Power Systems Engineering Research Center Webinar Series

Blockchain and Energy: A Case Study of Flexible Computing Loads in Texas

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The Scale of the Issue

Global trends in digital and energy indicators, 2015-2022

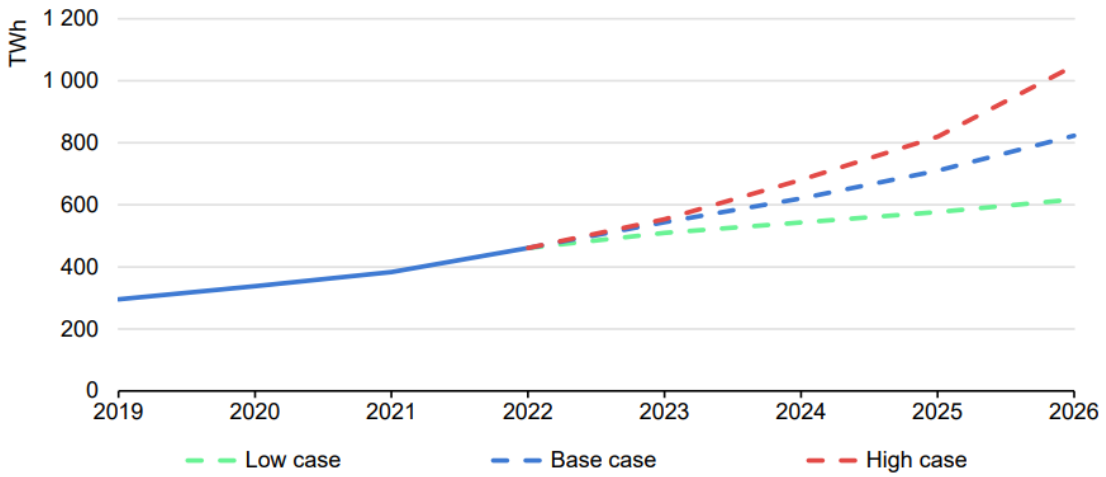
	2015	2022	Change
Internet users	3 billion	5.3 billion	+78%
Internet traffic	0.6 ZB	4.4 ZB	+600%
Data centre workloads	180 million	800 million	+340%
Data centre energy use (excluding crypto)	200 TWh	240-340 TWh	+20-70%
Crypto mining energy use	4 TWh	100-150 TWh	+2300-3500%
Data transmission network energy use	220 TWh	260-360 TWh	+18-64%

The State of Illinois uses about 143TWh of Electricity in 2020

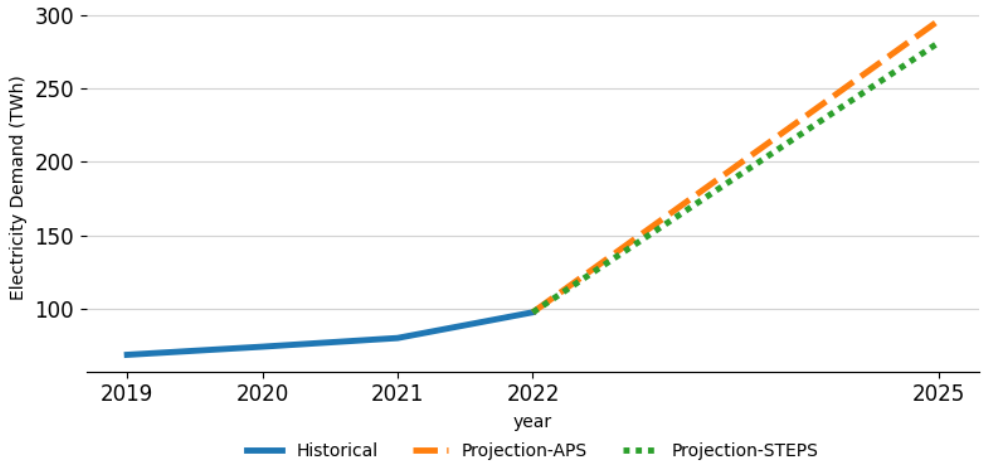
Source: https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks

Datacenters vs Electric Vehicle Electricity Demand

Global Datacenter, AI, cryptocurrency demand[1]



Global EV Electricity demand[2]



STEPS - Stated policies Scenario
APS - Announced Pledges Scenario

[1]IEA (2024), Electricity 2024, IEA, Paris https://www.iea.org/reports/electricity-2024, Licence: CC BY 4.0
[2] IEA (2023), Global EV Outlook 2023, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2023, Licence: CC BY 4.0

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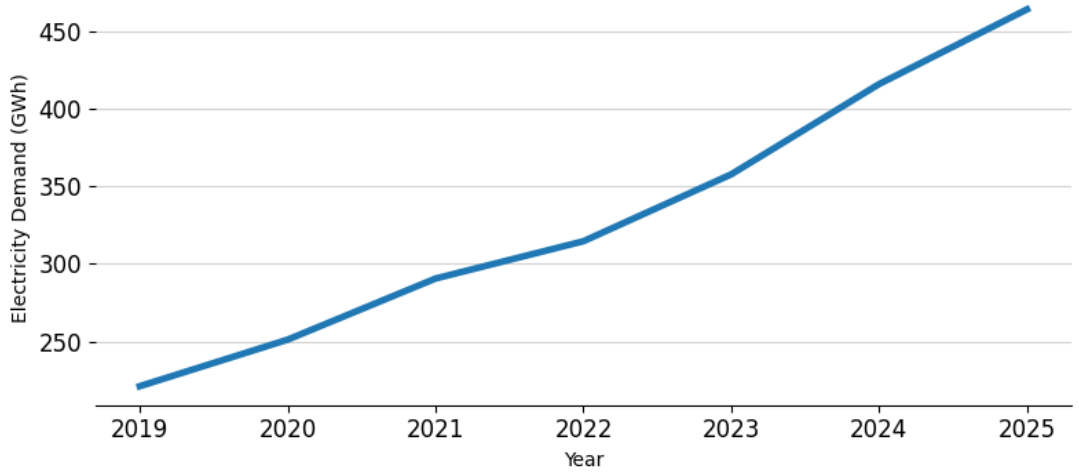
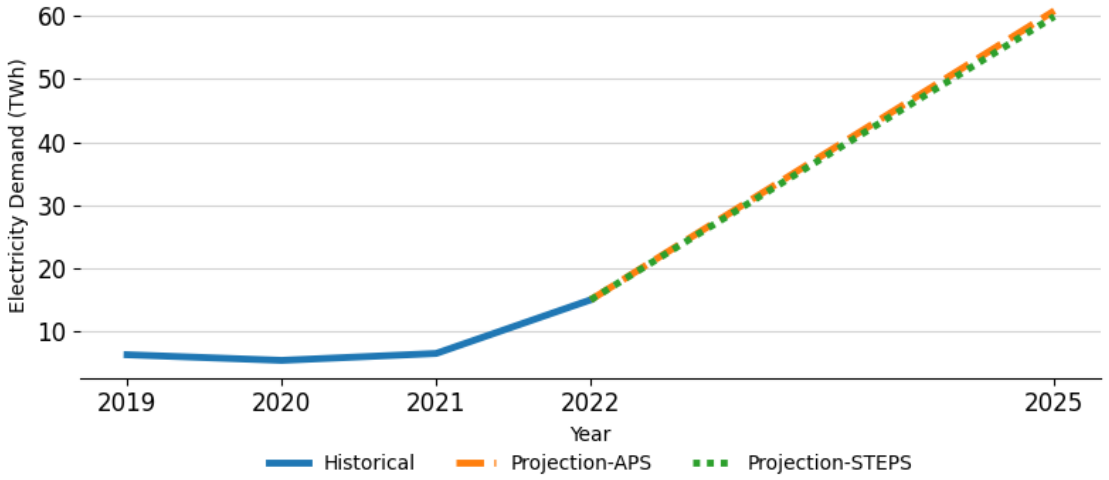
Datacenters vs Electric Vehicle Demand in the U.S.

Datacenter, AI, cryptocurrency demand in the U.S.[1]



Electric Vehicle Electricity demand in the U.S. [2]



STEPS - Stated policies Scenario
APS - Announced Pledges Scenario

[1] Cambridge Blockchain Network Sustainability Index: CBECI (ccaf.io)
[2] IEA (2023), Global EV Outlook 2023, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2023, Licence: CC BY 4.0

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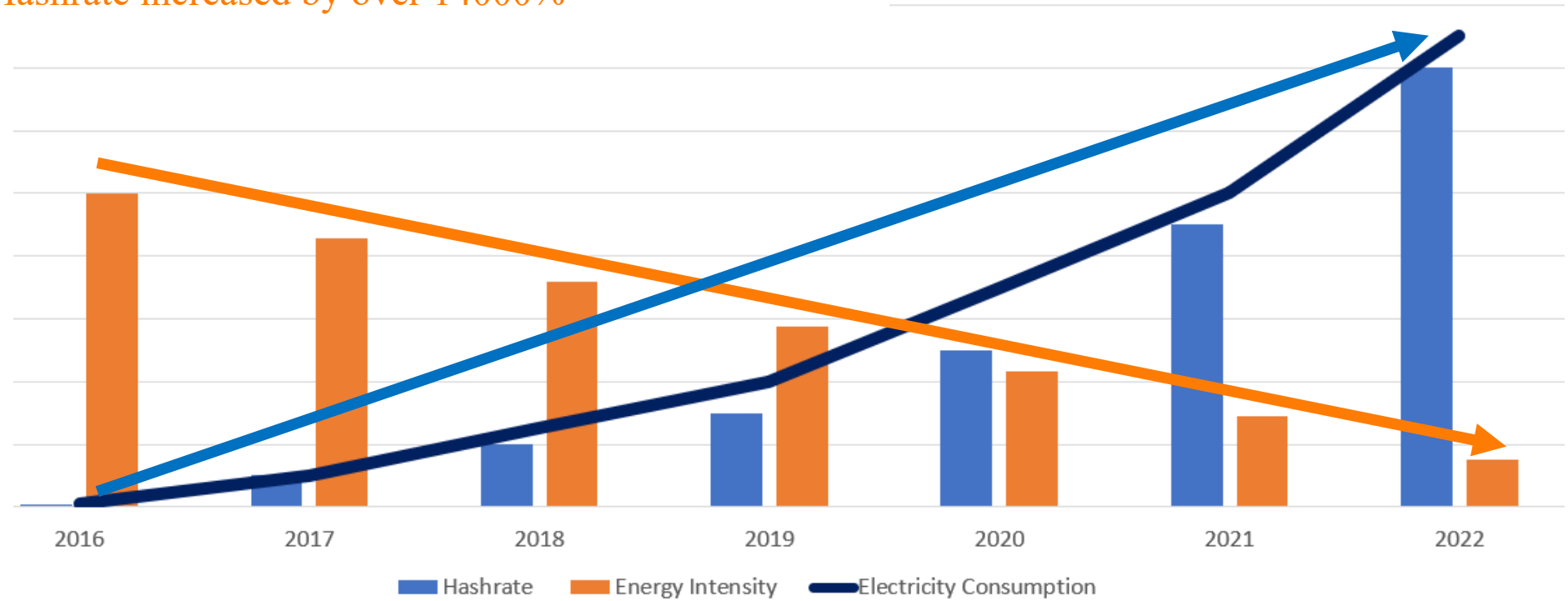
Mining Energy Intensity and Hashrate

The estimated deployed rig energy intensity (the energy needed for one unit of processing power kWh/TH(terahash)) decreased by around 85%

Network Hashrate increased by over 14000%

As a result: a total of 2000% rise in estimated network electricity usage



Source: Climate and Energy Implications of Crypto-Assets. The White House, 2022.

Blockchain and Its Implication in Energy/Environment

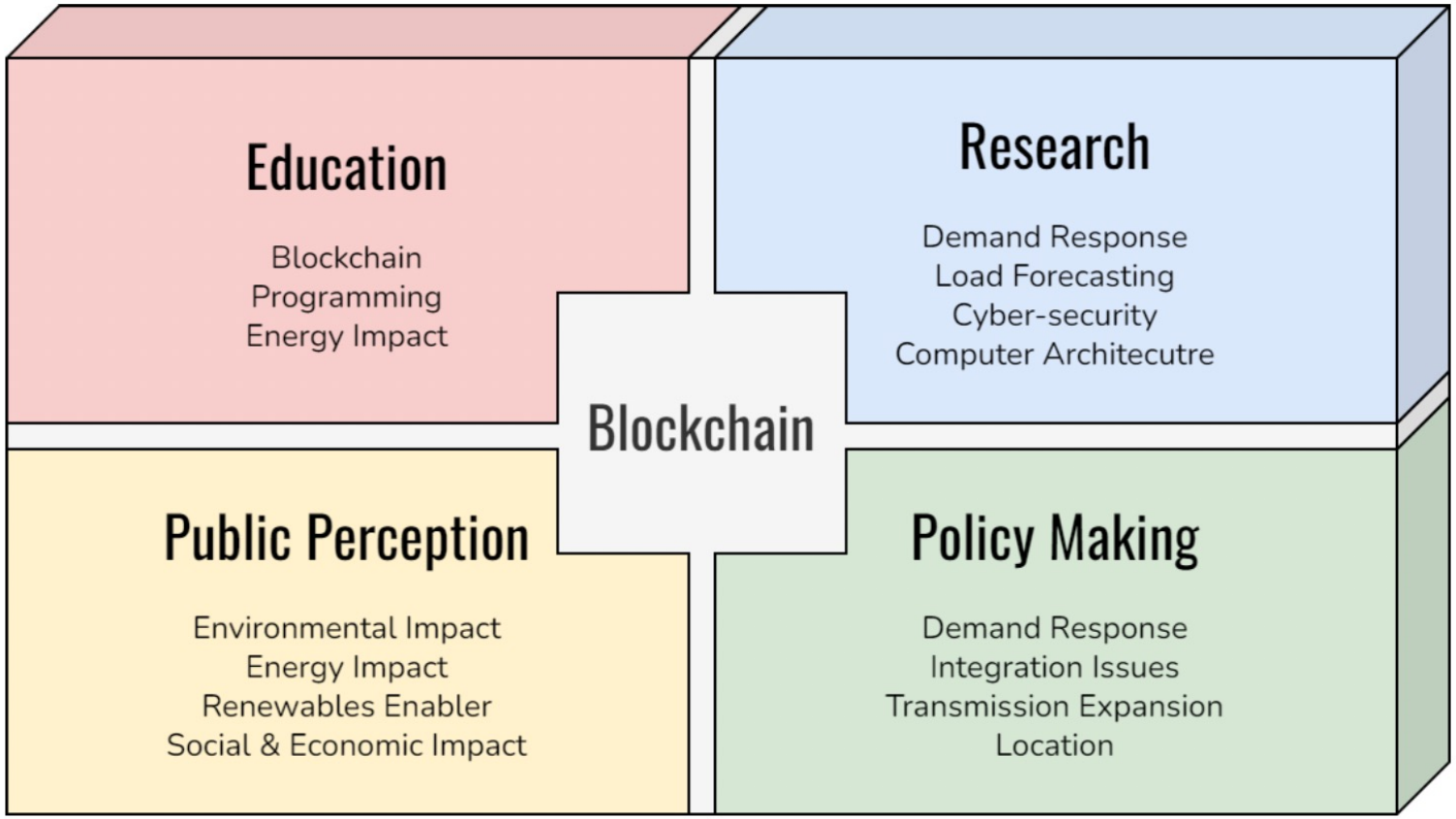


Figure 1 Proposed Areas of Activities

Le Xie, Ali Menati, Prasad Enjeti, and Korok Ray, "Scalable and Sustainable Energy for Crypto Mining," White Paper, Nov 2022

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The Blockchain & Energy Research Consortium

Site Visit to Riot (750MW)

Total Hash Rate (TH/s)

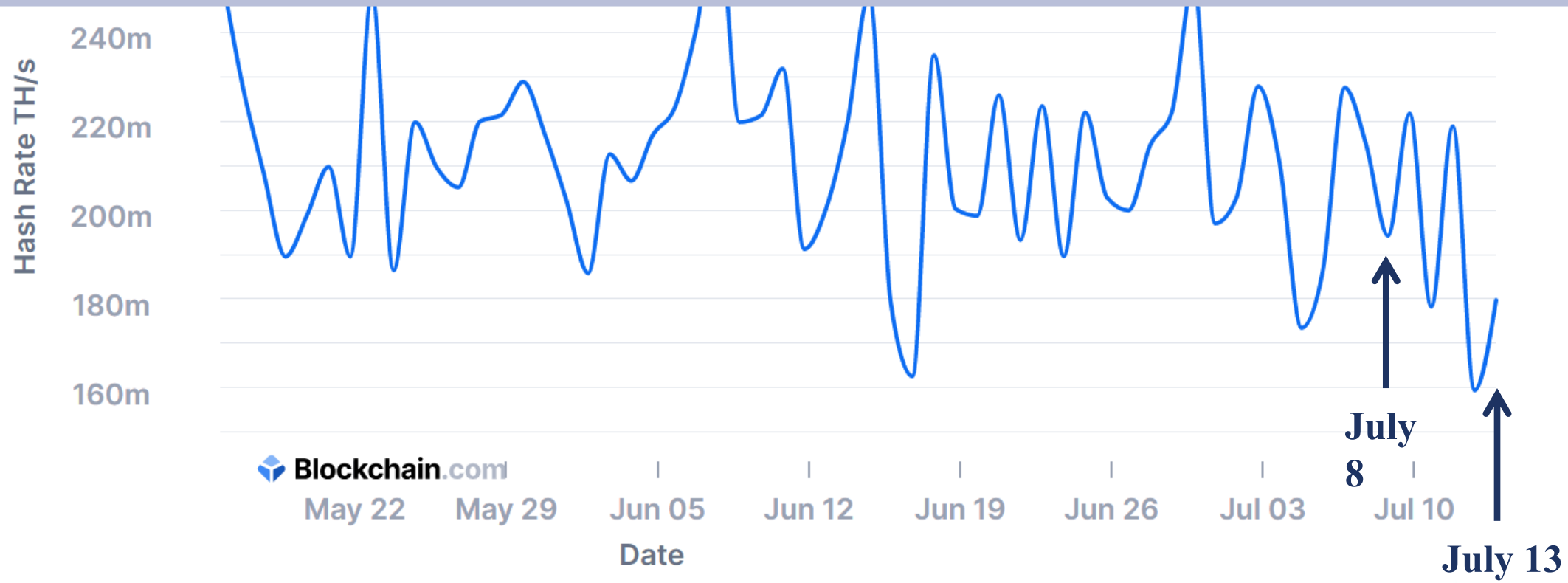
The estimated number of terahashes per second the bitcoin network is performing in the last 24 hours.

Jul 8, 2022 1:08:47 PM	At 13:06 approximately 1103 MW of Non-Spin has been deployed, anticipated duration is 23:59.

Total Hash Rate (TH/s)

The estimated number of terahashes per second the bitcoin network is performing in the last 24 hours.

Jul 13, 2022 3:01:43 PM	Reserves are below 3,000 MW. Emergency Response Service 10 minute and 30 minute, including Weather Sensitive have been deployed.



Total Hash Rate (TH/s)

The estimated number of terahashes per second the bitcoin network is performing in the last 24 hours.

Need of Demand Flexibility for the Grid Resiliency

How Much Demand Flexibility Could Have Spared Texas from the 2021 Outage?

Dongqi Wu[1], Xiangtian Zheng[1], Ali Menati[1], Lane Smith[2], Bainan Xia[3], Yixing Xu[3], Chanan Singh[1], and Le Xie[1,4,*]

[1]Department of Electrical and Computer Engineering, Texas A&M University, College Station, Texas, USA
[2]Department of Electrical and Computer Engineering, University of Washington, Seattle, Washington, USA
[3]Breakthrough Energy Sciences, Seattle, Washington, USA
[4]Texas A&M Energy Institute, College Station, Texas, USA
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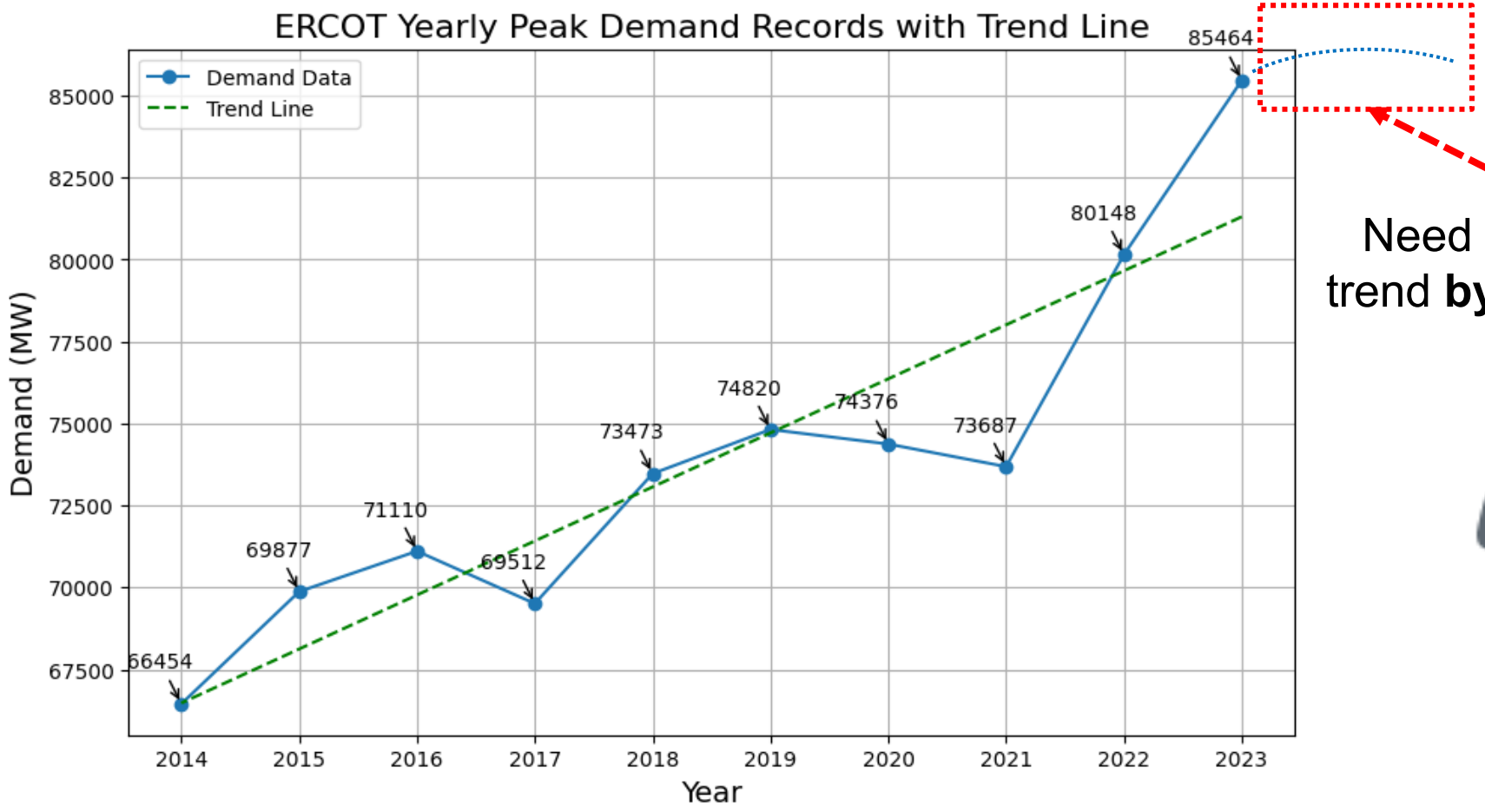
ABSTRACT

The February 2021 Texas winter power outage has led to hundreds of deaths and billions of dollars in economic losses, largely due to the generation failure and record-breaking electric demand. In this paper, we study the scaling-up of demand flexibility as a means to avoid load shedding during such an extreme weather event. The three mechanisms considered are interruptible load, residential load rationing, and incentive-based demand response. By simulating on a synthetic but realistic large-scale Texas grid model along with demand flexibility modeling and electricity outage data, we identify portfolios of mixing mechanisms that exactly avoid outages, which a single mechanism may fail due to decaying marginal effects. We also reveal a complementary relationship between interruptible load and residential load rationing and find nonlinear impacts of incentive-based demand response on the efficacy of other mechanisms.

Wu, Zheng, Menati, Smith, Xia, Xu, Singh, and Xie, Advances in Applied Energy, 2022

Source of Images:
https://www.nytimes.com/live/2021/02/17/us/winter-storm-weather-live
https://www.newsweek.com/pictures-videos-texas-snow-winter-storm-1569284
https://www.npr.org/sections/live-updates-winter-storms-2021/2021/02/18/969130855/white-house-adviser-says-texas-outages-show-how-u-s-is-unprepared-for-climate-ch
https://www.npr.org/2021/02/16/968357225/texas-governor-calls-for-investigation-into-group-that-manages-state-power-grid

Peak Demand Growth in TX



Need to break the upward trend **by improving Demand Flexibility**

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Potential for Scalable Demand Flexibility

Table 1 Correlation between total mining load, system-wide average LMP, and system-wide net load.

Correlation between	Whole period[1]	Summer peak[2]
Total mining load and system-wide average LMP	-0.042	-0.517
Total mining load and system-wide net load	0.0667	-0.757
Non-mining load and system-wide average LMP	0.009	0.378
Non-mining load and system-wide net load	0.922	0.971

[1] The whole period refers to the period from January 1st, 2021 to October 19th, 2022.
[2] The summer peak time refers to the period from July 7th, 2022 to July 21st, 2022.

A. Menati, X. Zheng, K. Lee, R. Shi, P. Du, C. Singh, and L. Xie "High Resolution Modeling and Analysis of Cryptocurrency Mining's Impact on Power Grids: Carbon Footprint, Reliability, and Electricity Price," Advances in Applied Energy, 2023
A. Menati, K. Lee, and L. Xie, “Modeling and Analysis of Utilizing Cryptocurrency Mining for Demand Flexibility in Electric Energy Systems: A Synthetic Texas Grid Case Study.” IEEE Transactions on Energy Markets, Policy and Regulation, 2023.

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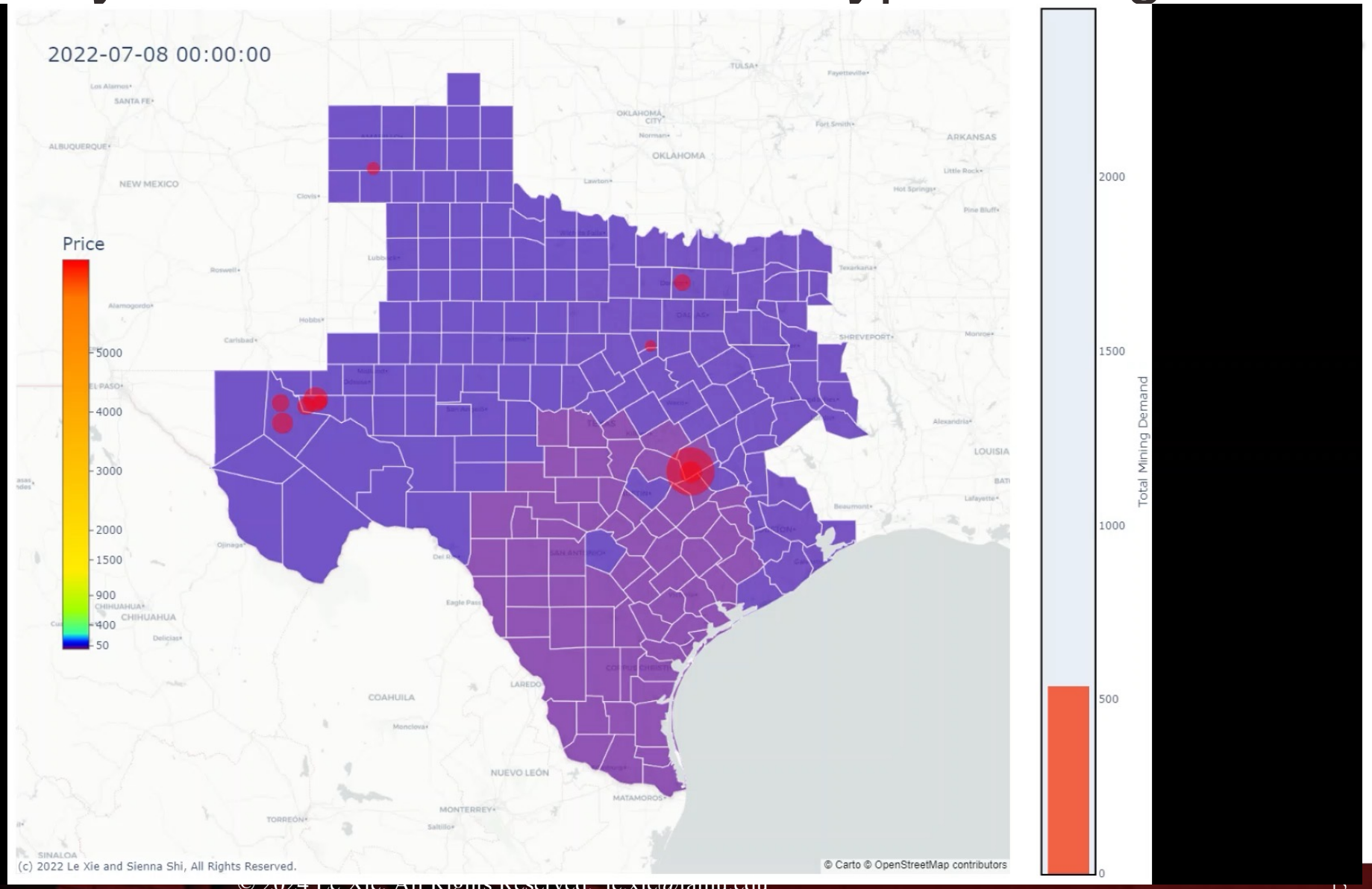
Electricity Price and Demand of Cryptomining



An Example of a Large Mining Company

Metric	August 2023	July 2023	August 2022	Comparison (%) Month/Month	Comparison (%) Year/Year
Bitcoin Produced	333	410	374	-19%	-11%
Average Bitcoin Produced per Day	10.8	13.2	12.1	-19%	-11%
Bitcoin Held[1]	7,309	7,275	6,720	0%	9%
Bitcoin Sold	300	400	350	-25%	-14%
Bitcoin Sales - Net Proceeds	$8.6 million	$12.1 million	$7.7 million	-29%	12%
Average Net Price per Bitcoin Sold	$28,617	$30,293	$21,926	-6%	31%
Deployed Hash Rate[1]	10.7 EH/s[2]	10.7 EH/s[2]	4.8 EH/s	0%	123%
Deployed Miners[1]	95,904[2]	95,904[2]	46,658	0%	106%
Power Credits[3,5]	$24.2 million[6]	$6.0 million[6]	$3.0 million	303%	709%
Demand Response Credits[4,5]	$7.4 million[6]	$1.8 million[6]	$0.2 million	316%	2,933%

3.Power curtailment credits received from the Company's ability, under its long-term power contracts, to sell power back to the ERCOT grid at market-driven spot prices.
4.Credits received from participation in ERCOT demand response programs.
5.The Company discloses this figure in its monthly updates if it exceeds $1 million for the current month.

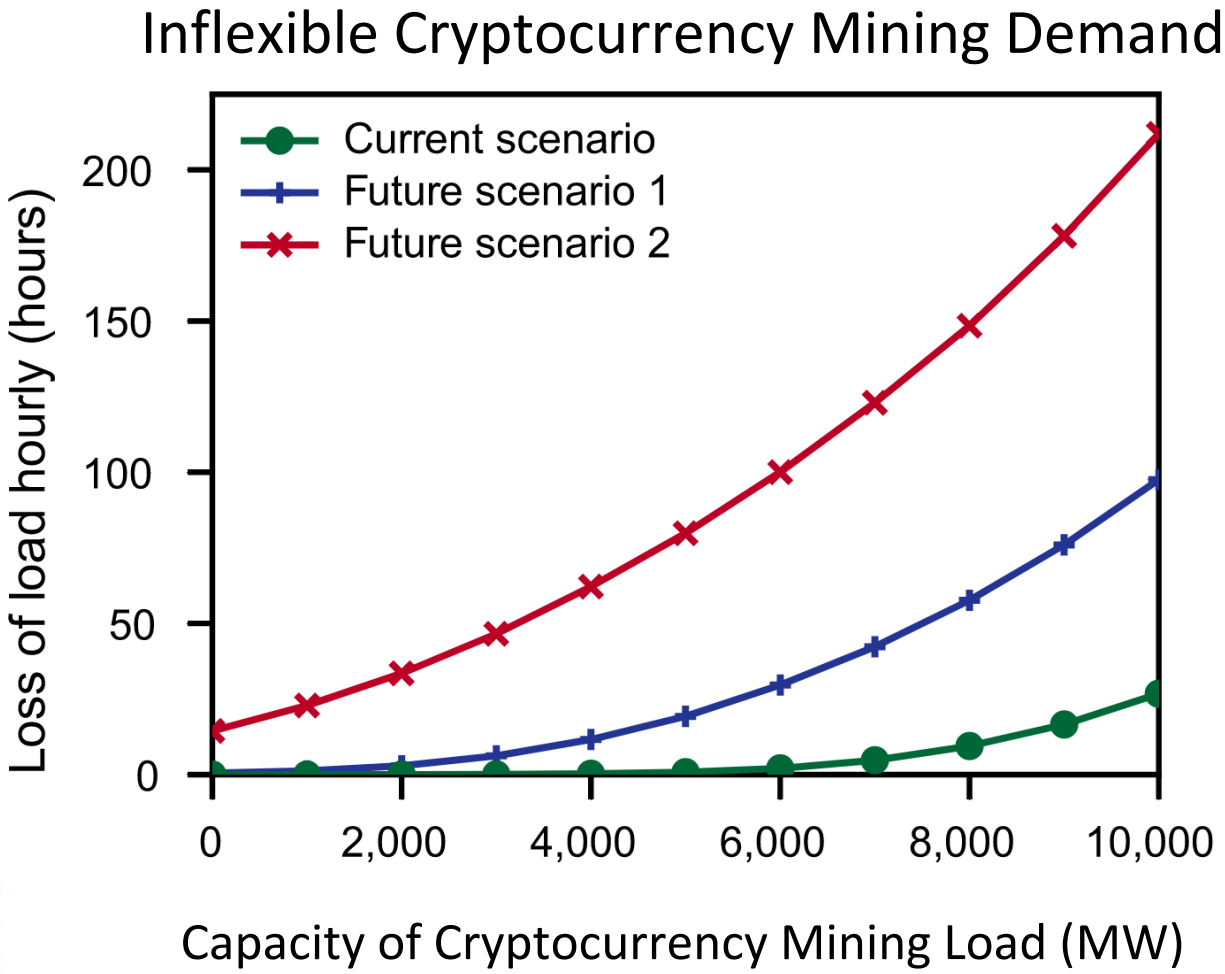
Source: https://www.sec.gov/Archives/edgar/data/1167419/000155837023015517/riot-20230906xex99d1.htm

High Resolution Spatial-temporal Analysis of Cryptocurrency Mining on Synthetic Texas Grid: Carbon Footprint, Reliability, and Price

Ali Menati, Xiangtian Zheng, Kiyeob Lee, Sienna Shi, Chanan Singh, Le Xie

Advances in Applied Energy, April 2023

System Reliability



Future Scenario 1: 10% additional firm load, 50% more renewable generation

Future Scenario 2: 20% additional firm load, 100% more renewable generation

In a **renewable-rich** future grid, reliability incidents will become more frequent due to the intermittent nature of renewable energy generation

If the additional mining demands are ***inflexible*** and without careful location planning, its impact to system reliability is significant

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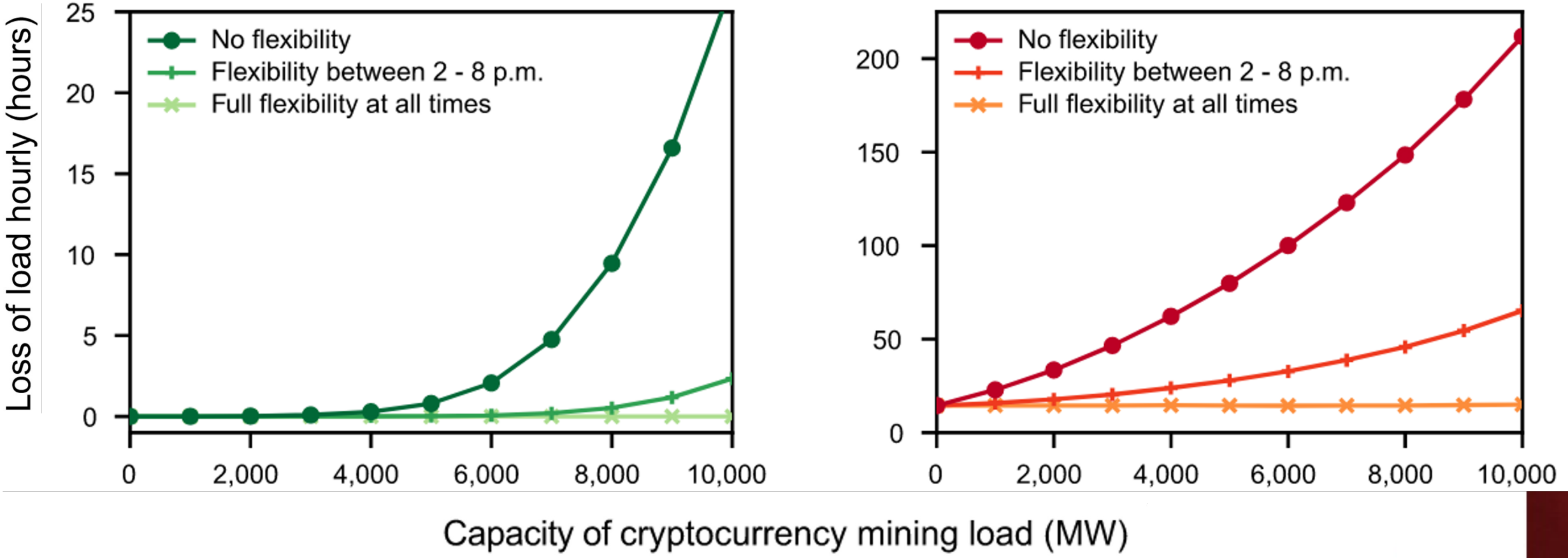
System Reliability

a. Current Synthetic Texas Grid

b. Future Scenario 2



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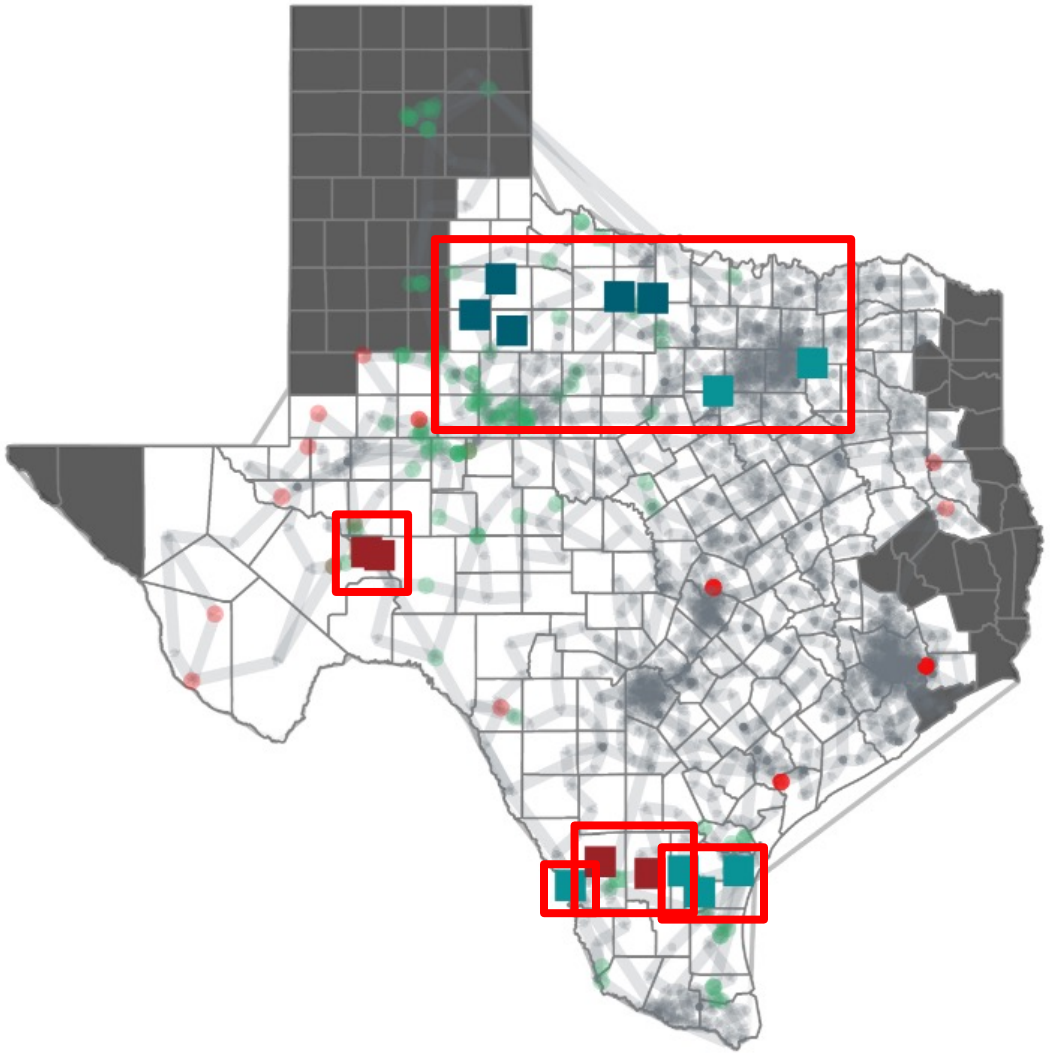
Carbon Footprint



Solar

Wind

Loc-A1

Loc-A2

Loc-B

close-to-renewable locations

low-electricity-price locations

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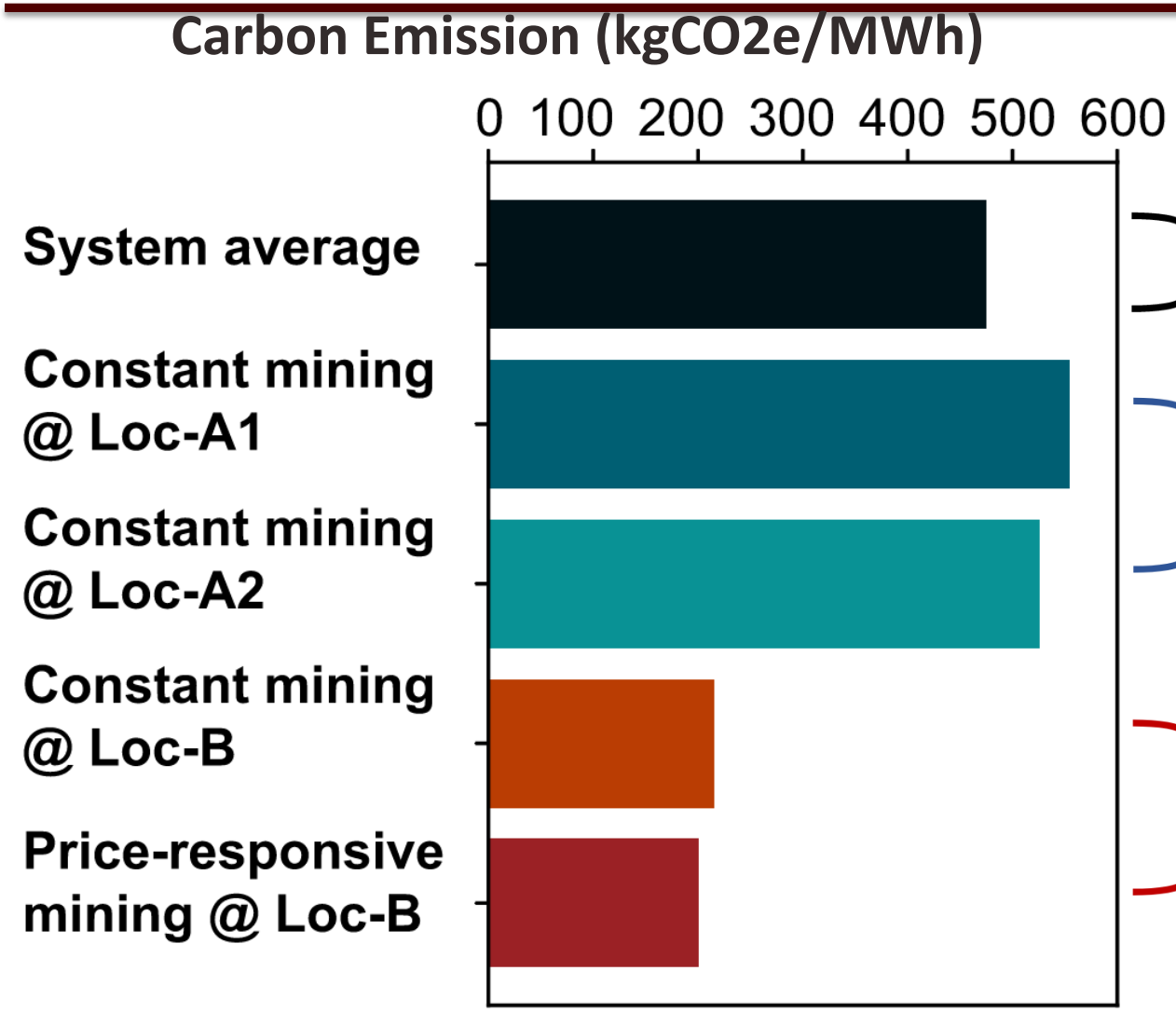
Carbon Footprint



Location Matters

Grid-agnostic estimation by existing studies are not accurate.

Close-to-renewable sites are not necessarily low-carbon.

Low-electricity-price sites control carbon footprint below 50% of the system average.

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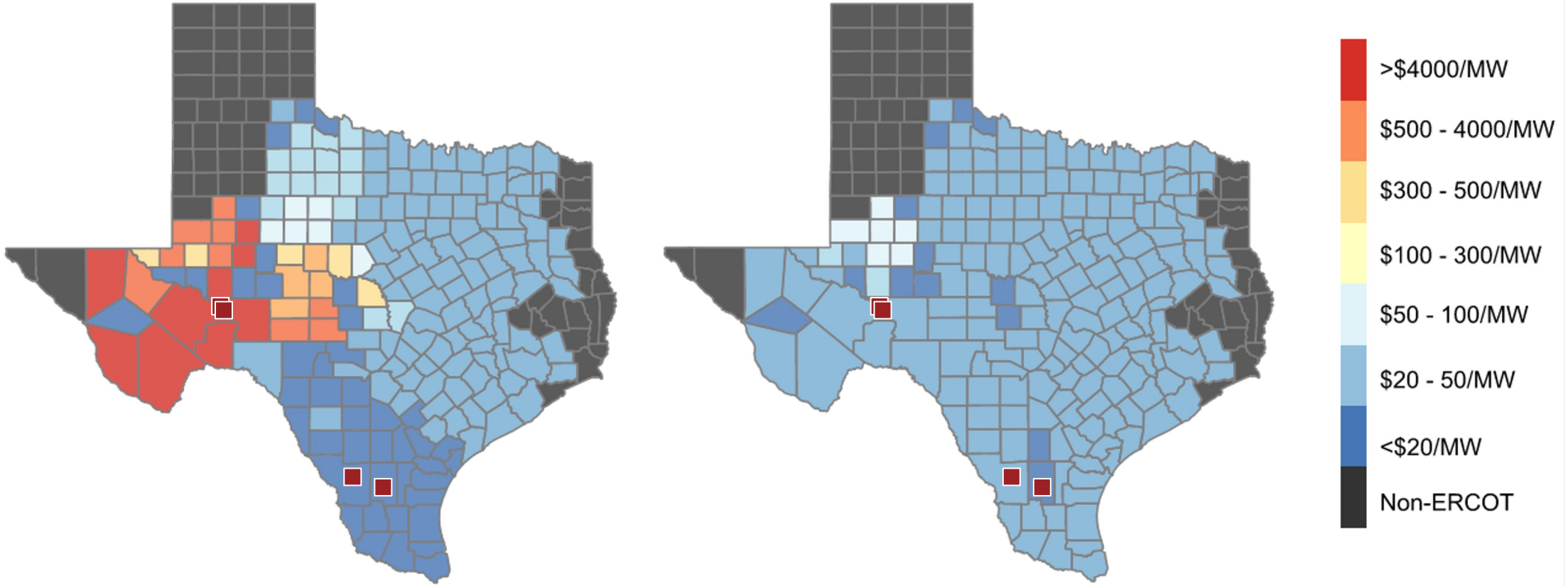
Market Price

- Mining loads at Loc-B



System with constant mining loads

System with price-responsive mining loads

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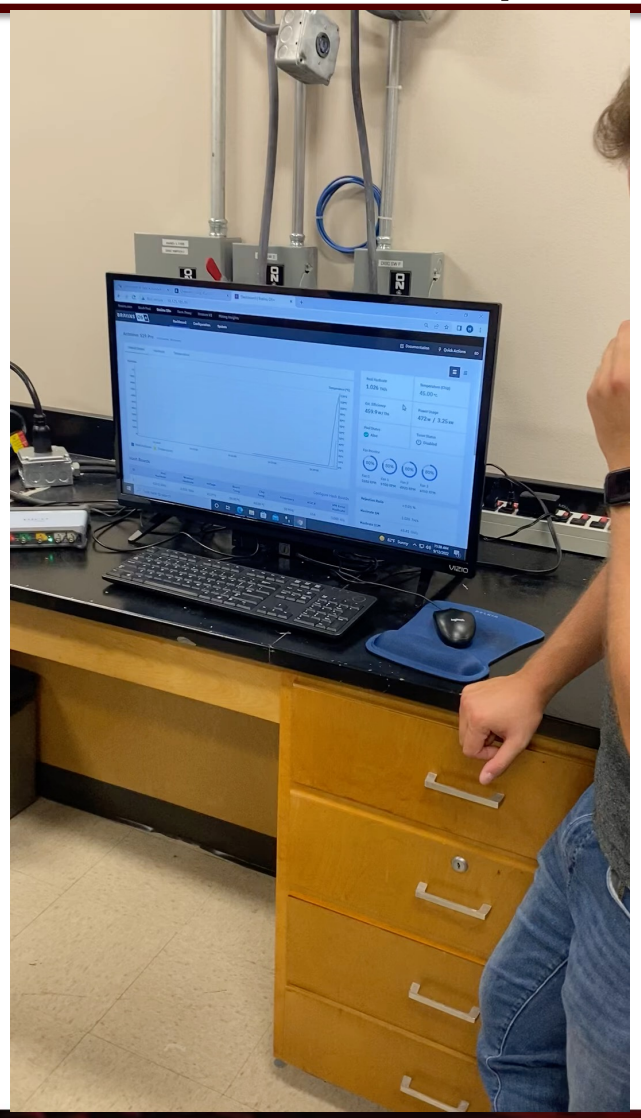
First Bitcoin Mining Unit Installed on Campus for Experiential Learning, Student Entrepreneurship, and Research



Sep 12, 2022
Wisenbaker 118
S-19 Pro Machine
(donated by Texas Blockchain Council)

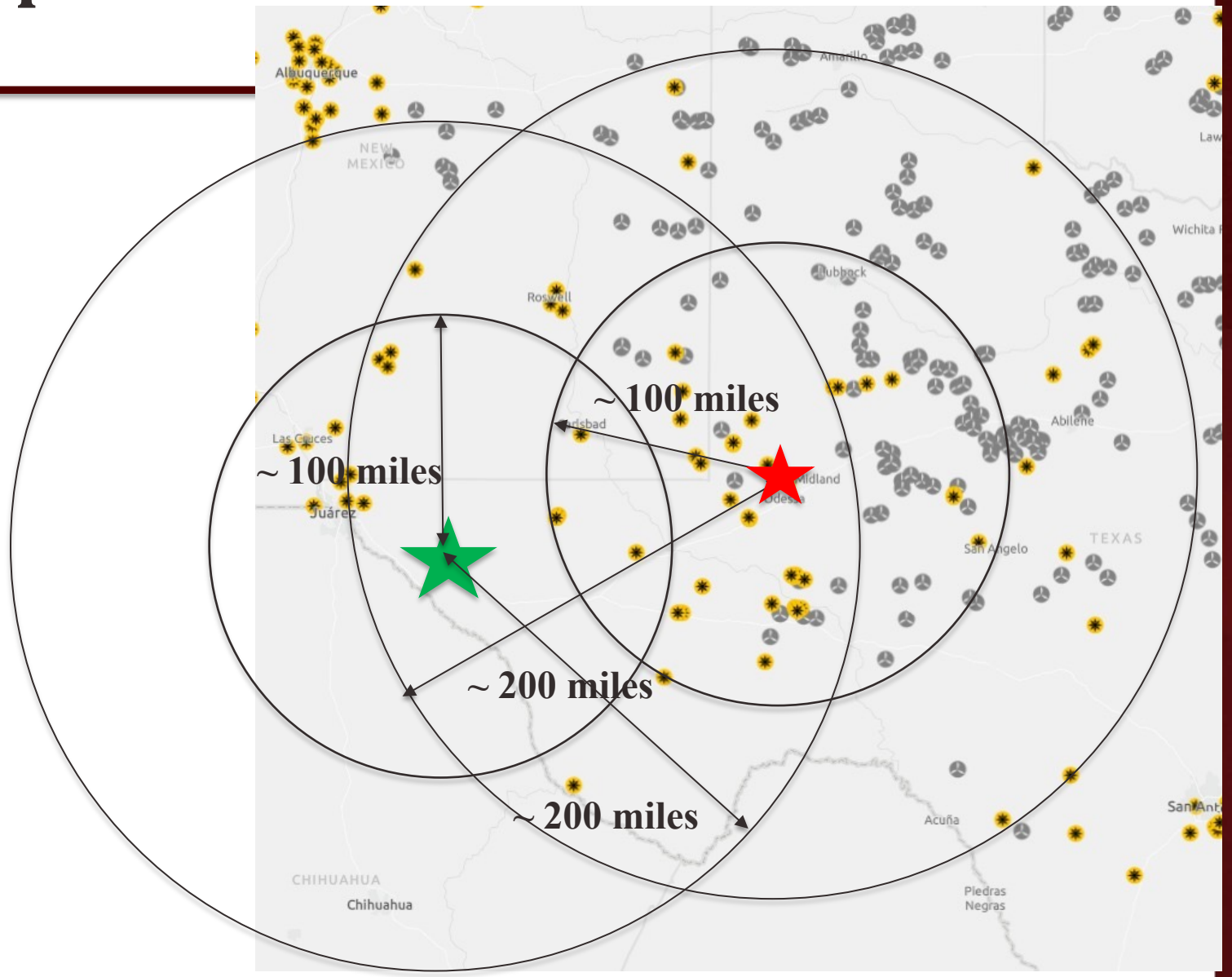
Recent Examples of Disturbances in TX

solar farms

wind farms

fault at West Texas

fault at Odessa

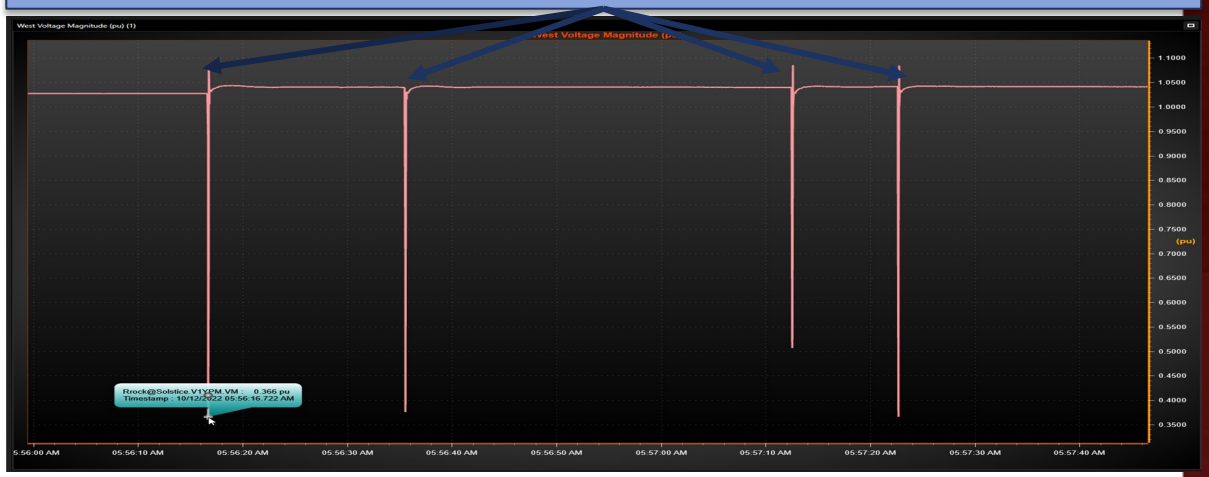


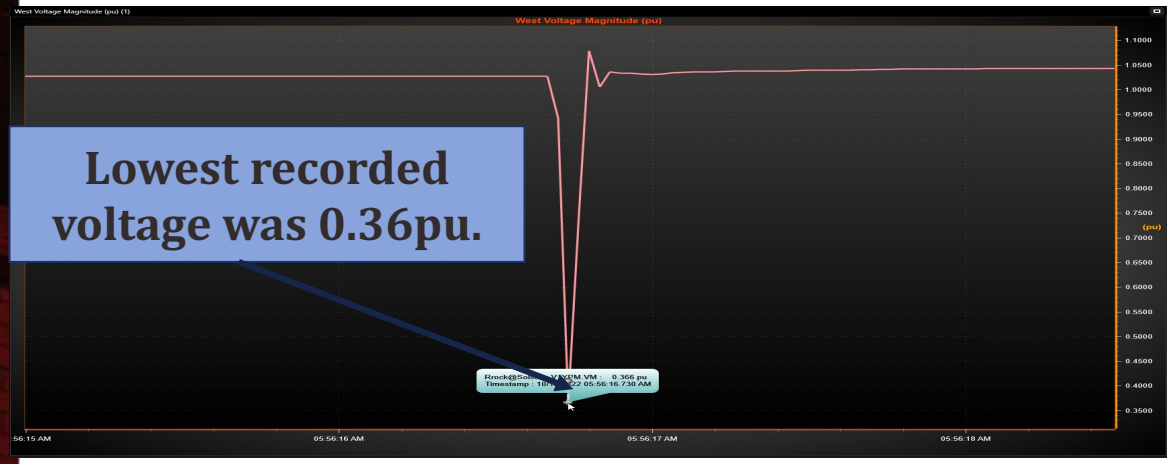
[1] https://atlas.eia.gov/apps/895faaf79d744f2ab3b72f8bd5778e68/explore

Example 1: West Texas | 10/12/2022 | 5:56AM

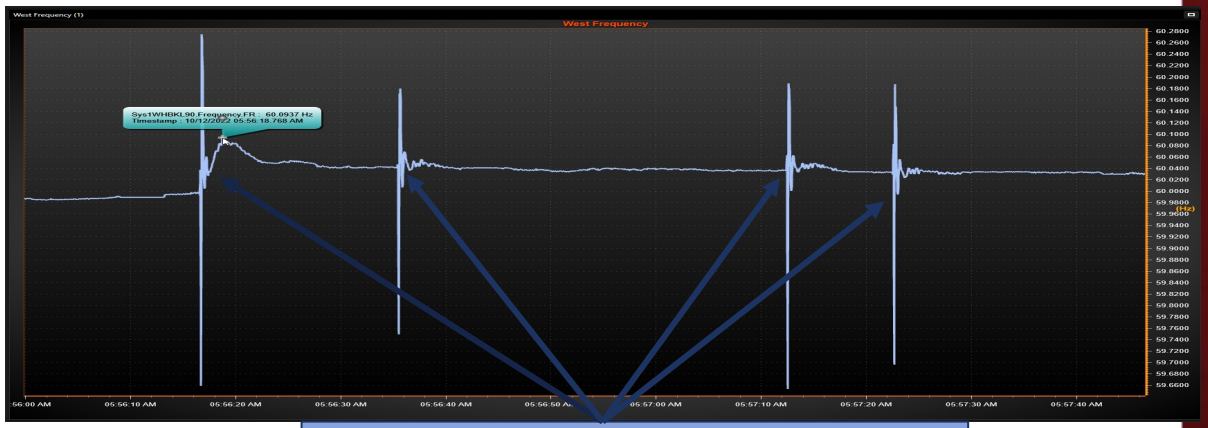
On 10/12/22 at 5:56 am, four faults occurred in the West region

- There was a load voltage ride-through event
- Several loads totaling >400 MWs tripped, including Mining Loads
- Frequency spiked to 60.09 Hz





Lowest recorded voltage was 0.36pu.



Four frequency swings. Highest frequency 60.09 Hz.

[1] ERCOT Public Presentation : Large Flexible Loads and ERCOT, Agee Springer, Evan Rowe, Evan Neel, LFL Interconnection & Resource Adequacy ERCOT, Texas A&M University, April 5th, 2023

Example 2 : Near Odessa | 12/7/2022 | 3:50AM

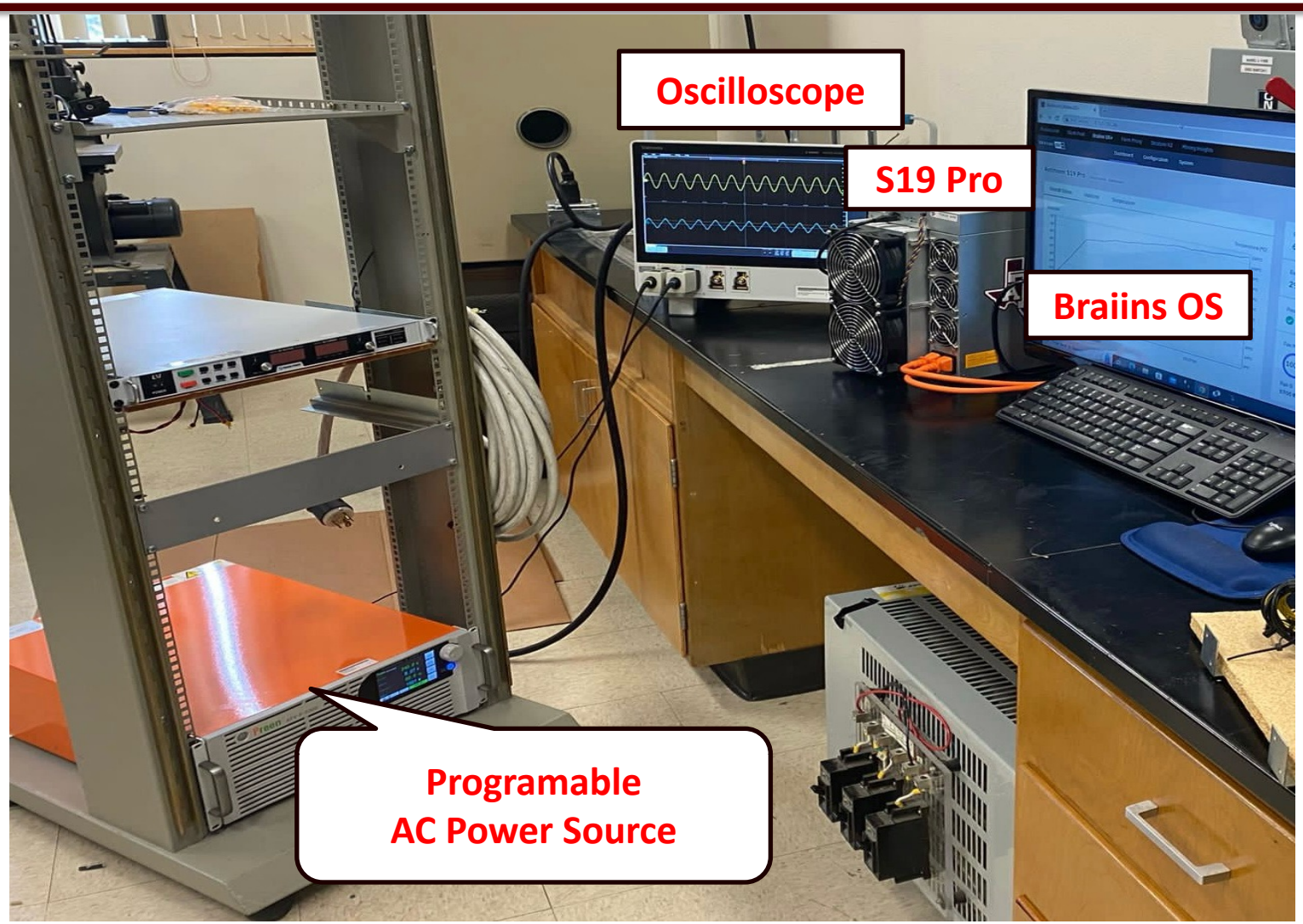
- **Largest load loss event to-date:**
  - Multiple faults on 138 kV lines including 3 phase fault due to breaker failure
  - Reduction in load of **~1,600 MW**
  - Load reduction included mix of large mining loads, oil/gas load, and other industrial loads
  - Two thermal generators tripped during the event, totaling 112 MW
  - System frequency spiked to 60.235 Hz

Key Takeaway : There is a need for improved interconnection process for large loads and improved simulation models of new load types.

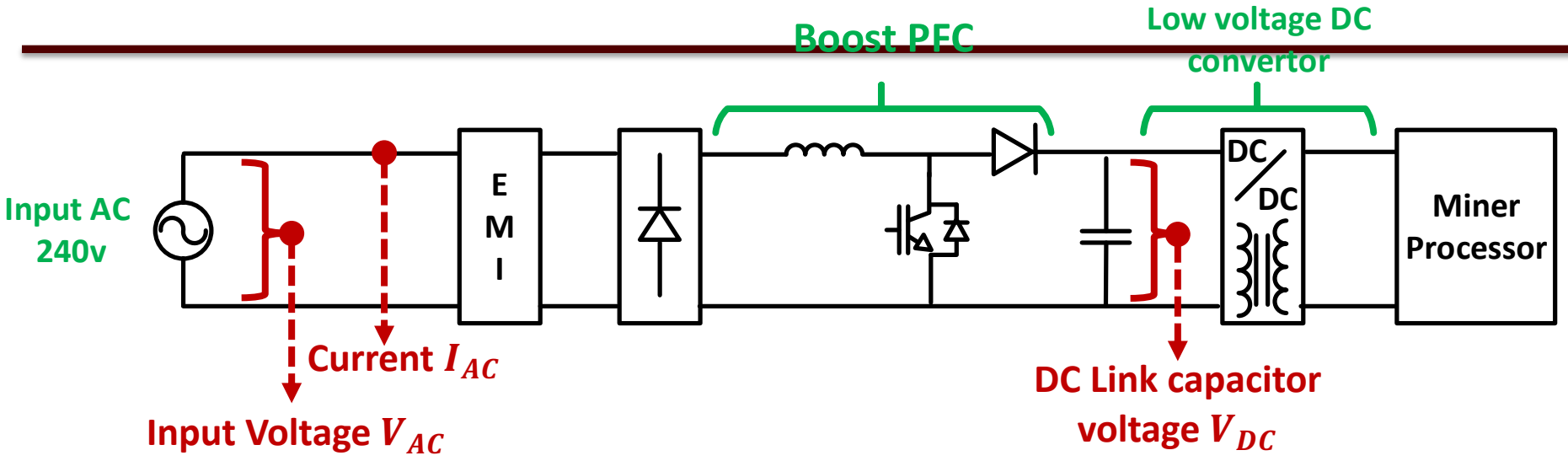
[1] ERCOT Public Presentation : LFLTF: Large Load Voltage Ride-Through Requirements, Jeff Billo, Operations Planning, May 31, 2023
[2] ERCOT Public Presentation : Item 7.2.1: Inverter-Based Resource and Large Load Ride Through Events: Background and Mitigation, Dan Woodfin, System Operations, Reliability and Markets Committee Meeting, June 19, 2023

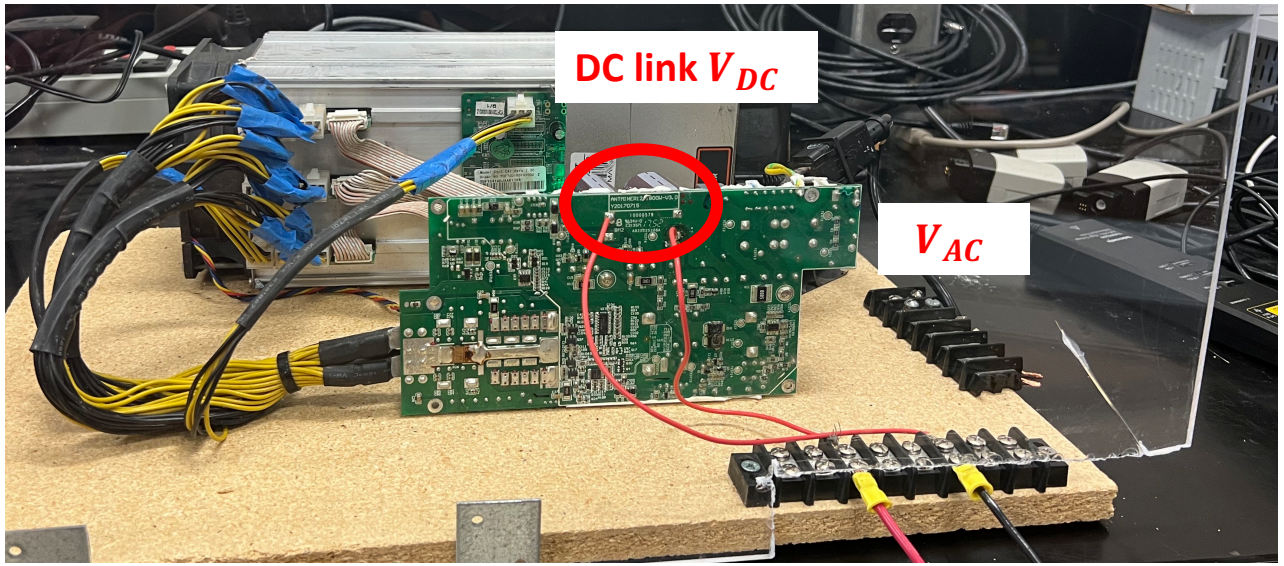
BERC Lab –Low Voltage Ride Through Test Setup

- Programmable AC power source
- Voltage output 0-310 VAC
- Frequency output 40-500Hz
- Step and ramp functions for voltage and frequency variation tests



Internal Circuit Topology of a Typical S19 Pro Miner

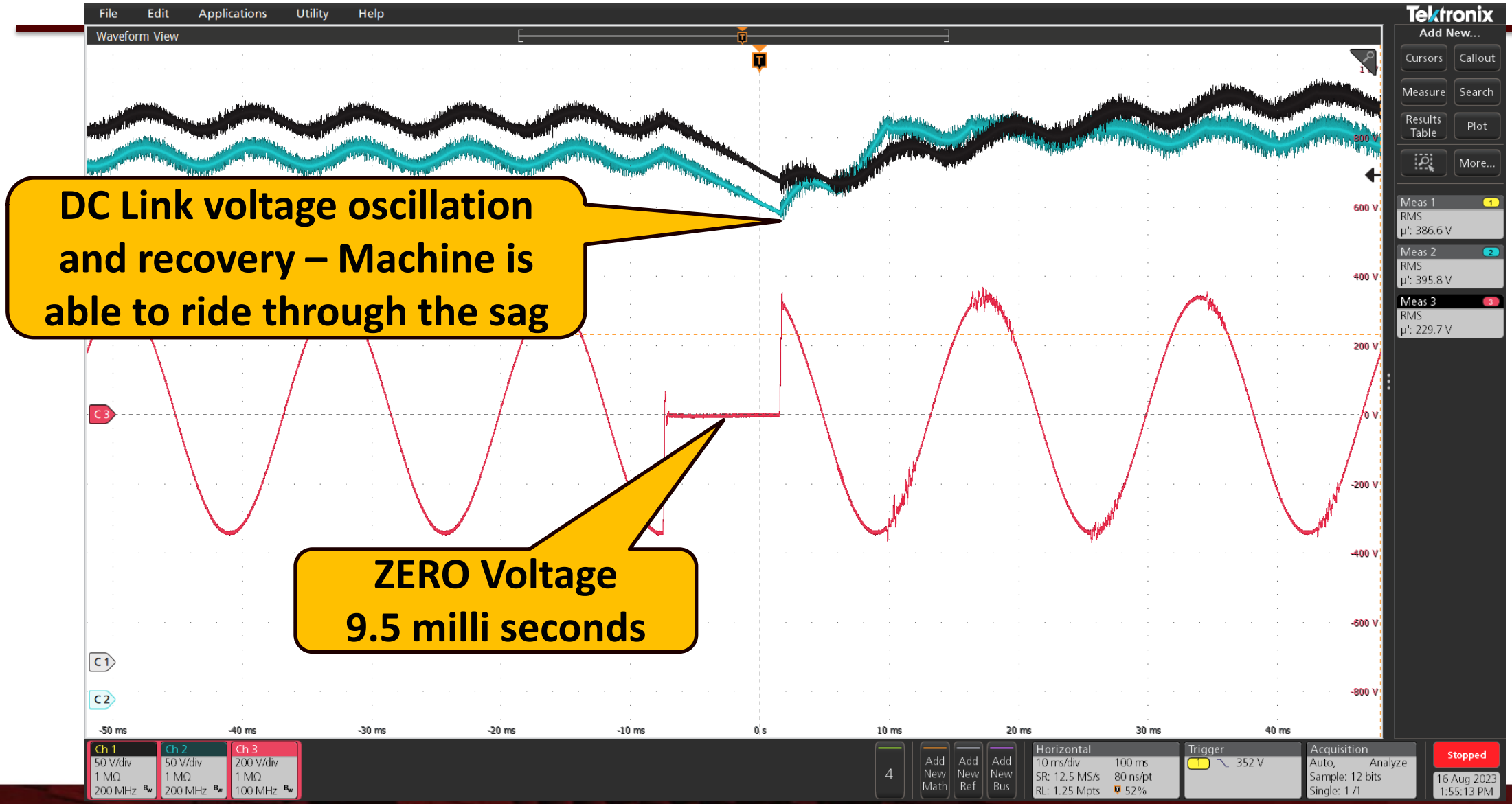




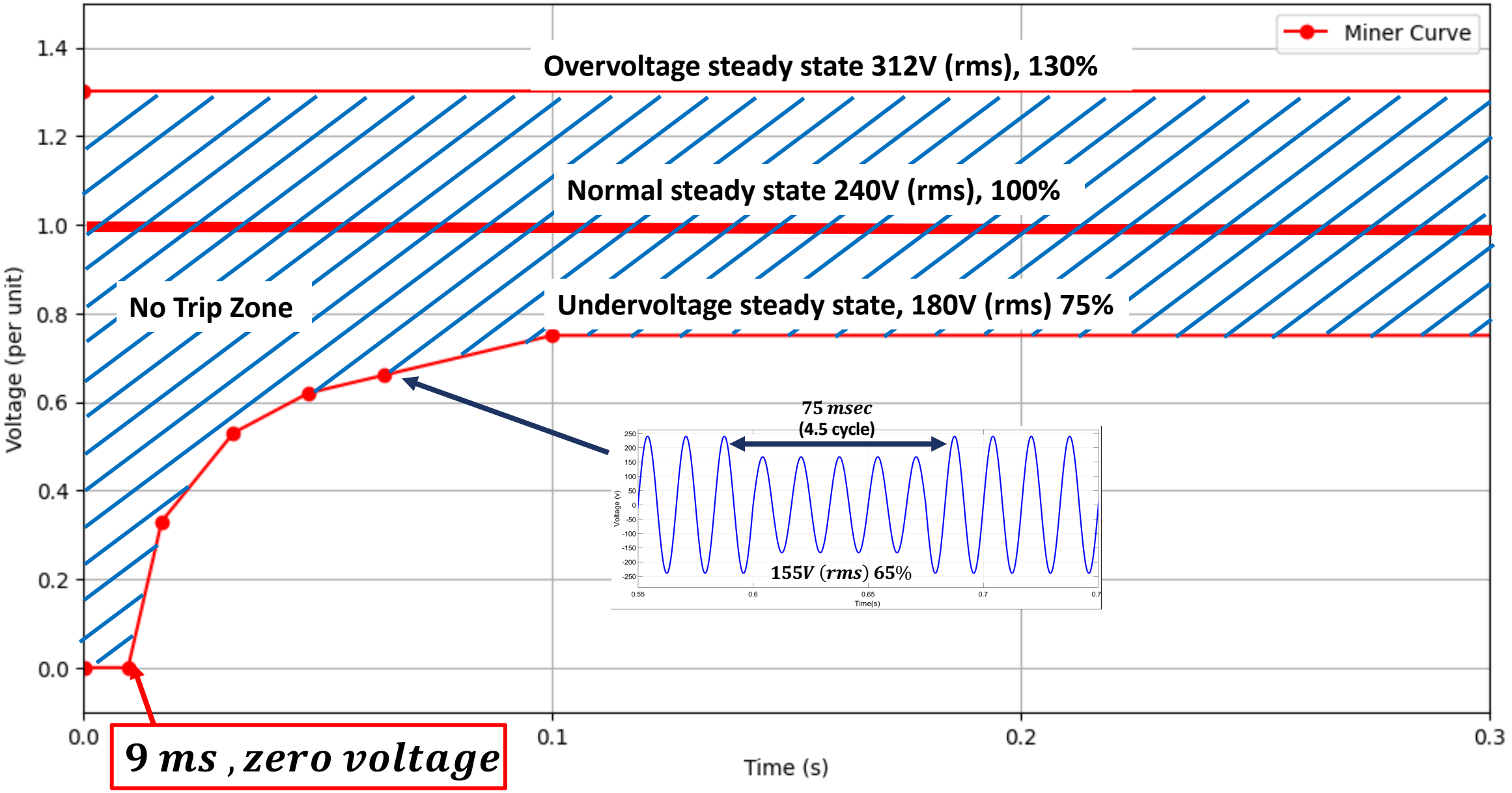
Power Range	Hashrate Range
2.4 - 6.5 kW	10 – 276 TH/S

Samanta, Anindita, et al. "Electromagnetic Transient Model of Cryptocurrency Mining Loads for Low-Voltage Ride Through Assessment in Transmission Grids." *IEEE PES GM 2024*

9.5 milli seconds Zero Voltage DC Link voltage

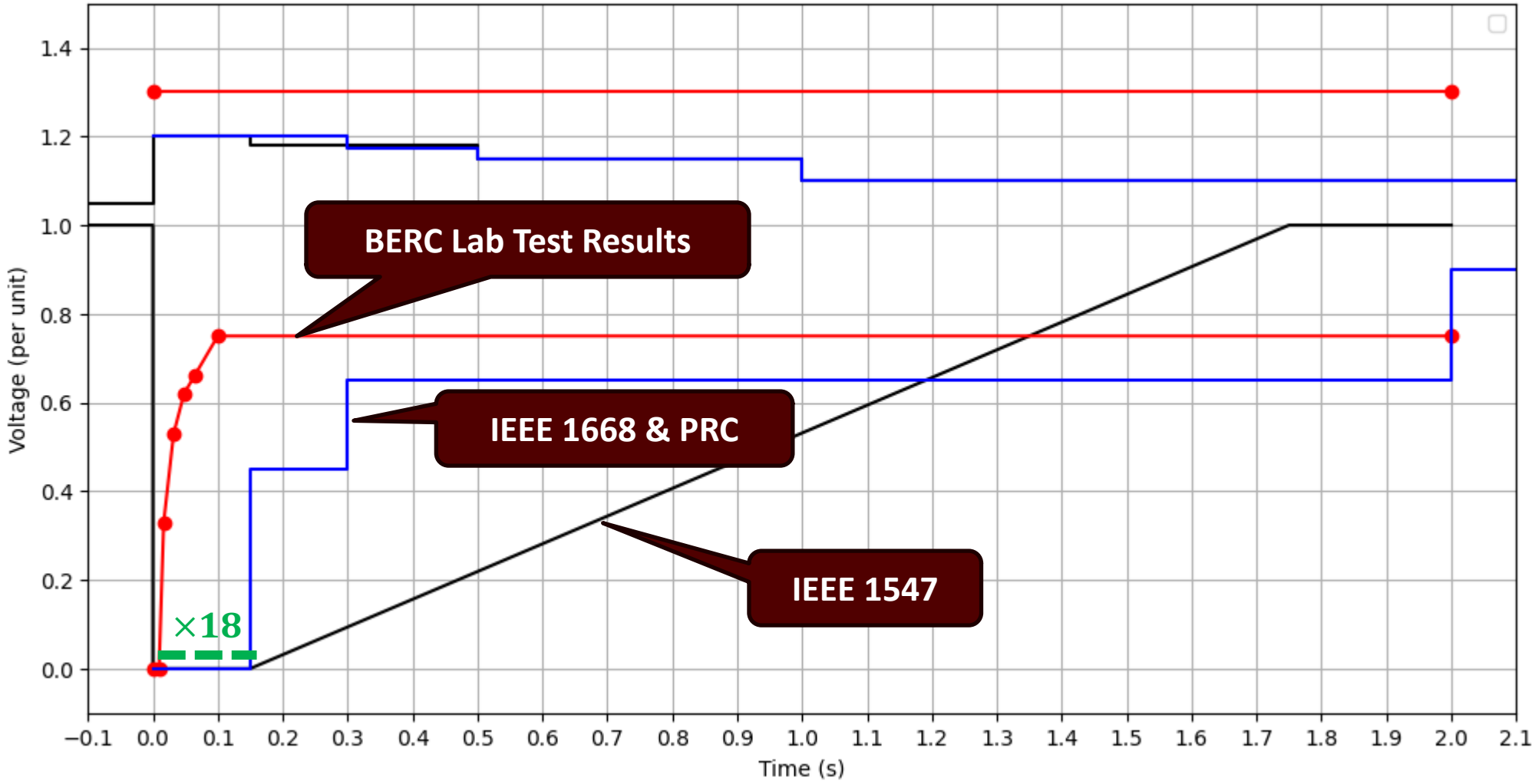


BERC Lab Voltage Ride-through Test Results – S19 Pro



Samanta, Anindita, et al. "Electromagnetic Transient Model of Cryptocurrency Mining Loads for Low-Voltage Ride Through Assessment in Transmission Grids." *IEEE PES GM 2024*

Bitcoin miner (S19 Pro) curve vs other curves



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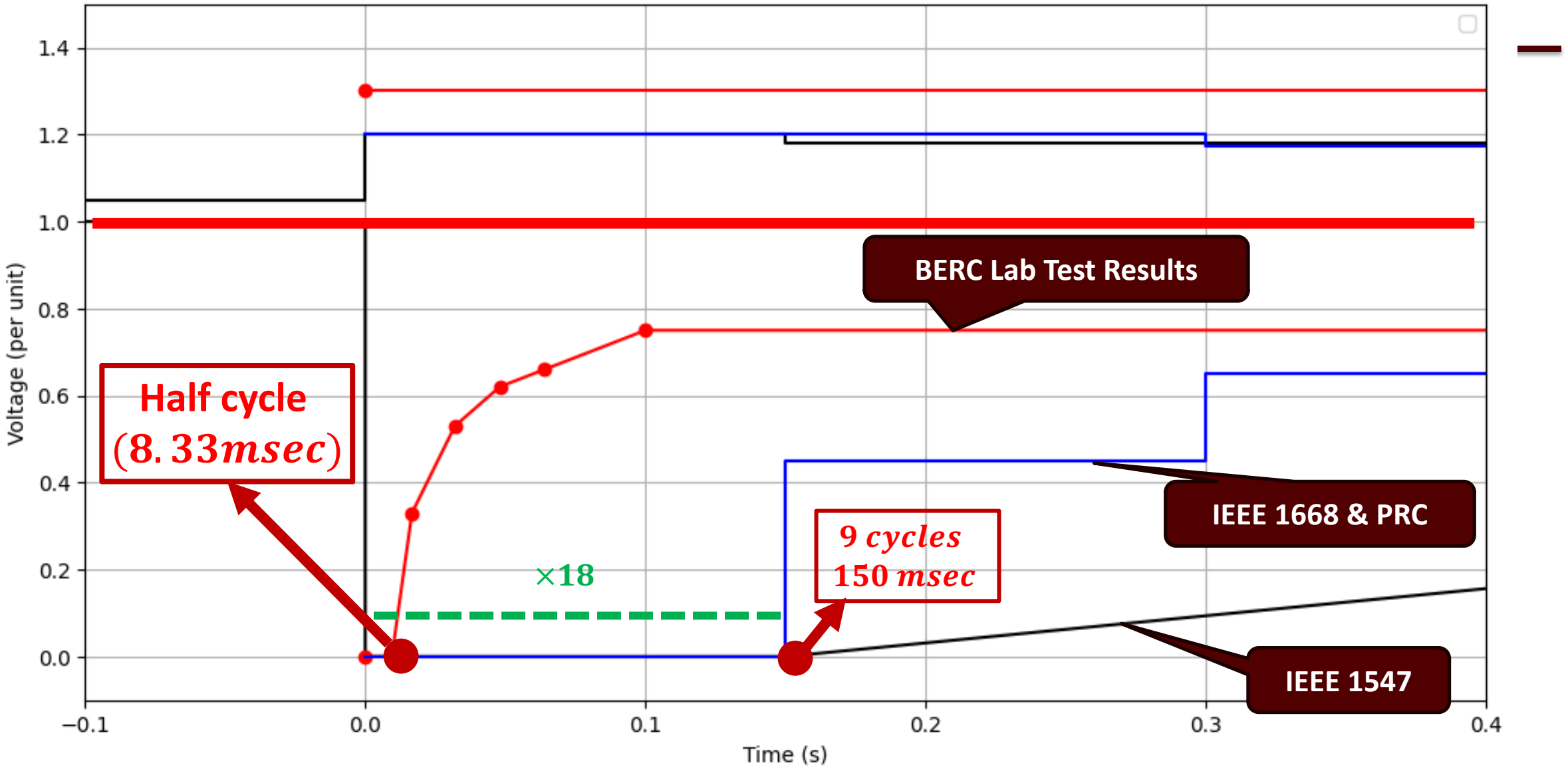
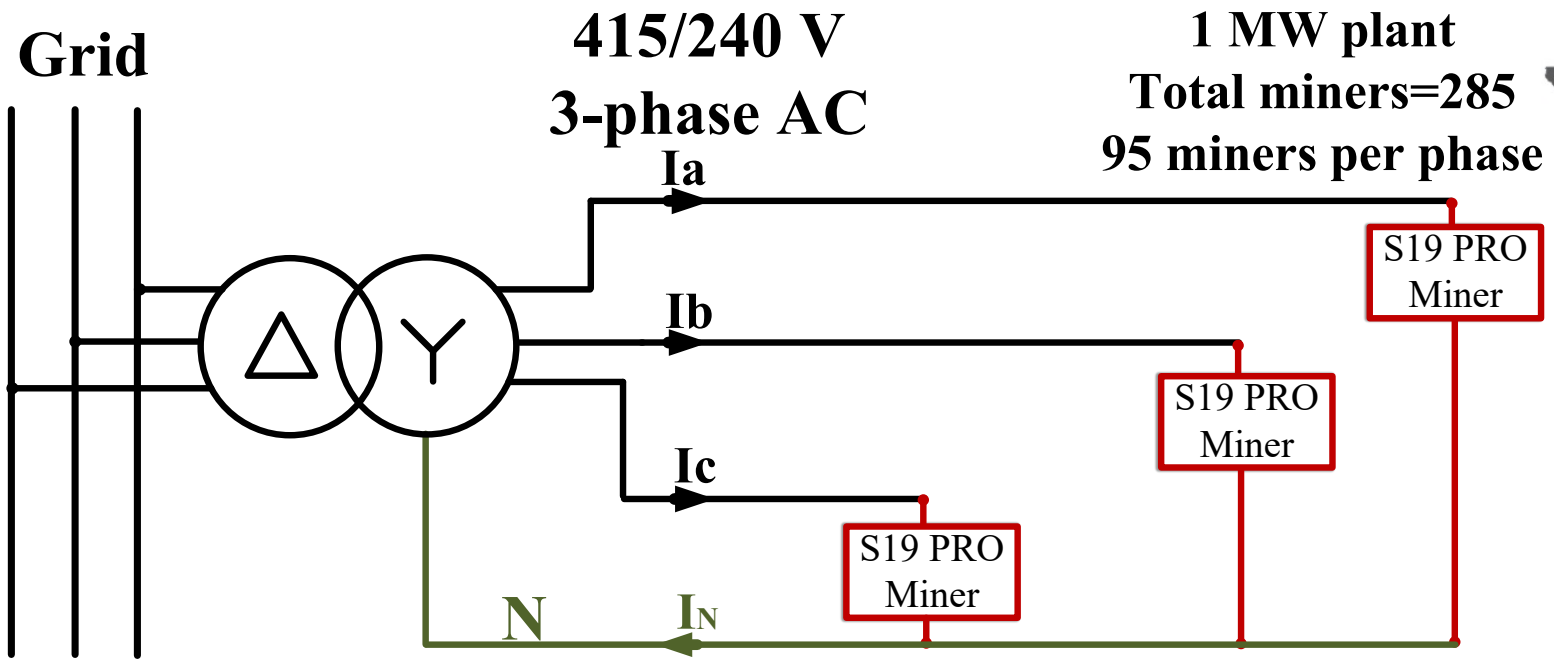
Bitcoin miner curve vs other curves

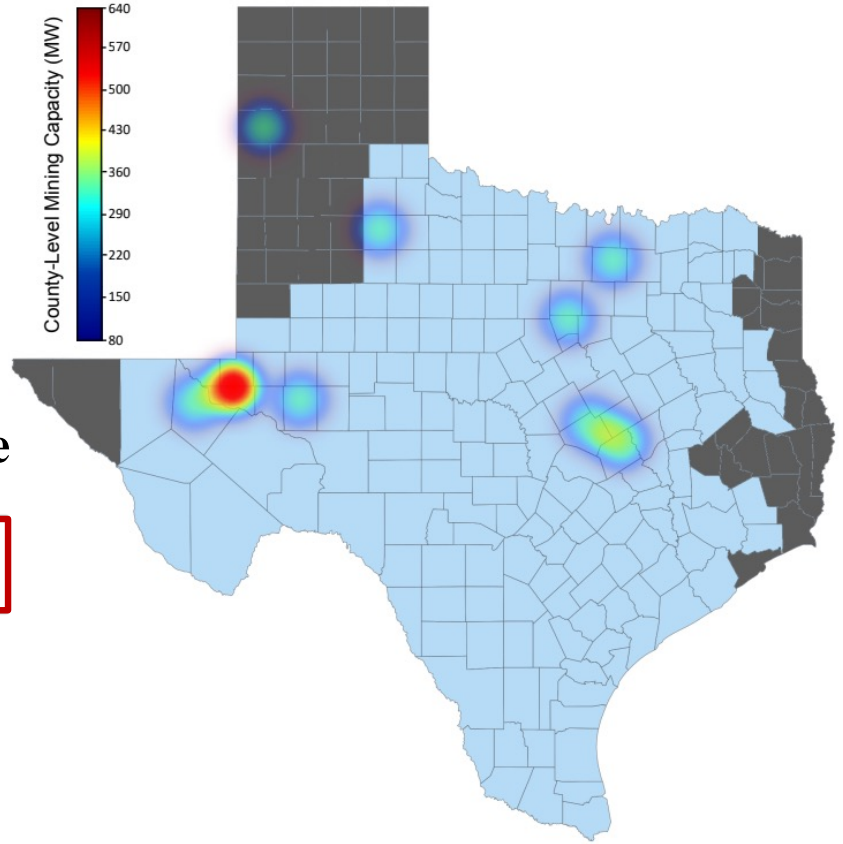


Samanta, Anindita, et al. "Electromagnetic Transient Model of Cryptocurrency Mining Loads for Low-Voltage Ride Through Assessment in Transmission Grids." *IEEE PES GM 2024*

Helping ERCOT on Large scale Bitcoin Mining Facilities

- Power consumption 3.5 kW per miner
- **100MW mining facility ~28,500 miners**
- Ramifications of VRT issues in large scale facilities on the grid





Samanta, Anindita, et al. "Electromagnetic Transient Model of Cryptocurrency Mining Loads for Low-Voltage Ride Through Assessment in Transmission Grids." *IEEE PES GM 2024*

Summary

- Blockchain and cryptocurrency is still at its infancy
- Increasing amount of energy will be needed for such applications
- How to make it a “win-win” for the energy sector and the computing industry remains a major challenge and opportunity

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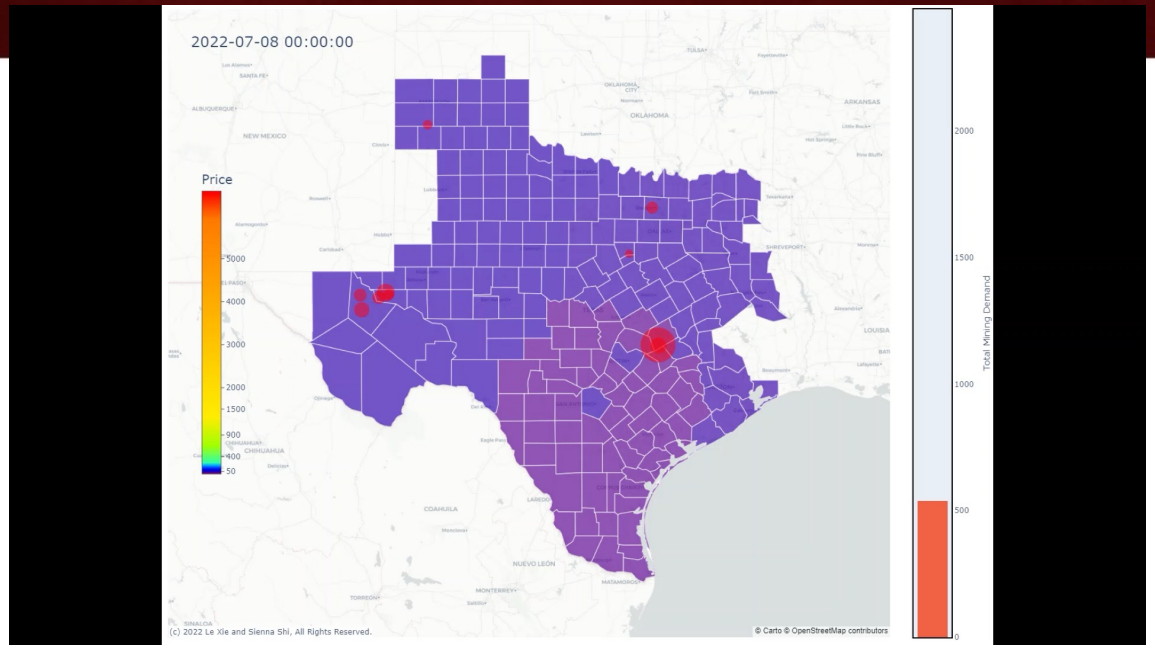
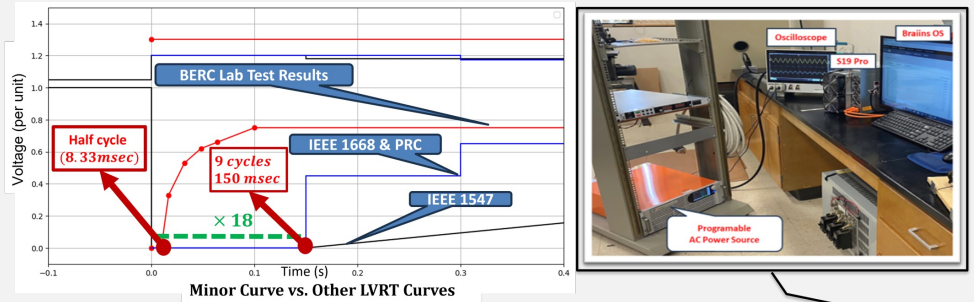
Texas A&M and ERCOT Tour Riot's Rockdale Facility



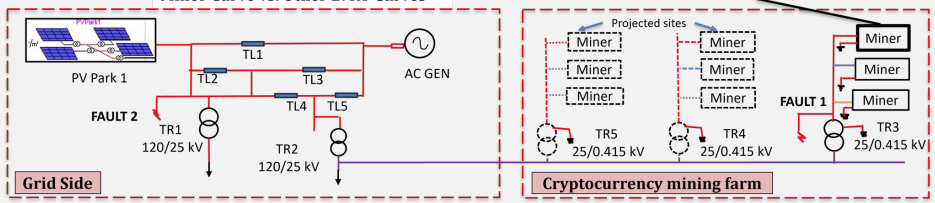
Transients (Control) — **Economics (Optimization)**

10^{-7} second | 10^{-3} second | 1 second | 1 min | 5 min | 1 hour | 1 day | 1 week | 1 year

Low-voltage Ride Through of Cryptocurrency Miners

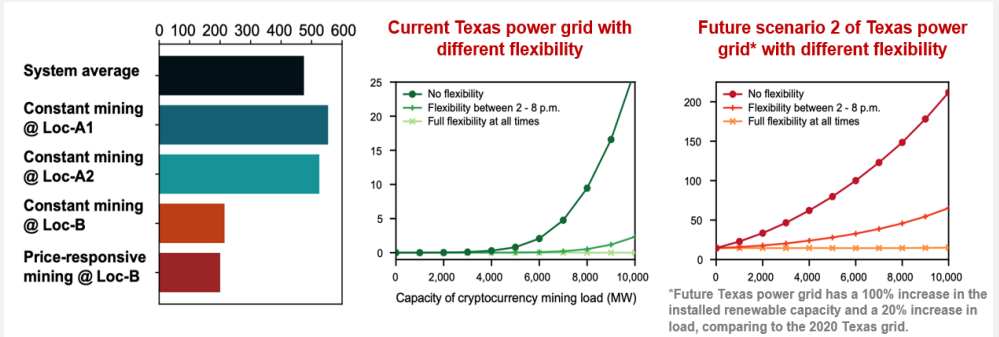


Minor Curve vs. Other LVRT Curves



The Blockchain & Energy Research Consortium, TAMU, https://tx.ag/berc

Crypto mining's impact on carbon footprint and reliability



Menati and Xie, et al. *IEEE Tran. On Energy Markets, Policy and Regulation*, 2023

Menati and Xie, et al. *Advances in Applied Energy*, 2023

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