\frac{\sum_{Fuel}(CO_2\ Factor * Thermal\ Output)}{Generation}$$

Reliability

Reliability as determined by **SAIDI (System Average Interruption Duration Index)**

SAIDI: The Sum of all Customer Outages in minutes over the total number of customers served.

$$\frac{\sum Outages}{\sum Customers}$$

Cost

Electricity Cost as determined by the Average Price per Kilowatt Hour for electricity sales within the state.