Client Report and Presentation

Snowy Hydro Limited

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Submitted by:

Student ID	Name	Email address
46242880	Hasan Mustafa Tarique	hasanmustafa.tarique@students.mq.edu.au
46279253	Fariha Mubasshira	fariha.mubasshira@students.mq.edu.au
46343229	Sidharth Sindhu	sidharth.sindhu@students.mq.edu.au
46806725	Saakshi Khatri	saakshimahesh.khatri@students.mq.edu.au
46843302	Raj Katare	rajkamlakar.katare@students.mq.edu.au
47259663	Mahsa Ebrahimian	mahsa.ebrahimian@students.mq.edu.au

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Overview:

The Australian energy system is currently undergoing a notable transformation, characterized by a transition towards renewable energy sources and a decline in coal-fired generation. It is anticipated that the retirement of coal plants will be succeeded by the emergence of wind and solar farms, which will be bolstered by diverse energy storage solutions such as battery energy storage systems (BESS), pumped hydro, and gas (AEMO, 2021).

According to the Australian Energy Market Operator (AEMO), a significant portion of coal-fired generation is expected to retire by 2040. This development will pave the way for renewable energy sources and an estimated 19 gigawatts of firming generation. According to industry projections, the distributed energy generation sector, with a particular emphasis on rooftop solar, is expected to experience a two to three-fold increase over the next 20 years. This growth is anticipated to result in distributed energy generation accounting for as much as 22% of the overall electricity supply.

Notwithstanding the expeditious expansion of renewable energy, there exists a necessity for power plants that are dispatchable and can be promptly dispatched as per the grid's exigencies. The utilization of battery technology has become a pivotal resolution to tackle the sporadic characteristic of sustainable energy. The implementation of battery energy storage systems enables the storage of surplus power generated during favourable conditions and its subsequent release during periods of high demand. This results in a more dependable and consistent supply of electricity (AEMO, 2021).

The incorporation of battery storage technology facilitates a seamless shift towards a grid predominantly powered by renewable energy sources by furnishing grid stability, frequency regulation, and the capacity to correspond to supply and demand. AEMO, in its capacity as the market operator, is confronted with technical challenges in effectively managing the growing capacity of distributed energy generation. The primary objective is to ensure that the grid remains both viable and stable.

Australian market for BESS:

The Australian renewable energy sector experienced significant expansion beginning in the early 2010s, coinciding with the implementation of the Renewable Energy Target (RET) aimed at achieving 33 TW/hr by 2020. Australia has successfully exceeded its target for renewable energy adoption, achieving it in advance of 2019. This remarkable achievement indicates significant progress in the country's efforts towards renewable energy.

The National Electricity Market (NEM) is currently dependent on a total of 43GW of firm capacity, comprising 23GW from coal and 20GW from dispatchable firming capacity sourced from storage and gas generation. The gradual phasing out of coal plants from the grid is expected to pave the way for the integration of renewable energy sources, which will be complemented by energy storage technologies such as batteries and pumped hydro, as well as gas generation (Australian Energy Council, 2022).

The BESS storage market can be categorized into two segments based on duration:

- **Shallow storage**: This refers to grid-connected energy storage systems with durations of less than four hours. The primary value of shallow storage lies in its capacity to provide fast ramping and frequency control ancillary services (FCAS), rather than its energy storage capacity.

- **Medium storage**: This category includes energy storage systems with durations between four and 12 hours. The key advantage of medium storage is its ability to shift energy within a single day, which is driven by the daily consumption patterns of energy consumers and the diurnal pattern of solar generation.

The market for energy storage systems (ESS) in Australia can be classified based on type and end user. The market is categorized into various segments based on type, including Lithium-ion battery, Lead-acid, Flow batteries and Flywheels battery. Market segmentation by end user includes residential, commercial and industrial, and utility scale.

By type	Lithium-ion battery
	Lead-acid
	Flow batteries
	Flywheels battery
By end user	Residential
	Commercial and industrial
	Utility scale

Competitive scenario**:**

The Battery Energy Storage Systems (BESS) Market ecosystem is comprised of many key companies and innovators, including those listed below ('Battery Energy Storage Systems (BESS) Market Size By 2031', 2023):

- Hitachi Chemical Co., Ltd.
- Fluence
- Narada
- Hitachi ABB Power Grids
- Siemens Energy
- Eve Energy Co. Ltd.
- Kokam
- Samsung SDI
- Black and Veatch
- VRB Energy
- LG Chem
- GE Renewable Energy
- ABB

The market for energy storage systems (ESS) in Australia is somewhat fragmented, with a few major suppliers leading the way. Pacific Green Technologies Group, LG Energy Solution Ltd, Tesla Inc., Century Yuasa Batteries Pty Ltd, and EVO Power Pty Ltd are a few of the well-known industry players. These businesses have a big impact on how energy storage is developed in Australia.

Commercial availability

According to market analysis, the utility segment maintained the highest market share in 2021 and is projected to sustain its leadership position throughout the forecast period spanning from 2022 to 2030. The main driving force behind this is the substantial investments made in utility-scale power plants. The commercial and industrial sector is anticipated to exhibit the most rapid expansion among all categories. This growth is attributed to the surge in decentralized renewable power projects, rural electrification initiatives, and the construction of commercial buildings, which collectively contribute to the market's upward trajectory ((Mandaokar, 2020). It is interesting to note that Australia experienced significant growth in residential battery energy storage system (BESS) installations in 2022, with 47,100 installations totalling 589 MWh, a 55% increase from the previous year. The cumulative energy storage capacity in Australia reached 1.92 GWh, with around 33% of battery installations being retrofitted to existing solar systems. Tesla secured a contract to supply 150 MW/300 MWh of its Megapack BESS solution for upcoming projects by Edify Energy, while collaborations involving Shell Energy, Edify, AMPYR Energy Australia, and Greenspot aim to support decarbonization efforts in industrial and commercial sectors. Utility companies in Australia, such as AGL Energy, have implemented BESS to improve grid stability, integrate renewable energy, and optimize energy operations ("Broken Hill Battery Energy Storage System | How We Source Energy | About AGL | AGL", n.d.) & (Colthorpe, 2022).

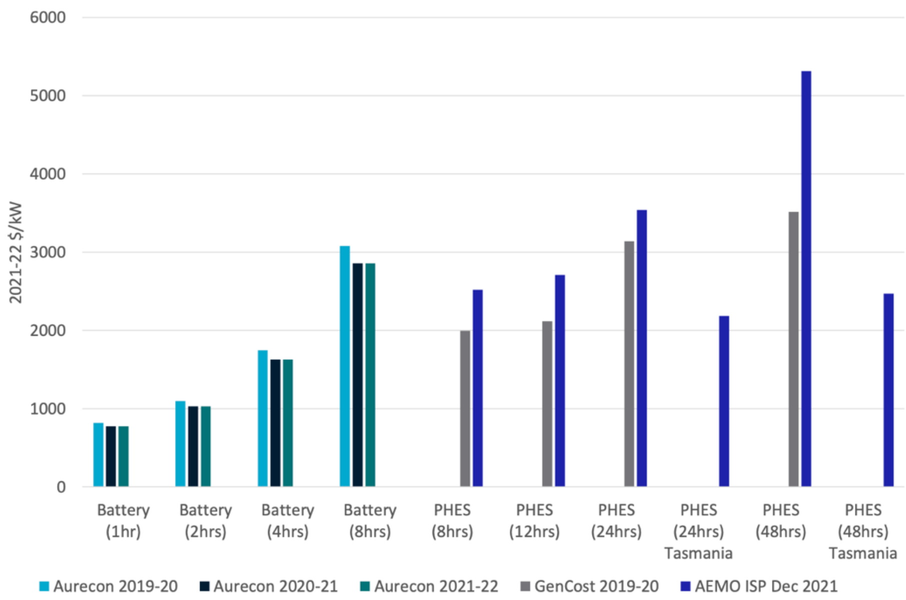
Technology:

Because of its mobility and high energy density, lithium-ion batteries are widely used. They are simple to move and set up, and they provide effective energy storage. Although lead-acid batteries are less expensive, they last less time and are less efficient. A more recent technology called flow batteries works by storing energy in an electrolyte solution and has a longer lifetime. When necessary, they may refocus energy. Flywheels are useful for short-term storage applications because they can store and release power using kinetic energy ('What Are Different Types Of Battery Energy Storage Systems (BESS)', n.d.)

The lithium-ion technology has gained prominence as the primary option for battery storage deployments, outpacing the utilization of lead-acid batteries. Lithium-ion technology boasts several advantages that render it highly appropriate for energy storage applications. These include its cost-effectiveness, superior performance, deep discharge cycle life, and high energy and power density. It is anticipated that the continuous progress in technology and growing market adoption will propel the lithium-ion battery prices to further decrease. Flow batteries, although currently constituting a smaller market share, exhibit potential as a viable long-term battery storage solution, especially for applications necessitating prolonged durations of 4 hours or more. The utilization of flow batteries presents several benefits, including substantial energy storage capacity and enhanced cycle longevity. The impact of nascent technologies on the market landscape cannot be overlooked, as they may lead to the emergence of novel battery types. The battery energy storage systems market is expected to maintain lithium-ion as the leading technology during the projected period (Australian Energy Council, 2022).

Costs

According to the CSIRO's 2021-22 GenCost report, battery costs have been consistently decreasing due to their widespread use in electric vehicles and consumer electronics. Specifically, battery costs experienced a 5-6% decline, whereas pumped hydro costs remained relatively stable. The report also forecasts that the adoption of rooftop solar capacity in the National Electricity Market (NEM) will surpass 50% of homes by 2032 and reach 65% (69 GW capacity) by 2050. As rooftop systems become more cost-effective, battery storage is expected to complement them. Initially, home batteries are primarily used to maximize solar output, but as their numbers increase, there is potential for energy storage aggregation. AEMO highlights the need for 4–12-hour utility-scale storage to manage renewable generation fluctuations and compensate for the declining presence of coal. Pumped hydro, particularly the Snowy 2.0 project, will contribute significantly to storage capacity until 2030, but additional deep storage solutions will be necessary in subsequent decades to support renewable energy. Vanadium redox batteries are considered a promising technology for medium-duration storage applications, complementing lithium-ion and other storage technologies. Meanwhile, large-scale flow batteries, despite having a higher capital cost, offer a longer lifespan. The concept of long-duration energy storage is also gaining attention, with more than 5 GW/65 GWh of capacity already announced or operational. (“Coal exits: What’s in store for batteries?”, 2022)

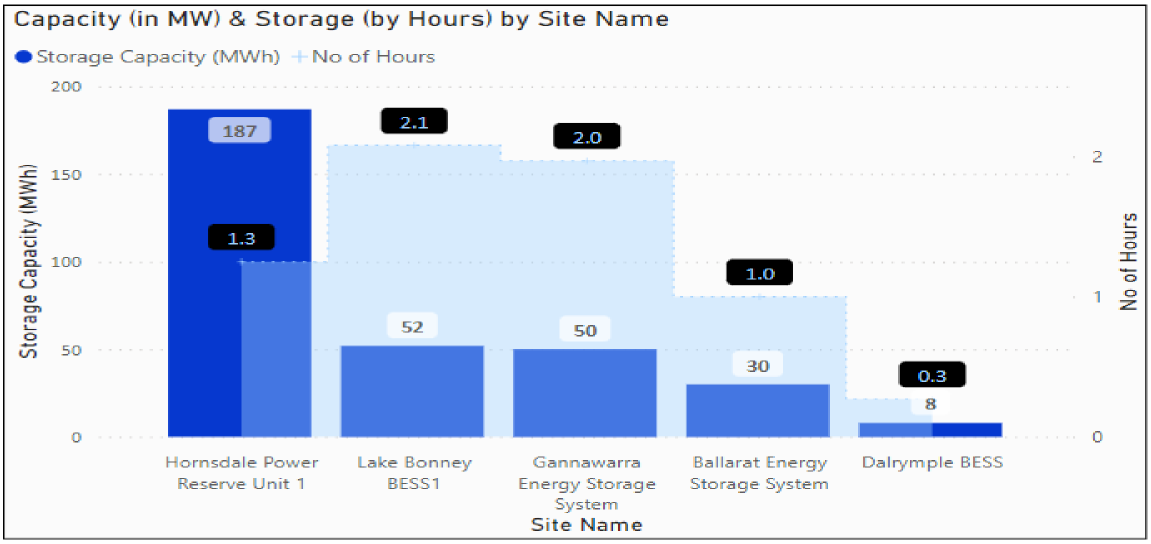


As storage time grows, so do the costs in dollars per kilowatt (kW). This is because more storage duration increases expenditures without boosting the project's power rating. Extra storage time is very expensive for batteries. Because of these cost trends, batteries are more competitive in applications requiring shorter storage durations, while pumped hydro energy storage (PHES) is more competitive in applications requiring longer storage durations. Depending on the behavior of the system's various power generating sources, particularly the quantity of variable renewable energy, a mix of batteries and pumped hydro with varying storage periods may be required (Graham et al., 2022).

Upcoming projects:

Five large-scale batteries with a total capacity of 260 MW are now in use in South Australia and Victoria. According to AEMO's Generation Information report, over 85 more huge batteries with a combined capacity of 18,660 MW are now under construction. With a predicted power capacity of up to 1,200 MW, which is almost eight times bigger than the battery at Hornsdale, the Hunter Valley in New South Wales plans to construct the biggest grid-scale battery in history. The Victorian Big Battery (VBB), which will have a capacity of 300 MW and 450 MWh, is also under development in Victoria. The VBB intends to improve grid safety and provide more capacity during the busiest summer months. The VBB will make it possible for the Victoria to New South Wales Interconnector to have up to 250 MW more peak capacity under a contract with AEMO under the System Integrity Protection Scheme (SIPS) (‘Energy Explained Big Batteries’, 2023).

Region	Site name	Capacity	Storage
SA	Hornsdale Power Reserve Unit 1	150	1.25
SA	Dalrymple BESS	30	0.27
VIC	Ballarat Energy Storage System	30	1.0
VIC	Gannawarra Energy Storage System	25	1.97
SA	Lake Bonney BESS1	25	2.08



Long-duration energy storage (LDES) and the use of big vanadium redox batteries are becoming more popular in Australia. The Yadlamalka project, backed by ARENA (Australian Renewable Energy Agency), aims to be the first grid-scale battery in the nation to use vanadium redox flow technology. Additionally, the country already has operational or stated plans for more than 5GW/65GWh of LDES capacity. Compared to lithium-ion batteries, vanadium redox flow batteries have longer lifespans while having greater initial costs. This suggests that battery energy storage systems (BESS) have a bright future in Australia, where they may complement other storage technologies in medium storage applications and meet the need for longer-term energy storage (‘Coal exits: What’s in store for batteries?’, 2022).

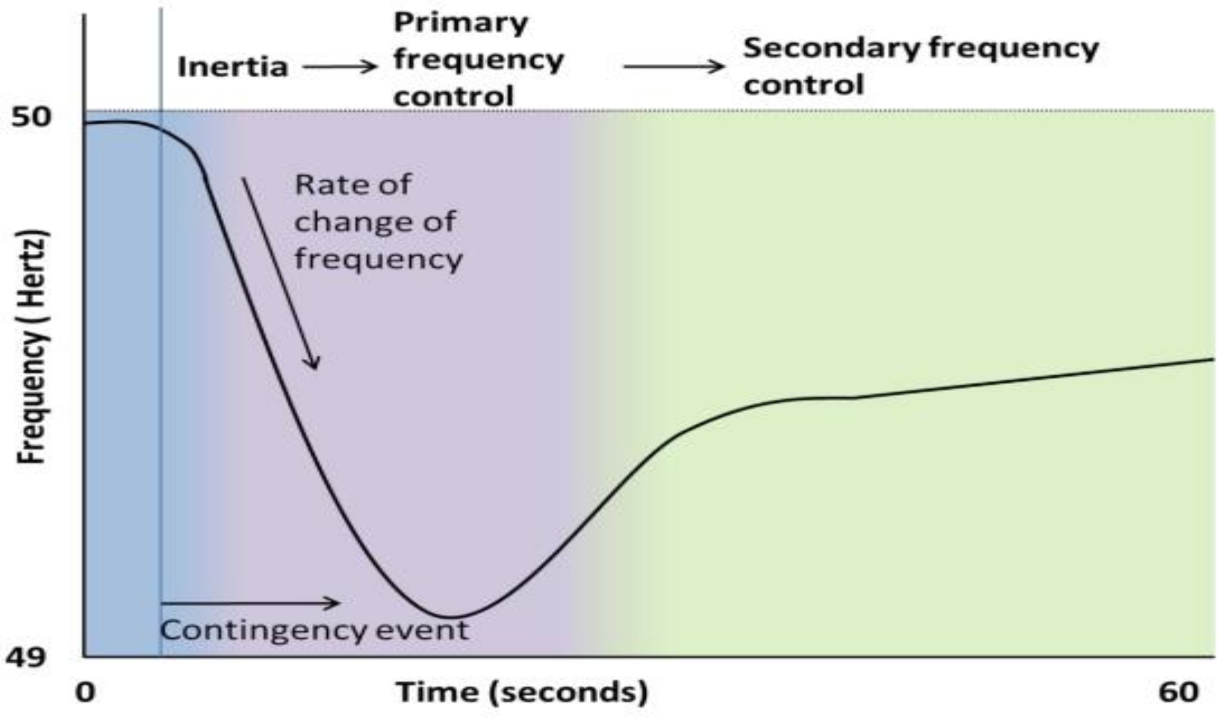
Frequency Control Ancillary Services

The Australian Energy Market Operator (AEMO) uses FCAS as one of its management tools for power system security.
FCAS is an essential component of the safety net measures that ensure AEMO can reach and sustain its goals, hence it is crucial that it is given when needed to maintain safety of the electricity system.

There are currently two types of FCAS – contingency and regulation

Contingency FCAS:

Contingency FCAS is procured to manage frequency recovery and return the frequency back within the normal operating frequency band (50 +/- 0.15 Hz), following a contingency event affecting the power system (such as the loss of a generator, load or network element).
These services are delivered automatically by enabled providers that have bid into the National Electricity Market (NEM) to deliver contingency FCAS in response to any frequency deviation outside the normal operating frequency band that may occur.



Regulation FCAS:

Regulation FCAS is procured to manage small perturbations around 50 Hz when frequency is within the normal operating frequency band.
Regulation FCAS is controlled by AEMO's Automatic Governor Control (AGC) system, which sends pulses to regulation-enabled generators to increase or decrease output every four seconds.

Further, there are eight different frequency markets across the NEM.
Two Regulation Market
These are used to correct a minor drop or rise in frequency and typically provided by thermal generators, including:

- Regulation market to raise
- Regulation market to lower

Six contingency Markets
These are used to arrest a major drop or rise in frequency, stabilize, or recover frequency following a major fall or rise in frequency, including:

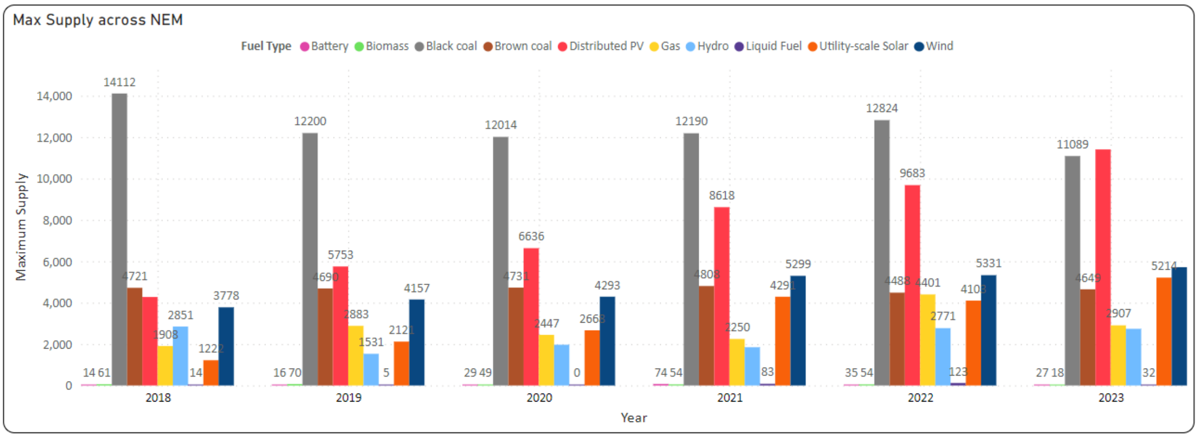
- 6-second contingency market to raise
- 6-second contingency market to lower
- 60-second contingency market to raise
- 60-second contingency market to lower
- 5-minute contingency market to raise
- 5-minute contingency market to lower

FCAS is becoming critical to the market as more variability exists within the system.
These variabilities can include the following:

- Sudden demand changes due to extreme temperatures
- Sudden rise or drop in renewable generation due to cloud cover
- The unexpected exit of generators like coal generators that typically provide FCAS services
- Increasingly unexpected transmission outages with extreme weather-driven events.

Put simply, there is a lot more volatility within the system that throws off the supply and demand balance, making frequency control more important than ever.

Supply Across NEM market



Between 2018 and 2023, Distributed PV had the largest increase in Maximum Supply (166.68%) while Black coal had the largest decrease (21.42%).

Across Fuel Type, Hydro had the most interesting recent trend and started trending up on 2021, rising by 48.16% (890.57) in 2 years.

Further performing prediction analysis to predict data for Demand, Supply and Revenue data. We have found out data for past 10 years from AEMO and performed analysis on same. Analysis is carried out using Python and Power BI.

Algorithm Model Used**:**

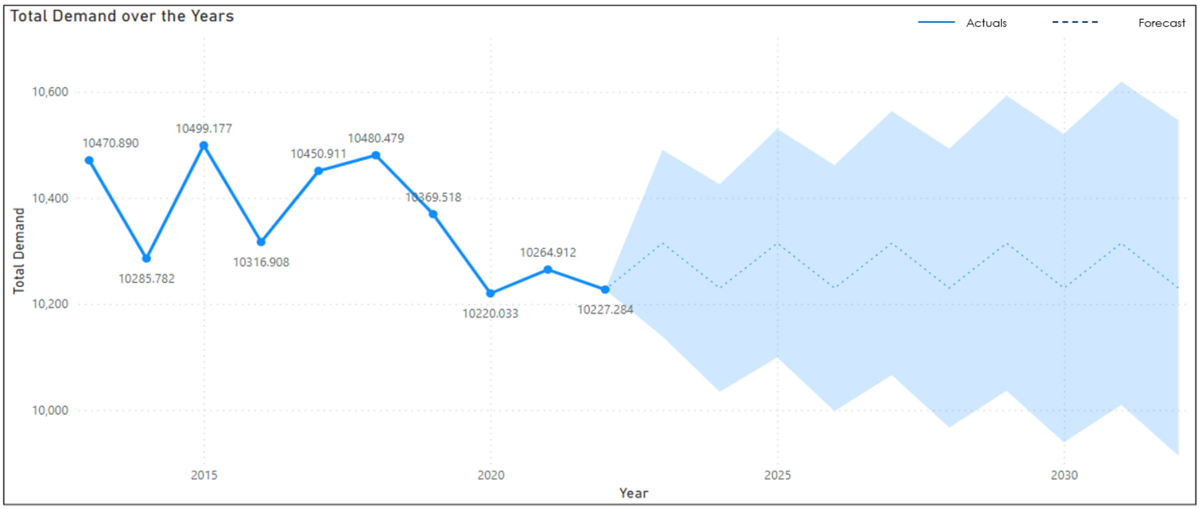
Prophet is a machine learning model developed by Facebook's Core Data Science team. It is designed specifically for time series forecasting, which involves predicting future values based on historical data.

What sets Prophet apart is its simplicity and ease of use. It employs an additive model that decomposes time series data into several components, such as trend, seasonality, and holidays. These components are then modelled individually and combined to make accurate predictions.

Prophet incorporates various advanced techniques, including non-linear growth trends, automatic handling of missing data and outliers, and the ability to incorporate external factors that may impact the time series.

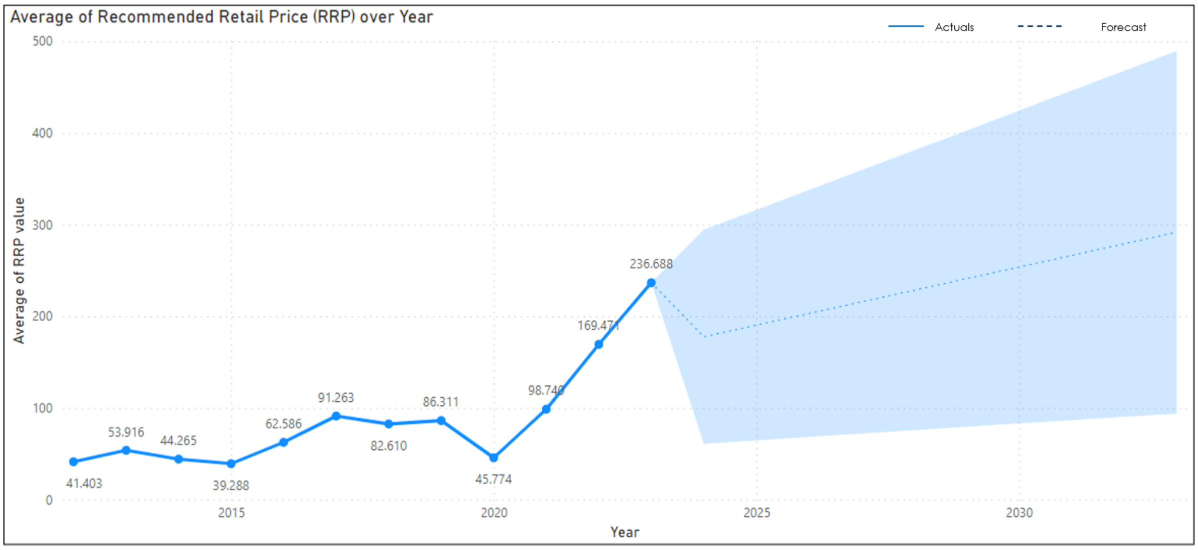
Prediction Analysis with respect to 3,5 & 10-years scope

Total Demand over the years



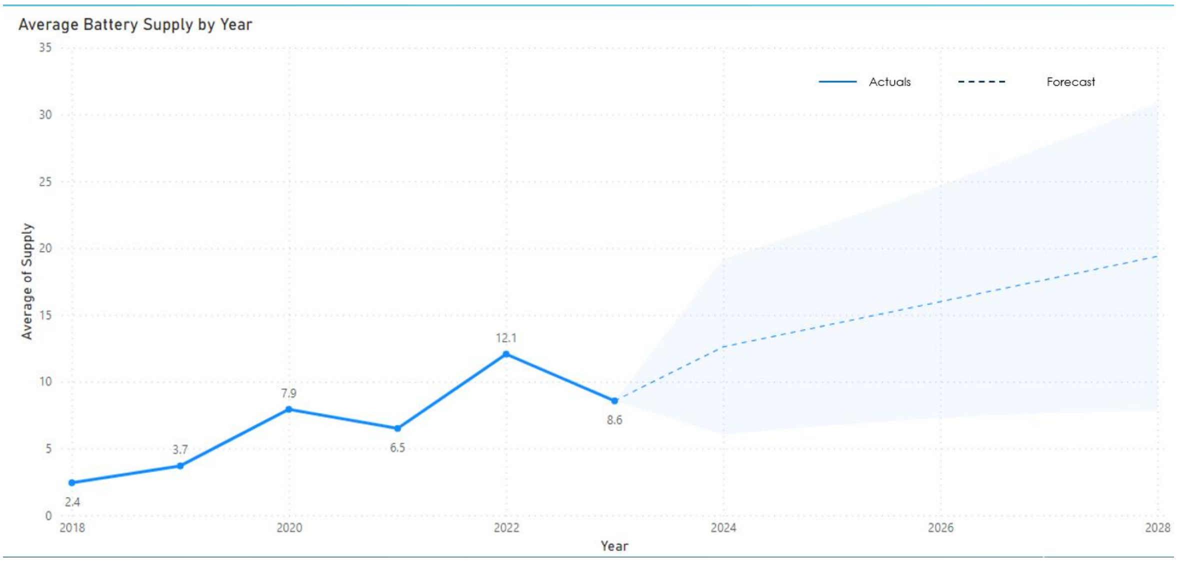
From the above graph we can see that:
Total Demand trended down, resulting in a 2.33% decrease between 2013 and 2022.
Total Demand started trending down on 2016, falling by 0.87% (89.62) in 6 years.
Total Demand dropped from 10,316.91 to 10,227.28 during its steepest decline between 2016 and 2022.
For forecast the range of maximum total demand is between 10229.99KW to 10314.65 KW

Predicting Average Revenue over the years



In the above graph we can comment on following points:
Average of RRP value jumped from 82.61 to 236.69 during its steepest incline between 2018 and 2023.
Average of RRP value trended up, resulting in a 471.67% increase between 2012 and 2023.
Average of RRP value started trending up on 2018, rising by 186.51% (154.08) in 5 years.
Average of RRP value for next 3 years would rise to 203.11, for 5 years would be 228.42 and for 10 years would be 291.69.

Average Battery Supply



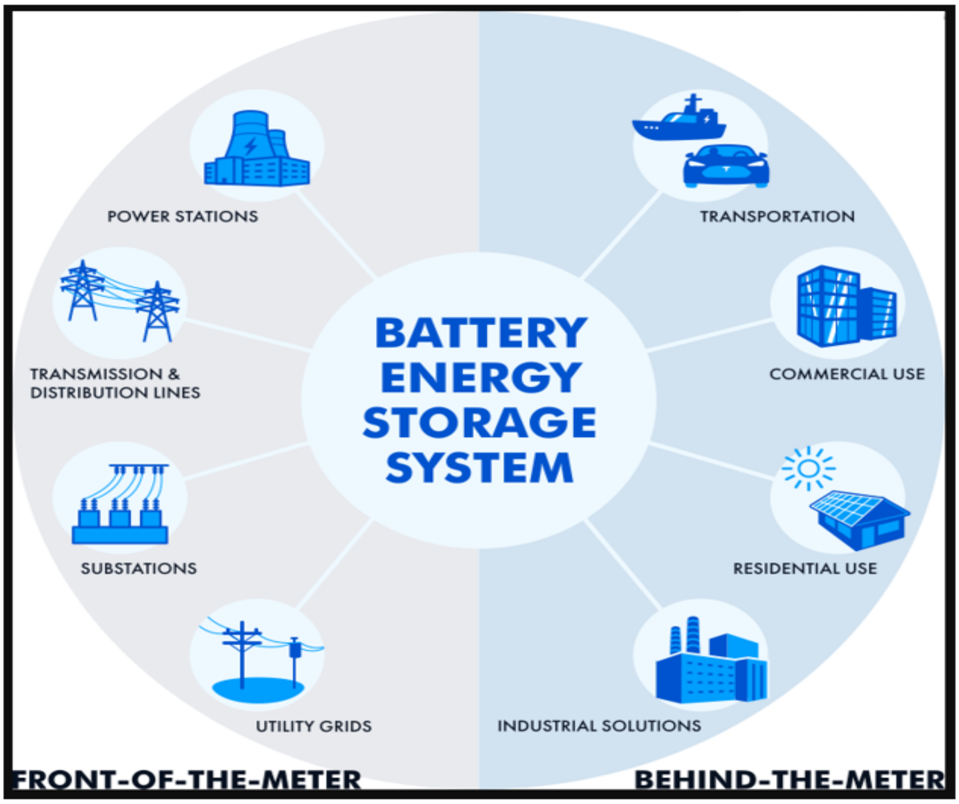
In the above graph, we have plotted Average Battery Supply Across Years with Actual from 2018-2023 and forecast from 2024 – 2028.
Average of Supply trended up, resulting in a 251.64% increase between 2018 and 2023.
Average of Supply started trending up on 2018, rising by 251.64% (6.13) in 5 years.

Average of Supply jumped from 2.44 to 8.57 during its steepest incline between 2018 and 2023. For 3 years the estimated supply is 14.30, for 5 years estimated supply is 17.69, and for 10 years it is 19.38.

Meter Analysis

In-front of the meter:

The electric grid is linked to a battery storage system in front of the metre before the metre. In other words, power from the grid is stored in the battery, which may subsequently be used to power the company during periods of high demand or power outages. By lowering the quantity of electricity that businesses must purchase from the grid, in-front-of-the-meter battery storage solutions can help them save money on their electricity bills.
Batteries are incorporated into the electrical network in front of the metre. There are currently twelve of them on the grid, and by regulating energy flows, they help the network.



Behind the meter:

After the metre, the electric grid is connected to a battery storage system behind the metre. This means that electricity produced by the company's own renewable energy sources, such as solar panels, is stored in the battery. Businesses can lessen their reliance on the grid and save money on their electricity bills by utilising behind-the-meter battery storage devices.
A behind-the-meter battery is located on the premises of a customer and is not connected to the electrical grid. Because energy production and storage are controlled on-site, the homeowner can enhance their solar self-consumption rather than export solar energy to the

grid. We now operate one behind-the-meter battery in Margaret River as part of an experiment.

By lowering the peak load (energy consumption) on the grid at particular times of the day, both batteries help to balance energy flows. As a result, they enhance electricity quality, assist the grid, and enable increased rooftop solar adoption.

Business Analysis for Storage Solutions

The optimal battery storage solution for your company will depend on its unique requirements and environment. An in-front of the metre battery storage system can be a suitable choice for you if you want to reduce the cost of your electricity bills. A behind-the-meter battery storage system might be a better choice for you if you're hoping to become more energy independent and less dependent on the grid.

When deciding between a battery storage system installed in front of the metre and one installed behind the metre, keep the following things in mind:

Your present electric bill is A battery storage device installed in front of the metre could help you save money if your electricity rates are excessive.

Your production of renewable energy A behind-the-meter battery storage system may be a smart way to store the extra energy that your system produces if you have your own solar panels or other renewable energy sources.

The rules of your neighbourhood utility company: For enterprises that install battery storage systems, certain power companies provide incentives. Ask your utility provider if they have any incentives that might be applicable to your firm.

Data Loads for Commercial and Industrial Size customers

Data on loads for commercial and industrial size customers can be used to:

- Calculate the power's peak demand:

Peak demand is the most electricity a customer or group of customers ever utilise at one time. Utility firms can better plan for and serve their customers' needs if they are aware of the peak demand for a particular commercial or industrial customer.

- Find options for energy conservation:

Utility companies can identify customers who might be able to reduce their electricity costs by making energy efficiency improvements by analysing data on loads.

- Create programmes for demand-side management:

Programmes known as demand-side management encourage users to use less electricity during periods of high demand. Load information can be utilised to create and implement demand-side management initiatives that successfully lower peak demand.

A useful resource that may be used to increase the effectiveness of the electric grid and reduce consumers' electricity costs is data on loads for commercial and industrial size customers.

Also, there are some additional information regarding the kinds of data that can be gathered on loads for customers with commercial and industrial size orders that we can talk about:

A load profile is a graph that displays a customer's average daily electricity use. Peak demand detection, energy efficiency possibilities detection, and demand-side management programme development can all be done using load profiles.

Demand factor measures how much of a customer's maximal demand is met during periods of high demand. The price of peak demand charges can be calculated using demand variables.

Energy consumption which is the entire amount of electricity a client uses over a given period of time is referred to as energy consumption.

a database including data on all commercial and industrial consumers connected to the LV network was created. Each consumer's name, address, activity category, energy consumption for the entire year, as well as the monthly average energy use for that same year, were all collected. Data were first classified by activity, and within that activity, consumers were shown in ascending order of monthly average energy consumption. Following that, the activities were sorted depending on the quantity of customers and their overall energy use. More than 67% of the energy use and more than 64% of the consumers are represented in the chosen group.

When establishing the representative curve for the business users, only measurements relating to weekdays (excluding Saturday and Sunday) were considered. When the daily load profiles are similar, the standard deviation values are minimal.

The deviation curve is low relative to the mean for the majority of business operations. One of the load curves (m, s) of different customers participating in the same activity was chosen to represent the activity (however in some situations the average of the consumers' curves was chosen). 47 models were created as a result, one for each research activity. Group activities with comparable load profiles were tried out in order to have another basic model.

In relation to the standard deviation numbers for industrial activity, it is important to keep in mind that most industrial activities include small motors that run intermittently over the day. Their loads can be rather high when compared to the typical power of the industry, which might result in quite large standard deviation values. There was no attempt to create a straightforward model for industrial consumers like there was for commercial consumers.

Market Revenue

For both types of battery installations, there are a variety of potential market revenue streams available to commercial and industrial-sized businesses that we can talk about them here.

- In-front of the meter:

Energy market: Battery storage can be utilised to buy and sell electricity at wholesale rates on the energy market. For companies with battery storage systems, this can be a way to make money.

Market for ancillary services: Services that support the grid's reliability are known as ancillary services. Frequency regulation and voltage support are only two examples of the additional services that battery storage can offer. For companies with battery storage systems, this can be a way to make money.

The capacity market: It’s a place for companies to compete to supply capacity to the grid. The ability to produce power on demand is referred to as capacity. Grid capacity can be increased via battery storage, and companies that achieve this can profit.

- Behind the meter:

Self-consumption: Organisations with behind-the-meter battery storage systems can use the batteries to store electricity produced by their own solar panels or other renewable energy sources. Businesses may be able to spend less on electricity costs and lessen their reliance on the grid thanks to this.

Demand charge reduction: Companies with battery storage systems installed behind the metre can use the batteries to lower their peak demand. This can assist businesses in lowering their demand charge, which is a fee based on the peak demand of a customer.
Virtual power plant (VPP) programmes are available to companies who have behind-the-meter battery storage systems. VPPs are collections of distributed energy resources that are combined and managed as a single entity, such as battery storage systems. Businesses that take part in VPPs can make money by offering the grid services like voltage support and frequency regulation.

A company's unique requirements and circumstances will determine the appropriate market income mechanism for it. A company may want to think about taking part in the energy market, the ancillary services market, or the capacity market if it wants to make money from its battery storage system. A company could wish to think about self-consumption or demand charge reduction if it wants to lessen its dependency on the grid and cut its electricity costs. A corporation may want to get more information about VPP programmes by getting in touch with the local utility company.

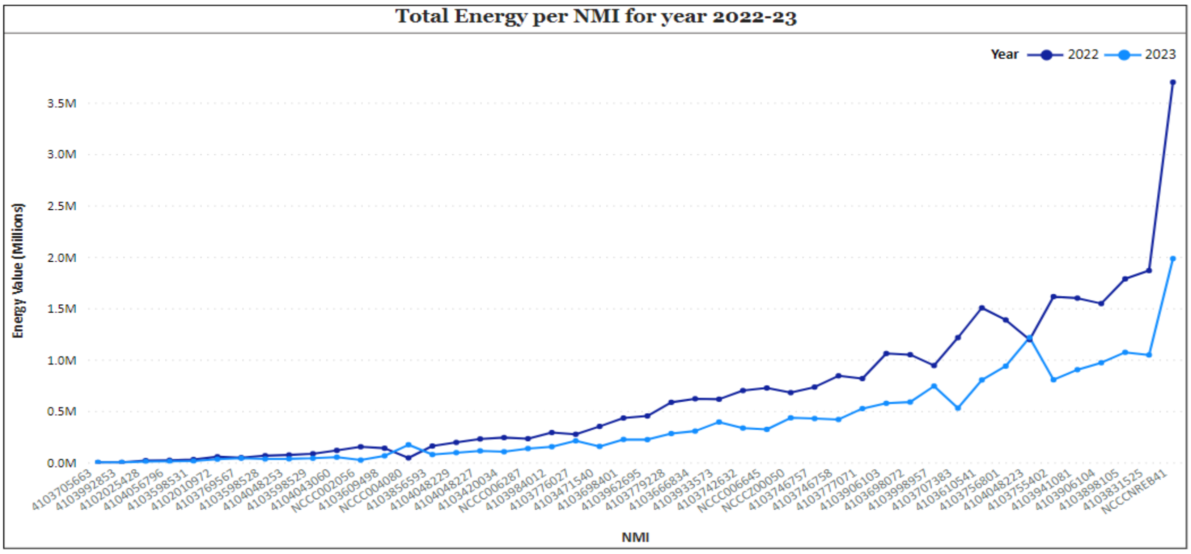
We have to know the market revenue streams for battery storage systems are continually changing, therefore it is vital to consider that. New market revenue models will probably develop as the technology progresses and the grid becomes more dispersed.

NMI’s Analysis

We have been given data for various meters across Macquarie University.
There are roughly 46-meter readings. The data is given from start of year 2022 till April 2023.

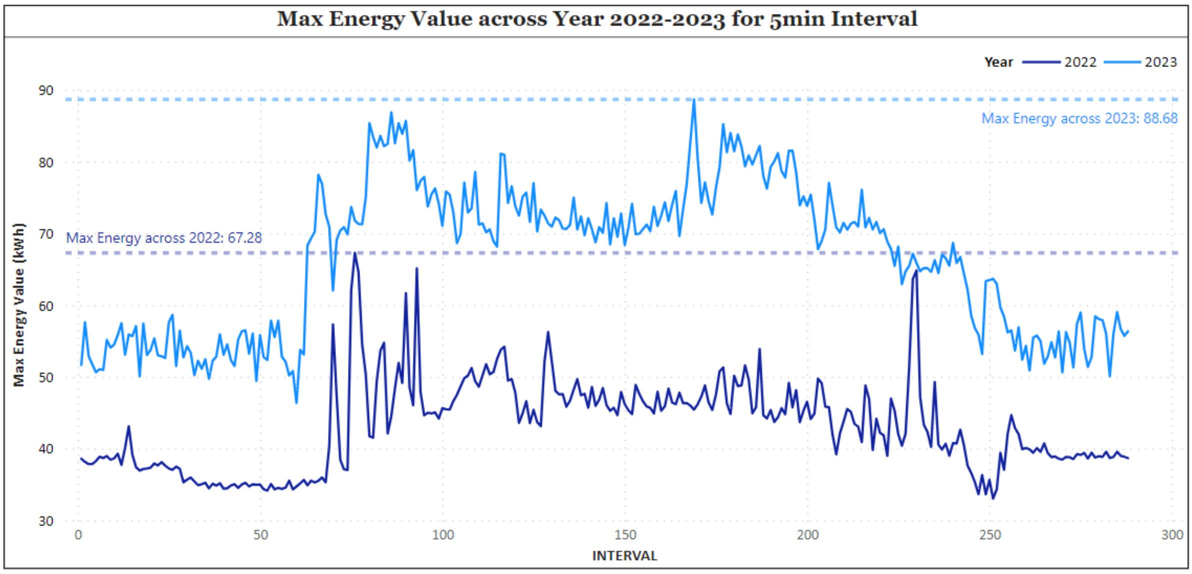
Few plotting’s have been done to find the threshold value of the meters

Plot 1:



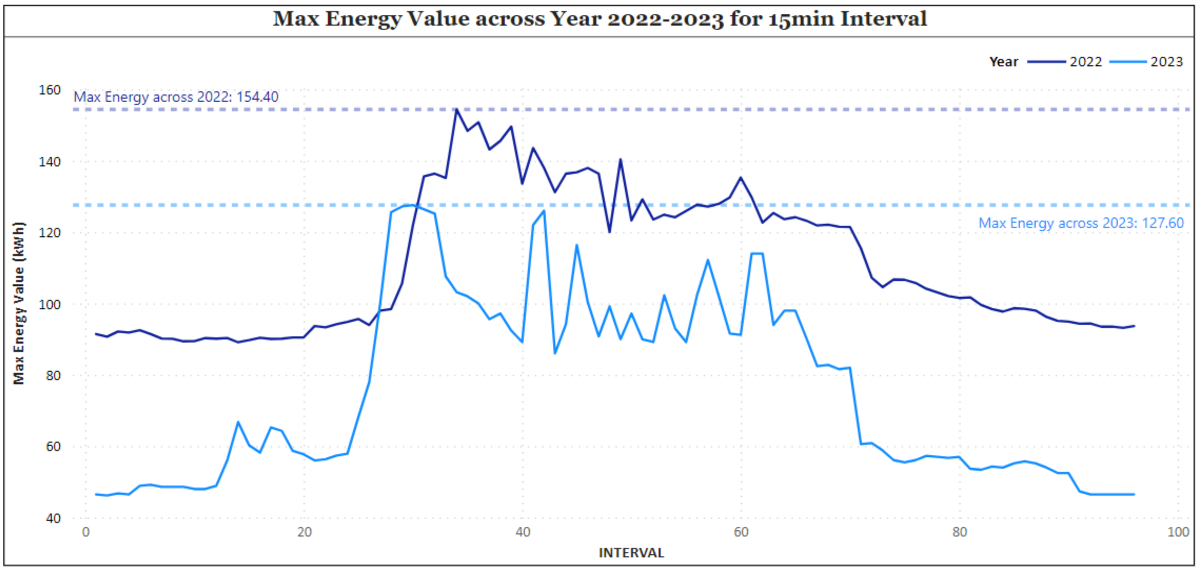
- Total Energy was higher for 2022 (3,04,91,121.01) than 2023 (1,76,35,922.00).
- NMI NCCCNREB41 in Year 2022 made up 7.69% of total Energy.
- Energy value for 2022 and 2023 diverged the most when the NMI was NCCCNREB41, when 2022 were 17,16,247.96 higher than 2023.

Plot 2:



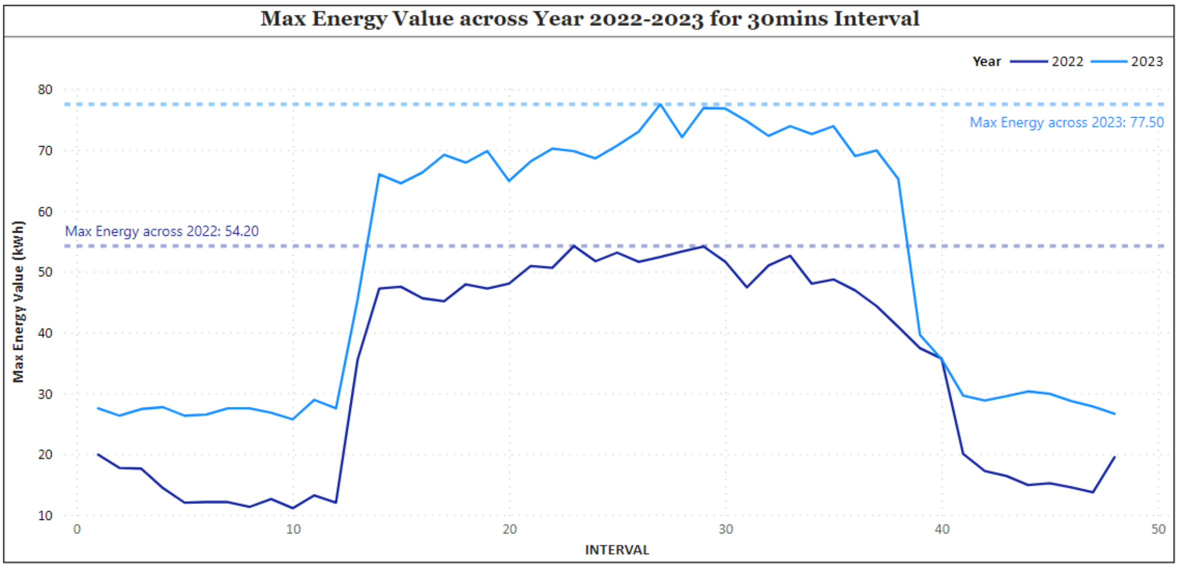
- At interval for 169 it has the highest Max Energy Value per day of 88.68 and was 91.29% higher than that at interval 60, which had the lowest Max Energy Value per day at 46.36.
- Across all 288 INTERVAL, Max Energy Value per day ranged from 46.36 to 88.68.
- Interval 169 had the highest Max Energy Value per day at 88.68, followed by 86 and 90. 60 had the lowest Max Energy Value per day at 46.36.
- On further analysis, we found out that these intervals are during afternoon and early mornings, that mean's energy consumed is more.

Plot 3:



- Interval 34 in year 2022 made up 0.86% of max energy value (kwh).
- Average max energy value (kwh) was higher for 2022 (111.33) than 2023 (75.77).
- Max energy value (kwh) for 2022 and 2023 diverged the most when the INTERVAL was 39, when 2022 were 57.20 higher than 2023.

Plot 4:

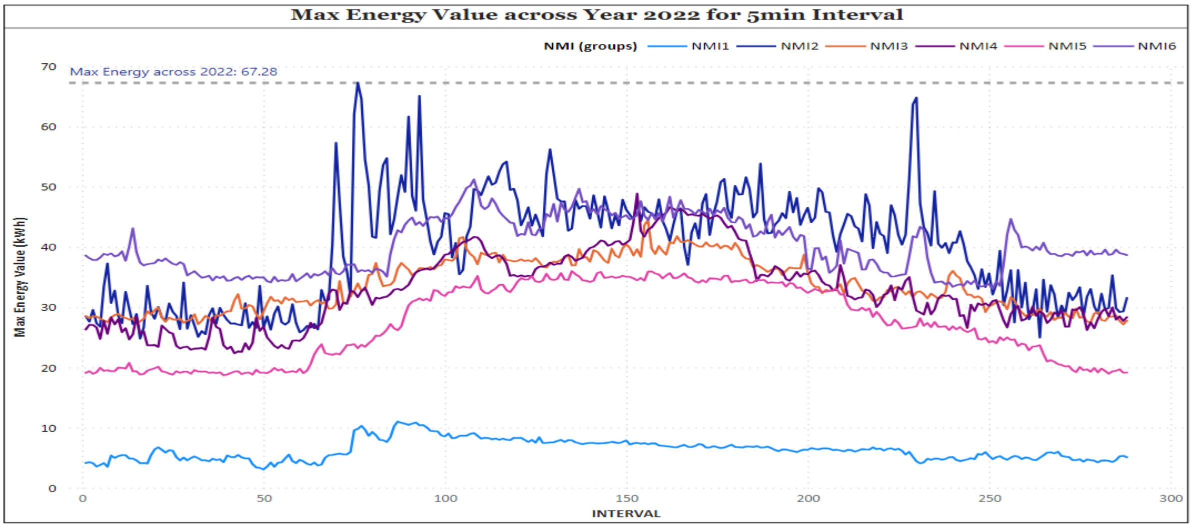


- Average max energy value (kwh) was higher for 2023 (50.86) than 2022 (34.12).

- Max energy value (kwh) for 2023 and 2022 diverged the most when the INTERVAL was interval 31, when 2023 were 27.30 higher than 2022.
- 4104056796 has data only for one month in year 2022, i.e. In May-2022

Plot 4:

Grouping of NMIs into 6 groups



NMI group 2 has the highest energy peaks across the intervals at interval 76 and 230

On Analysing the data, we can see that potential cutoff value should be around average data.

The average KW for cutoff should be around 35 kW, and accordingly batteries can be installed across the University.

Load factor (LF) = Energy draw/total possible for the factor of 1.2

Load Factor here would be:

Total Energy Consumed over year 2022 is 22.32 MW

Max Usage in that year 67.28 KW

In a year, 365 days and each day has 24 hrs.', hence the load factor would be given as follows

LF = 22320.00 K / (365*67.28*24) =~ approx. 0.03

Since LF is between 0.03 – 0.04, that means battery usage will depend on spill of energy, and there is high potential to save excess energy.

Conclusion

We can further say that the Behind the meter is more beneficial to be installed within the universities.

- Across the report, we have seen that the demand has been somewhat same, however supply and Storage capacity is been increasing
- With exhaustion of renewable sources, it would be beneficial to increase the battery capacity storage across the utilization
- We can further analyse on revenue generated to work on battery installations across the universities, which will help to let know the capacity for charging and discharging at appropriate amount of time.
- With coal and other renewable energies are on exhaustion, it's important to have a backup for energy storage, in form of batteries so as to store and let it be beneficial for the future. It is known that installing battery is quite expensive, but over the time its highly beneficial for long run.

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