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Policy Brief

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How Falling Battery Prices Create New Pathways for Malaysia's Energy Transition

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ABOUT THE SERIES

This policy brief is a series of research documents summarizing the knowledge of area contextualized to Southeast Asia and Malaysia, in particular from ongoing research work by the Center for Technology, Strategy & Sustainability (CTSS) at the Asia School of Business. The author of this issue is Roy Rodenburg**, ASB CTSS Visiting Research Associate (VRA).**

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Executive Summary

CONTEXT AND OPPORTUNITY

Malaysia stands at a pivotal moment in its energy transition. Rapidly falling battery prices are making grid-scale Battery Energy Storage Systems (BESS) economically viable, enabling the storage of inexpensive solar energy for use during peak demand. This policy brief explores how Malaysia can leverage BESS to accelerate its transition to Net Zero, avoiding the challenges faced by early adopters in Europe and North America, who expanded renewable energy without adequate storage solutions.

MALAYSIA'S STARTING POSITION

- Malaysia's energy mix remains dominated by fossil fuels (60% coal, 33% natural gas), with only 5% hydro and 2% solar as of early 2025.
- The National Energy Transition Roadmap targets 70% renewable energy in installed capacity by 2050 and a 32% reduction in CO_2 emissions relative to 2019 levels.
- Solar power is the most viable renewable option due to Malaysia's geographic advantages, but grid stability and intermittency concerns limit solar penetration to 24% of peak demand.

CHALLENGES FACED BY EARLY ADOPTERS

- Western countries, which liberalized energy markets before BESS became viable, now face volatility, market power abuses, and net congestion.
- Volatility in electricity prices, driven by intermittent renewable generation, has led to extreme price swings and speculative behavior.
- Net congestion, caused by mismatched supply and demand locations, results in economic losses and grid inefficiencies.

ALTERNATIVE TRANSITION PATHWAY TO MALAYSIA

Malaysia can avoid these pitfalls by integrating BESS with solar deployment from the outset. This approach focuses on two pillars:

1. Developing a stable energy market structure by using centralized BESS dispatch to maintain grid stability without complex balancing markets.
2. Creating financial incentives to promote BESS deployment alongside renewable energy generation.

POLICY RECOMMENDATIONS

- **Centralized BESS Dispatch:** Ensure grid stability by centrally managing BESS, avoiding the need for a volatile balancing market.
- **Hourly Matching:** Adjust the Corporate Renewable Energy Supply Scheme (CRESS) to operate on an hourly basis, incentivizing BESS use to shift solar energy to peak demand periods.
- **Virtual Dispatch Profile:** Allow solar operators to submit virtual BESS dispatch profiles for billing purposes, while the Grid System Operator retains control over physical dispatch.
- **BESS Capacity Contracts:** Introduce contracts to provide predictable revenue streams for BESS operators, ensuring sufficient investment.
- **Hourly-Based Electricity Tariffs:** Reform tariffs to incentivize load shifting and BESS use among industrial consumers.
- **Efficient Grid Interconnection:** Allocate grid capacity based on cost and incentivize BESS co-location to reduce grid congestion and improve utilization.

Introduction

Rapidly falling battery prices are making grid-scale battery energy storage systems (BESS) viable, creating a paradigm shift in electricity systems by enabling inexpensive solar energy to be stored during the day and used later during the evening peak. This policy brief examines how the Malaysian grid can best leverage BESS to enable a more efficient path to Net Zero, in contrast to early-adopters mainly in Europe and North America, which expanded wind and solar generation without corresponding storage deployment.

We will first discuss Malaysia's current position and the problems that early adopters of renewable energy face in its energy transition, before setting high-level goals for Malaysia's transition, accompanied by policy recommendations.

This policy brief focuses on the role of solar and BESS in Peninsular Malaysia. While other renewable generation and storage technologies exist, the peninsula's geographic potential for hydro, wind, and biomass is limited, making BESS particularly relevant at this stage of the energy transition. Extended discussions of other solutions, such as the ASEAN power grid or long-duration storage, fall outside this brief's primary focus on BESS.

In Section 1, we will discuss Malaysia's starting position for the energy transition. In Section 2, the challenges faced by early adopters in the energy transition are discussed. In Section 3, an alternative transition pathway is proposed for Malaysia within two main pillars: (1) developing a grid with stable pricing and electricity supply, and (2) incentivising BESS deployment. In Section 4, we will give policy recommendations. In Section 5, we give a conclusion and summary of the recommendations.

Malaysia's Starting Position

NATIONAL ENERGY TRANSITION ROADMAP (NETR)

In 2023, the Malaysian government published its latest National Energy Transition Roadmap (TNB, 2025), setting out long-term decarbonisation and energy transition targets. The roadmap commits to achieving a 70% share of renewable energy in installed electricity generation capacity by 2050, alongside a 32% reduction in nationwide CO_2-equivalent emissions relative to 2019 levels. Central to the roadmap is an emphasis on a responsible and equitable transition, aiming to balance emissions reductions with energy security, affordability, and socio-economic considerations. However, the roadmap assumes that energy demand will not grow, but the rise of hyperscale data centres, among other industry factors, is making that assumption questionable.

The energy mix in peninsular Malaysia remains heavily dominated by fossil fuels, primarily coal and natural gas, which constitute 60% and 33% of energy generated in the first half of 2025, with 5% hydro and 2% solar renewable generation (TNB, 2025), indicating that Malaysia still has a long way to go in the energy transition. Domestic natural gas production is expected to decline as its gas fields become depleted, according to a private-sector consultant report (Omarali & Dong, 2025). Combined with a government pledge not to build new coal power plants, and to phase out coal by 2044, a switch to renewables is necessary (Yun, 2024). However, Malaysia's investments into renewable energy are trailing behind other ASEAN countries, considering Malaysia has similar GDP and higher per capita income relative to Vietnam and the Philippines, as shown in Figure 1.

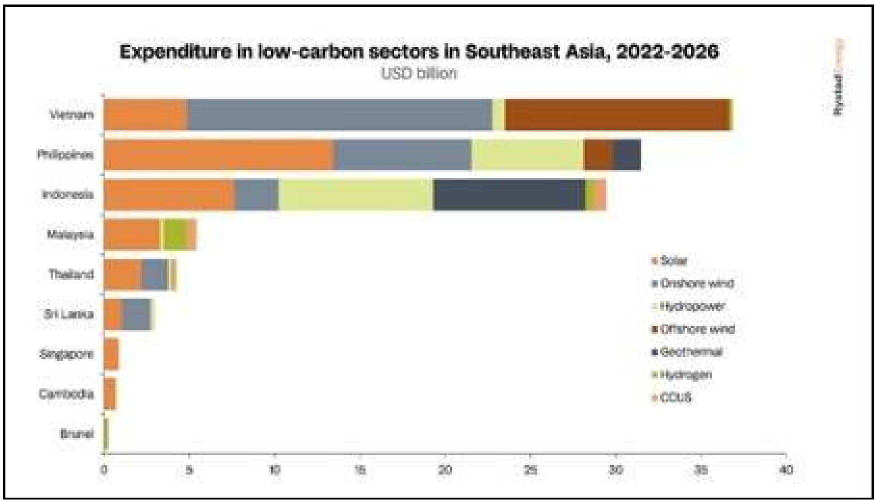

Figure 1: (Rystad, 2023)

he Report on Peninsular Malaysia Generation Development Plan 2020 (Energy Commission (ST), 2021) states that the penetration limit of 24% of estimated peak demand for grid-connected solar PV, reflecting concerns over system stability and the costs associated with handling intermittency. However, measures, such as BESS deployment and increased system flexibility, could enable higher levels of solar penetration.

GEOGRAPHIC RENEWABLE POTENTIAL

From a geographic perspective, Malaysia has strong potential for solar power. Its location near the equator provides high and relatively consistent solar irradiation throughout the year, with minimal seasonal variation. In contrast, Malaysia's equatorial location also results in generally low average wind speeds, limiting the economic viability of utility-scale wind power across most of the country. Solar power will most likely be the primary driver of Peninsular Malaysia's energy transition, as hydropower potential is limited compared to that of Sarawak and Sabah.

SOLAR PV AND BESS COSTS

In the last few years, manufacturing costs for solar PV and battery energy storage systems (BESS) have fallen rapidly, driven by global manufacturing scale-up, technological improvements, and intense price competition.

As a result, new solar generation, and increasingly solar paired with BESS, is now cheaper than building new thermal power plants in many markets. In Peninsular Malaysia, the levelised cost of electricity is about 40 USD/MWh according to recent auctions, compared to 63 USD/MWh for fossil power, according to a UK-based thinktank (Nadhila & Setyawati, 2024), which does not include the significant capacity payments that those plants receive. In 2025, the cost of BESS installations fell 45% according to BloombergNEF (McKerracher, 2025) with a UK-based thinktank (Rangelova & Jones, 2025) suggesting a levelised cost of storage at 65 USD/MWh as of October 2025. Therefore, it is already feasible to store one-third of solar power in BESS to meet evening demand, with this fraction likely to increase significantly in 2026.

MARKET STRUCTURE

The electricity sector in Peninsular Malaysia currently operates under a ring-fenced Single Buyer market structure, in which a designated Single Buyer within the utility company, Tenaga Nasional Berhad (TNB), procures electricity and dispatches it to meet system demand. TNB is also responsible for the transmission and distribution of electricity and operates a significant amount of the peninsula's generation capacity. The ring-fenced Grid System Operator department of TNB is responsible for the day-to-day real-time operation and management of the high-voltage grid in Peninsular Malaysia.

Under this model, both TNB and Independent Power Producers (IPPs) sell electricity to the Single Buyer, which then sells it to end consumers, dispatching based on least-cost principles rather than operators bidding into the market, and thermal power plants generally fall under long-term Power Purchasing Agreements (PPAs) that include significant capacity payments. This market structure provides price stability and investment certainty, but limits competition and the deployment of renewable generation because the Single Buyer is locked into long-term PPAs with fossil power. This could mean that inefficient, more expensive thermal power plants keep running until their PPAs expire, without being replaced by cheaper solar.

In 2023, the government announced plans to carve out an independent Single Buyer from TNB (Aziz, 2023), to promote greater market confidence from its independence from TNB.

There is no market-based mechanism. This makes it difficult to put a price on such ancillary services.

Frequency and balancing response obligations are generally included in long-term PPAs concluded with thermal power plants. Variable renewable energy (VRE) assets require significant balancing if they don’t use on-site energy storage or conclude a balancing contract with a flexible power producer or consumer. Such balancing contracts do not exist yet in Malaysia.

After the Single Buyer contracts the required power from generators, it then sells the power to consumers. They are charged an energy charge per kWh consumed. For industrial consumers, a Time-of-Use tariff structure is available, charging higher rates during peak hours[1]. Low-voltage customers are charged transmission charges, which are also based on the amount of MWh consumed. However, customers with 6.6 kV connections are charged a transmission tariff based on their maximum monthly demand per kW during peak hours, which incentivises avoiding large demand spikes that could overload the local grid.

[1] Currently, peak hours are from 14:00-22:00 everyday, except weekends and national holidays.

LSS TENDERS

Malaysia's Large Scale Solar (LSS) programmes, launched in 2016 and now entering their sixth round in 2025, have been the primary means of introducing utility-scale VRE to the grid, awarding around 6 GWp of solar. These LSS tenders are limited in size and consistently oversubscribed, reflecting significant investor appetite. However, the pace of solar rollout remains heavily constrained by TNB, which has set a VRE penetration limit of 24%, citing system stability concerns (New Straits Times, 2025). This is because the Malaysian peninsular grid was originally designed around large dispatchable thermal power plants, and accommodating solar requires additional investments.

CORPORATE RENEWABLE ENERGY SUPPLY SCHEME (CRESS)

One important policy introduced in 2024 is CRESS, which enables large industrial consumers, such as data centres, to enter into green PPAs with renewable energy generators, such as solar farms, without the Single Buyer as an intermediary.

The solar farm operator is charged a System Access Charge by the Single Buyer to cover transmission costs. The consumer receives a discount on their monthly energy bill proportional to the solar farm's monthly energy production.

For VRE generation, the scheme requires the co-location of BESS. However, under the current regulatory design, the BESS will be operated by the Grid System Operator and functions as a shared system resource, delivering benefits that are not directly tied to the green PPA.

This separation makes it essential to establish appropriate incentive structures to ensure that an economically efficient level of BESS capacity is deployed. Currently, CRESS participants whose demand profiles are least aligned with solar generation have no incentive to invest in additional storage capacity.

In June 2025, up to 1.3 GW of solar was being developed, where the CRESS contract had been signed, with most confirming the inclusion of on-site BESS for the lower system access charge (The Star, 2025).

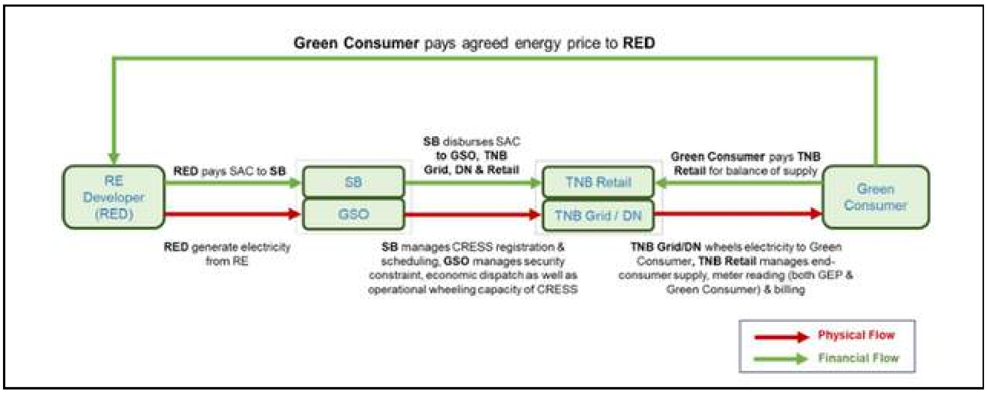

Figure 2: Physical and Financial Framework for the CRESS (Energy Commission, 2025)

INCREASING ELECTRICITY DEMANDS

On the demand side, data centres are expected to be a major driver of electricity consumption, with strong interest in building new data centres in Malaysia. Some forecasts suggest that total data centre demand could exceed 5 GW by 2035 (Kaur, 2025). To manage this anticipated growth, TNB has instituted the Ultra-High Voltage tariff structure, specifically designed for data centres and with the highest costs of any tariff structure, which is meant to encourage data centres to use the CRESS framework. Another driver will be electrification, with electricity consumption increasing due to the adoption of electric cooking and EVs, as well as the electrification of industrial processes.

Challenges in the Energy Transition of Early Adopters

Malaysia benefits from learning from countries that are further along in the energy transition, like the EU and Australia. Most Western countries began liberalising their energy markets in the 90s (Haas et al., 2006) and started introducing renewables to the grid before grid-scale BESS became financially viable, meaning the intermittent nature of VRE generation was dealt with through a massive expansion of balancing markets (Weiss & Veillard, 2025). Currently, developers in the West are rushing to deploy BESS to profit from the massive volatility in the balancing markets and the significant opportunities for energy arbitrage. In Q2, it happened 66 times that a market zone had 30-minute electricity prices reach 3500 USD/MWh (Australian Energy Regulator, 2025). Germany had negative wholesale electricity prices for 573 hours in 2025 (Bundesnetzagentur, 2026). However, with drastically reduced BESS manufacturing costs, different pathways to transition to renewables should be considered, distinct from the example given in countries with liberalised energy markets. We will now discuss the challenges that Western transitions have been facing.

VOLATILITY

VRE is prone to significant intraday price swings due to its variable, sometimes unpredictable nature. Only liberalised electricity markets can accommodate such volatility; however, this volatility creates a high-risk environment that requires advanced trading algorithms and risk management to ensure market participants are not in imbalance.

One major downside of volatility is an excess of solar energy, which can cause negative electricity prices during the day, as solar PV is operated under simplistic subsidy terms that provide a fixed compensation for solar energy even when there is no demand to match production. That leads to useful energy being wasted since consumers are literally being paid to consume energy, whilst in the early evening, prices will again spike. By incorporating BESS into VRE generation assets, such issues could be prevented.

MARKET POWER ABUSES AND ALGORITHMIC BIDDING

These more volatile markets could also enable greater abuses of market power. For example, balancing markets have shown to be susceptible to market power abuse (Poplavskaya et al., 2020). Another example is the California electricity crisis of 2000-2001(Wikipedia, 2026), in which energy traders took power plants offline to create artificial shortages and trigger profitable price spikes, while also causing rolling blackouts. More recently, in California, an operator of a 40 MWh battery system was fined USD 1 Million for filing invalid bids during the summer of 2022 (Howland, 2024); it was also forced to pay back 1.7 Million USD of profits made through those invalid bids.

Australia has been at the forefront of the BESS revolution, and traders make heavy use of algorithmic bidding software, with new bids submitted to the energy market up to 5 minutes before dispatch. Because of the short-term nature of the energy market, it also serves as a balancing market. Algorithmic bidding software heavily rebids up to this 5-minute limit, raising concerns about market stability and strategic behaviour that amplifies price volatility for financial benefits, as documented in a recent report by the Australian Energy Market Operator (Australian Energy Market Operator, 2025). Market participants who do not employ algorithmic bidding would suffer increased prices. Another recent report commissioned by the Australian government noted that “Algorithmic bidding may facilitate non-competitive outcomes and price distortion”, and advised further research and, if needed, rule changes (Nelson et al., 2025). The Australian Energy Market Commission has also published a working paper on the risks of strategic collusion between market participants using autobidding software (Australian Energy Market Commission, 2025). Some economic papers have also come out stating that economic withholding is beneficial for BESS operators (Anunrojwong et al., 2025).

NET CONGESTION

Multiple countries are now experiencing net congestion, with rapidly growing queues for new grid connections as system operators struggle to guarantee grid stability amid expanding demand. A recent report by a Dutch energy firm identifies two primary drivers (Eneco, 2025). First, the strong growth of renewable generation in remote or low-voltage areas, often far from demand centres, and the weather-driven variability that places acute stress on the grid. Second, electrification is causing peak demand to grow whilst total demand barely rises, as ageing parts of the grid are not designed for current peak levels.

The Netherlands is missing out on 0.8% to 2.7% of nominal GDP in annual economic losses due to constraints on business creation and expansion. Revenue losses are estimated at €1,200–4,000 per unused MWh (Venema et al., 2024). There are 9 million MWh currently awaiting connection, which far exceeds the planned €6–9 billion annual investment in grid upgrades.

One of the causes of net congestion is the locational mismatch between supply and demand: solar parks are built far away from demand centres. Most likely, when a load centre is served by solar during the day and a gas plant at night, different transmission lines are used, reducing the return on investment for both. However, the decision-making process investors use to determine solar farm locations is dominated by land prices and availability, rather than transmission constraints. Because transmission lines used to transport solar power are not in use at night, if a solar farm doesn't have BESS, the return on investment takes significantly longer.

By smoothing VRE generation peaks and using peak shaving, BESS can help mitigate net congestion, especially when placed at specific congested nodes such as industrial areas. However, this depends on the operating strategy employed for the BESS installation (van Someren et al., 2025).

Alternative Transition Pathway for Malaysia

Unlike the West, which deployed significant VRE generation before BESS became economically viable, Malaysia can combine its solar rollout with BESS, offering the opportunity to choose a different transition pathway from the West and avoid its issues with volatility, market power abuse, and net congestion. However, policies must be specifically designed to facilitate such a transition, with sufficient BESS built alongside solar PV deployments to address solar's intermittency.

Electricity prices in Malaysia are not very volatile, with the daily average spread being 25% of the average system marginal price for 2025 (Single Buyer, 2025), whilst in the same year, Germany's daily price spread was 140% of its yearly average price, with the average daily price spread increasing 4-fold since 2020 (FfE, 2026), However, because BESS costs have fallen so sharply, a sufficient amount of it will be deployed to suppress increases in volatility. However, the benefits of BESS to the grid go beyond price arbitrage; therefore, policy should be designed to provide sufficient incentives for BESS, for example, through capacity payments, compensation for ancillary services, and BESS requirements for new solar farms.

Malaysia currently has a Single-Buyer electricity market model. Instead of making further VRE integration dependent on the lengthy transformation to a liberalised electricity market, it would be wise to adjust the current Single Buyer system to incentivise more renewables and to set technical requirements that ensure BESS smooths out solar's intermittency. Using batteries, the power output of a solar farm can be precisely controlled, operating similarly to a gas-powered plant, making it easily incorporated into the dispatch system.

Although weather-dependent intermittent generation from solar farms would complicate the centralised dispatch that the Single Buyer currently performs, by including BESS, the requirement that, at every moment in time, production and consumption of electricity are in balance is removed. With batteries ensuring balance, the dispatcher has more time to respond.

However, this doesn't mean not moving to a more liberalised market structure in the future; however, using (centralised) BESS dispatch, the requirement of a balancing market, which has been so volatile, is avoided. Additionally, complex bidding algorithms for BESS are avoided, keeping the market structure simpler and more comprehensible for all market participants.

Based upon the above considerations, these are two pillars around which policy can be designed:

PILLAR 1: DEVELOPING AN ENERGY MARKET STRUCTURE THAT ENSURES THE GRID-FRIENDLY OPERATION OF BESS TO CREATE A STABLE ENERGY MARKET

As solar's share of generation increases, generally, the electricity market becomes more volatile. Because of Malaysia's current infrastructure and market design, this volatility is difficult to deal with.

Therefore, it would be beneficial to incorporate BESS into the energy system in a way that maximises its benefits to the grid. For example, by smoothing out the ups and downs of solar PV generation using on-site batteries, avoiding additional balancing or frequency response resources being required, thereby increasing grid stability and reducing the need for a balancing market that would take a long time to develop.

PILLAR 2: CREATING FINANCIAL INCENTIVES TO PROMOTE BESS DEPLOYMENT ALONGSIDE VRE GENERATION

BESS offers many benefits for the electricity grid, including peak shaving, avoiding curtailment of cheap solar, balancing services, and stabilising a solar farm's energy exports. However, in Malaysia's current market structure, developers are not always financially rewarded for these services. To ensure that developers invest enough in BESS, a coherent incentive structure should be built for BESS.

Policy Recommendations

We will discuss the two pillars introduced in the previous section: creating an energy market structure which incentivizes the grid-friendly operation of BESS, and secondly, the incentivization of BESS installations. At the end of this policy brief, the recommendations are summarised for the reader's convenience.

DEVELOPING AN ENERGY MARKET STRUCTURE WHICH ENSURES GRID-FRIENDLY OPERATION OF BESS TO CREATE A STABLE ENERGY MARKET

The core objective is to reduce the volatility of the electricity market through incorporating BESS into the market design and dispatch protocols. We should aim to reduce volatility across all time scales: minutes, hours, and days. Although these measures might lead to higher average electricity prices, by reducing volatility, they remove investment risks, lowering the cost of capital and making renewable power more competitive. This objective can be achieved through the following means:

1) Employing centralised BESS dispatch, to avoid the need to introduce a balancing market

2) Operating under hourly matching, to sufficiently incentivise energy storage to ensure that renewable energy production and electricity consumption can be balanced throughout the day.

3) Using a virtual dispatch profile, to ensure that BESS is used to optimise total system costs effectively instead of optimising for the specific needs for each consumer.

CENTRALISED BESS DISPATCH

The primary challenge for Malaysia in increasing solar PV generation capacity is integrating it into the grid without undermining grid stability. Keeping BESS dispatch centralised maintains system stability without a complex transition to market-based balancing mechanisms by ensuring that every renewable generation asset can provide synthetic inertia and balancing capabilities through on-site BESS. The key operational requirement for centralised BESS dispatch is that the GSO has access to accurate solar generation forecasts and real-time BESS state-of-charge data, which requires a robust digital infrastructure. China has recently demonstrated the capability to centrally dispatch BESS at GW-scales during a recent demand spike (Shaw, 2025), (Neng, 2025).

Ensuring that solar farms are equipped with sufficient co-located BESS enables each installation to be effectively self-balancing, limiting the expansion of system-wide balancing services and reducing transaction costs compared to a market-based balancing framework. This approach also avoids the volatility and complexity associated with balancing markets, reinforcing a low-complexity, centrally coordinated pathway for renewable integration.

HOURLY MATCHING

As currently designed, CRESS operates on a monthly netting basis: the monthly net balance of electricity consumed by the customer and the PPA partner determines the discount the customer gets on its TNB electricity bill. To achieve a 100% discount, a developer could build additional solar generation capacity to offset the nightly energy consumption of its CRESS partner. However, the consumer would still use fossil grid power at night, and as more solar is installed, there will be excess solar generation that must be curtailed because there is no matching demand.

Hourly matching is gaining traction worldwide as an alternative to address these issues; many major companies, such as Google and Microsoft, have committed to matching their electricity consumption with 100% renewable energy on an hourly basis[2] (Aiman, 2023). Adjusting CRESS to work on an hourly basis would incentivise installing BESS to shift midday solar into the night and avoid excessive solar production that overloads the local transmission grid.

VIRTUAL DISPATCH PROFILE

Under the current CRESS framework, the GSO controls BESS dispatch for both energy discharge and balancing services. Maintaining this structure avoids the need for a more liberalised electricity market, but it creates tensions with solar farm operators, who, under hourly matching schemes, aim to operate BESS in line with data centre load profiles to minimise the hourly grid-supplied power usage of the data centre since that leads to a lower electricity bill for the data centre.

To reconcile these objectives while preserving system control, solar operators could submit a virtual BESS dispatch profile, which is used to calculate their offtaker's net load profile and resulting electricity bill, while the GSO retains authority over actual physical dispatch. This preserves grid stability, limits complexity, and still provides clear investment incentives for BESS.

	Physical Dispatch Profile	**Virtual Dispatch Profile**
Determined by:	Grid System Operator	solar farm operator
Used for:	determining energy generation of the solar farm	calculation of electricity tariffs for the CRESS partner of the solar farm
Goal:	decreasing total system costs	decreasing the electricity bill of the CRESS partner
Typical usage:	lowering evening peak demand and ancillary services like balancing and frequency regulation	used to decrease the grid power usage of the CRESS partner when electricity costs are high

[2] or a shorter time interval, as the peninsula operates a market with 30 minute intervals

In such an hourly matching scheme, industrial consumers whose demand profiles closely align with solar generation would require less storage investment, while those with a significant mismatch would invest more in BESS capacity. This leads to a more efficient and equitable allocation of storage investments. With these measures, the grid costs of incorporating solar power can be reduced, meaning that the tariffs targeted at renewable power, such as the system access charge in CRESS, can be reduced as well.

CREATING FINANCIAL INCENTIVES TO PROMOTE BESS DEPLOYMENT ALONGSIDE VRE GENERATION

To ensure sufficient investment in BESS, it is important to create robust revenue streams that make it a profitable additional investment for solar farm operators. This can be achieved by multiple means, which we will expand upon in this section.

1) Introduction of BESS capacity contracts, which provide predictable revenues in exchange for the right to dispatch the BESS installation.

2) Adoption of hourly-based electricity usage tariffs, that incentive load shifting by industrial consumers using BESS.

3) More efficient allocation of grid interconnection capacity, by adding batteries to a solar farm, less grid interconnection capacity is required, because excess solar produced midday can be stored and then exported to the grid in the evening.

INTRODUCTION OF BESS CAPACITY CONTRACTS

Under current regulations, BESS will be dispatched by the Grid System Operator. To compensate the BESS owner for the GSO's use of its battery, a contract could be concluded covering a flat capacity charge and an energy charge to compensate battery degradation resulting from the GSO's use. This would leave the GSO free to decide how to best dispatch the battery, whilst also giving the BESS a clear revenue stream. If BESS capacity growth keeps up with solar PV growth, electricity price volatility will likely remain low, meaning that price arbitrage will not be a sufficiently large revenue stream on its own.

To reconcile these objectives while preserving system control, solar operators could submit a virtual BESS dispatch profile, which is used to calculate their offtaker’s net load profile and resulting electricity bill, while the GSO retains authority over actual physical dispatch. This preserves grid stability, limits complexity, and still provides clear investment incentives for BESS.

ADOPTION OF HOURLY-BASED ELECTRICITY TARIFFS

Another important policy measure is to give (large) industrial electricity consumers more time-based price signals, for example, by exposing them to the half-hourly system marginal price, or by increasing the effect of the existing Time-of-Use tariff structure[3], to incentivise load shifting using BESS or through other means.

[3] The current difference between the peak and off-peak tariffs is too small to compensate for the ~10 energy loss when storing electricity, and therefore doesn’t encourage load shifting using BESS.

The consumer can either use onsite BESS or, if it employs CRESS with hourly matching, the BESS at its PPA partner's solar farm. Through the virtual dispatch profile, which was discussed in the previous section, the potential cost savings of installing BESS are realised, although the GSO still dispatches the BESS as it sees fit.

The capacity charges in TNB's current tariff structure are proportional to the maximum monthly electricity demand during peak hours. Therefore, a consumer who employs CRESS with hourly matching is incentivised to minimise their monthly maximum grid power demand during peak hours. Therefore, they are further incentivised to partner with a renewable energy generator which can consistently deliver renewable energy every day. This improves the reliability of renewable energy supply, ensuring fewer fossil power plants need to be kept on standby for days on which renewables underperform. However, it might be beneficial to increase the capacity charge as a proportion of the total average tariff bill to sufficiently incentivise consumers to lower peak energy demand.

MORE EFFICIENT ALLOCATION OF GRID INTERCONNECTION CAPACITY

The three main metrics to determine where a solar farm gets built are: land prices and availability, yearly solar radiation, and (grid) infrastructure access.

Setting a price for grid interconnection capacity based on the cost of grid reinforcements would help strike an optimal balance among those three factors, leading to lower grid system costs and incentivizing investments in co-located BESS, as it would allow a solar farm to lower its peak grid export without curtailment.

In areas with high demand for limited grid interconnection capacity, auctions could be held to allocate capacity. This means that developers who choose the most grid-friendly locations, which may, for example, have less yearly solar radiation, benefit the most. Additionally, developers would choose to install more BESS rather than requesting needlessly large grid interconnection capacity, leading to higher utilisation of transmission infrastructure and more renewable power at night.

Another specific recommendation that takes advantage of future reductions in PV and BESS prices is to ensure that all solar farms are upgradeable with additional PV and BESS when prices have fallen further and technology has improved. If additional PV and BESS are built in the right proportions, the additional solar power can be exported at night without curtailment or increased grid interconnection, helping better utilize the grid.

Conclusion

Malaysia's energy transition does not have to follow the same path as the early renewable energy adopters. Due to falling BESS prices and strong domestic solar potential, it can become a solar energy powerhouse by incorporating BESS into all solar power generation. Incorporating BESS will smooth out the intermittency of solar PV, and to shift cheap solar from the abundant midday hours, to meet evening peak demand.

This pathway avoids the volatility, speculative behaviour, and net congestion faced by Western countries. Maintaining centralised BESS dispatch also averts delays, as complex energy market transformation processes are not required; whilst BESS profitability can be maintained through capacity contracts, tariff reform, and the allocation of grid-interconnection capacity.

Pillar 1: Developing an energy market structure which ensures grid-friendly operation of BESS to create a stable energy market	
Policy Recommendations	**Summary**
Centralised BESS Dispatch	Employing centralised BESS dispatch, to avoid the need to introduce a balancing market
Hourly Matching	Operating under hourly matching, to sufficiently incentivise energy storage to ensure that renewable energy production and electricity consumption can be balanced throughout the
Virtual Dispatch Profile	Using a virtual dispatch profile, to ensure that BESS is used to optimise total system costs effectively, instead of optimising for the specific needs for each consumer

Pillar 2: Creating financial incentives to promote BESS deployment alongside VRE generation	
Policy Recommendations	**Summary**
BESS Capacity Contracts	Introduction of BESS capacity contracts, which provide predictable revenues in exchange for the right to dispatch the BESS installation.
Hourly-based Electricity Tariffs	Adoption of hourly-based electricity usage tariffs, that incentive load shifting by industrial consumers using BESS.
Efficient Allocation of Grid-Interconnection Capacity	More efficient allocation of grid interconnection capacity, by adding batteries to a solar farm, less grid interconnection capacity is required, because excess solar produced midday can be stored and then exported to the grid in the evening.

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