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Policy Brief

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Balancing Investment Incentives with Grid Stability: A Techno-Economic Analysis of CRESS and its Future Development

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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

Malaysia has the chance to combine its efforts to liberalise its electricity market with the deployment of grid-scale Battery Energy Storage Systems (BESS), which has become financially viable in the last few years, with costs dropping by an estimated 45% in 2025 according to BloombergNEF [1], and with further cost decreases expected. This would allow Malaysia to accelerate towards its energy transition goals embedded in the National Energy Transition Roadmap, of having 70% renewable generation capacity by 2050, by allowing low-cost solar energy to be stored during the day and consumed at other times, which allows for the rapid expansion of renewables, without destabilizing the grid through generation fluctuations and daytime solar production surpluses.

Realizing this potential, however, will require Malaysia to adopt innovative and forward-looking policy approaches. In particular, regulatory frameworks must be adapted to explicitly account for the role of energy storage within the electricity market. At the same time, a recent surge in demand for gigawatt-scale data centres presents a strategic opportunity to drive new renewable energy investments. By linking this demand to dedicated clean energy supply, Malaysia can expand its renewable capacity without causing existing thermal power plants to become stranded assets.

In 2024, the Ministry of Energy and Natural Resources announced the Corporate Renewable Energy Supply Scheme (CRESS), which enables large industrial consumers, such as data centres, to enter into Power Purchase Agreements (PPAs) with renewable energy generators, such as solar farms without the Single Buyer acting as an intermediary. The scheme is part of an ongoing move towards a more liberalized energy market and enables GWh-scale battery storage through private investment.

However, it should be considered whether the current design of the CRESS framework could lead to strain on the electricity grid, especially if it is adopted at scale. Currently, CRESS operates on a monthly matching principle, meaning that electricity exported to the grid through CRESS does not need to match the consumption of the partnered CRESS customer; only the total electricity generated and consumed on a monthly basis is considered. In the future, this could lead to increasing the midday solar surplus, whilst at the same time increasing the evening demand peak, leading to more fossil generation capacity with low utilization or additional third-party BESS systems being required to address peak demand. By moving to an hourly matching mechanism, where electricity generated through CRESS only counts towards the PPA if it can be matched by electricity consumption occurring in the same hour, moving to an hourly matching mechanism, largely addresses this potential mismatch.

In parallel, the current BESS dispatch protocol leaves some of the benefits of BESS underutilized due to its rigid, simplistic approach. Under the current scheme, the battery is discharged in the late afternoon, immediately after solar generation falls below 50% of its rated capacity, without consideration for the wider electricity system's needs. However, at the same time, with the move to hourly matching, developers should be incentivized to have sufficient BESS capacity to match generation with demand. Therefore, we propose a dual system in which the grid system operator retains centralized control over BESS dispatch, while investors are rewarded for their investments based on a separate virtual dispatch profile optimized for their benefit under hourly matching.

Section 1 explains the current electricity market design in Malaysia. In Section 2, policy recommendations are proposed, and their real-world implementations are discussed. In Section 3, the financial modelling parameters are discussed and used in Section 4, where the modelling is presented. In Section 5, the resulting findings are discussed.

Electricity Market Design

In this section, the key design features of the Malaysian electricity market are analyzed. This is followed by an introduction to the concepts that will be employed to enable BESS to provide the maximum possible benefits in the Malaysian electricity market. A previous CTSS policy brief ”How Falling Battery Prices Create New Pathways for Malaysia’s Energy Transition” provides a more in-depth justification of these changes, while this policy brief focuses on how to implement them effectively.

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, and biomass potential limited to 2 GW in Peninsular Malaysia.

ELECTRICITY MARKET STRUCTURE

The electricity sector in Peninsular Malaysia currently operates under a Single Buyer market structure, in which a ring-fenced Single Buyer department within the utility company, Tenaga Nasional Berhad (TNB), is responsible for procuring electricity from generators and scheduling its dispatch 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 day-to-day real-time operation and management of the high-voltage grid is handled by the Grid System Operator (GSO), a separate ring-fenced department within TNB. However, as TNB is also a major owner of generation capacity, governance concerns remain.

Under this model, both TNB and Independent Power Producers (IPPs) sell electricity to the Single Buyer, which then sells it to end consumers, dispatching power plants based on least-cost principles rather than operators bidding into the market. 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 result in inefficient, more expensive thermal power plants continuing to operate until their PPAs expire, without being replaced by lower cost solar, as capacity payments act as a kind of sunk-cost.

In 2023, the government announced plans to carve out an independent Single Buyer from TNB to promote greater market confidence through its independence from TNB. Frequency and balancing response obligations are generally included in long-term PPAs concluded with thermal power plants.

There is currently no market-based mechanism, which makes it difficult to put a price to such ancillary services. 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. As far as the author is aware, such balancing contracts do not yet exist in Malaysia.

After the Single Buyer contracts the required power from generators, it then sells the power to consumers. They are charged a fixed energy charge per MWh consumed, independent of the generation cost of the marginal electricity generator. For industrial consumers, a Time-of-Use tariff structure is available, charging higher rates during peak hours. 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

ULTRA-HIGH-VOLTAGE TARIFF STRUCTURE

The Ultra-High-Voltage Tariff was created specifically for data centres with a grid connection of at least 50 kV. It uses a Time-of-Use (ToU) structure with discounts during off-peak hours: 22:00-14:00, weekends, and public holidays. Most importantly, capacity charges are applied only to the monthly maximum demand during peak hours, serving as an incentive to shift grid consumption to off-peak hours consistently

Additionally, the Green Electricity Tariff (GET) programme allows consumers to obtain green electricity certified under the Malaysia Renewable Energy Certificates (mRECs). The costs range from 30 to 50 MYR/MWh (8 to 13 USD/MWh)[1], depending on the length of the subscription, and also exempt consumers from the Automatic Fuel Adjustment mechanism, which links the Malaysian electricity price to fuel prices and foreign exchange rates. The costs[2] are summarized in the following table:

[1] An approximate exchange rate of MYR 1 = USD 0.25 is used throughout this policy brief. All calculations are performed in MYR, with rounded results presented in USD; as of 6 April 2026, the exchange rate was MYR 1 = USD 0.24792.

[2] Here the non-bulk tariff structure is employed, the bulk tariff structure contains discounted energy charges, but is only applicable to industrial parks which constructed their own distribution infrastructure

Energy Charges	MYR/MWh	USD/MWh
peak	551.8	138
off-peak	510.9	128
Monthly Charges	**RM/MW**	**USD/MW**
Capacity Charge	21,760	5,440
Network Charge	23,060	5,765

Table 1: UHV tariff structure: Energy charges are levied per MWh consumed during peak and off-peak periods, while monthly charges are determined based on the maximum demand (MW) recorded during peak periods.

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CORPORATE RENEWABLE ENERGY SUPPLE SCHEME (CRESS)

In 2024, the Ministry of Energy and Natural Resources announced the Corporate Renewable Energy Supply Scheme (CRESS), which enables large industrial consumers, such as data centres, to enter into direct PPAs with renewable energy generators, such as solar farms, without the Single Buyer as an intermediary. The scheme is part of an ongoing move towards a more liberalised energy market. Malaysia's Energy Commission is in charge of the regulations.

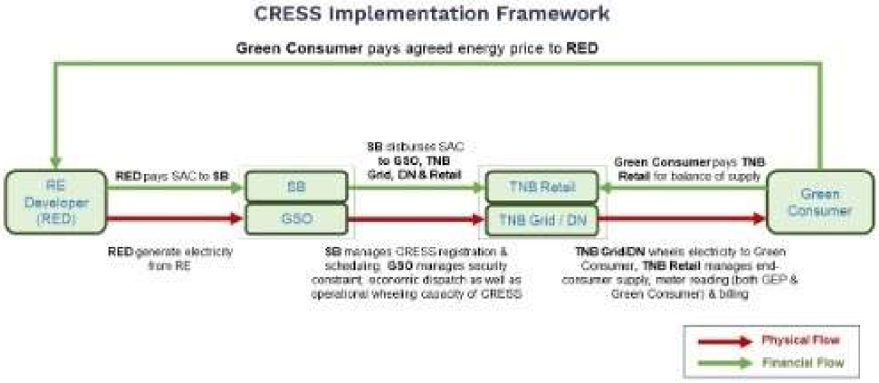
The scheme is primarily aimed at hyper-scale data centres, whose development requires GWs of new generation capacity. CRESS enables data centres, together with their IPP partners, to raise private funding for this generation capacity, instead of requiring the government to invest to meet data centre electricity demand through TNB, which is otherwise responsible for those investments. Until recently, solar farm projects were largely funded through the government's Large-Scale Solar (LSS) auctions, which had a fixed quota and were oversubscribed, leading to IPP bids so low that their solar farm projects became financially untenable. By letting IPPs connect directly with companies, IPP's negotiating position is improved, and they receive a fair price for the renewable energy they generate.

As of March 2026, announced CRESS projects have totalled 4 GW of capacity [4], with most including on-site BESS to secure discounted system access charges [5]. Installed solar capacity reached 5.7 GW the next month [6], suggesting that CRESS could be a significant growth driver for renewable energy in Peninsular Malaysia.

The CRESS customer pays the CRESS developer for the green electricity produced. In return, the CRESS customer receives a bill offset on their TNB electricity bill through a monthly matching mechanism, whereby the total electricity produced by the CRESS developer in that month is subtracted from the customer's bill. TNB charges a system access charge for costs relating to transmission and the monthly matching mechanism. In Figure 1, the monetary flows are shown in detail.

Since there is a time-of-use tariff in place, CRESS energy is first subtracted from the monthly energy consumed during peak hours, and the remaining CRESS energy is then subtracted from the energy consumed during off-peak hours [7]. For the remaining energy, the CRESS customer is charged under the UHV tariff structure; the monthly capacity and network charges are based on the monthly maximum demand during peak periods, without discounting for energy produced through CRESS. Although CRESS is open for any industrial customer, we will assume that the CRESS customer belongs to the UHV tariff structure, as only data centres have announced CRESS projects so far.

Figure 1: Physical and Financial Framework for the CRESS. The abbreviations used are: RED: renewable energy developer, SB: Single Buyer, GSO: Grid System Operator. [8]



For VRE, like solar, the system access charge is reduced from 400 MYR/MWh to 200 MYR/MWh (50 USD/MWh) if there is on-site BESS, provided the BESS has storage capacity to store 4 hours of 50% of the registered maximum solar generation output. This means that any solar generation below 50% of peak power is exported directly to the grid, and the rest is stored for discharge at the Grid System Operator's (GSO) discretion, allowing the GSO to use the BESS to balance electricity consumption and demand in real time. The dispatch strategy, which is currently under consideration, is depicted in Figure 2. In this policy brief, we assume every CRESS project installs BESS for the discounted system access charge, as all announced projects have done so, and in Section 3, we show that it is financially beneficial as well.

CONCERNS ABOUT THE CURRENT DESIGN OF CRESS

While CRESS supports Malaysia's energy transition, certain design elements may disrupt the electricity grid during a large-scale rollout. The main concerns are the monthly matching mechanism and on-site BESS dispatch.

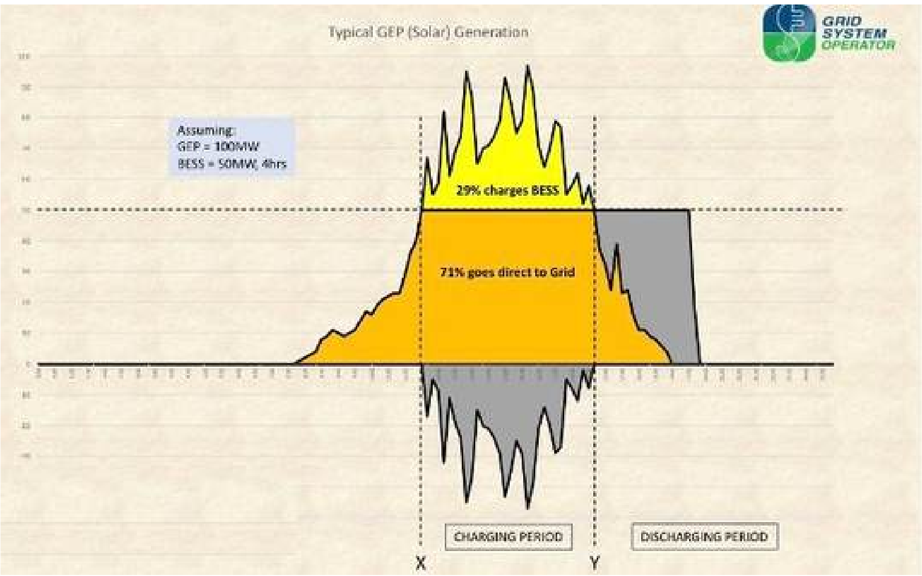
Firstly, the monthly matching mechanism means there is no temporal connection between electricity generated and consumed. Cheap daytime solar is equated with more expensive nighttime electricity, creating an indirect subsidy for data centres. Furthermore, TNB must maintain additional generation capacity to meet data centre demand on cloudy days and at night after BESS discharge. At the same time, they are forced to ramp down fossil power plants during the daytime. This cycle of higher fossil power demand at night and on cloudy days, combined with lower demand during daylight, lowers the utilization factors for fossil plants. As a result, total generation costs for the Single Buyer would increase, as fossil power plant PPAs come with a capacity charge. The system access charge is designed to include these costs, [4], not just the transmission costs.

Secondly, monthly matching means that customers are not incentivized to adjust their load profile or invest in additional BESS to ensure that their electricity consumption aligns with the solar farm's generation profile.

As discussed, if the CRESS customer's load profile is not aligned with the solar + BESS dispatch, TNB incurs additional costs. If a CRESS customer predominantly consumes energy at night, it would be sensible to incentivize it to invest in additional BESS or shift its load profile to lower TNB's costs.

Thirdly, the current BESS dispatch design could worsen the strain on fossil generation capacity during evening peak demand: during the day, solar farms with on-site BESS are exporting more to the grid, than their CRESS customers are consuming, leading to a solar surplus and fossil power plants being ramped down, on days that the BESS finishes discharging before the evening demand peak, fossil power plants would have to ramp up abruptly to compensate for CRESS power, whilst also dealing with the demand increase.

Figure 2: Graphic illustrating how BESS would be dispatched under the current CRESS regulations.



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Policy Design for Integrating Grid-Scale BESS

This section examines potential regulatory changes to the CRESS framework and the broader Malaysian electricity market to fully capitalise on the emergence of affordable grid-scale BESS technologies. These systems enable the storage of low-cost solar energy for dispatch at any time of day while also enhancing grid stability through ancillary services, such as balancing, enabled by their highly controllable charging and discharging capabilities. The policy recommendations derived from the first pillar form the foundation of the modelling framework used in this policy brief, while those associated with the second pillar are not discussed in detail; interested readers should refer to the CTSS policy brief ”How Falling Battery Prices Create New Pathways for Malaysia’s Energy Transition”.

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 manage, as fossil power is contracted under long-term PPAs that inadequately address flexibility needs, and there is insufficient compensation for providing balancing services.

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.

Following Pillar 1, 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, as regulatory timelines are longer than BESS development projects.

In the previous CTSS policy brief, policy recommendations were presented based on the aforementioned pillars. The recommendations related to the first pillar will provide the foundation of our modelling. The main points of those policy recommendations will now be restated.

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, ensuring that every renewable generation asset can provide balancing services 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, whilst also avoiding the potential for harmful strategic bidding among market operators. However, once Malaysia’s electricity market matures, a decentralised bid-based BESS dispatch could become viable as market signals would incentivize each market participant to operate their batteries based upon demand and supply.

HOURLY MATCHING

As currently designed, CRESS operates on a monthly matching 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, excess solar generation will need to 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 (Aiman, 2023). Adjusting CRESS to work on an hourly basis would incentivize 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 could create tension 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. The differences between the physical and virtual dispatch profiles are illustrated in Table 2.

Table 2: Comparison between physical and virtual dispatch profiles

	Physical Dispatch Profile	**Virtual Dispatch Profile**
Determined by	Grid system operator	Solar farm operator
Used for	Determining energy generation of the solar farm	Calculating electricity tariffs for the CRESS partner
Goal	Decreasing total system costs	Reducing the electricity bill of the CRESS partner
Typical usage	Lowering evening peak demand and providing ancillary services (balancing, frequency regulation)	Reducing grid power usage of the CRESS partner during high electricity price periods

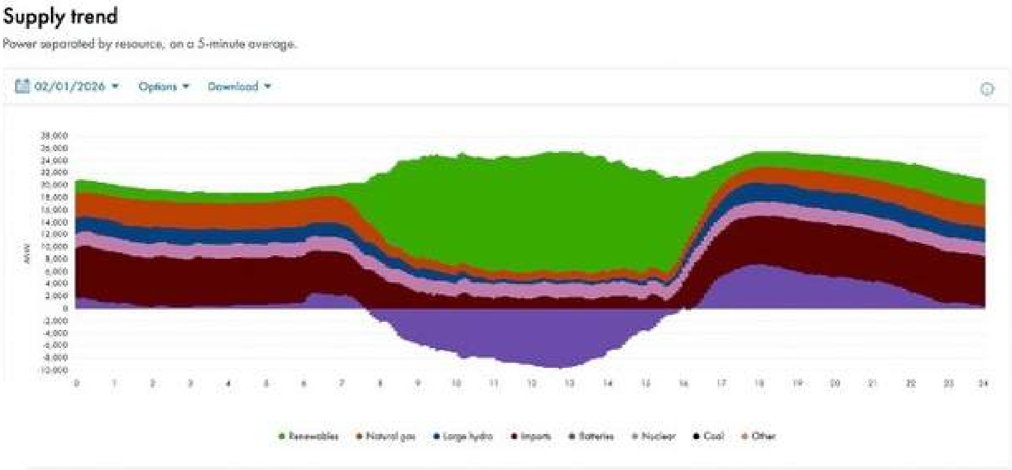
In such an hourly matching scheme, industrial consumers whose demand profiles closely align with solar generation would require less storage investment, while those with a significant mismatch would invest more in BESS capacity. This leads to a more efficient and equitable allocation of storage investments.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

OPERATIONAL DESIGN OF CENTRALISED BESS DISPATCH

This subsection discusses how centralised BESS dispatch can be organised in practice, providing a practical means of integrating VRE generation into the electricity grid with relatively low complexity and without compromising system stability. It also examines how BESS can firm solar generation, provide ancillary services to the grid, and allow time for thermal power plants to ramp up when solar output is lower than forecast.

The GSO would likely operate the battery similarly to the western US grid, which has a lot of BESS, as depicted in figure 3, as this combats the duck curve, where thermal power plants have to rapidly ramp up to match the evening demand peak, as solar generation drops, with it performing ancillary services throughout the day.

Figure 3: Shows batteries in the Californian electricity market absorbing a solar surplus during the day and then discharging in the evening to compensate the decrease in solar power and prevent thermal power plants from having to quickly ramp up



Supply trend

Power separated by resource, on a 5-minute average.

For daytime operation, the GSO can select a dispatch profile for the combined solar + BESS plant below the expected solar generation, ensuring its delivery is essentially guaranteed, and storing the rest in the BESS, which is added to the evening energy pool to address the evening demand peak, after solar generation drops. The combined power output of the solar farm and the battery can be fully regulated by the battery, and any additional balancing services can also be performed using the battery. This is similar to the current dispatch under CRESS as depicted in Figure 2, with the difference that the evening BESS discharge profile does not need to be constant; it can respond to grid demand.

Battery storage removes the ”fundamental truth” of electricity networks that generation and consumption must match on a second-by-second basis, or else risk voltage fluctuations that can cause a blackout. BESS can pick up the balance, discharging when generation is short of consumption, and charging when the opposite is true. This makes dispatching more forgiving.

If solar generation is lower than expected throughout the day, the expected amount of stored energy in the evening energy pool can be adjusted, allowing fossil power plants to ramp up to meet evening demand if needed. Additionally, the GSO could decide to downregulate the solar farms’ output during the day whilst ramping up thermal power, ensuring the batteries remain sufficiently charged for the evening peak. If peak demand can always be partially satisfied by stored solar energy, total fossil generation capacity can be reduced.

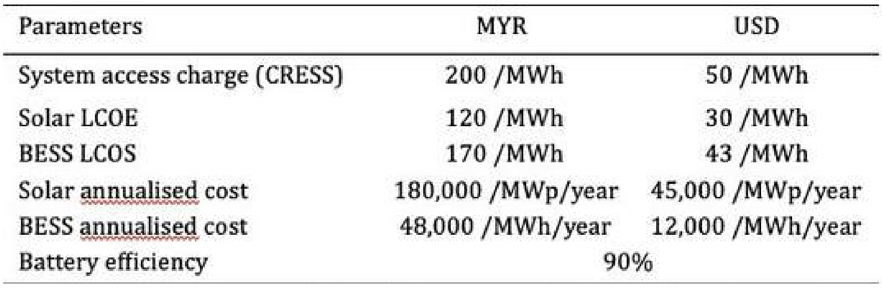
Introducing hourly matching and the virtual dispatch profile allows the GSO to control BESS dispatch, whilst the BESS operator under CRESS is financially rewarded for its investment as if it controlled the BESS dispatch itself, and is therefore incentivized to develop the optimal amount of BESS capacity to meet its CRESS partner’s electricity demand. In the next section, the choice of modelling parameters is discussed, after the optimal BESS dispatch under both monthly and hourly matching is modelled.

Solar and BESS Modelling Parameters

Before we can model the financial costs of a solar + BESS project, we need to select the cost and production parameters for both technologies. This can be difficult because the total development costs for such a project are also dependent on where it is built, including land prices, terrain type, and the possible lack of infrastructure at the site. Malaysia's humid weather could also lead to additional costs from increased degradation and increased mitigation efforts. Therefore, these cost parameters should not be taken as indicative of any particular solar + BESS project. Additionally, the costs of solar PV and battery modules are falling rapidly, meaning that a choice of cost parameters could become outdated within a year.

The parameters used for both solar PV and BESS are summarised in Table 3.

Table 3: Parameters relevant for modelling the costs of CRESS power.



Parameters	MYR	USD
System access charge (CRESS)	200 /MWh	50 /MWh
Solar LCOE	120 /MWh	30 /MWh
BESS LCOS	170 /MWh	43 /MWh
Solar annualised cost	180,000 /MWp/year	45,000 /MWp/year
BESS annualised cost	48,000 /MWh/year	12,000 /MWh/year
Battery efficiency	90%	

Solar

The levelised cost of electricity (LCOE) of solar has fallen drastically in the last few years, with it now being significantly cheaper than fossil fuels [13]. Based upon this report, we assume a solar LCOE of 120 MYR/MWh (30 USD/MWh). We convert it to an annualised cost of 180,000 MYR/MWp (rounded-up) using an expected annual generation of 1,460 MWh/MWp.

Battery

The levelised cost of storage (LCOS) is the cost of shifting 1 MWh of electricity in time and includes both CAPEX and OPEX, while excluding the cost of electricity used to charge the BESS. According to a renewable think-tank report [14] on BESS from December 2025, the CAPEX for BESS is now 509 MYR/kWh (127 USD/kWh) outside of China and the US. Using Ember's assumptions of a 20-year lifetime and a 7% interest rate, this leads to an annualised cost of 48 MYR/kWh/year (12 USD/kWh/year). Assuming the BESS averages 0.8 charge-discharge cycles per day, the resulting LCOS is 170 MYR/MWh (43 USD/MWh). When you add up the solar LCOE, BESS LCOS and the SAC, you get 490 MYR/MWh (123 USD/MWh), which is competitive with the UHV tariff.

Load Profile

Our financial modelling for hourly matching CRESS depends on the CRESS customer's load profile, as it affects the grid tariffs TNB charges for the remaining grid electricity and the amount of BESS required to effectively shift the solar energy to match the load profile.

Therefore, we introduce three different load profiles, depicted in Figure 4. A constant load profile, an eveningcentred load profile and an afternoon-centred load profile, with each profile using a daily consumption of 24 MWh. Each of these profiles is not meant to represent a realistic load profile, but they illustrate the demand profiles of data centres, households and offices to some degree.

Solar Generation Profile

We use the PVGIS-ERA5 dataset for 2023 for the hourly solar PV generation for our model. The annual production per MWp of solar is set at 1,460 MWh/year, resulting in an average production of 4 MWh/day. Our usage of this data set is further explained in Section A of the Appendix.

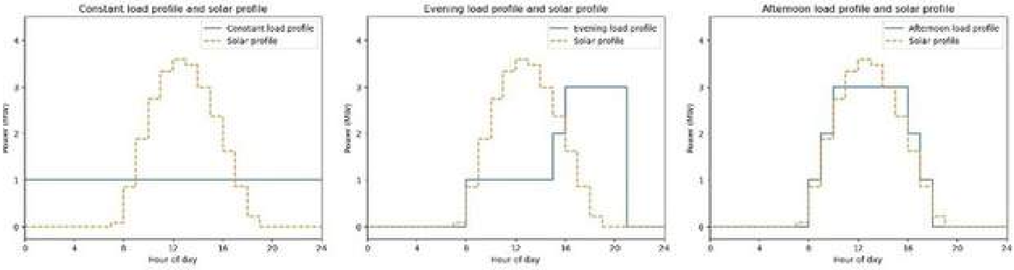


Figure 4: Illustration of the constant, evening and afternoon load profiles and of the solar generation profile

To match the load profiles, which consume 24 MWh per day, we install 6 MWp of solar. However, solar panels rarely reach their maximum generation capacity; therefore, developers limit the maximum export capacity through the DC-AC ratio [1]. In this analysis, a ratio of 1.5 is selected, meaning the maximum export capacity is 4 MW, with any excess generation being curtailed.

Per CRESS regulations, this means a 2 MW, 8 MWh battery should be on-site for the discounted System Access Charge. The effect of reducing the maximum solar generation capacity is illustrated in Figure 11 of the Appendix, which shows a minimal reduction; it would primarily affect generation on sunny days, when a solar surplus is likely.

In Figure 12, the distribution of the daily energy production is shown for the solar + BESS installation described in the above paragraph. To match the electricity consumed by the CRESS customer, independent of its load profiles, the production target is 24 MWh/day. The majority of the days exceed or approach this production target. However, there is a long tail of cloudy days where the production target is missed by more than 50%. When accounting for the BESS's limited storage capacity, 1.6% of the solar farm's energy generation is curtailed on sunny days, when the value of solar energy is likely low due to abundance.

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[3] Solar panels produce DC power; however, the grid operates on AC power, therefore, a converter is required. The DC-AC ratio is the ratio of the maximum solar generation capacity and the converter capacity.

Modelling of CRESS

This section presents a modelling analysis of the CRESS framework, examining how tariff cost structures change under both monthly and hourly matching approaches across different load profiles, relative to a fully grid-powered baseline. The analysis begins by establishing the baseline and monthly matching cases before extending to hourly matching using a virtual dispatch profile, enabling an assessment of potential cost savings as well as the optimal sizing of solar photovoltaic (PV) and battery energy storage systems (BESS).

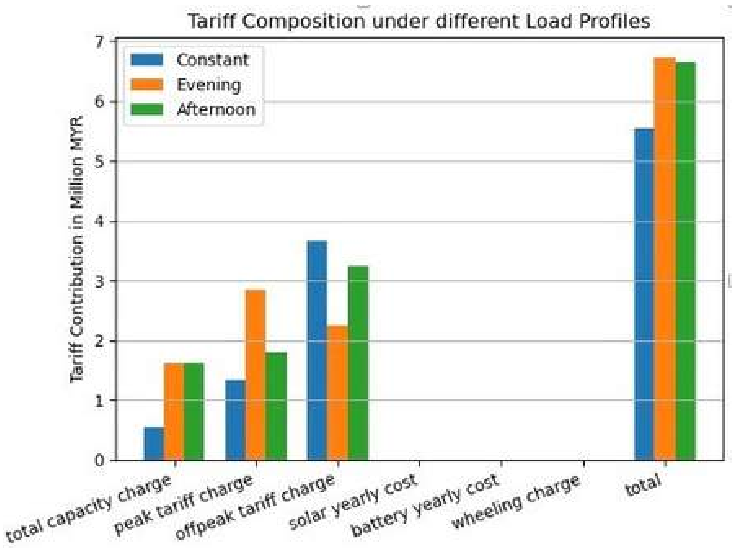
The modelling incorporates realistic operational conditions, including weekends and Malaysian public holidays based on the 2026 calendar to determine peak period distributions, alongside a discounted system access charge (SAC) of 200 MYR/MWh (50 USD/MWh).

Optimisation of BESS charging and discharging is carried out using the PyPSA framework, with all parameter values drawn from Tables 1 and 3. The code and Jupyter notebooks supporting this analysis are publicly available on GitHub.

FULLY GRID-POWERED COSTS

The costs for each of the three load profiles are first evaluated, Figure 5 displays the tariff composition per MW of average demand. The capacity charge is lowest for the constant load profile, as the other two profiles both exhibit a peak demand of 3 MW. For the constant and afternoon load profiles, off-peak tariff charges are higher because a larger share of consumption occurs during off-peak grid hours. However, because the modest spread between off-peak and peak tariffs, the cost savings for an afternoon profile are minimal.

Figure 5: Annual tariff costs for the three load profiles are as follows: MYR 5.54 million (USD 1.39 million) for the constant profile, MYR 6.72 million (USD 1.68 million) for the evening profile, and MYR 6,65 million (USD 1,66 million) for the afternoon profile.



CRESS WITH HOURLY MATCHING

This section models the energy production of a solar farm with on-site BESS under the current CRESS framework. Figure 6 compares the resulting tariff structure under monthly matching with that of a constant load profile, highlighting the substantial cost savings that can be achieved. For the evening and afternoon load profiles shown in Figure 4, these cost savings would be similar, as their increased total capacity charge will remain unchanged.

Under the monthly matching regime, days with excess generation above 24 MWh/day can compensate for days with very low solar output. In the case of a large-scale rollout of CRESS, this may pose risks to system stability, as CRESS customers face little incentive to adjust their behaviour. By contrast, under hourly matching, insufficient solar generation on a given day would result in higher electricity costs unless backup solutions, such as additional storage capacity, are deployed.

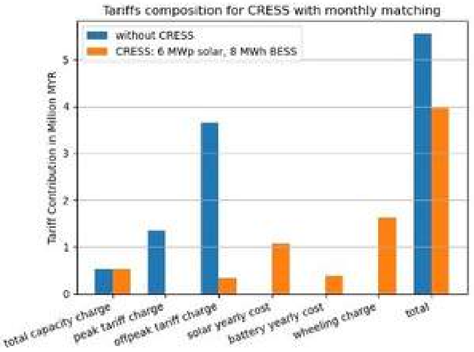


Figure 6: A comparison of tariff costs for the constant load profile shows that total annual costs decrease from MYR 5.54 million (USD 1.39 million) without CRESS to MYR 3.97 million (USD 0.99 million) with CRESS (6 MWp solar and 8 MWh battery).

Under the monthly matching regime, days with excess generation above 24 MWh/day can compensate for days with very low solar output. In the case of a large-scale rollout of CRESS, this may pose risks to system stability, as CRESS customers face little incentive to adjust their behaviour. By contrast, under hourly matching, insufficient solar generation on a given day would result in higher electricity costs unless backup solutions, such as additional storage capacity, are deployed.

MODELLING OF CRESS WITH HOURLY MATCHING

The effect of implementing hourly matching for CRESS is now examined, initially using the same solar and BESS capacities as in the previous section. The charging capacity of the BESS is increased from 2 MW to 3 MW to allow for greater dispatch flexibility, although the associated increase in inverter capacity is not considered. Subsequently, the optimal solar and BESS capacities for each of the three load profiles are determined.

The financial outcomes for the CRESS customer are governed by the virtual dispatch profile. The analysis therefore focuses on identifying the optimal virtual dispatch profile for each load profile. Physical dispatch, however, remains under the control of the GSO and is influenced by system-wide demand and the provision of ancillary services.

On a representative day, as shown in Figure 7, 24% of solar energy is curtailed, indicating that the BESS storage capacity is insufficient.

The virtual dispatch profile prioritises matching demand between 9:00 and 22:00. Since solar generation begins around 9:00, and the period from 14:00 to 22:00 corresponds to peak grid hours, a significant portion of residual demand is met at higher time-of-use tariffs.

The optimal configuration of solar and battery storage for a constant load profile is then determined. As shown in Figure 8, a system comprising 6 MWp of solar capacity and 14 MWh of battery storage minimises costs. This result is intuitive: 6 MWp of solar capacity is sufficient to meet the energy demand of a 1 MW constant load, while approximately 14 MWh of storage is required to supply demand during non-solar hours, assuming around 10 hours of daily solar generation.

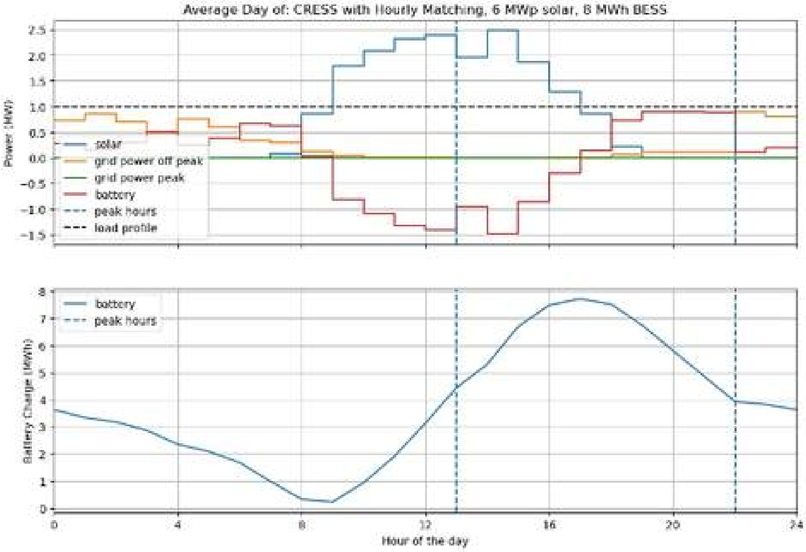


Figure 7: In the top figure, the average generation from each source is shown for each hour of the day. In the bottom figure, the battery's state of charge is shown. Notice that the average cycling rate is nearly one cycle per day.

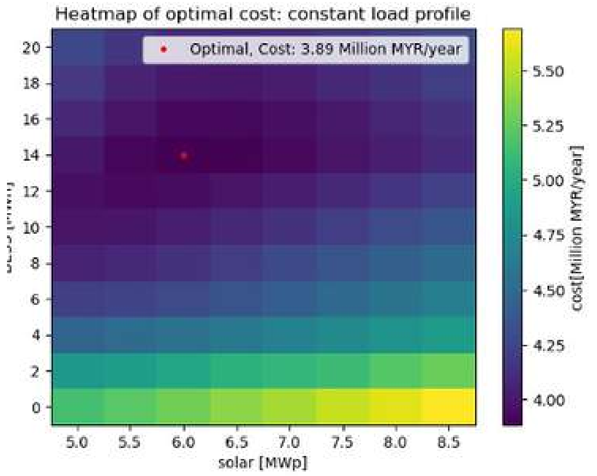
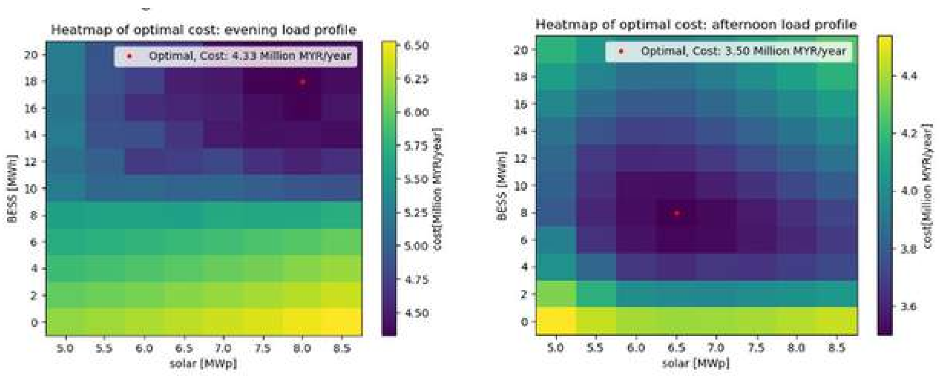


Figure 8: Here the configuration of 6 MWp solar and 14 MWh battery is optimal, with annual costs of MYR 3.89 million (USD 0.97 million), whilst the CRESS configuration of 6 MWp solar and 8 MWh battery would lead to annual costs of MYR 4.15 million (USD 1.04 million). In Figure 13, the tariff composition is displayed.

THE EFFECTS OF DIFFERENT LOAD PROFILES

The impact of different load profiles on optimal investment decisions under hourly matching is next examined. Figures 9a and 9b present the optimal configurations for the evening and afternoon profiles, respectively. A clear distinction emerges: the afternoon profile requires relatively less investment in BESS than the evening profile to achieve optimal cost savings.

This difference arises because the evening load profile has less temporal overlap with solar generation, necessitating greater reliance on storage. However, this relationship does not extend directly to the constant load profile. Although the constant profile has a lower peak demand than the other profiles, profiles with higher peak demand face larger potential capacity charges. As a result, they have stronger incentives to invest in additional solar and BESS capacity to reduce these charges.



(a) The optimal configuration is 8 MWp solar and 18 MWh BESS, resulting in annual costs of MYR 4.33 million (USD 1.08 million).

(b) The optimal configuration is 6.5 MWp solar and 8 MWh BESS, resulting in annual costs of MYR 3.50 million (USD 0.88 million).

Figure 9: Heat maps showing the tariff costs for CRESS with hourly matching for different solar and battery configurations. With the evening and afternoon load profiles and the left and right sides, respectively.

Conclusion

The modelling performed in the previous section shows that under our choice of parameters, it is economically attractive for data centre operators to invest in renewable energy through CRESS. First demonstrating how different load profiles affect grid tariffs in the absence of CRESS, and how CRESS with monthly matching effectively weakens the incentives created by the time-of-use tariff system. 100% matching is most profitable under monthly matching. Under hourly matching with a constant profile, 88% matching is most profitable, but because hourly matching incentives additional investments in BESS, a system in which the GSO dispatches according to a virtual dispatch profile results in significantly lower reliance on non-CRESS electricity. This, in turn, reduces system costs for TNB relative to monthly matching and supports the case for a lower system access charge.
In addition, policy measures based on the second pillar from the previous CTSS policy brief ”How Falling Battery Prices Create New Pathways for Malaysia’s Energy Transition” should also be considered. The second pillar centres on ensuring that BESS operators are compensated for all the benefits their batteries provide, thereby incentivizing sufficient BESS deployment. For more details, please consult the previous CTSS policy brief.

Overall, this framework lowers total system generation costs, benefiting all stakeholders involved with CRESS[1] by enabling a reduction in the System Access Charge. Furthermore, the virtual dispatch profile aligns incentives by ensuring that CRESS participants capture the financial value of additional BESS capacity, while the GSO retains full operational control over dispatch.

One potential improvement to this system would be to allow the batteries to charge from the grid at night ahead of cloudy days. At night, electricity demand is low, and there is thus leftover thermal generation capacity, which can be used to compensate for lower solar PV generation during the day, ensuring that less total thermal generation capacity is required during demand peaks on cloudy days, which would allow TNB to avoid investments in additional thermal generation capacity for evening demand peaks on days where solar radiation is subpar.

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[1] Fossil power plants operators like TNB’s generation arm would however lose revenues.

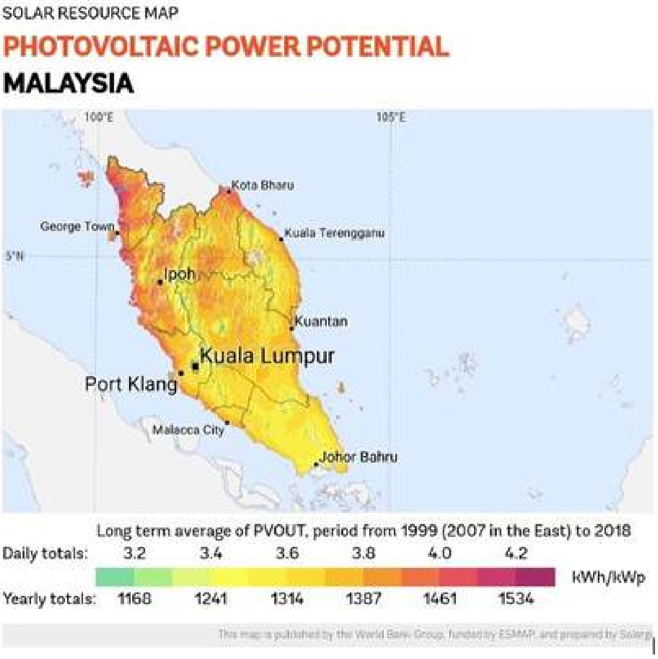
Appendix

SOLAR RADIATION PROFILES

To find the electricity generated by a 1 MWp solar PV installation during a particular year, the tool PVGIS calculator [15] can be used. It accounts not only for weather but also for losses in the solar PV installation, the type of solar panels, and the orientation of the panels. For the location, we picked the Sultan Abdul Halim Airport in Kedah, as it receives above average solar radiation compared to the rest of Peninsular Malaysia, but it is also not an exceptional outlier as is evidenced in Figure 10.

The PV-GIS tool provides two solar PV technologies: 2025 spec crystalline silicon and a lower performance variant of crystalline silicon. However, for the 2025 spec, only monthly data is accessible, whilst for the lower performance spec, hourly data is also available. In the analysis, a scaled-up version of the hourly generation profile for the outdated spec is used, whose annual production matches that of the 2025 spec. The annual production of the 2025 spec is 1457 MWh/MWp, which is rounded up to 1460 MWh/MWp, as that corresponds to a daily production of 4 MWh.

The data is based on a 30 km by 30 km grid, so it might not be indicative of a single solar farm's performance. However, it could still be reasonably accurate for a collection of solar farms in relative proximity. Figures 11 and 12 in the Appendix provide additional information about the simulated solar generation profile and its variability.



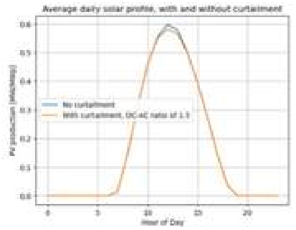


Figure 11: Average daily profile of PV production, without taking into account storage constraints: the battery might still get fully charged leading to additional curtailment

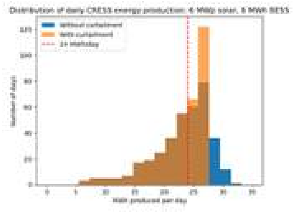


Figure 12: In blue is the energy produced by the solar farm, in orange is the energy exported to the grid, when a DC-AC ratio of 1.5, with energy being curtailed on sunny days because of limited BESS storage capacity.

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