Macquarie Global Listed Infrastructure[1]

Should we fear renewables in the power system...

The repowering of global economies this century has sought to deliver relatively cheap, clean, and reliable electricity. One of the biggest concerns amongst consumers and observers of energy markets is that renewable energy, which has seen the most significant rate of growth in recent times, does not produce electricity in a manner that appears predictable, in short it has intermittency issues.

In more common terminology, renewables "don't work when the wind doesn't blow, and the sun doesn't shine". This seemingly unpredictable output strikes at the core of consumer concerns – the worry that electricity is not available when the switch is flicked.

What is it about renewables that is attractive from an investment perspective?

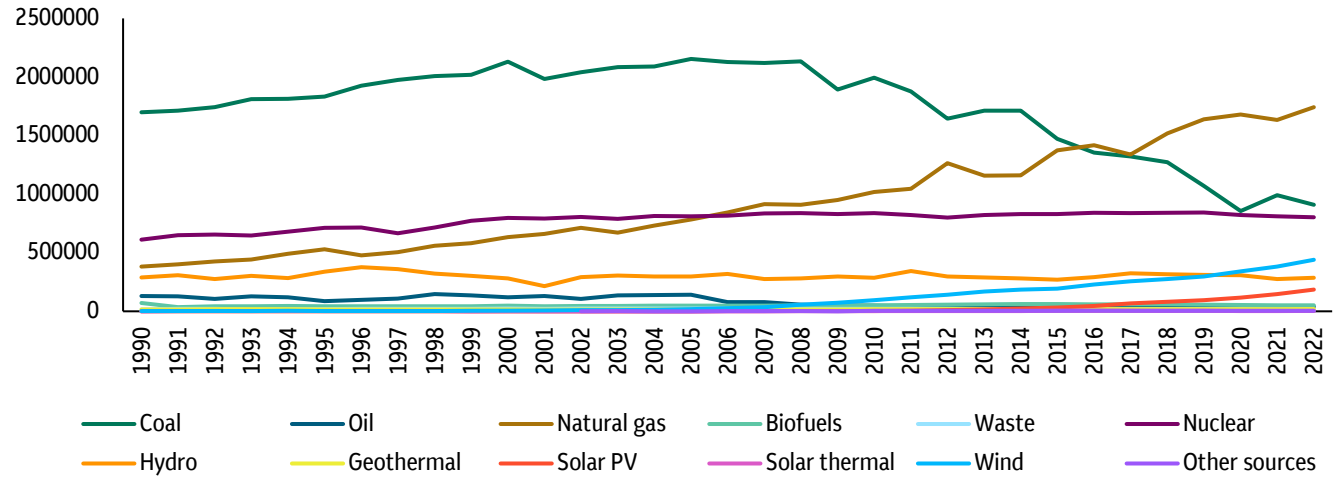
Macquarie seeks investments in listed infrastructure companies that feature returns linked to contracted or regulated revenue streams. Renewables offer an attractive investment opportunity given the quantum being invested, and the attractive investment features, such as high operating margins due to no input cost of fuel; and preferential access to the grid due to zero marginal cost of operation. Intermittent operation of renewable assets has few implications from an investment standpoint... in the short run they have highly volatile performance ('wind doesn't blow, sun doesn't shine'), but over each year of operation they have significantly more predictable operational performance.

[1] Macquarie Listed Infrastructure is an equity team within Macquarie Asset Management's (MAM) Equity & Multi-Asset business.

In this note we explore the relationship between different generation technologies and electricity system reliability, with the United States, a significant electricity market as well as a significant part of the listed infrastructure universe, as a case study. In doing so we aim to answer the question **"should consumers fear growing proportions of renewables within the power system?",** or are there other factors that are correlated with unreliability. The United States is the world's second largest producer of electricity in the world, only behind China. Since 1990 the generation mix has altered significantly, with coal output declining by -58% since 2005, and gas-fired generation increasing by +123% over the same period, a result of the significant increase in gas supplies from the shale gas revolution.

Renewable energy from Solar and Wind have increased from 0.4% of the country's output in 2005 to 14.0% in 2022, a factor of 33x.

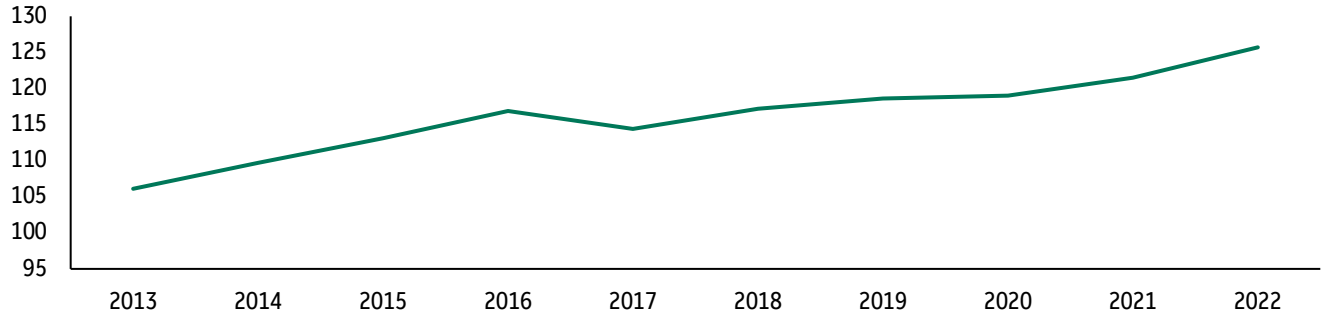
Electricity generation by source, United States, 1990-2022



Source: International Energy Agency.

In recent years, the United States has been experiencing declining levels of electricity system reliability. The most frequently used measure of unreliability is the number of minutes that electricity consumers are without electricity supply on average across a service area. This measure of unreliability is known as System Average Interruption Duration Index or "SAIDI". As can be seen below, SAIDI has been rising across the United States in recent years, a period during which coal has been reducing in significance and gas and renewable energy has been rapidly gaining. This statistic alone is often cited as drawback of the growing levels of investment in renewables.

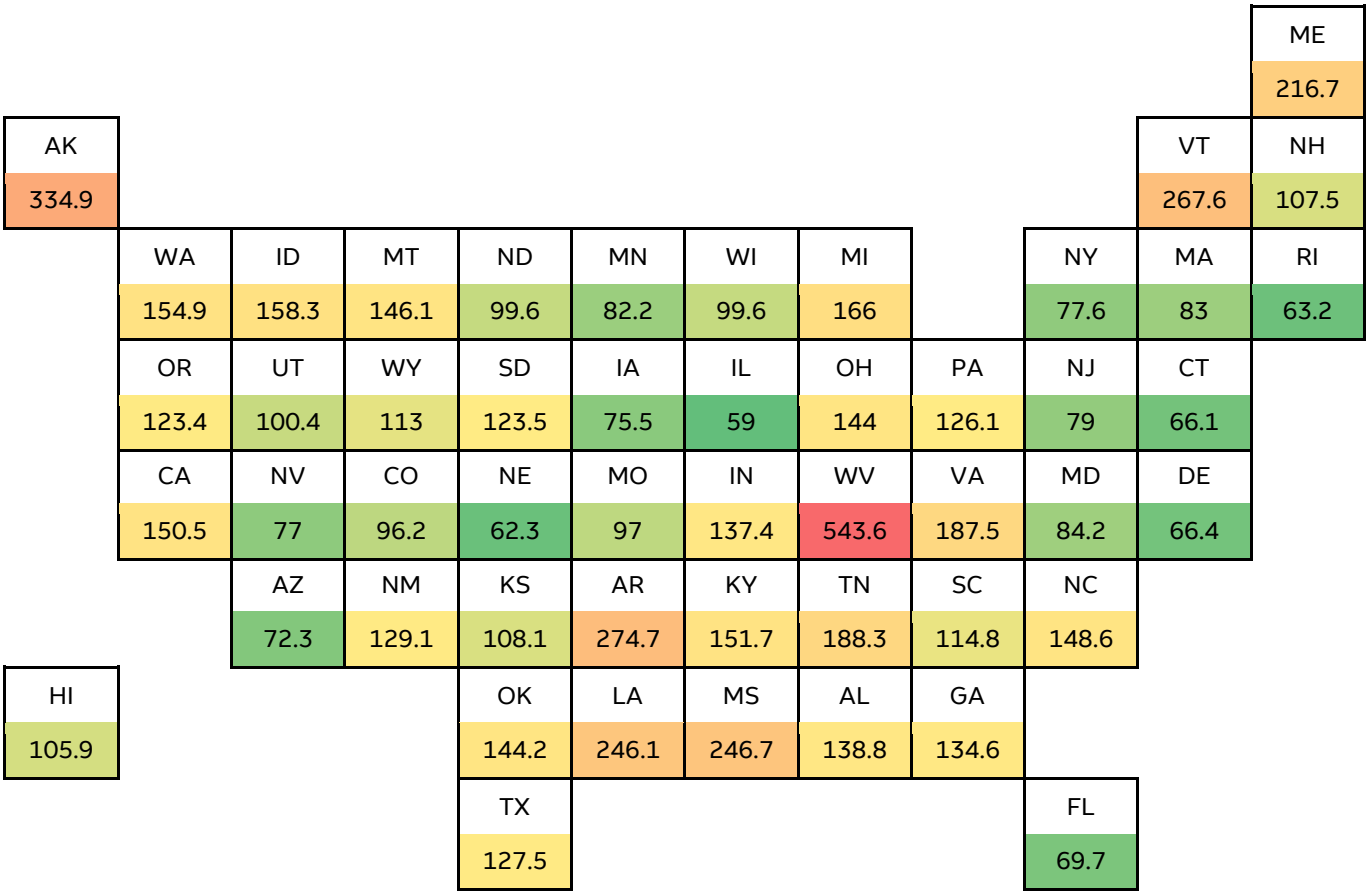
SAIDI - United States - 2013-2022



Source: United States Energy Information Administration.

Reliability in United States – State vs state

Access to reliable electricity is an essential ingredient in developing a prosperous, innovative, and equal opportunity society. The diagram below provides a comparison of the best and worst states with respect to electricity supply reliability (green the best, red the worst). The diagram shows that across the United States there exists a wide range of reliability outcomes for consumers. The best reliability outcomes appear in the east of the country, and across a broad number of states in the Mid-West. Outages are also higher at the extremities (such as Alaska and the far Northeast), and the central southern states.



Source: United States Energy Information Administration.

The state with the least reliable electricity supply is West Virginia at 544 minutes on average per customer. It also has five near neighbours that also sit in the ten least reliable electricity suppliers.

A significant proportion of the top ten most reliable states are on the East Coast. An additional clustered group of states in the central north of the country perform well with respect to reliability.

The outcomes are clearly not random in nature, rather clustered in certain regions. So, what is driving these outcomes if not random in nature? What are the factors that are correlated with higher unreliability?

Renewables penetration in the United States

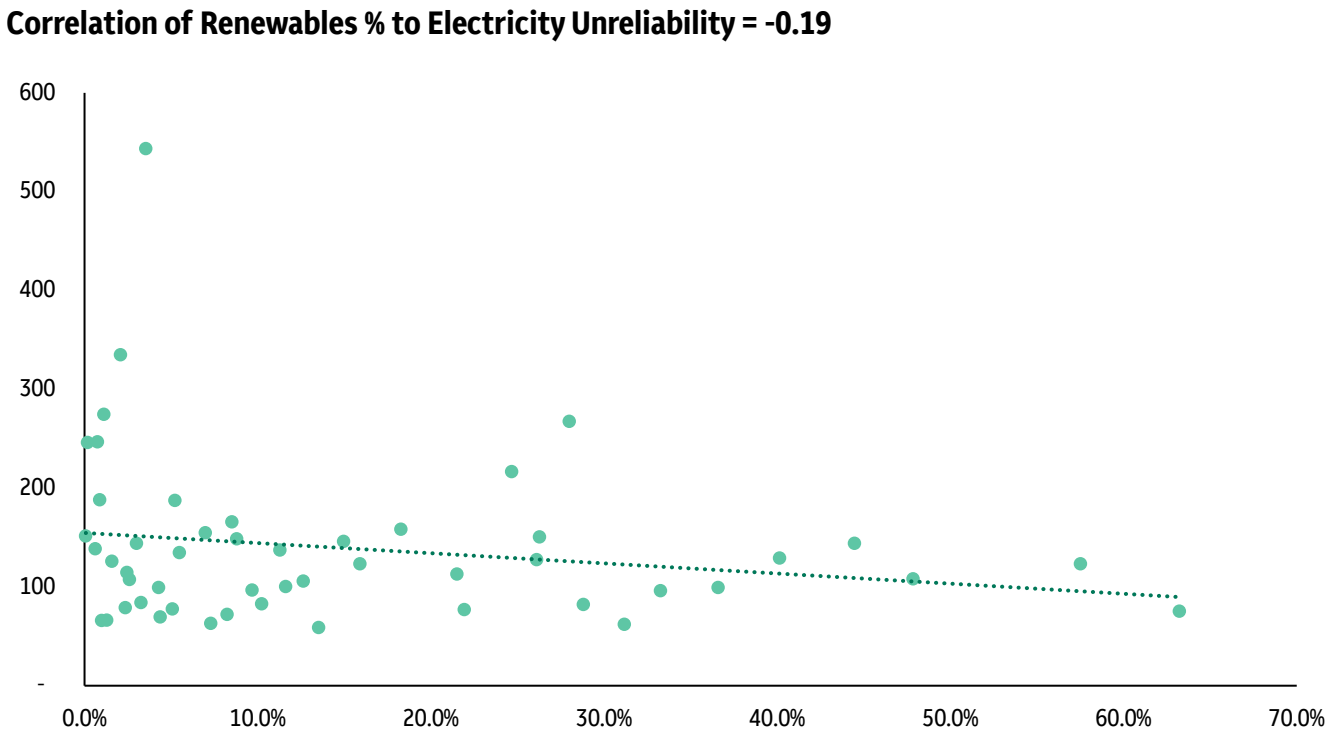
Renewable energy adoption rates (defined as electricity generation from wind and solar for this analysis) have, for various reasons, been uneven across different states. As at the end of 2022, the state with the highest penetration of wind and solar was Iowa which is located near similarly equipped states of North and South Dakota, and further south, Kansas and New Mexico. The states with the lowest renewable penetration rates, despite significant natural resources, are Louisiana, Kentucky, Arkansas, Tennessee, and Alabama. Further afield sit Connecticut and Delaware with 1% penetration. Renewable generation assets benefit from high wind resources in the Mid-West. Higher solar resources act as an incentive to install solar generation in those states closer to the equator.

											ME
											25%
AK										VT	NH
2%										28%	3%
	WA	ID	MT	ND	MN	WI	MI		NY	MA	RI
	7%	18%	15%	37%	29%	4%	9%		5%	10%	7%
	OR	UT	WY	SD	IA	IL	OH	PA	NJ	CT	
	16%	12%	22%	58%	63%	14%	3%	2%	2%	1%	
	CA	NV	CO	NE	MO	IN	WV	VA	MD	DE	
	26%	22%	33%	31%	10%	11%	4%	5%	3%	1%	
		AZ	NM	KS	AR	KY	TN	SC	NC		
		8%	40%	48%	1%	0%	1%	2%	9%		
HI				OK	LA	MS	AL	GA			
13%				44%	0%	1%	1%	5%			
				TX					FL		
				26%					4%		

Source: United States Energy Information Administration.

Is there a positive relationship between unreliable supply of electricity and renewable penetration?

In short, no. **There is a clear negative correlation between higher levels of wind and solar generation in a state and unreliable electricity supply to end customers.** States with renewables penetration over 30% such as New Mexico, Colorado and South Dakota have average SAIDI levels of 105 minutes compared to states with less than 5% renewables penetration, such as Pennsylvania, Maryland and Arkansas which have 171 minutes on average, a 63% higher level.

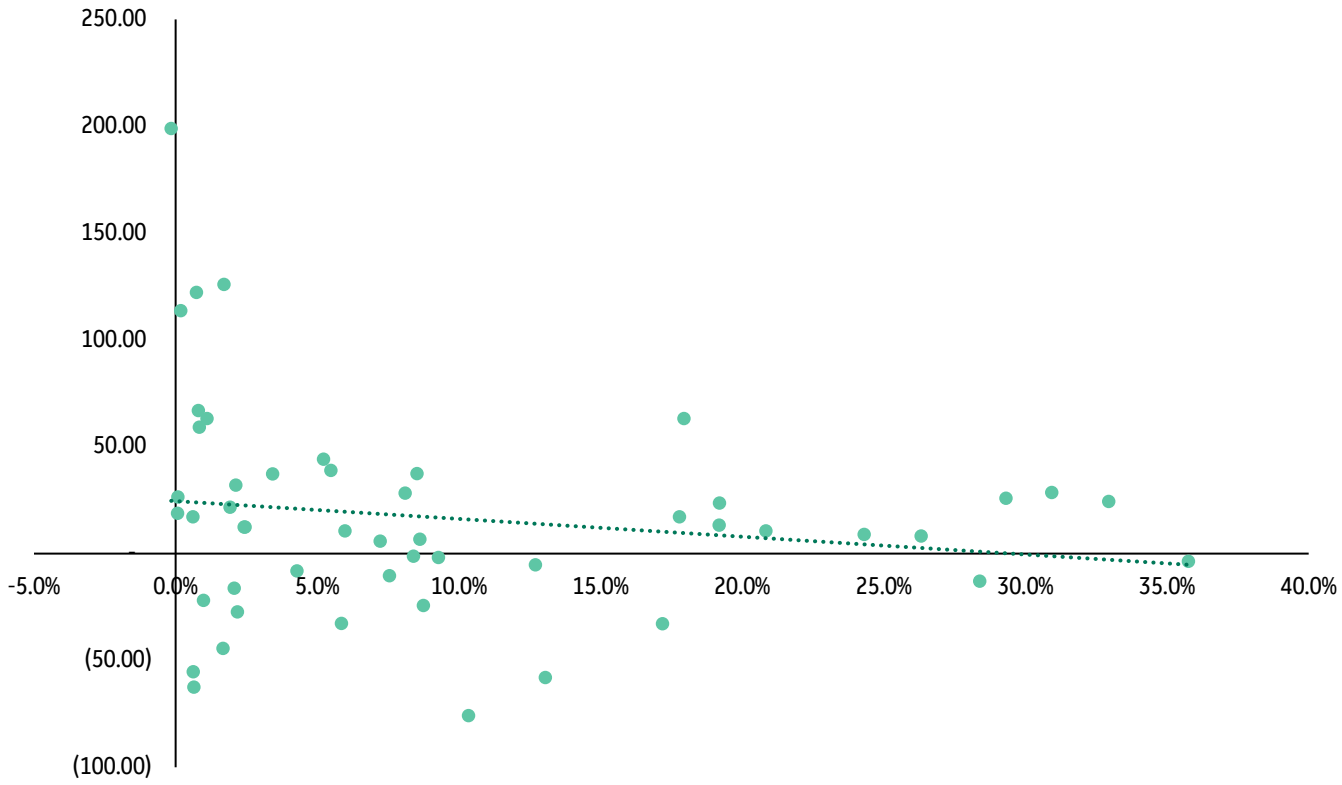


Source: United States Energy Information Administration.

Has more renewables investment led to better or worse reliability?

Better reliability. In the US, there is a negative correlation between electricity unreliability and increased renewable investment over the period 2013-22. The chart below shows the increase in renewables as a percent of the energy mix relative to the change in SAIDI, or electricity unreliability. The largest increase in renewables has been seen in Iowa which has increased renewables as a percent of generation by +36%. Reliability has remained relatively flat: four minutes less outage per annum. A number of states have seen SAIDI decreases with increased renewables, the most notable being Utah, a state that has increased renewables by +10.3% between 2013 and 2022. At the other end of the spectrum, the five worse performers with respect to reliability have each lifted renewables generation as a percent of total generation by less than 2% over 2013-22.

2013-22 wind/solar change as % generation mix vs change in unreliability (SAIDI) by US state, corr = -0.17



Source: United States Energy Information Administration.

What factors are correlated with unreliability in the US?

Recall the clustered nature of unreliability in the US. As we've seen there is no positive correlation between renewables and unreliability, in fact the opposite. We next explore other variables that may explain the drivers of unreliability. Below we investigate, by state: population density, forest cover, precipitation levels, personal income, and geographic proximity to coast.

Factor	Correlation	Comment
Population density	Correlation with unreliability = -0.24	Higher population density is correlated with more reliable electricity supply. We compared population density using the metric of population per square mile of land based on US census data.
Forest Cover	Correlation with unreliability = 0.43	There is a relatively strong correlation between forest cover and less reliable electricity supply. We used data from the US Department of Agriculture to investigate the level of timberland by US state. Service disruptions from network damage resulting from falling trees or tree limbs is a significant cost for utilities due to preventative maintenance programs.
Precipitation level	Correlation with unreliability = 0.18	There is a relatively strong correlation between precipitation levels and less reliable electricity supply. Precipitation levels in the United States are highest along the eastern half of the country. A second geographic region with higher rainfall is the US Gulf Coast, a result of tropical storm activity. A driver of power outages is storm activity due to high winds which can directly or indirectly (via storm debris) interrupt network services.
Personal income	Correlation with unreliability = -0.43	There is a relatively strong negative correlation between income levels and less reliable electricity supply. Higher incomes on the east and west coasts of the US reflect concentrations of economic activity within and around large cities. Higher incomes clearly imply a greater ability to invest in electricity supply systems to improve service levels.
Geographic proximity to the coast	Correlation with unreliability = 0.12	There is a weak positive correlation between proximity to the coast and less reliable electricity supply. We explored whether being exposed to the natural elements to a greater degree (such as for Hawaii or the Florida peninsula) leads to lesser reliability.

Source: https://www2.census.gov/programs-surveys/decennial/2020/data/apportionment/population-density-data-table.pdf

"Forest Inventory and Analysis Fiscal Year 2016 Business Report" (PDF). United States Department of Agriculture.

Source: https://coolweather.net/extremes/wettest_driest_us_states.htm#google_vignette

Source: U.S. Bureau of Economic Analysis, Census Bureau midyear population estimates available as of December 2023.

Conclusion

A false conclusion can be easily drawn from a simple analysis of rising renewables deployment and rising electricity system interruptions, or SAIDI, over the last decade. Increases in electricity outages has been greatest in US states that have increased renewables penetration the least. Data strongly suggests that electricity unreliability is most closely related to natural features such as the level of tree cover and rainfall/storm activity, factors that largely impact network assets, as opposed to electricity generation assets themselves. Economic and geographic factors such as income levels and population density can potentially insulate consumers from system outages due to greater investment. Crucially, there exists a negative relationship between renewables penetration and system unreliability, or more simply put, the more renewables, the more reliable electricity supply appears to be.

Correlation between unreliability and six key drivers

	Unreliability (SAIDI)
Forest Cover	0.43
Precipitation (in)	0.18
Proximity to coast	0.12
Renewables %	-0.19
Population Density	-0.24
Personal Income	-0.43

Source: Macquarie

https://www2.census.gov/programs-surveys/decennial/2020/data/apportionment/population-density-data-table.pdf

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The potential for adverse events in the global infrastructure sector to impact the performance of the investments of the Strategy. Investments in securities issued by companies which are principally engaged in the infrastructure business will subject the Strategy to risks associated with direct investment in infrastructure assets. Factors such as the availability of finance, the cost of such finance in general as well as in comparison to prior periods, the level of supply of suitable infrastructure projects and government regulations relating to infrastructure may influence the value of these investments and hence the Strategy.

The risks of investing in the infrastructure sector include those listed here.

New project risk: Where an infrastructure issuer invests in new infrastructure projects, it is likely to retain some residual risk that the project will not be completed within budget, within the agreed time frame and to the agreed specification.

Strategic asset risk: Infrastructure assets may include strategic assets, that is, assets that have a national or regional profile, and may have monopolistic characteristics. The nature of these assets may generate additional risk given the national/regional profile and/or their irreplaceable nature and may constitute a higher risk target for terrorist acts or political actions.

Documentation risk: Infrastructure assets are often governed by a complex series of legal documents and contracts. As a result, the risk of a dispute over interpretation or enforceability of the documentation may be higher than for other issuers.

Operation risk: Should an infrastructure issuer fail to maintain and operate the assets efficiently, the ability to maintain payments of dividends or interest to shareholders may be impaired. Failure by the infrastructure issuer to carry adequate insurance or to operate the asset appropriately could lead to significant losses and damages.

International investments entail risks including fluctuation in currency values, differences in accounting principles, or economic or political instability. Investing in emerging markets can be riskier than investing in established foreign markets due to increased volatility, lower trading volume, and higher risk of market closures. In many emerging markets, there is substantially less publicly available information, and the available information may be incomplete or misleading. Legal claims are generally more difficult to pursue. The Strategy may invest in preferred stock and hybrid securities, which may have special risks. Preferred and hybrid securities may include provisions that permit the issuer, at its discretion, to defer distributions for a stated period without any adverse consequences to the issuer. Some preferred and hybrid securities are non-cumulative, meaning that the dividends do not accumulate and need not ever be paid. A portion of the Strategy's assets may include investments in non-cumulative preferred or hybrid securities, under which the issuer does not have an obligation to make up any arrears to its investors. Preferred and hybrid securities may be substantially less liquid than many other securities, such as common stocks or US government securities. Generally, preferred and hybrid security holders (such as the Strategy) have no voting rights with respect to the issuing company unless preferred dividends have been in arrears for a specified number of periods, at which time the security holders generally may select a number of directors to the issuer's board. Generally, once all the arrears have been paid, the security holders no longer have voting rights. In certain varying circumstances, an issuer of preferred or hybrid securities may redeem the securities prior to a specified date. For instance, for certain types of preferred or hybrid securities, a redemption may be triggered by a change in federal income tax or securities laws. A redemption by the issuer may negatively impact the return of the security held by the Strategy.

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Source for all performance data unless noted: Macquarie.
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