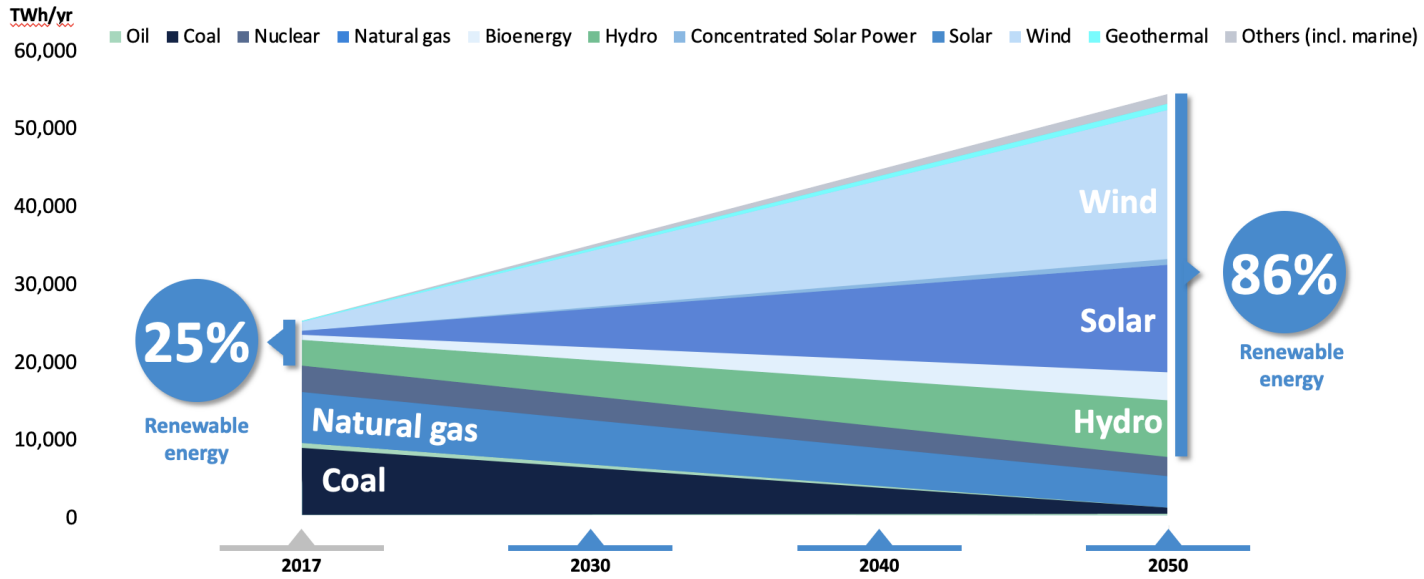
Controllable Loads for Ancillary Services

Green Hydrogen and Beyond

LANCIUM

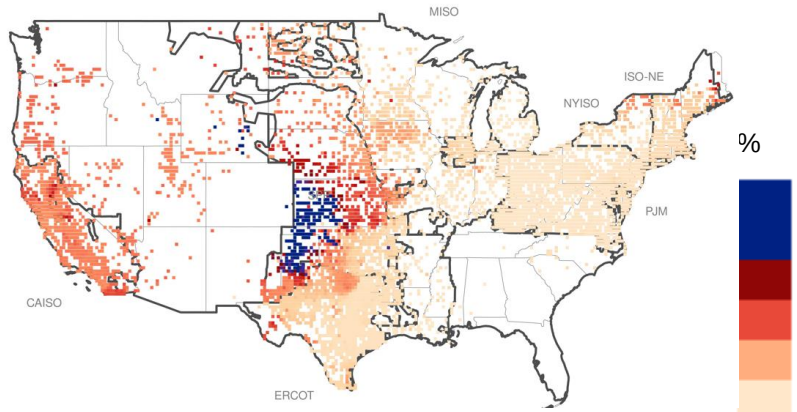
Market Forces: Increased Renewables Share and Negative Pricing

Depressed power prices can inhibit the buildout of new renewable generation

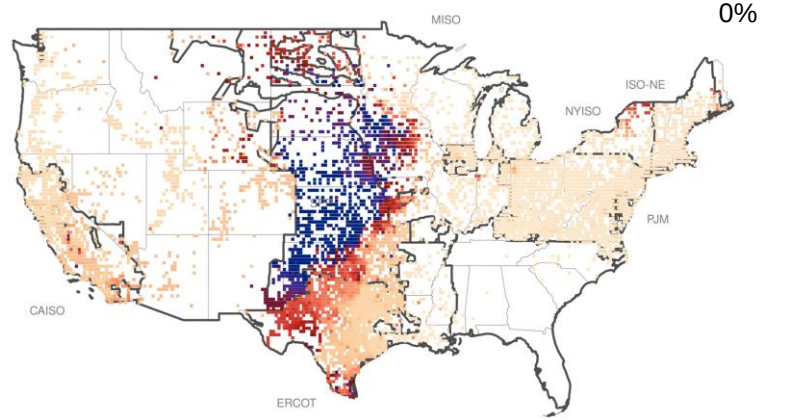


Renewables mix is expected to grow to over 85% of electricity generation by 2050

Negative Frequency (2017)



Negative Frequency (2021)



Source: International Renewable Energy Agency

Flexibility in the Grid is Essential to a Net Zero Future

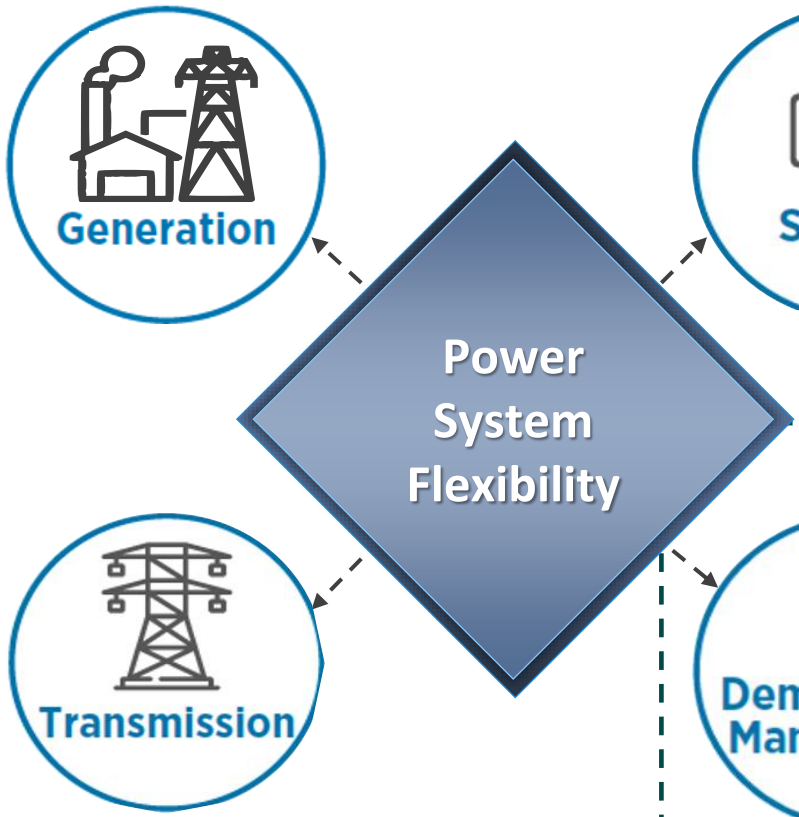
Technological options and solutions for power system flexibility

LANCIUM® BALANCING ENERGY

Supply Solutions

Flexibility from Generation

Flexibility from Transmission



Demand Solutions

Flexibility from Storage

- Pumped hydro
- Batteries
- Mechanical storage (ie: flywheel, gravity-based, etc.)

Flexibility from Load

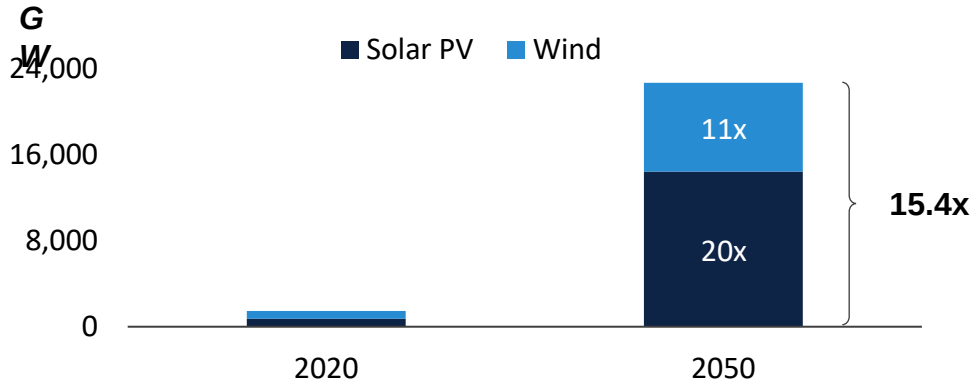
- Demand response from commercial and domestic sectors
- Large scale demand management
- **Lancium is the only load-only controllable load in the market**

Batteries and Demand Response Will Become the Primary Sources of Flexibility

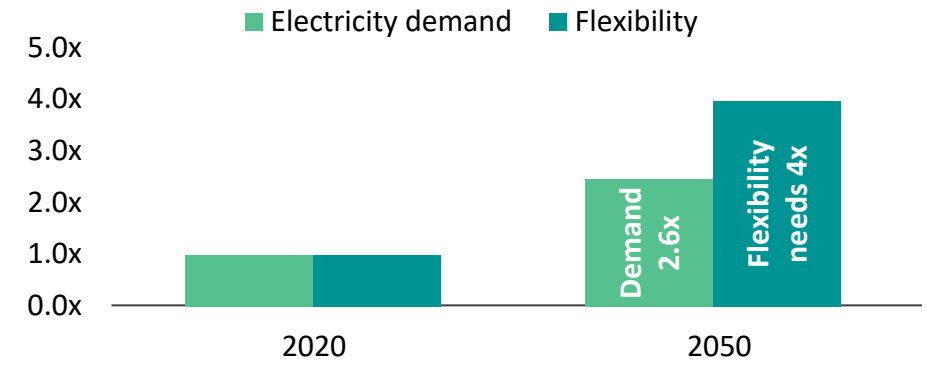
Grid of the future – power system flexibility

LANCIUM® BALANCING ENERGY

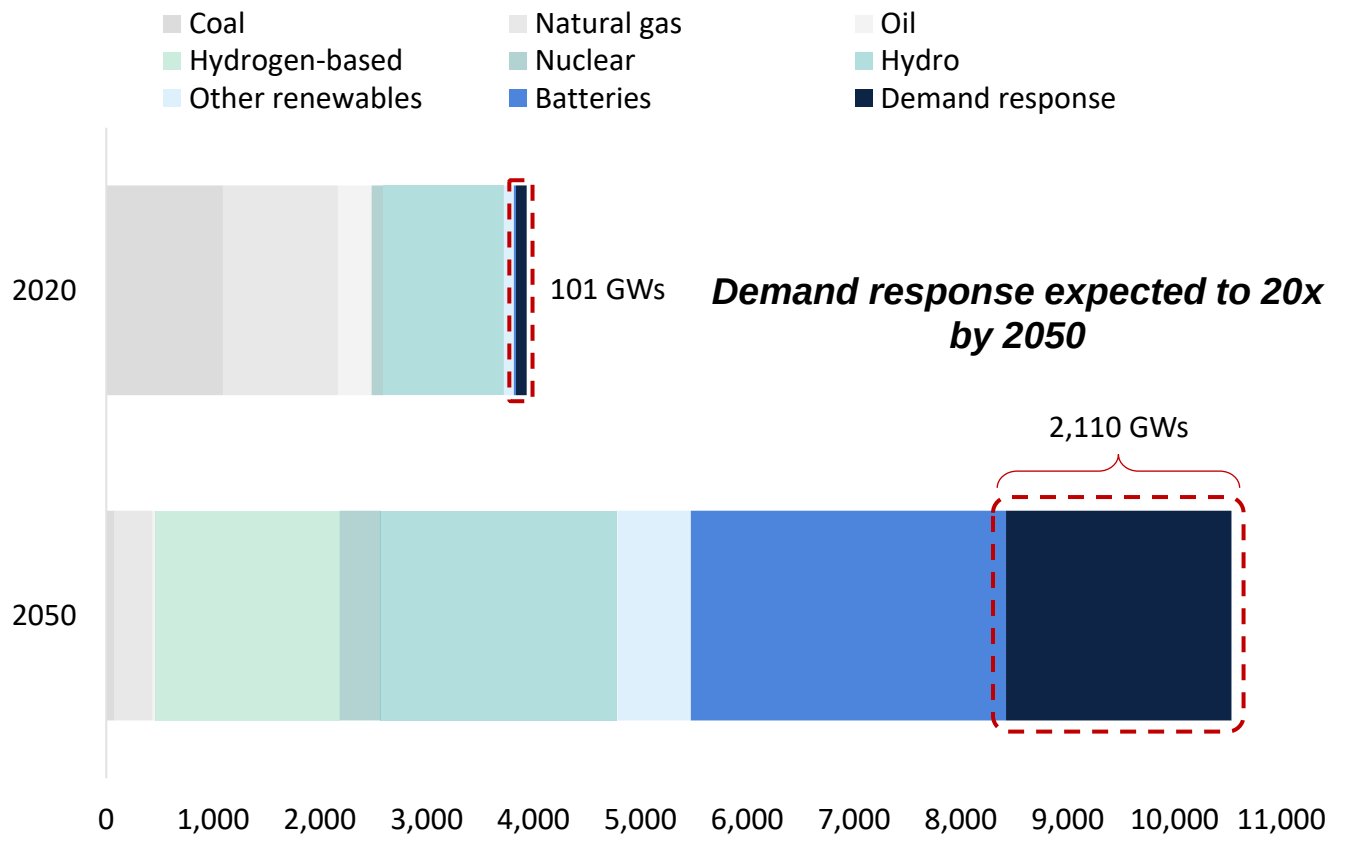
Solar and Wind Capacity Additions[1]



Electricity System Flexibility Needs[2]



Electricity System Flexibility by Source[1]



With solar and wind capacity expected to increase >15x, power system flexibility will need to increase 4x

Sources and Notes: [1] International Energy Agency (2021), Net Zero by 2050, IEA, Paris; Demand estimates sourced from BNEF, International Renewable Energy Agency. [2] International Energy Agency, Achieving Net Zero Electricity Sectors in G7 Members.

ERCOT's Growing Need and Market Value for Ancillary Services

Overview of Ancillary Services products at ERCOT

LANCIUM® BALANCING ENERGY

ercot

Types of Ancillary Services

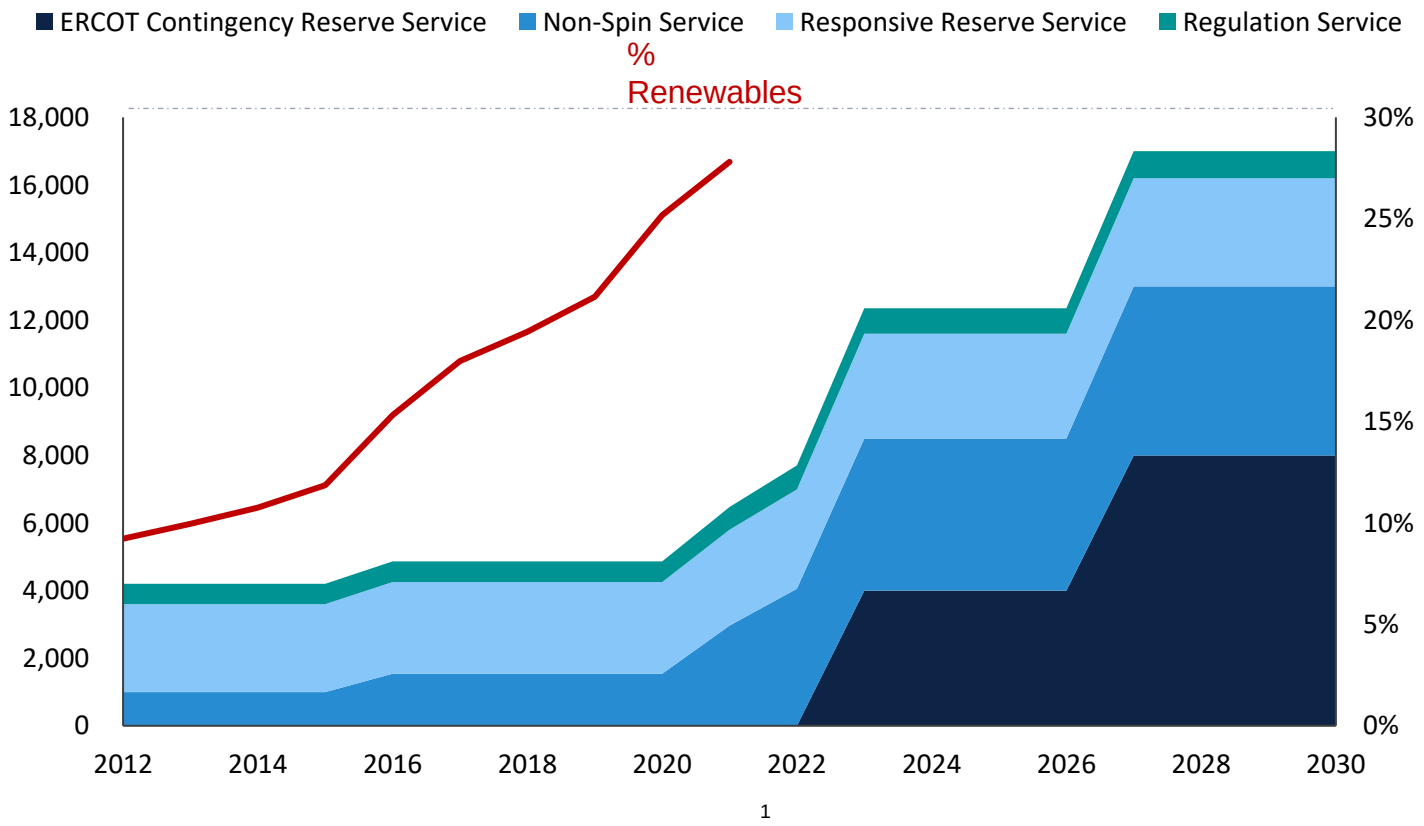
Regulation Service
Generators providing Regulation receive a signal from ERCOT every four seconds to increase or decrease output

Responsive Reserve Service
Capacity from generators or load resources that is reserved from the energy market in order to be readily available to respond to frequency events

Non-Spin Reserve Service
Capacity that can be started in 10 or 30 minutes to cover forecast errors or ramps

ERCOT Contingency Reserve Service (ECRS)
Capacity that can be sustained for two consecutive hours to cover sustained ramps in net Load

Average Hourly Ancillary Service Volume (MWs)

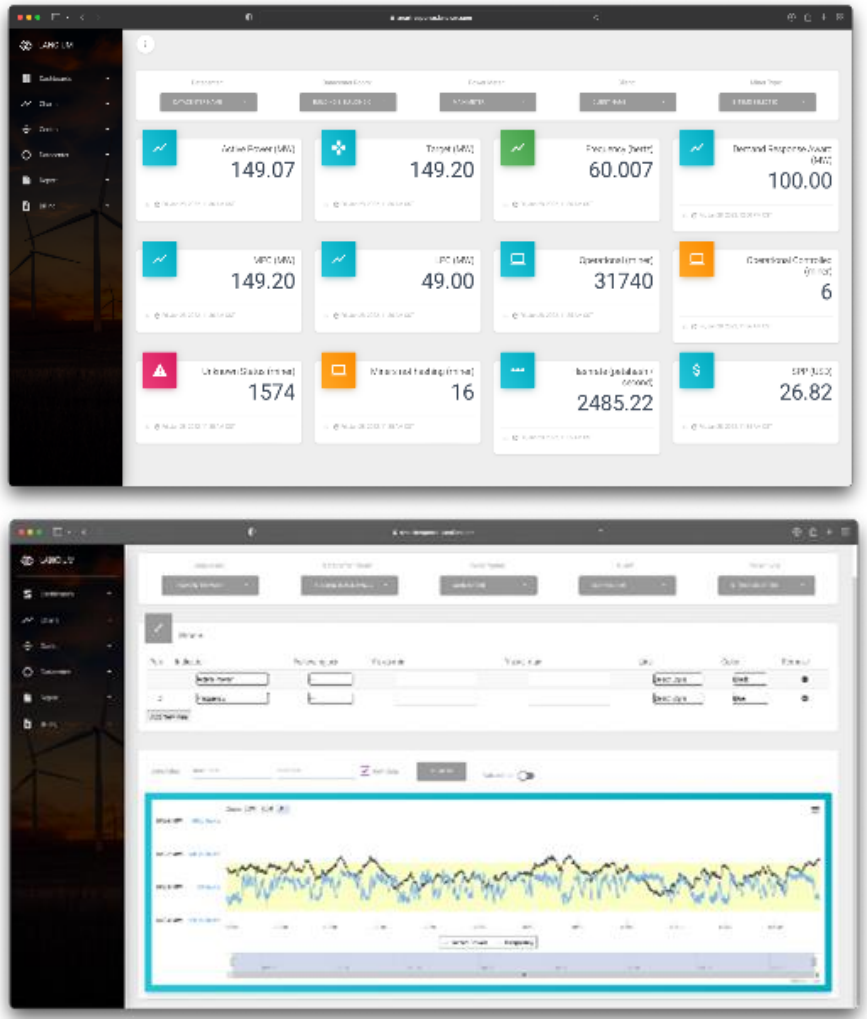


[1]

Source: YES Energy (ERCOT Data), Forward Data - Lancium forecasts based on ERCOT publications ; [1] Ancillary Service market cleared $13.7B in 2021 due to Winter Storm Uri.

Lancium Smart Response® Solutions

End-to-end integrated energy management solution



Lancium Smart Response® communicates with the grid in real-time to adjust load based on several factors:

- ✓ Grid supply/demand balance
- ✓ Power market prices
- ✓ Ancillary Services commitments
- ✓ Load matching with zero-carbon energy

Deployed at our Lancium Clean Campus as well as at several large Bitcoin mining facilities in Texas

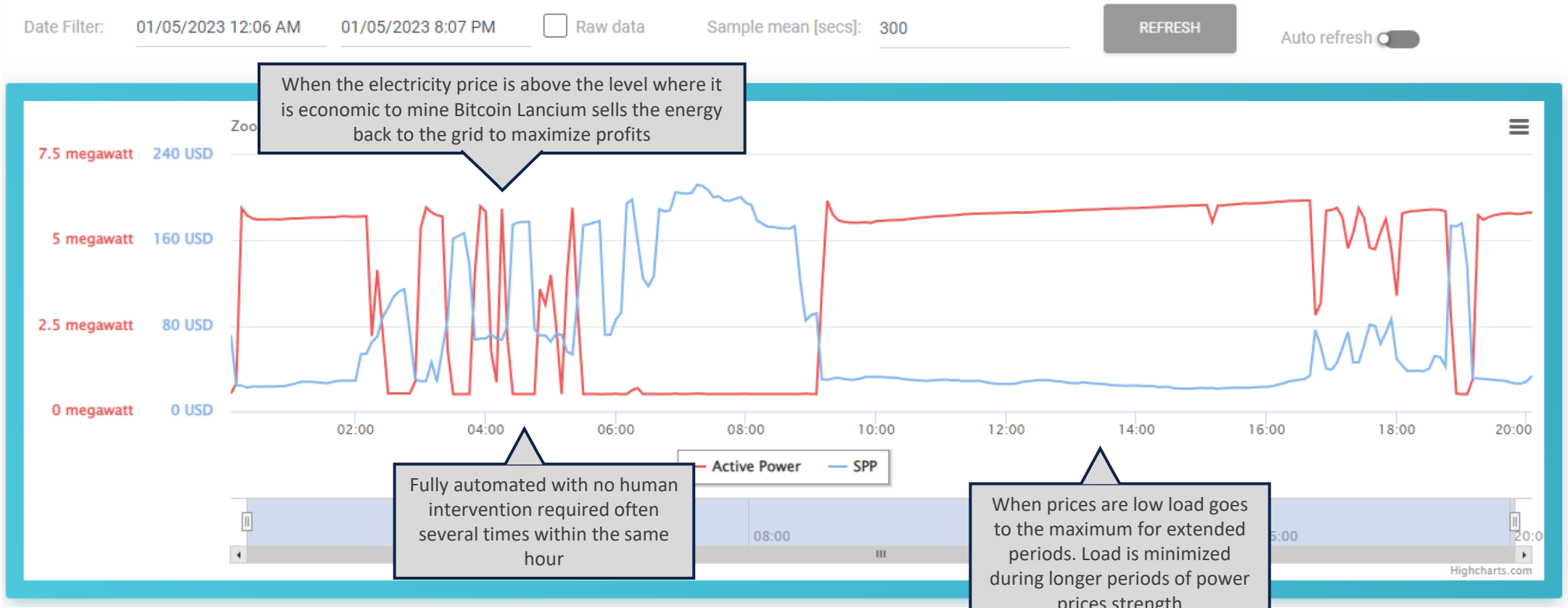
- ✓ Proven technology that is patented
- ✓ Allows energy-intensive applications to ramp their power consumption up or down in as little as 5 seconds
- ✓ Lancium Smart Response ® dashboards give end-users real-time visibility into their environment

Lancium is actively developing additional interfaces with conventional data center loads and other potential applications

Smart Response Real Use Case

Curtailing load in response to market prices above a pre-determined threshold

LANCIUM

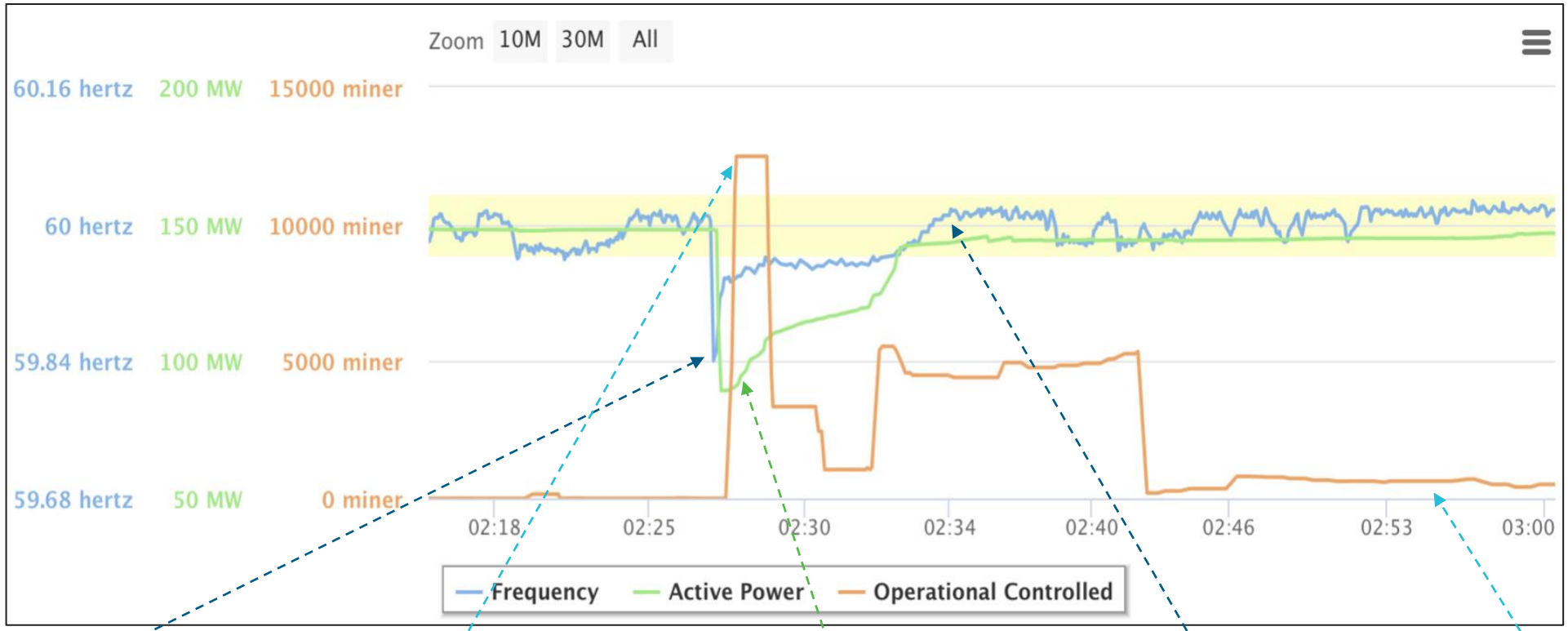


Smart Response systematically controls mining in response to real-time power prices

**Graph represents the largest mining site currently operating in the U.S.*

Lancium Smart Response™ Stabilizes Power Grids – Real Use Case

Automatically detect undesired grid frequency and power down miners in seconds



Grid frequency went down from 60 Hz to undesirable low level of 59.84 Hz

Smart Response™ detects the undesired frequency and power down more than 12,000 miners.

Active Power consumption is lowered from 150 MW to less than 100MW in seconds.

Frequency comes back to normal levels due to power consumption reduction.

Smart Response™ turns miners back on once frequency is reestablished.

Actual real time data showing a Smart Response™ enabled Bitcoin mine stabilizing frequency and following grid operator instructions on January 2022.

Basics of Demand Side Bidding for Ancillary Services

- **The price at which a load is indifferent about providing AS depends on:**
  - The net value produced by the load (ie, "break-even" price)
  - The probability of being turned down, ie, likelihood of AS deployment
  - The opportunity cost of being obligated to run to provide AS rather than liquidating energy at a high RTM price
- **Historical deployment (hourly, seasonal) is approximately 15% for REGUP and <1% for RRS, NSPIN**
- **Without real-time co-optimization of energy and AS, AS awards are physical obligation to provide (beware of SASM). AS Bids are submitted in DAM, but energy settles in RTM**

Illustrative Example
Breakeven Price = $100/MWh

Hour Ending	AS Award	AS Price	RTM Energy Price
6	RRS	2	20
7	**REGUP**	**500**	50
8	RRS	2	20
9	NSPIN	2	30
10	NSPIN	2	35
11	RRS	2	40
12	RRS	10	45
13	NSPIN	10	50
14	RRS	15	55
15	NSPIN	25	60
16	RRS	25	80
17	-	-	120
18	-	-	250
19	-	-	180
20	NSPIN	10	50

Green Hydrogen is a Significant Controllable Load Opportunity

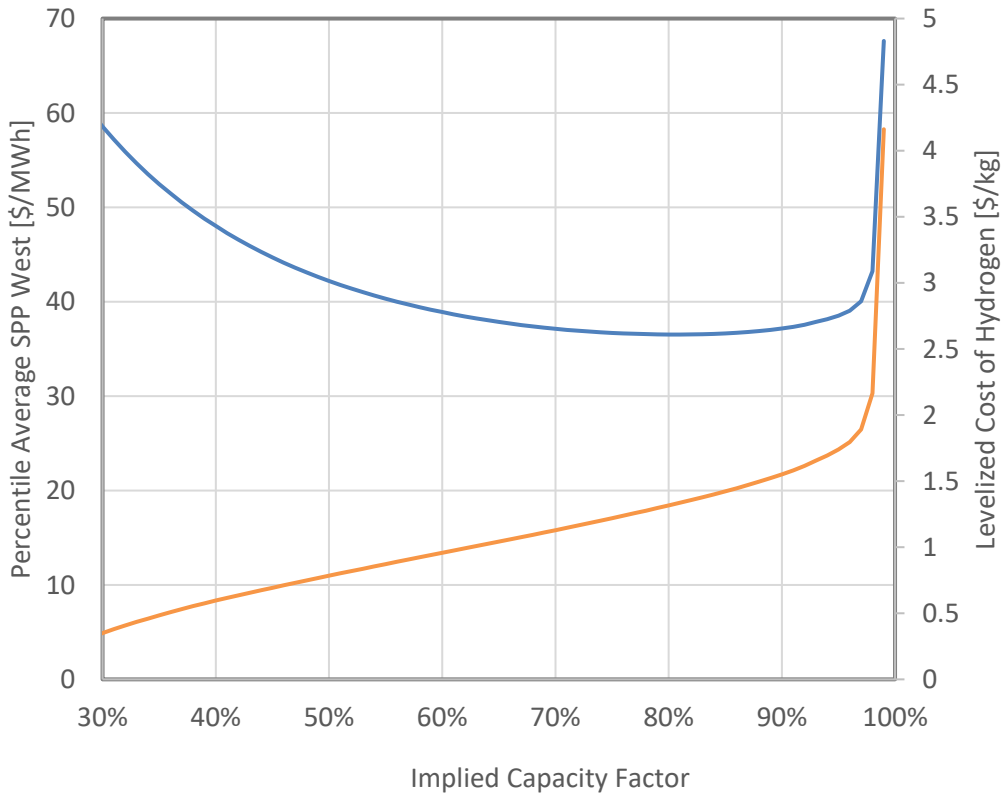
LANCIUM® BALANCING ENERGY

Large Consumers of Power	By 2025, an additional 3,205 MW of electrolyzers dedicated to green hydrogen production will be deployed globally, representing a 1,272% increase
Enabling Reduced Emissions Footprint	Electrolysis itself does not produce any emissions other than hydrogen/oxygen
Individually Controllable	Modular electrolyzer design allows more flexibility and turn-down to avoid high prices and provide ancillary services
Consistently Use Power	Steady power draw means units can respond to grid signals in real-time
Interruptible	Electrolyzers can be turned down without significant impact to energy intensity

Hydrogen Production as a Controllable Load

Operating Hydrogen Electrolyzers as Controllable Load Resources Greatly Reduces the Cost of Production

- We have identified two electrolyzer technologies that have operational characteristics to be controlled as a CLR (PEM, AEM)
- The combination of providing AS (earning revenue) and responding to real-time prices (avoiding costs) can make green hydrogen cost competitive with conventionally produced hydrogen on a levelized cost basis, especially with PTC
- High frequency of negative/low electricity prices allows green hydrogen to be cost-competitive even with lower capacity factors (70-90%, see chart right)
- Smart Response can be used to match green hydrogen production with zero carbon energy production



Challenges for Green Hydrogen

- Off-take Problem: end-markets and transportation infrastructure are not present at scale
- Coastal export-oriented projects don't benefit from as high occurrence of negative pricing, require economies of scale
- Inland projects may benefit from lower electricity costs, but transportation cost/capacity is a limiting factor
- Green Ammonia is a viable solution to the off-take problem, as storage, transportation, and markets for ammonia already exist, and markets for ammonia are coincident with low electricity prices in much of the US. However…
- Seemingly attractive pricing nodes throughout Middle America do not have the transmission/distribution capacity available for MW-scale loads
- New interconnections increase both cost and timeline for loads
- Regulated service territories can't generally offer rate structures needed for green hydrogen economics to pencil out
  - Tend to offer fixed rates with no/limited exposure to the wholesale market
  - IOUs need to file rate case for new rate structures
  - Co-ops, non-profit by definition, have little incentive to enter novel commercial agreements that could incur additional costs to their other owner-customers