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Applied Derivatives

The Role of Electricity Derivatives in The Texas Power Crisis of February 2021

Texas is a unique energy market as electricity is provided through a deregulated intra-state grid. Additionally, not only is Texas the highest-ranking state in terms of both electricity and natural gas consumption, it also the nation's leader in production. The management of electricity supply in Texas is operated by the Electric Reliability Council of Texas (ERCOT) an independent system operator. ERCOT is one of many reliability councils under the North American Electric Reliability Corporation (NERC). NERC is responsible for ensuring the reliability, security, and adequacy of the bulk power systems in the USA, Canada, and parts of Mexico. Reliability is defined by NERC in terms of adequacy which focuses on the ability of the system to always supply the aggregate demand of users, as well as reliability which measures the ability of the system to withstand sudden disturbances. ERCOT also handles reserves, controls generation in system emergencies, and most importantly ensures maximum efficiency and reliability as a part of NERC. Electricity operators ensure the continuous balance of electrical frequency to ensure that supply and demand (load) move in parallel quantity. Damaging effects are observed when each supply outpaces demand, and demand outpaces supply, forcing operators to ensure that the input and output of electricity remain around 60hz.

A worst-case scenario (system-wide blackout) occurs when the system becomes unbalanced causing for demand(load) to exponentially increase while supply dwindles and capacity decreases or vice versa. Some may question, why would such a large imbalance ever occur? Systems are kept in sync, because most generators and energy suppliers operate under the tightly imposed state regulations, and federal regulations in some states where energy is imported/exported across state lines. ERCOT has little federal oversight which has allowed for the restructure of the Texas electricity market which in turn, has proliferated severe competition amongst energy generators. The electricity generators compete to sell electricity in two markets, both via wholesale methods and directly to consumers in the retail market. Prior to the restructure under ERCOT in 2001, the masses of Texas were served by investor-owned systems that were vertically integrated. Most would think that a system that is owned directly by investors would serve them better. However, due to competition under the new restructuring, prices were driven down as various entities competed for customers. Supply and demand issues can be difficult to solve when in Texas the state oversight organizations are different entities for electricity and natural gas. Under the current structure, electricity is overseen by the Public Utility Commission of Texas (PUCT), whereas natural gas within the state is overseen by the Texas Railroad Commission (RRC.)

The main downfall to this specific structuring emerges from the razor thin margins that many electricity suppliers must operate within to continue to compete in a highly competitive price focused market. Power suppliers only justify new expenditures if consistent demand trends are revealed when reviewing a longer-term electricity consumption pattern. On top of the delayed responsiveness of the insular Texas grid which only meets demand after it has been consistently observed, no state mandates exist that would require system upgrades to create more reliability in production. In addition, there are no penalties that would hypothetically force electricity generators to increase their supply in response to rapid demand or to winterize their equipment to prevent lack of reliability. Lastly, to maximize profits, electricity generators strategically do annual maintenance to gear up for the hot summer months during the winter when demand is historically low.

Akin to many other systems, Texas relies predominantly on natural gas for electricity production, however because of low long-term overhead costs, renewable energy sources have also emerged as a significant option. Despite this new eco-friendly way to produce power, any measures that could be taken to winterize were also avoided due to the associated costs that would create competitive disadvantages. Wind turbines and solar both have the capability to install cold-weather packages, but these steps were intentionally avoided.

Weather is by far the biggest determinant in electricity production. Poor weather especially in a place like Texas where the oversight and regulation are quite relaxed can create significant operating capacity issues on the supply side. Texans rely on electric based heating for their poorly insulated homes causing cold weather events to exponentially spike the demand quite rapidly. On the flip side, the supply systems which are not winterized struggle to sufficiently stay operational, causing for a significant spread to grow between the necessary balance required by ERCOT to keep the system stable. There are significant weather conditions that can adversely increase consumer demand (load).

Winter Storm Uri was one of the most impactful events in recent Texas history. The storm brought extremely low temperatures, sleet, and freezing rain, which eventually turned into snow. The first storm led to multiday road closures, broken pipes, and subsequent power losses which caused loss of heat. As the first storm wound down, Texan weather authorities were concerned that, yet another winter storm was on the horizon. The next storm brought more freezing rain causing for weather authorities to transmit another “Winter Storm

Warning". Unfortunately, as the other storm's snow began to melt, that same moisture began to refreeze making for hazardous road conditions once again. The second storm's "Hard Freeze Warning" did not expire until 5 days later at 9am. The potential impact of a storm like Uri was grossly underestimated by ERCOT who relied on the Seasonal Assessment of Resource Adequacy (SARA) for load estimation and load shedding protocols for any inclement weather. Interestingly upon review, SARA's predictions, even in the worst scenario possible, depicted in figure 1, still fell short. The possibility of a complete system failure wasn't taken into consideration and weather conditions were almost impossible to predict.

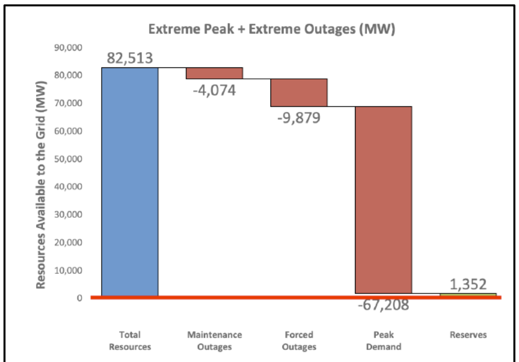


Figure 2.b. Waterfall chart of the ERCOT "Extreme Peak Load / Extreme Generation Outages During Extreme Peak Load" Winter 2020/2021 SARA scenario. This scenario indicated that ERCOT would have only 1,352 MW of reserves, insufficient capacity to prevent an Energy Emergency Alert.

Figure 1

Despite warning signs leading up to the event, very few electricity generators took any steps to help mitigate the impact of a continual winter storm that would cause various plants to shut down. In fact, the first concerning reports were presented to ERCOT on February 8th and as of February 13th weather models still disagreed on the difference in forecasted temperatures by 10-degrees Fahrenheit. ERCOT was proactive in issuing operating notices out to generators to review fuel supplies and gauge output capability on February 8th, however as previously mentioned the reliability council still fell significantly short. The failure from a lack of regulation and lack of incentive for generators to winterize their plants due to costs escalated the impact of the storm as depicted in Figure 2. Interestingly, the price of electricity began to increase before the crisis. Such an occurrence most likely indicates that generators were worried about

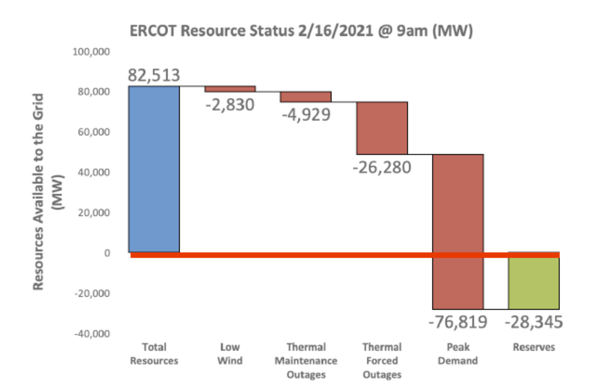


Figure 2.c. Waterfall chart of the actual resource availability at the time of peak demand (February 16, 2021 at 9 am) indicating a shortage of 28,345 MW in capacity due to lower than forecasted wind output, a higher capacity offline for maintenance, and over 26,000 MW of capacity triggered offline as instigated by the weather conditions.[14]

Figure 2

their plants capabilities to withstand the storm. However, if the storm was not bad enough, the implementation of winterization costs would undoubtedly undermine their competitive capability. In addition, not only was the weather forecast timing and severity inaccurate, but the symptoms of a polar vortex that were to come would also make it impossible for mothballed plants to attempt to initiate electricity generation.

When the storm finally hit, ERCOT began to deploy Responsive Reserves in conjunction with an Emergency Notice as large generators began to go offline. As of Valentine’s Day, ERCOT began to issue a public appeal for energy conservation across the grid to help mitigate the level of load that was becoming increasingly harder to meet. First, wind energy failed as blades became frozen and internal components such as the nacelles and gearbox began to fail. Other causes of failure ensued such as frozen water intakes and sensing lines. As subsequent generators failed, many were mothballed (under maintenance) making the supply side of the system weaker. Likewise, fuel imitations also caused issues as some plants are unable to operate with lower fuel pressure. Thus, as renewable, gas, coal, and other sources of electricity generation failed as the load significantly increased, ERCOT had no choice but to shed load quickly to keep the frequency of the grid in balance. Specifically, ERCOT had to keep the states grid frequency above 59.4 hz otherwise any value above or below would cause a system wide blackout. A system-wide black out would completely take down a significant part, if not the whole state's power, most likely taking 2-3 months to restore power across the system. To fully digest what specifically caused so many issues in Texas costing the state billions of dollars in damage and resulting in multiple deaths, it is important to understand how electricity derivatives work. The hedging strategies of different companies, especially in a deregulated marketplace, are key components to understanding specific motivations to above all, develop an ideal business structure, remain competitive, and ensure future profitability.

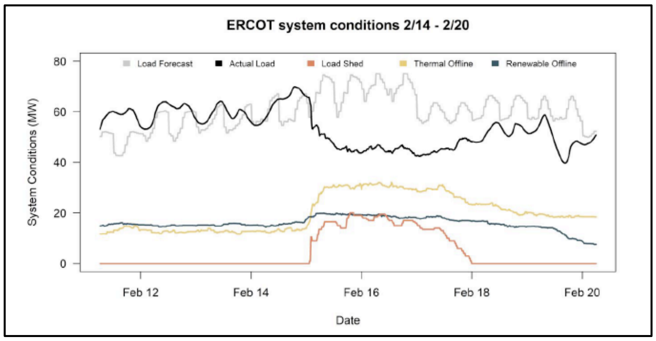


Figure 3

In Texas, electricity is generated from three primary sources including natural gas, non-hydroelectric renewables, and coal-fired generation. To begin, for the most part the entire United States electric grid had largely switched from coal for electricity generation to natural gas as both the carbon imprint and efficiency were predominantly more favorable under this model. As mentioned previously, the demand for electricity is quantified into a term called load which specifically represent the amount of power carried by a system, or the amount of power consumed by an electrical device at a specified time. To understand measurements in charts and references, it is vital to explain the two main ways in which electricity is quantified. Specifically, the watts rating of a specific good illustrates the split-second quantity of electricity being consumed. Simply measuring electricity in such a manner would not be ideal to understand overall consumption as split seconds would be far less

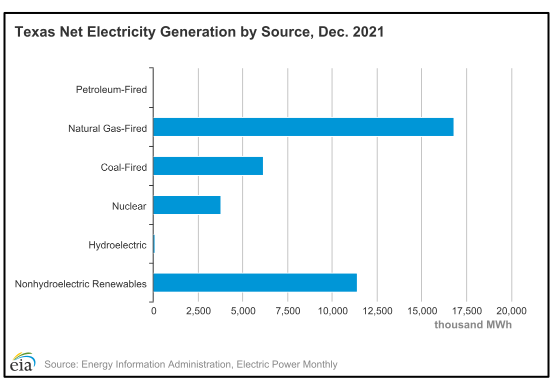


Figure 4

relevant than better understood time frames. Thus, most electric usage is measured in watt-hours (Wh). Watt-hours is calculated by multiplying the number of watts used by the number of hours. Units of 1000Wh each represent 1 kilowatt hour (kWh).

An important commodity that is essential to the market of electricity derivatives is natural gas. Methane, is the main component of natural gas, is referred to as wet or dry and found in the same locale as crude oil. 35% of natural gas is utilized to generate electricity in the US. Electricity needs would be impossible to meet with a single fuel source, thus, other methods such as non-hydroelectric renewables such as wind and solar are also utilized along with small amounts of coal-fired sources. Interestingly, ERCOT had a non-firm delivery agreement in place at the time of the weather crisis. A non-firm delivery dictates that any residential demand is prioritized if the overall gas system is constrained, therefore establishing a hierarchy that restricts the capability for power plants to have gas delivered.

There are 3 main processes that are utilized to generate electricity. They are: Combined Heat and Power (CHP), Combined Cycle Gas Turbine (CCGT), and lastly Open Cycle Gas Turbine (OCGT). The generation of electricity stems from concepts like that of the discovery of the world's first steam engine. Heat from coal or natural gas is utilized to heat water to a boil and then the subsequent steam is utilized to spin a turbine which powers a generator that produces electricity. The generator creates electricity via the process of electromagnetic induction which simply involves the rotation of a wire within a magnetic field that subsequently induces an electric current. The same concept is utilized by solar panels which absorb energy that is used to heat water into steam. Lastly, wind power simply removes the necessity to boil water to drive the turbine, as the movement of the blades directly drives the generator. CHP produces electricity through the usage of natural gas. CCGT electricity generators are more efficient as they utilize gas produced from primary fuel to power the primary turbine and the subsequent byproduct gas from combustion to heat a boiler which creates steam that powers a second turbine. Lastly, OCGT also produces their electricity from the gases created from fuel combustion and is the least efficient however the most agile in scalability, a process that is typically utilized to respond to sharper increases in demand.

In order to better understand how specific derivatives are traded on electricity it is important to understand the concept of heat-rate. Heat rate is the measurement based on a "conversion factor required to turn an input fuel (i.e., natural gas, coal) into electricity. This pricing method is common in regions where natural gas plays a significant role in the mix of generation resources," (Engie 1). Additionally, heat-rate should also be considered an efficiency rating as it measures the ability to convert a commodity to one unit of electricity. The cross-commodity costs help determine the overall price of electricity by multiplying the heat rate by the natural gas cost (NYMEX or OTC) plus a fixed retail adder which usually entails services and fees by the provider. Thus, by owning the heat-rate options, a supplier can choose when to fulfill electricity demand by purchasing gas at an idealistic time. The heat-rate also directly ties to the concept of the spark spread. The spark spread is a measurement between the overall price of electricity and the price of natural gas. Such spreads are not as simple as simple subtraction but also involve converting natural gas from British thermal units (BTU's) to MWh by utilizing an industry standard of 49.13% thermal efficiency. A 49.13% thermal efficiency indicates that every 49.13 of 100 units of natural gas can be converted into electricity.

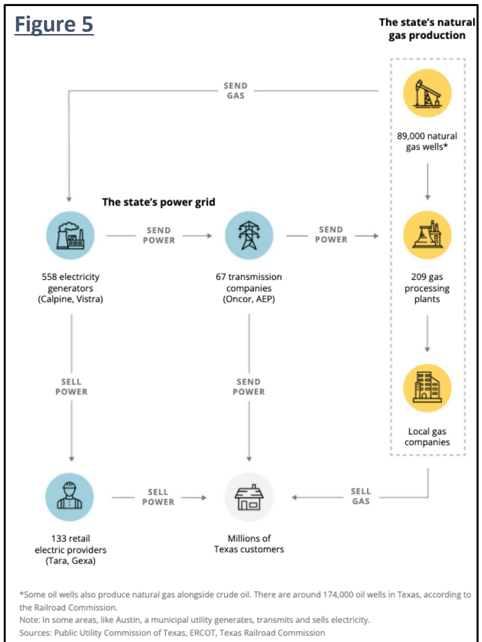
Nevertheless, the last component that is frequently subtracted from the calculation is the overall cost of carbon emissions the company emits.

Spark Spread = Price of Electricity – (Price of Fuel/Thermal Efficiency)

Adjusted Spark Spread = Spark Spread – (CO^2 adjustment * CO^2 price)

ERCOT has two main markets in which participants can purchase their load, these include ERCOT's Day-Ahead and Real-Time Markets. Real-Time markets typically quote new prices every 5 minutes. Nevertheless, ERCOTs market participants typically choose to purchase their load through bilateral contracts which occur outside of ERCOT administered markets. Bilaterally structured markets, require for both the sellers and buyers in the market to enter agreed upon contracts for the sale of electricity.

Figure 5



As a result of the deregulated structure of ERCOT, electricity must be produced in scale to the load that is demanded. Undeniably, this has a direct effect on the spot price and the potential for price volatility if there are transmission constraints due to issues with generation or physical delivery is stymied. Generating companies utilize load curves to predict potential needs over the course of the day. The worst-case scenario is that they end up long the position but still come close to anticipating the power level needed. Load curves are constructed with a few components in mind. First the generator must consider the type of user that is requesting electricity and if they are commercial, industrial, or residential. Equally important, the load curve gets its shape from the time of day in which electricity is primarily demanded, illustrating low usage in the early hours and higher demands around dusk onward. The time of the year is important to note, especially as many depend on electric power AC units and in some cases such as Texas, electric powered heat. Parallel to the same consideration for time of year, the physical location where power is needed also heavily influences load curve.

When specifically looking into the Texas Energy Crisis of 2021, there were two load curves that were taken by generators to help hedge against the volatility in commodity prices. Predominantly the two basic hedges that are utilized within the Texas grid vary in terms of how the overall hedge is settled and the considerations surrounding production risk. The first type of hedge is a fixed shape hedge this “settles pursuant to a set megawatt hour production (MWh) schedule that is independent of the actual megawatt hour production from the facility. The second type, a percentage-offtake hedge, settles pursuant to a percent (sometimes 100%) of the megawatt hour production from the facilities,” (Lynch 2). The specific generators that were in percentage-offtake hedge positions, develop a hedge that can flexibly scale based on price. If the price of the commodity rose rapidly while utilizing this strategy, then the hedge only reflects the agreed percent of production which has most likely been downscaled. The second strategy which ended up more costly was the fixed-hedge strategy. Fixed hedge strategies continue to be active despite profitability from production. Thus, these companies who were in this position must continue to pay for the hedge despite lack of revenue.

The overall demand for electricity is quite easy to predict as most economic activity within society requires a power source. On the demand side, determinant factors include weather changes with seasonality, time of day/week/month in correspondence to usage, any event that causes increased overall demand, and the overall change in demand as entities become more environmentally efficient with power consumption. Specifically, when looking at the demand side of electricity, the different usage amounts typically determine the degree of output on the supply side as generators attempt to hedge their expenses. In an extremely competitive market like the one in Texas, excess expenditure and lack of a hedge could be the difference between feast or famine. Nevertheless, feast or famine is a concept that frequently observed in commodity trading as global geopolitical and socioeconomic events can tip the scales greatly influencing price.

Supply comes down to the systems overall capability to generate electricity. The commodity that fuels the creation of electricity typically determines the generation cost and therefore has a direct impact on market pricing. Additionally, the overall capacity for generation is strongly dependent on the physical health of power plants and the capability of withstanding adverse circumstances. Regarding the Texas power crisis, the power plants in Texas operated on a thin margin and therefore took minimal safeguards to ensure overall operational health. The systemic negligence led to compounding issues that eventually threatened the overall functionality of the grid. Specifically, when looking at the optionality when attempting to hedge fuel price risk there are both long- and short-term maturities that can cause significant fluctuations. Typically, in states with multiple sources of electricity generation, suppliers will first seek out renewable energy, then subsequently nuclear, and after this natural gas. Short-term maturities are influenced by plant availability, fuel price, precipitation, wind speed, and temperature whereas longer maturities are typically influenced by generation capacity, weather forecast/past trends, and the forward fuel prices.

To fully understand the Texas Grid Crisis caused by Winter Storm Uri, it is essential to understand the positions that are taken by generators to hedge against risk as demand, despite being somewhat predictable, can still have large variable shifts. Texas generators are almost all long forward contracts on natural gas as they are constantly exposed to the price volatility and like to have the capability to exercise the option when appropriate. To get an insider perspective on the crisis, I interviewed Karol Semczuk a real time trader who was on the desk both before and during the crisis in Texas and subsequently had to "dispatch ancillary service products into the ERCOT market," (Semczuk 2022). When questioned about the specific shape of the load curve, Semczuk claimed that almost all providers in Texas would most likely have a similar load curve shape to that of ERCOT.

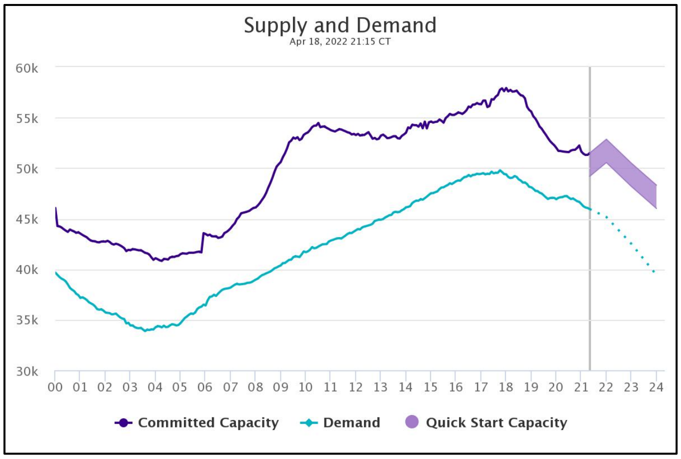


Figure 6

Embedded in the load curve, the committed capacity stays higher than the demand as depicted in Figure 5. Power generators are typically long during the early hours of the day when demand is typically quite low and short in the middle of the day as they begin to exercise heat-rate contracts to fulfill and match the market demand. Utilizing this strategy generators can come closer to the load demanded by being long heat-rate call options and long natural gas.

Looking at historical Texas weather patterns, weather expectations for February was usually around 70 degrees. As a result of historically predictable weather conditions, the predicted load sat at the same value for most of the winter as companies got prepared for the upcoming load increases that were more profitable once the summer spark spreads hit. Due to the lack winter spark spreads, generators will take this time of predictability to complete planned maintenance. The process entails completely shutting of electricity generation to take the plant apart to ensure that summer spreads are optimized when demand surges. Planned outages greatly contributed to the crisis in February 2021 as the plants who were mothballed had no viable means of quickly transitioning to possible electricity generation.

Renewable energy sources are a great, low-cost tool that will reduce overall volatility in the long run as they will reduce the continuous exposure to fuels that are used to produce the heat-rate. Despite the great benefits, renewable energy sources create significant volatility in the short term due to their unpredictable generation potential. Texas, despite popular belief, utilizes a substantial amount of renewable energy sources. Such renewable energy sources despite the usual widespread cost benefits provided to customers year-round, caused significant issues during Winter Storm Uri. Strong predictable wind production and consistent sun in the winter were the reasons that renewable energy in 2021, roughly constituted 28% of power generation (24% wind, solar 4%). Thus, when renewable sources went offline because of Winter Uri natural gas power plants were unable to pick up the deficit. Primarily, this was due to outages from the lack of winterization in most natural gas power plants and scheduled annual maintenance as few had planned the need to generate electricity midwinter. As a result of limited production capability those who were able to deliver natural gas to make electricity benefitted from soaring electricity prices (**Figure 7)**, that went

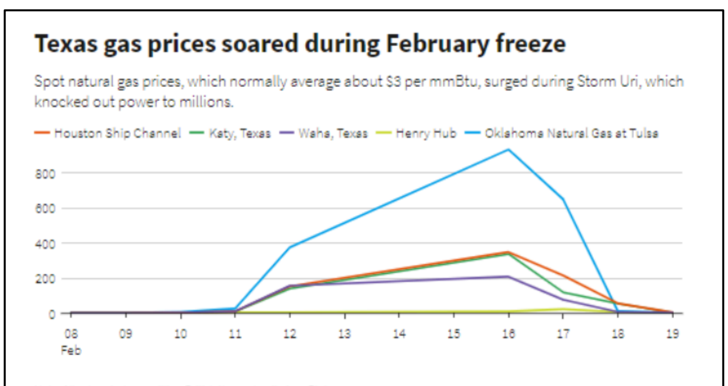


Figure 7

from trading at $34 on ICE in January to the maximum cap of $9,000 for 5 days straight.

The paper set out to evaluate the role of derivatives in the Texas Power Grid Crisis of 2021. The analysis of the deregulated power grid structure, poor risk mitigation at power plants to maintain competitiveness, the anomalous winter storm, actions taken to curb impact, an overview of electricity derivatives, how electricity derivatives promote lack of operation under minimal spread, all help illustrate the need for a system that, despite being deregulated, is still accountable to ensure that their supply capacity remains significantly above the level of public necessity. Although a tail end event, Winter Storm Uri, was the perfect storm to jolt the Texas Grid into near blackout. Increased population growth, homes built with poor insulation and electric heat led to an increase in demand when the storm hit, highlighting critical shortcomings of a system that had little incentive to prepare itself because of its own deregulation. Derivative spark spreads within the competitive market led various generators to always run the thinnest possible margins to remain competitive while profitable. The new popularity of renewables that consumed roughly 30% of the market left the remaining 70% that much more competitive for power generators. As an energy reliability council, ERCOT must enact more baseline requirements to mend a fractured system that is skating on thin ice and bound to fall through.

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