Solar and grid flexibility critical for Malaysia's future electricity affordability and security

Naturally endowed with huge solar power resources, Malaysia is well-positioned to leverage it to meet its electricity needs and substantially enhance its energy security and affordability.

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About

The report examines Malaysia's electricity transition roadmap, focusing on how it can maximise its plentiful solar potential with targeted policies for faster solar growth and battery storage. It also evaluates the electricity trends in each key region, Peninsular Malaysia, Sabah and Sarawak, offering an overview of the opportunities and challenges and suggesting how they can contribute to Malaysia's renewable energy targets. The transition pathway provided in a Malaysia-specific energy transition study by the International Renewable Energy Agency (IRENA) is used as a benchmark to demonstrate that a pathway to clean electricity can deliver increased affordability and security benefits for the country.

Highlights

10%	95%	-53%
Highest generation share of solar and hydro in meeting Peninsular Malaysia's daytime demand in 2023	Untapped solar power potential in Malaysia in 2035 after solar is built as per NETR (National Energy Transition Roadmap)	Electricity generation costs from solar compared with fossil fuels in 2023 for Peninsular Malaysia

Executive summary

Malaysia can reap affordability and security benefits from rapid solar growth

Malaysia’s National Energy Transition Roadmap (NETR) sets an ambitious commitment for the country to reach 70% renewable capacity in the energy mix by 2050, with solar power as the dominant source and gas utilised as the transitional fuel away from baseload coal.

From data provided in the NETR, Ember estimates that the generation share of renewables will contribute to about 52%, and gas will account for the remaining 48% of the mix in 2050. This could leave Malaysia's power sector vulnerable to global fuel price volatility and domestic reserve depletion. Hence, the government could look to raise renewable energy ambitions for the power mix to be better diversified.

By utilising more of its abundant solar power resources, Malaysia can unlock affordability and security benefits in the power sector. Technically, solar power can reliably meet Malaysia's daytime demand, while the non-solar hours demand could be addressed by utilising hydropower and building more storage facilities over time. Despite the high cost, investing in energy storage solutions such as battery energy storage systems (BESS) is critical. Efficiently managing the increasing solar loads requires upgrading the current grid infrastructure.

A gradual increase in solar power could also strengthen affordability in Malaysia's power sector, insulating the country from the risk of rising electricity tariffs, which may be caused by fossil fuel price volatility. Therefore, policies to further support solar growth and BESS adoption across Peninsular Malaysia, Sabah and Sarawak regions can allow each region to excel in its solar power adoption and contribute to the national power transition target.

01 Solar and grid flexibility are key to meeting Malaysia’s growing electricity demand, given the nature of its daily demand profile

Peninsular Malaysia, accounting for 74% of the country's electricity demand, exhibits a daily demand profile with “twin” peaks in the daytime at 4 pm and evening at 8 pm. Malaysia, with its massive untapped solar resources, is uniquely positioned to fulfil the daytime peak using solar power, while other options, such as hydropower and battery storage, can complement solar in meeting evening peak demand. In 2023, solar and hydropower collectively account for 10% of the generation share during the daytime peak, while hydro contributed 7% towards meeting the evening peak. Peninsular Malaysia’s grid can accommodate about 2.4 GW more of solar (up to 20% of grid penetration) before storage systems are essential.

02 Solar power offers a win-win solution to Malaysia’s power sector, unlocking energy security benefits

With about 268 GW of indigenous solar capacity, Malaysia is well-positioned to bolster its energy security. The NETR pathway aims to utilise about 5% of this solar potential (14 GW) by 2035, leaving a significant amount of solar resources untapped. Integrating the grids of the three regions can fast-track solar growth and enhance their grid stability, allowing Sabah to strengthen its power supply security, Sarawak to access more solar during the day and Peninsular Malaysia to use hydropower during evening peaks. Developing more domestic solar will help diversify the power mix and reduce the risks of fossil fuel supply shocks.

03 Solar generation costs in Peninsular Malaysia are 53% lower than fossil fuel options in 2023

From the beginning of the Large Scale Solar programme in 2016 until 2021, the lowest auction rates for 30-50 MW solar plants dropped by 64% from $0.082 USD per kilowatt-hour (kWh) to $0.029 USD per kWh in Peninsular Malaysia. This trend aligns with the global solar generation costs that decreased by 55%. These costs represent the price at which electricity is sold upon project commissioning, with projects from auctions held between 2016 and 2021 starting to generate electricity from 2017 to 2023. This means solar generation costs dropped to $0.029 USD per kWh by 2023, making them 53% cheaper than fossil fuel generation costs, which stood at $0.063 USD per kWh.

04 Promoting policies that combine battery and solar technology key to Malaysia's energy transition

Malaysia's deployment plans for battery energy storage systems (BESS) could benefit from policies integrating solar and BESS technologies. Conducting feasibility studies to analyse the economic and technical viability of BESS could be a stepping stone. Existing programmes, such as Large Scale Solar and Corporate Green Power Programme, could be further enhanced by integrating BESS technologies and offering a different tariff scheme for BESS services, broadening flexible grid development responsibilities beyond utilities to other market participants.

The 64% reduction in utility-scale solar generation costs in Malaysia from 2016 to 2021 presents a significant opportunity to expedite the country's journey towards achieving net zero ambitions in its power sector. By adopting a holistic system-wide plan targeting solar and grid flexibility, Malaysia can accelerate its transition to clean energy, thereby reducing its vulnerability to fuel price volatility and mitigating the risk of becoming a net importer of power generation fuels.

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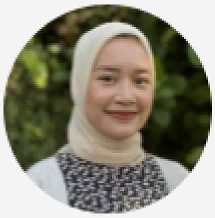

Accelerating solar adoption and enhancing grid reliability necessitate the integration of Malaysia's grids. This strategy should extend beyond national borders through strategic ASEAN interconnections, prioritising regional collaboration over isolated national expansion. By fostering a unified energy market, we can optimise resource allocation, reduce costs and bolster grid resilience.

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Director, Sustainability Studies, UN Sustainable Development Solutions Networks (SDSN), Asia Headquarters / Professor, Sunway University

Overcoming significant challenges in integrating high levels of solar power and implementing effective solar firming is crucial for ensuring grid stability and reliability. Despite the high cost, investing in energy storage solutions such as battery energy storage systems (BESS) is critical. By strategically planning, embracing technological advancements, and promoting public-private cooperation, Malaysia has the potential to harness its immense solar resources and pave the way for a secure and resilient energy future.

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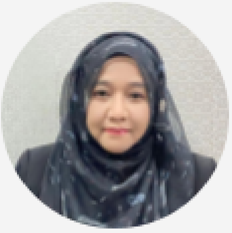


Malaysia’s electricity landscape

Malaysia aims for 29% renewables in its energy mix, with fossil fuels accounting for the rest

Malaysia’s renewable energy under the National Energy Transition Roadmap is expected to contribute 29% of the generation mix in 2035, while fossil fuels will account for 71%.

Malaysia is an upper-middle-income country in Southeast Asia. It ranked third among the Association of Southeast Asian Nations (ASEAN) members in Gross Domestic Product per capita ($11,993 USD) in 2022. As the economy grows, electricity generation in the country has also shown a steep growth during the last two decades, adding 116 TWh of power generation from 2000 to 2023.

Much of the electricity generation is sourced from coal and gas. In 2023, coal and gas accounted for 43% and 37% of total generation, respectively. The renewable share in 2023 was 19.5%, and most of the generation comes from hydropower (17%, 32 TWh). Solar and bioenergy each contributed 1.7% and 0.6%.

Malaysia's three key regions operate independent electricity markets, influencing their clean transition strategies

As a parliamentary democracy with a constitutional monarchy, the Federation of Malaysia was formed following the merger of the Federation of Malaya, Singapore, North Borneo (Sabah) and Sarawak on 16 September 1963.

As an electricity grid, the country can be separated into three main electricity regions: Peninsular Malaysia and the states of Sabah and Sarawak. Peninsular Malaysia is located on the mainland of Southeast Asia, while Sabah and Sarawak are on the island of Borneo. The South China Sea separates these two geographical areas. In accordance with the centralisation of the power sector structure, the electricity supply is mainly provided by the state-owned utility companies in each region. There is no existing grid interconnection between regions, thus the markets are independent of each other. The government has plans to connect the grids across regions in the coming years.

Across Peninsular Malaysia, Tenaga National Berhad (TNB) operates as the sole publicly listed electricity provider, with the government owning a 66% stake. The region implements a single buyer market structure whereby independent power producers generate almost half of the electricity. Single Buyer is assigned to manage electricity procurement to fulfil demand in Peninsular Malaysia.

TNB also has an 83% share in its subsidiary, Sabah Electricity Sdn. Bhd (SESB), which serves Sabah, while the State Government of Sabah retains 17% of the remaining stake.

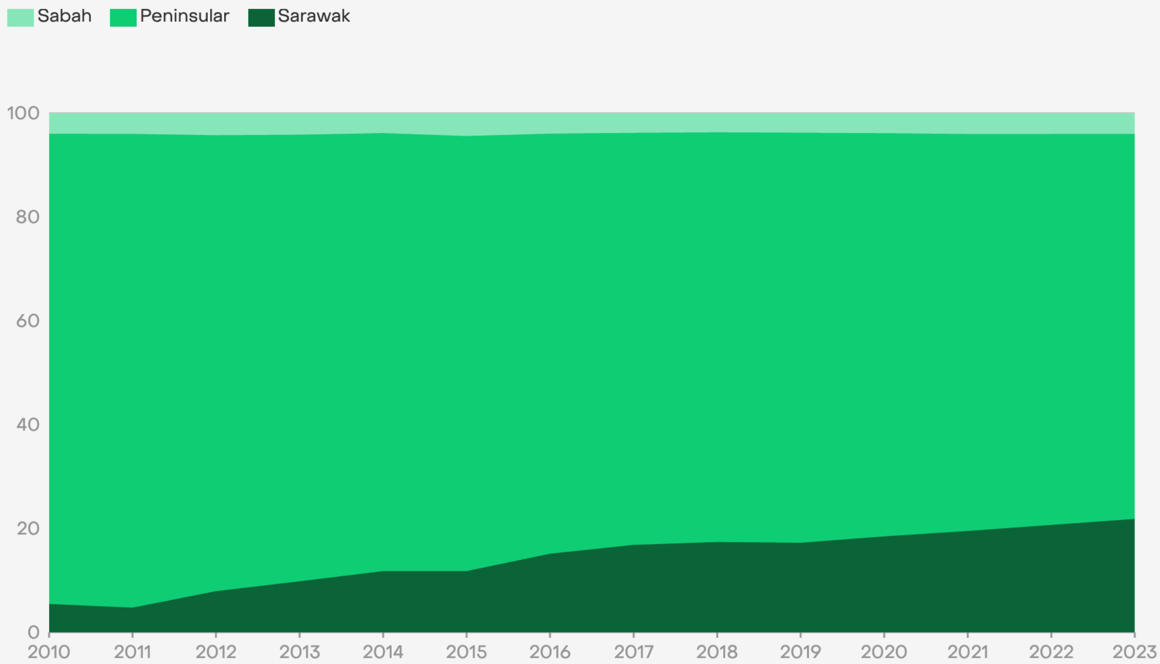
A regulatory transfer of Sabah's power supply from the federal government to the state government began in early 2024, slated for completion by 2030. Prior to this, Sabah's power sector was governed by the federal government and, along with Peninsular Malaysia, adhered to the Electricity Supply Act of 1990. Therefore, some of Peninsular Malaysia's renewable energy programmes were extended to Sabah.

Meanwhile, Sarawak has managed its electricity-related affairs under its own self-governance. The state's electricity supply is provided by Sarawak Energy Berhad (SEB), fully owned by the State Government of Sarawak. This arrangement allows Sarawak to establish its own power-related targets instead of following the federal targets.

About three-quarters of Malaysia's electricity demand is driven by Peninsular Malaysia where most of the population inhabits, amounting to 118 TWh in 2020 (the latest year available) and 137 TWh in 2023 (estimated). Even though the highest demand is in Peninsular Malaysia, Sarawak has seen the most significant demand growth compared to Sabah and Peninsular Malaysia in recent years, with 13% annual growth from 2010 to 2020.

Sarawak posts the fastest demand growth rate while Peninsular consumes the most

Electricity demand share per region (%)

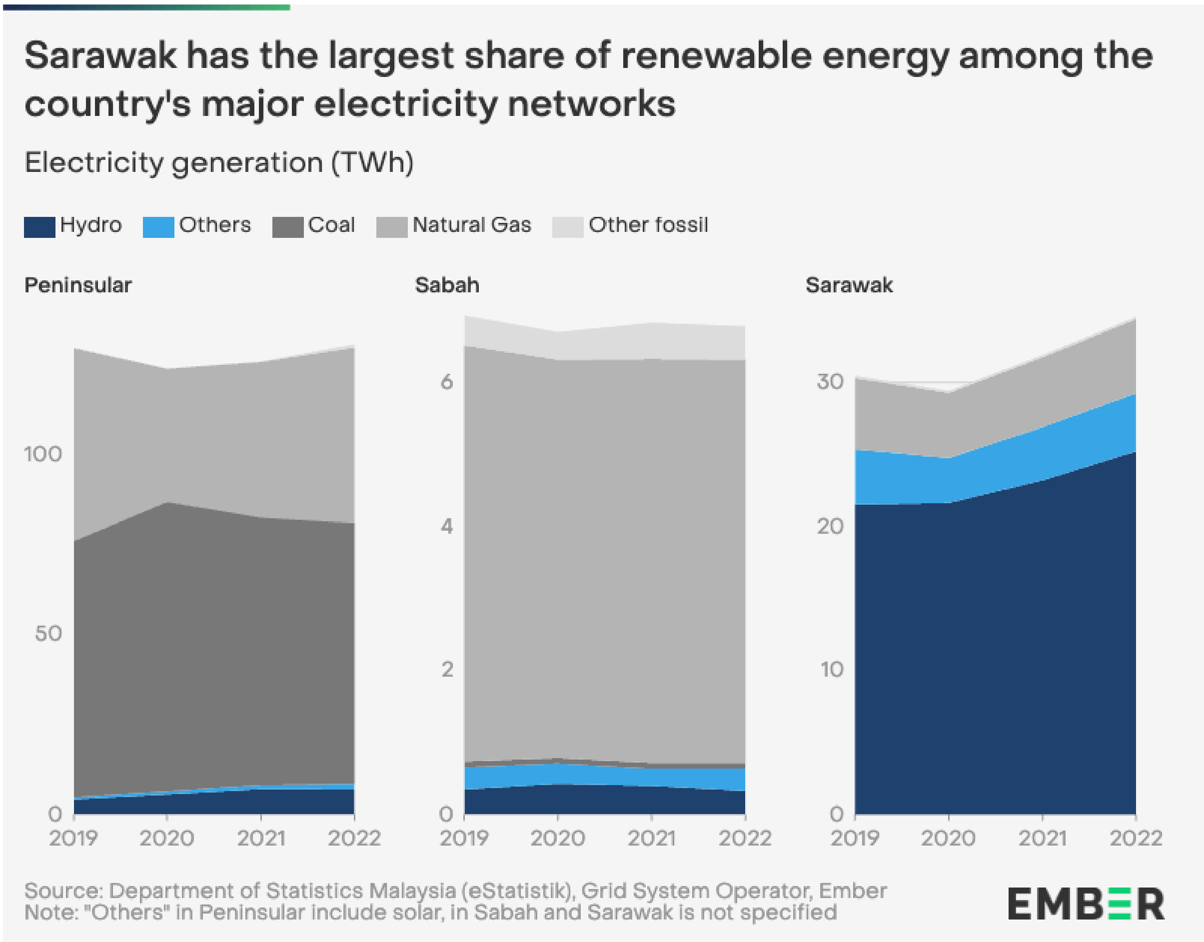


Source: Energy Commission
Ember's estimates for 2021 – 2023 based on electricity demand data

Fossil fuels are the primary source of power across Peninsular Malaysia and Sabah, meeting most of their power demand. In 2022, coal power plants account for 56% of Peninsular Malaysia's power generation, while gas dominates Sabah's power generation at 83%.

In contrast, their neighbour Sarawak is leading in renewable generation share from hydropower. Sarawak's electricity demand is mainly met by large hydropower, which accounted for 73% (25 TWh) of total generation in 2022.

Renewable energy progress varies across Malaysia's regions. In Peninsular Malaysia, solar generation rose to 36% year-on-year from 2019 to 2022, adding a total of 1 TWh over this period, with hydropower remaining the largest renewable source, supplying 6.8 TWh out of 8.4 TWh of the total renewables in 2022. In Sabah, renewable generation from hydro, solar and bioenergy has plateaued over the last four years, averaging 0.7 TWh annually from 2019 to 2022.



Pathways to clean electricity are available

The Malaysian government has announced energy transition plans in Malaysia's net-zero commitment in 2050. The Malaysia Renewable Energy Roadmap (MyRER), published in 2021, outlines the strategies and detailed plans for clean power transition until 2035. A year later, the National Energy Policy 2022-2040 (NEP) laid the groundwork and the overarching strategy for how the energy transition will shape up to achieve a net zero.

As an updated and extended strategy of MyRER, the country introduced the National Energy Transition Roadmap (NETR) in 2023 to pave the way for the decarbonisation of its energy sector. The roadmap outlines reforms aimed at achieving renewable energy comprising 70% of total capacity by 2050, with solar power making up the majority share at 58% and gas serving as a transition fuel.

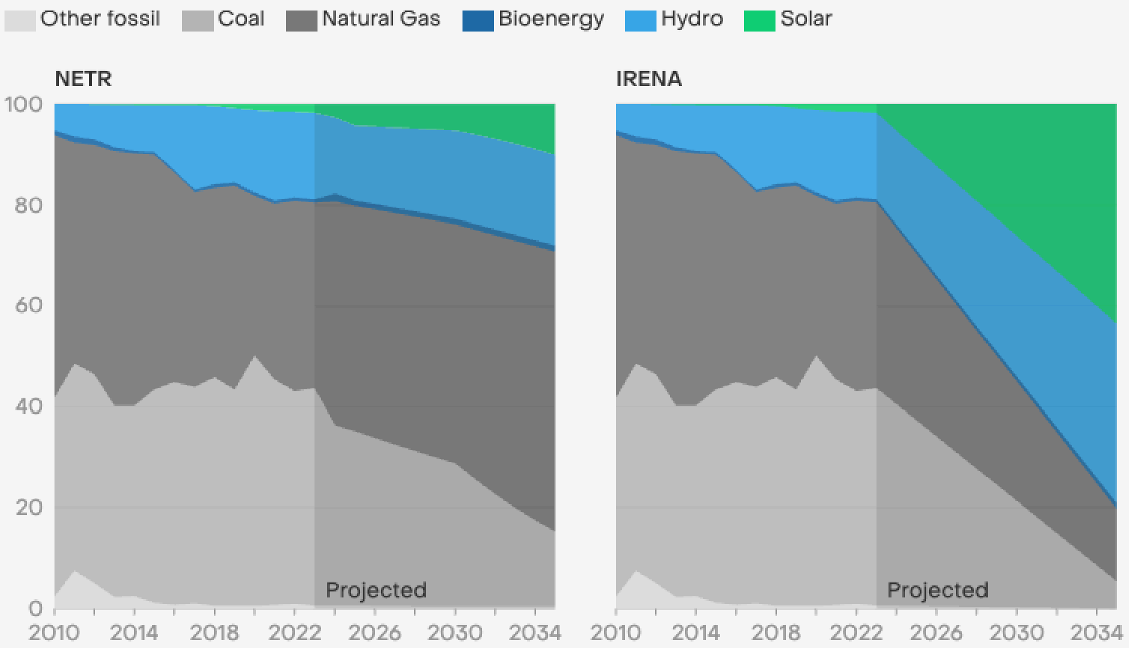
In the roadmap, Malaysia also aims to reduce its dependency on coal, with plans for a near-complete phase-out by 2045. As a start, Malaysia is committed to seizing the construction of new plants and setting out a phase-out plan for existing plants. The government recently revealed that half of the coal power plants will be retired by 2035, with a full phase-out scheduled by 2044.

Despite ambitious targets for renewable capacity additions, the estimated generation of gas will remain significant. Ember calculates renewables will constitute 52% (160 TWh) of the total generation in 2050, slightly more than gas, which is projected to account for 48% (149 TWh).

More ambitious targets are underway to achieve global and national climate goals. Several studies indicate that the 1.5 degree Celsius global warming threshold by 2100 and net zero targets by 2050 can be achieved if countries are powered with renewables while reducing fossil fuel reliance. The International Energy Agency (IEA) underscores the need for a complete phase-out of unabated coal by 2040 to align with 1.5C pathways. In addition, the IEA envisions gas power generation peaking in the mid-2030s before finally declining in the long term, and the electricity sector in developing economies reaching net zero emissions by 2045. A study by the ASEAN Climate and Energy Project (ACCEPT) also suggests that renewables should constitute 99.5% of ASEAN countries' electricity generation in 2050, with solar share comprising 61% of the energy mix.

Malaysia needs fourfold increase in solar generation to meet the 1.5°C warming threshold

Share of generation (%)



Source: National Energy Transition Roadmap (NETR), International Renewable Energy Agency (IRENA), Ember's annual electricity data

A study by the International Renewable Energy Agency (IRENA) especially suggests that to align with IRENA's 1.5C scenario, Malaysia should be fully powered by renewables in 2050, with solar power as the dominant source. Solar energy is projected to constitute a 66% share (243 TWh) of Malaysia's energy mix, playing a significant role in facilitating the decline of fossil fuels in the country's energy sector.

To align with MyRER's 2035 milestone year, Ember calculates the required increase of solar power generation based on IRENA's pathway, using Malaysia's 2050 NETR target as the baseline. Ember uses a Compound Annual Growth Rate (CAGR) approach, projecting Malaysia's solar generation to reach 83 TWh in 2035, representing a 44% share of the generation mix under the IRENA pathway. This represents a four-fold increase over Malaysia's current NETR pathway target of 10% (25 TWh) for solar generation share, as per Ember's calculation.

What is CAGR?

Compound Annual Growth Rate (CAGR) is the average annual growth rate of something—like an investment or business—over multiple years. It's a reliable way to figure out how much something grows or shrinks in value over time, making it useful for understanding how well investments are performing or how a business is growing financially.

More ambitious targets not only help Malaysia contribute to global goals but also reap the benefits of accelerating its renewable energy development, as targeted by IRENA.

In the MyRER report, Malaysia recognises the challenges arising from increasing reliance on fossil fuels, which is "slowly pushing Malaysia toward becoming a net importer of power generation fuels". The increasing price of imported coal and depletion of local gas reserves also pose risks such as fuel price fluctuations and an unstable supply of fuels, potentially leading to higher electricity tariffs. Improving Malaysia's renewables targets under the NETR promises benefits like affordability and enhanced energy security.

Renewable energy policy landscape

Due to the unique political and socioeconomic context, each region of Malaysia adopts a different approach tailored to its own challenges in progressing its clean power transition.

Peninsular Malaysia and Sabah's renewable journey began with the Renewable Energy Act 2011. The policy framework entailed the Feed-in Tariff (FiT) programme, paving the way for renewable growth. FiT is a policy mechanism that offers a long-term contract with a guaranteed premium rate for every renewable electricity supply to the producers. Subsequently, many renewable programmes have been introduced ever since.

Sarawak's renewable energy journey embarked mostly with the introduction of the Sarawak Corridor of Renewable Energy (SCORE) in 2008. SCORE is an economic development corridor initiated by the federal government of Malaysia with an emphasis on hydroelectric power owned and operated by the utility, SEB. The programme outlined 12 large hydropower projects for the period 2008-2020. As of April 2024, three of the projects are operational, with the remaining in various stages of construction, delay or cancellation.

Evolution of main renewable energy policies over the years in Peninsular, Sabah and Sarawak

Year	Peninsular	Sarawak	Sabah
2008		Sarawak Corridor of Renewable Energy (SCORE)	
2011	Renewable Energy Act 2011 Feed-in Tariff (FiT)		Renewable Energy Act 2011
2014			Feed-in Tariff (FiT)
2015		Rural Power Master Plan	
2016	Large Scale Solar 1 Net Energy Metering 1.0		Large Scale Solar 1 Net Energy Metering 1.0
2017	Self-Consumption programme (SELCO) Feed-in Tariff for solar replaced by Net Energy Metering Large Scale Solar 2 New Enhanced Dispatch Arrangement		Feed-in Tariff halted Large Scale Solar 2
2019	Large Scale Solar 3 Net Energy Metering 2.0 Renewable Energy Certificate	Renewable Energy Certificate	Net Energy Metering 2.0 implemented then displaced by SELCO
2020	Large Scale Solar 4		
2021	Net Energy Metering 3.0 Green Electricity Tariff		
2022		50 MW Floating solar pilot project started	
2023	Corporate Green Power Program	Net Energy Metering Electricity Amendment Bill 2023	
2024	Large Scale Solar 5		Self-Consumption & Large Scale Solar programmes reintroduced by Energy Commission of Sabah

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Options for transition

Solar, hydro and grid flexibility are key to meeting Malaysia's future power demand

Malaysia's twin peaks demand profile enables solar power to fulfil the daytime peak, while other options, such as hydropower and battery storage, can complement solar in meeting evening peak demand.

Almost all energy transition pathways for Malaysia see solar power as the prominent renewable source for the coming decades. But before mainstream deployment, it is essential to understand the daily electricity demand pattern and what portion of it could be met by solar without affecting grid stability or affordability.

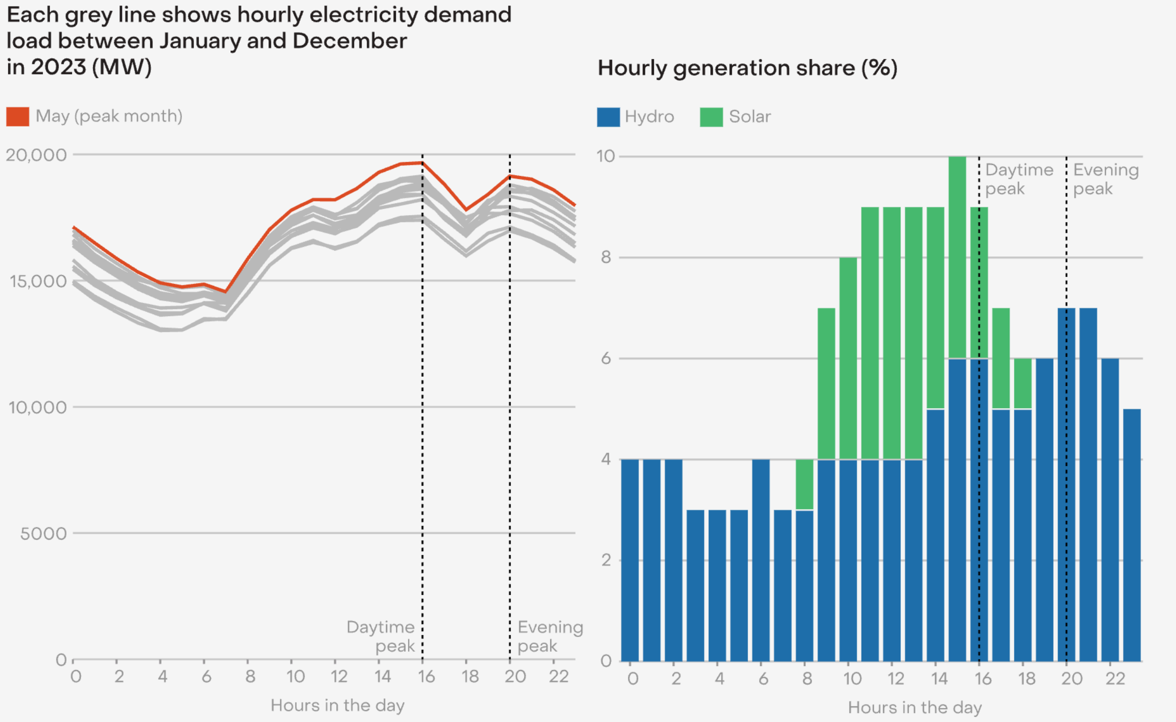
Since over 74% of Malaysia's electricity demand comes from Peninsular Malaysia, this report analyses the region's hourly electricity demand and generation profile data from 2023 to provide an indicative understanding of the country's demand patterns. Daily electricity demand patterns for Sabah and Sarawak are not calculated, as the hourly electricity demand profiles are not yet publicly available.

The "twin peaks" in the daily electricity demand profile

In 2023, Peninsular Malaysia's average hourly demand load in each month followed similar patterns, with electricity consumption recording the highest at around 4 pm in the afternoon and the second highest at 8 pm in the evening. The region's ability to meet these "twin peaks" will determine the pace of Malaysia's transition to clean energy. Peninsular Malaysia already has options to meet one of these peaks, as solar power can contribute to fulfilling the daytime peak demand when sunlight is still available.

But solar power alone will not be enough to meet the evening peak due to the absence of sunlight. Therefore, other firm dispatchable sources of electricity, especially renewables, remain necessary to complement solar power and provide flexibility in power generation based on demand.

Peninsular's hydro and solar provide 10% of the generation for the daytime peak at 4 pm, while hydro alone covers 7% for the evening peak at 8 pm in 2023



Source: Grid System Operator, Ember's analysis
Note: Average generation share of hydro and solar in a year and the highest demand load per hour in a year

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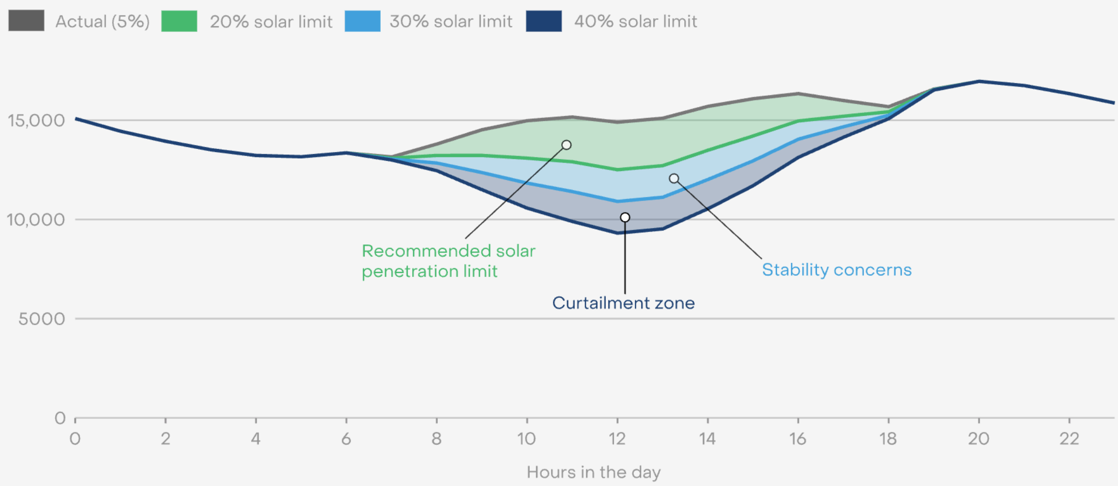
Meeting the daytime peak

A study by Det Norske Veritas (DNV) for Single Buyer has identified the solar penetration limit that Peninsular Malaysia grid can bear to maintain grid stability. The report indicates that a 20% solar and wind penetration rate into the grid is an ideal limit to ensure electricity affordability, security, and reliability (see green line in the chart below). The system can technically accommodate up to 30% penetration level. However, a 30-40% injection of intermittent solar and wind can drive higher electricity costs, risking affordability. At an above 40% rate, scheduled solar curtailment will be required to maintain a stable power supply.

Peninsular's grid can technically accept more solar penetration while still maintaining grid stability

Actual and net electricity demand (MW)



Solar penetration	5% (Actual)	20%	30%	40%
Solar capacity	799	3,195	4,792	6,390

Source: Grid System Operator, Single Buyer, Det Norske Veritas (DNV), Ember's analysis
Note: Net electricity demand is the deviation of highest demand and average generation of solar in 2023. Solar capacity for 20%, 30% and 40% is an estimate for 2023

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Based on this, the solar capacity in Peninsular Malaysia's grid can be increased further from the current level. In 2023, the highest solar penetration in the grid at any given time hit 5% (799 MW) of the mix, meaning that the grid can actually accommodate four times the amount to adhere to the 20% recommended limit (3,195 MW estimated for 2023) with no significant risk of technical impacts on the system operation, even before storage facility is needed for the system.

Meeting the evening peak is key to transition

One solution to meet the evening demand peaks is complementing solar power generation with hydropower. While fossil fuel-based power plants currently serve this flexibility in Peninsular Malaysia's grid, hydropower can offer a viable long-term replacement as Malaysia moves closer to its net zero ambitions. As a mature technology, hydropower can generate energy at all hours. However, climate change-induced changes to water levels and social and environmental impacts from large and mega hydropower plants need to be taken into account. This is how solar could contribute to the equation.

In fact, hydropower played a crucial role in 2023 by supplying electricity to Peninsular Malaysia throughout the day and ramping up in the evening as the sun set. On average, solar and hydro combined met up to 10% of Peninsular Malaysia's daytime peak in 2023. Hydropower alone, complementing solar during the evening, accounted for an average of 7% of the generation mix.

Another solution is to adopt storage facilities such as pumped-storage hydro and battery energy storage systems (BESS), which have yet to be deployed on a utility scale in Malaysia. Storage technology is a crucial facilitator to a flexible grid that can accommodate and balance the dominant supply of intermittent renewables to ensure grid stability. Intermittent renewables, such as solar, are dependent on fluctuating environmental conditions. If coupled with storage, solar energy captured in the daytime can be kept and dispatched around the clock whenever needed. For example, with 10.3 GW of installed battery capacity in California in 2023, BESS has become a significant source for meeting evening peak demand, reducing the need for high amounts of gas generation.

A high level of solar power coming into the grid can also cause possible grid disruptions without energy storage. High solar power levels can produce more electricity than the daytime demand. Over-generation can occur in such cases, leading to power curtailment.

Moreover, a dramatic increase in power supply to compensate for solar's unavailability at night can add a burden to grid stability. At very high levels of solar penetration, a portion of electricity demand is met by solar power during the day, with the remaining demand (i.e. net electricity demand) supplied with other traditional firm generation sources in the grid, such as gas and coal. As the sun sets, demand spikes, potentially leading to power system instability as the grid attempts to cope with extreme demand fluctuations during the day. Large-scale energy storage can help flatten these fluctuations. However, since storage is still limited in Malaysia, the government introduced measures to limit solar penetration to the grid at 24% of the peak demand.

To flatten the demand curve, the government has also implemented the Enhanced Time of Use (ETOU) scheme in Peninsular Malaysia. This scheme allows eligible commercial and industrial consumers to manage their electricity consumption more efficiently by choosing to use more electricity during off-peak times when the tariffs are lower and reduce the consumption during peak and mid-peak times when the tariffs are higher. By applying this scheme, TNB charges real-time pricing, disincentivising consumers from using electricity during peak hours, thus shifting the demand curve.

While recognising the crucial role of energy storage for a stable and reliable grid, Peninsular Malaysia's grid stability is expected to remain controlled with increased solar power penetration up to the recommended 20% level. Until storage technology becomes essential, the system can ramp up the use of solar energy and complement it with hydropower to meet electricity demand. This approach will naturally displace fossil fuel-based electricity generation, decreasing Peninsular Malaysia's dependency on fossil fuels.

Unlocking the benefits

Solar offers a win-win solution

Massive resource potential, energy security benefits and affordability make solar a promising energy transition option

Peninsular Malaysia and Sabah's solar power resources can improve energy security

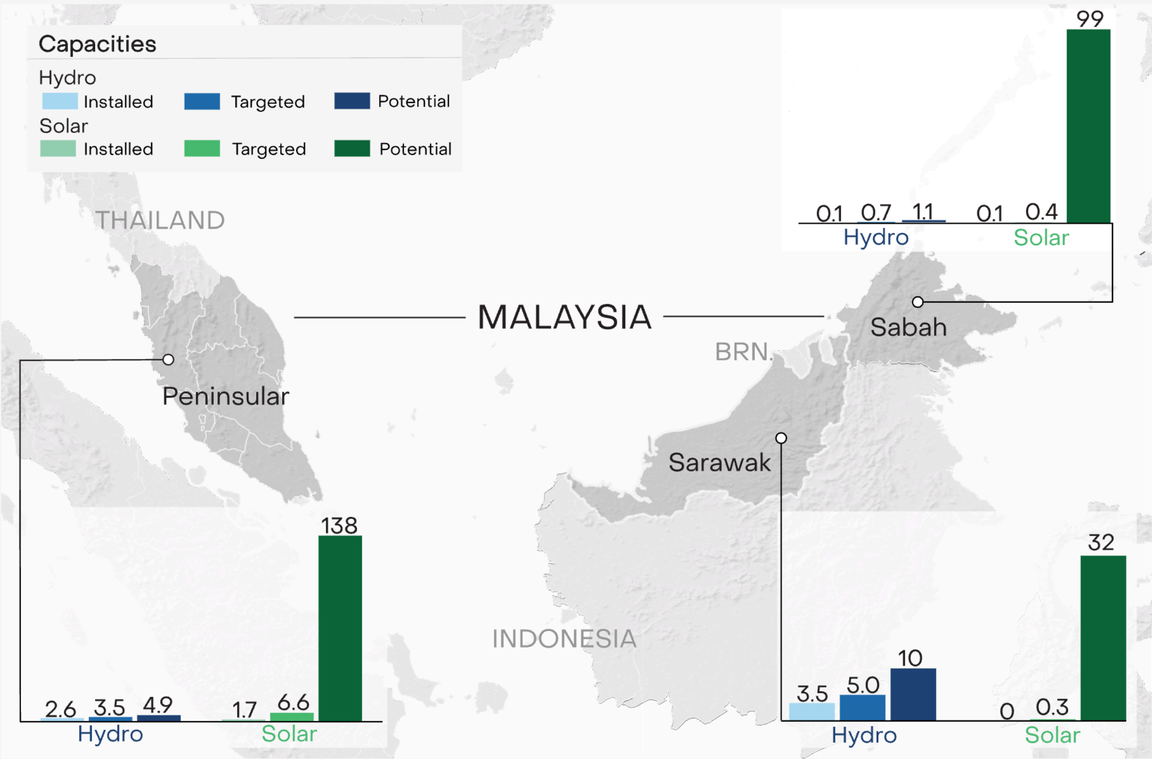
Identifying the scale of potential renewable resources is vital for implementing the proper and effective policies and programmes to boost renewables uptake. According to the MyRER report by the Sustainable Energy Development Authority, Malaysia's most abundant renewable energy sources are solar and hydropower, with resource potentials of 269 GW and 16 GW, respectively.

About half of Malaysia's solar power potential (138 GW) is located in Peninsular Malaysia, 37% (99 GW) in Sabah and 12% (32 GW) in Sarawak. Almost all of this solar resource is currently untapped. Peninsular Malaysia had the highest installed solar power capacity among the three regions, with about 1.7 GW by 2021, which is still 1.2% of its solar potential. Sabah and Sarawak developed much smaller fractions of their solar power potentials, with installed capacities of about 0.1 GW in 2021 and 0.1 MW in 2020, respectively.

Sarawak has the highest hydro potential at 10.2 GW, followed by Peninsular Malaysia at 4.9 GW and Sabah at 1.1 GW. As of 2020, Sarawak's total installed hydro capacity was the highest among the three regions at 3.5 GW, which is a third of its potential. Peninsular Malaysia developed slightly over half of its full hydro potential (55%) with 2.7 GW in 2021, while Sabah developed 9.1% of its hydro potential with about 0.1 GW.

Malaysia's solar potential remains largely untapped while over half of hydro potential will be utilised by 2030

Installed, targeted and potential capacities (GW)



Source: Energy Commission, Malaysia Renewable Energy Roadmap (MyRER) by Sustainable Energy Development Authority (SEDA) ·
Note: Peninsular and Sabah's installed capacity in 2021 and Sarawak's in 2020

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Each region has established its own renewable energy targets to support Malaysia's energy transition agenda. Sabah aims to boost its renewable generation mix to 35% by 2035, with 29% from hydro and the remaining 6.6% from other renewables. Sarawak plans to reach 10 GW total power capacity by 2030, comprising hydropower, bioenergy, solar and gas, while maintaining a minimum 60% renewable energy capacity, which can be equivalent to 6 GW. In the Generation Development Plan 2020, Peninsular Malaysia targets 8.5 GW of renewable capacity by 2025, expanding to 11 GW by 2035.

As not all regional renewable energy targets explicitly state the breakdown of planned solar and hydropower capacity, the New Capacity Target scenario in 2035 under MyRER is used as a reference. According to this plan, the proposed hydro capacities are 3.5 GW for Peninsular Malaysia, 0.7 GW for Sabah and 5.1 GW for Sarawak. However, these capacities may not be fully developed due to concerns regarding significant social and environmental impacts associated with large and mega hydropower projects. If the hydro capacities are indeed developed as outlined in MyRER, Malaysia would have utilised slightly over 50% of its identified hydro potential.

The MyRER solar capacity targets are set at 6.6 GW for Peninsular Malaysia, 0.4 GW for Sabah, and 0.3 GW for Sarawak, which collectively represents approximately 2.7% of Malaysia's total solar potential. Following MyRER, the NETR publication has raised the goal to 14 GW of total installed solar capacity by 2035. This adjustment increases the planned solar utilisation to 5.2% of the country's potential, leaving 95% of Malaysia's solar potential untapped.

Grid interconnections between the regions can unlock solar growth

Connecting the grids of Malaysia's three regions can fast-track solar growth and strengthen the country's power security. Sarawak's ample hydropower supply can help improve Sabah's low reserve margin and strengthen its power security through the grid connection planned by Sabah and Sarawak.

Furthermore, the undersea power transmission plan between Sarawak and Peninsular Malaysia can enhance the country's grid stability, allowing Sarawak to access more solar during the day and Peninsular Malaysia to use hydropower during evening peaks. This interconnection will encourage greater sharing of renewable resources amongst the regions, enabling Malaysia to rely more on its indigenous renewable power supply.

This indigenous supply of renewable energy, especially solar, can provide better energy security for Malaysia than fossil fuels. With Malaysia's massive resource potential, solar energy can meet the bulk of the country's growing electricity demand. On the other hand, the depletion of domestic fossil fuel reserves, such as gas, poses risks to power supply security.

The MyRER report indicates that the country started to shift from being a net exporter to a net importer of power generation fuel in 2018. The ASEAN Centre for Energy also forecasted that the demand for gas in Malaysia will grow fast, with a 5.2% annual growth rate from 2020 until 2050. Moreover, international geopolitical tensions, such as in Europe and the Middle East, can further destabilise gas availability in international markets, making the country's power sector more vulnerable to price volatility and supply shocks.

More affordable electricity tariff through solar

The different patterns of electricity generation mix in each region contribute to the disparity in electricity tariffs across Peninsular Malaysia, Sabah and Sarawak. In the Peninsular, where coal dominates power generation, the electricity tariff is the highest at RM38 sen per kWh for low-voltage industrial customers. Sarawak, powered mainly by hydropower, has the lowest electricity tariff at RM24 sen per kWh.

In contrast, Sabah's gas-dominant electricity results in a tariff of RM37.6 sen per kWh. These tariffs are taken from the same customer classification: low-voltage industrial customers. The industrial sector consumes the most electricity in the country (50% of total demand in 2021) and is thus taken as a representative example.

Global fuel price volatility on tariff structures risk impacting affordability

The discrepancy in tariffs across the regions can be mainly attributed to the tariff structure, which also considers the volatility of global fuel prices. The electricity tariff in Peninsular Malaysia and Sabah constitutes two main components: the base tariff and the Imbalance Cost Pass-Through (ICPT) mechanism.

The base tariff, fixed for three years and approved by the government, includes generation, transmission and distribution costs. The ICPT is a mechanism that allows the utility to adjust the government-approved tariff every six months based on fluctuations in global fuel prices (coal and gas). As a result, the ICPT determines whether there is a surcharge or rebate to the electricity tariff for customers. This structure is designed for electricity tariffs to reflect the actual generation cost as fairly as possible, mitigating the risk of fuel price volatility for the utility managing the whole electricity supply chain.

Due to the reliance on fossil fuel power plants in Sabah and Peninsular Malaysia, this mechanism can impose an additional financial burden on consumers in the regions, risking the affordability of the power sector. Furthermore, the ICPT mechanism has laid out the disparity in electricity tariffs in the three regions, especially for Sarawak, where the ICPT is irrelevant. As the utility has claimed, Sarawak has the lowest unsubsidised electricity tariff in the country, thanks to hydropower established through the Sarawak Corridor of Renewable Energy (SCORE) programme. This disparity builds a strong case for accelerating renewables, which are not susceptible to fuel price volatility, to achieve electricity affordability for all regions.

According to the Energy Commission of Malaysia, fuel prices contributed 42% of the average base tariff of Peninsular Malaysia in 2018, while other non-fuel generation costs accounted for 26%, highlighting the significant impact of fuel price volatility on affordability. Therefore, increasing renewables uptake, especially solar, can reduce the exposure to price fluctuations and the lack of fuel price factoring in solar generation costs.

Declining cost of solar power generation

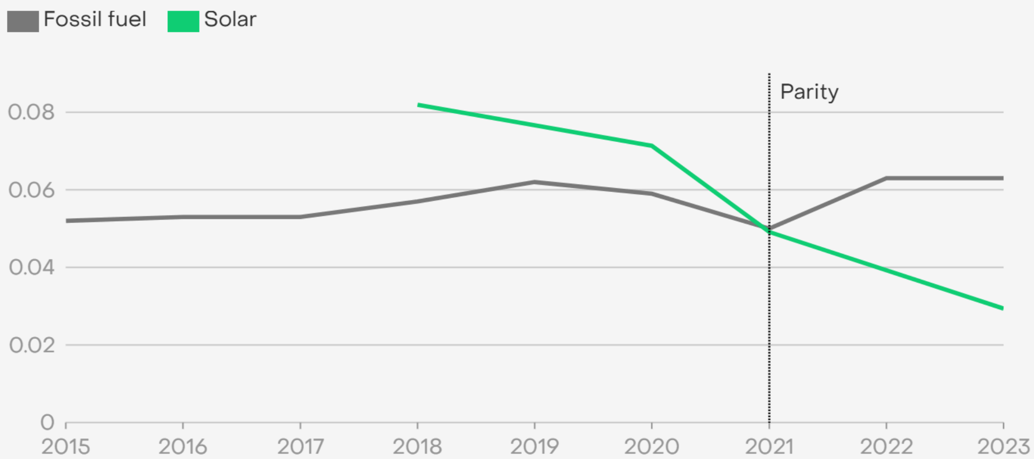
The trends of solar generation costs in Malaysia can be seen in the lowest auction rates of the Large Scale Solar (LSS) programme, mainly implemented in Peninsular Malaysia. Although the rates for awarded projects are not made publicly available, the government disclosed the auction rates submitted by bidders. The lowest auction rates have dropped by 64% since LSS 1, from $0.082 USD in 2016 (for commissioning in 2017-2018) to $0.029 USD in LSS 4 in 2021 (for commissioning in 2022-2023). This trend aligns with global trends of solar generation costs based on IRENA's study, which dropped at an even slower rate of 55% in the same period.

While the auctions were held between 2016 and 2021, the auctioned projects were targeted to start commissioning and selling electricity between 2017 and 2023. Solar generation costs calculated in past auctions represent the price at which electricity will be sold when the project is commissioned in the future.

Analysing from the years when the auctioned projects started generating electricity, solar generation costs have reached parity since 2021 and have continued decreasing while fossil fuel generation costs have fluctuated over time. The solar costs would have dropped to $0.029 USD per kWh in 2023, 53% cheaper than fossil fuel generation costs at $0.063 USD per kWh.

Having achieved parity since 2021, Peninsular Malaysia's solar costs dropped to $0.029 USD per kWh in 2023, nearly half of fossil fuel costs

Power generation cost (USD/kWh)



Source: Single Buyer, Energy Commission, Ember's analysis
Note: Solar generation costs are based on the lowest auction rates of LSS 1-4 with 30-50 MW size range to be commissioned by 2018 to 2023. Fossil fuel generation costs are obtained from electricity tariff, including surcharge and rebate fees under Imbalance Cost Pass-Through mechanism.

By looking at these trends, Ember calculates the shift of solar from fossil fuels could potentially reduce the electricity tariff for non-domestic customers by 38% in 2023, cheaper than the actual electricity tariff applied after the surcharge ($0.089 USD per kWh). However, it is worth noting that grid system upgrades are necessary to accommodate the transition in this analysis. We did not include the costs for system integration and updates in this estimate. The DNV study estimates that an 8.1% increase in total system cost may be needed if the solar penetration rate rises from 5% to 70% of the power mix in 2030, which may impact the electricity tariff rate calculation.

It is also worth noting that the bid prices from competitive solar auctions in Peninsular Malaysia can be lower than the levelised costs of electricity (LCOE), demonstrating a challenge when comparing both prices. In addition, final contract prices of selected solar plants may differ from the lowest auction rates due to the consideration of other factors, such as technical requirements, when awarding projects. Despite the discrepancies, using these tender-determined prices as a benchmark to see solar price trends in Malaysia is a useful indication that the government should consider prioritising solar projects in the coming years.

This analysis shows that Peninsular Malaysia can potentially benefit from boosting solar power generation, as it can lower and stabilise electricity tariffs, not only in Peninsular Malaysia but also in Sabah. This can help Peninsular Malaysia and Sabah bring their tariffs closer to Sarawak's. With decreasing technology costs, solar power is cheaper than fossil fuels for meeting the growing electricity demand in the long run. By decoupling the power sector from fossil fuels, Malaysia can make significant progress in sustaining and enhancing electricity affordability for all, which is an integral part of the country's vision in its National Energy Policy framework.

Addressing the barriers

Raising solar ambitions with targeted policies for solar and battery storage

Introducing policies to support initiatives in combining battery and solar technology can help further solar deployment.

Recognising the high demand from private sector customers for renewables, the government introduced the Renewable Energy Certificate (REC) and Green Electricity Tariff (GET) to support companies in achieving their sustainability goals. Implemented in Peninsular Malaysia and Sarawak, REC is a certification system that endorses every megawatt-hour of renewable energy generated.

While REC is sold separately from electricity, GET, which is implemented in Peninsular Malaysia, offers electricity bundled with REC, verifying the renewable energy use under a subscription-based contract. The customer is then charged an additional subscription fee and can claim the renewable electricity consumption from solar, hydropower and other renewables. The total subscription quota in 2023 is 6.5 TWh, an increase from 4.5 TWh in 2022.

This was made possible mainly due to the rise of solar installations in Peninsular Malaysia after 2016 when the government introduced a reverse auction programme, or the LSS programme, which has become a significant contributor to Peninsular Malaysia's solar power uptake. By May 2024, 2.3 GW MW of solar power plants contracts have been awarded, 81% of which are already operational.

The Net Metering Scheme (NEM), launched in 2016, targets households, commercial and industrial consumers and government buildings, facilitating the consumers to export excess electricity produced by their solar installations back to the grid. They are then compensated for the electricity export with a reduced electricity bill. The scheme resulted in the deployment of 1 GW solar capacity under NEM 2.0 and 3.0, making it the second-largest contributor to solar capacity after LSS. A significant fraction (89%) of the approved solar installations come from commercial, industrial and agricultural consumers.

To boost solar uptake from the private sector, the Energy Commission of Peninsular Malaysia also launched the Corporate Green Power Program (CGPP) in 2023 under the Third-Party Access (TPA) framework known as the New Enhanced Dispatch Arrangement (NEDA) in 2017.

TPA framework offers opportunities for non-conventional market participants, such as small renewable generators, co-generation plants and franchise utilities, to be merchant generators selling energy to Single Buyer through short-run (daily) competition.

CGPP is a power trading mechanism under the TPA framework that allows customers to purchase electricity directly from an independent power producer through a virtual power purchase agreement (VPPA). The power producer pays the utility a wheeling fee to compensate for the electricity distribution through the grid. VPPA is purely a financial transaction with a fixed price paid by the customer to the producer along with the transfer of a Renewable Energy Certificate (if applicable).

Wheeling fees or wheeling charges

Wheeling fees or wheeling charges on an electricity bill refer to the costs imposed by the utility company for transporting electricity through its transmission and distribution infrastructure.

With an allocated quota of 800 MW, the programme was fully subscribed to 32 participants who will receive solar energy by 2025 through virtual power purchase agreements (VPPAs) with power producers. Although corporate customers do not actually receive electricity from the solar plant, they can attribute their renewable energy use to the VPPAs for their sustainability goals.

Supportive policies are available but challenges remain

Third-Party Access framework needs more clarity on the wheeling charge

TPA can potentially reform the power market to support Malaysia's electricity export plan to neighbouring countries (i.e. Singapore). Malaysia has also lifted the ban on cross-border power trading and established an energy exchange platform. Improvements to the TPA framework, including more clarity on the wheeling fee paid to TNB, have been suggested by industry players. Determining the wheeling charge also takes into account grid development costs required to facilitate solar growth. Therefore, finding the middle ground to ensure an economical wheeling fee for power producers is key to keeping the programme running successfully.

Challenges in grid infrastructure and incentive availability slowed Sabah's solar growth

Sabah also introduced LSS and NEM in 2016, although on a smaller scale compared to Peninsular Malaysia. As of the first quarter of 2024, Sabah has awarded solar plants a total capacity of 112 MW, with 60 MW already installed. The LSS programme in Sabah was recently reintroduced as LSS-SABAH2024.

Sabah's second NEM was introduced in 2019 but later replaced by the Self-Consumption (SELCO) mechanism due to the unpopularity of the NEM scheme. The SELCO mechanism, which entails on-site solar power installations for consumers without exporting excess power to the grid, was deemed more appropriate for the grid's technicality. However, as of 2020, there are no records of SELCO installations in Sabah, indicating a need for better incentives and promotion to encourage solar power adoption in the state.

Due to the geographical spread, population density, and existing nature of the grid system, Sabah experiences a higher frequency of interruptions than Peninsular Malaysia. Consequently, Sabah's total solar quota from the LSS programme was only 150 MW (allocated in LSS 1 and 2), much less than that of Peninsular Malaysia (2,060 MW from LSS 1 to 4).

From the perspective of Sabah's power producers, long-term fuel supply commitment and securing financing for solar projects may be challenging. On top of that, geographical challenges in remote project areas can lead to high costs of grid interconnection from the power plant to the primary grid.

Sarawak's consumers may need incentives to participate in Net Energy Metering

As Sarawak has autonomy over its electricity supply governance, its approaches to developing the state's solar resources differ from those of Sabah and Peninsular Malaysia. Until recently, Sarawak did not have a wide array of programmes to boost solar growth in its territory. In 2023, the state established a NEM mechanism similar to those implemented in neighbouring regions. Additionally, Sarawak proposed an amendment to the Electricity Bill 2023 that will provide the enablers for solar panels, cascading dam installations and electricity export to other areas and countries.

However, Sarawak's cheap electricity tariffs may disincentivise consumers from participating in the NEM programme. Consumers may perceive the extra effort and costs of installing solar panels on their premises as unnecessary since they are mainly supplied by green electricity from hydropower at low tariffs. Nevertheless, as Sarawak faces increasing electricity demand and aims to be the regional powerhouse supplying electricity to neighbouring countries, the enhanced NEM programme can serve as a stepping stone towards securing and diversifying its power supply.

Harnessing opportunities with targeted policies for solar and battery storage

Promoting solar growth in Malaysia poses challenges given its historical ties between economic growth and rising electricity demand. However, Malaysia has shown that focusing on solar uptake is possible with targeted policies (e.g. LSS) and instruments that support such policies. For Sabah and Sarawak, accompanying the NEM scheme with policy instruments such as subsidies to help initial solar deployment and solar loan programmes with zero or low interest rates could make the investments and operational costs more affordable throughout the project's lifetime.

Malaysia's plans to adopt energy storage technologies should also demonstrate bankability

Maximising the solar resource potential requires updating the grid and investing in storage technologies that vary across the three regions. Without adequate grid upgrades and storage implementation, rapid solar uptake could disrupt the power systems. While diversifying electricity generation with other renewable sources like hydropower can support grid flexibility, storage facilities will be important in the long run when solar picks up the pace to lead the transition.

Malaysia's plans for grid upgrades and storage facilities are included in the roadmaps, but there are limited details on the pathway for further development of these technologies.

In the MyRER report, there is a preliminary analysis that Peninsular Malaysia will require 5.7 GWh of energy storage by 2035, anticipating a 30% solar penetration. The Peninsular Malaysia's Generation Development Plan also includes developing a 100 MW capacity of BESS every year from 2030 until 2034, bringing a total of 500 MW installed capacity. Additionally, NETR outlines a plan to develop storage facilities from a total of 2,500 MW hybrid hydro-floating solar plants at TNB hydro dam reservoirs.

Sabah plans to install 120 MW of BESS capacity between 2023 and 2026 while enhancing its grid infrastructure and establishing interconnection with Sarawak. The plans for grid upgrades and storage facilities in Sarawak are not yet specified. Still, the state has started the initiative through its electricity amendment bill for pumped storage hydro with cascading dams and the plan to enhance grid interconnection, including the undersea cable across the South China Sea.

In addition to these grid interconnection plans, a feasibility study is underway to evaluate the possibility of connecting Peninsular Malaysia with Sumatra, and Sabah with Kalimantan. Similar studies can also be carried out to explore the potential of Malaysia's domestic grid interconnection.

Amidst the plans for implementing BESS in the near to medium term, the government has initiated research, development and early engagements with the private sector. However, private sector investment in BESS technology remains limited. To boost investor interest in BESS technology, relevant authorities in Malaysia need to establish dedicated guidelines for BESS connections, similar to those for LSS connections.

BESS technology has been included as an optional installation in the LSS 3 and 4 programmes, aimed at on-site consumption and reducing power plant intermittency. However, successful bidders have yet to install BESS in the projects because BESS installation could result in more expensive solar project costs.

Conducting studies to analyse the economic and technical viability of utility-scale BESS systems would be beneficial. These studies will enable the government to demonstrate the bankability of BESS projects in Malaysia.

Options to stimulate battery storage growth

Tapping into the private sector's expertise and financing to develop BESS is crucial. As one of the favourable investment destinations for green energy technology in Asia, Malaysia has the potential to leverage BESS investment opportunities. While tax incentives for battery technology are provided under the guidelines for Green Investment Tax Allowance (GITA) and Green Income Tax Exemption (GITE), more policy instruments such as increased financial incentives from subsidies for BESS technology imports may increase the attractiveness of investing in BESS.

A tender can attract BESS industry players. In 2023, India launched a tender called Firm and Dispatchable Renewable Energy (FDRE), which integrates intermittent energies like solar with energy storage systems, transforming solar power into dispatchable energy that supplies round-the-clock electricity market demand as a single power plant. This concept acts as a Virtual Power Plant (VPP).

Targeted policies for solar growth and utility scale Battery Energy Storage System (BESS) adoption

Technology: Solar, BESS

Boosting solar adoption in Sabah and Sarawak

Offering solar loan programme with zero to low interest rates and subsidies to initiate solar deployment in the Net Energy Metering programme

Integration of BESS in the LSS and CGPP programmes

Applying a Virtual Power Plant concept to integrate BESS in the Large Scale Solar auction and Corporate Green Power Programme.

Virtual Power Plant (VPP) means transforming solar power into dispatchable energy that supplies round-the-clock electricity market demand as a single power plant.

A different tariff scheme for BESS

A different tariff scheme to compensate BESS services in power system, such as ancillary service and energy arbitrage.

Ancillary services include providing system backup and maintaining grid stability through peak demand reduction. Energy arbitrage means storing energy when electricity prices are low and releasing it when they are high.

Source: W.S.W. Abdullah et al. (2021), W.H. Tee et al. (2024) EMBER

Power producers can measure the price bid based on the demand specified by the utility and the estimated power output of the installation. Similar tender designs can be implemented in the LSS programme across Malaysia to stimulate BESS market competition, thus driving BESS costs down. Considering the limited local BESS industry players in Malaysia and the early stage of development of the market, the LSS programme may need provisions for foreign companies to participate in the tender. Expanding the quota for foreign bidders in Malaysia may allow more competitiveness and technology transfers of BESS.

A similar approach can also be replicated under the NEDA programmes to relieve the utility's burden of upgrading grid infrastructure. The CGPP, one of the NEDA programmes, allows corporate consumers to secure renewable electricity from a power producer through the utility grid, with BESS as an optional technology to reduce intermittency.

However, a different tariff scheme should be provided to compensate for the solar-BESS services as a VPP. The programme can cover some possible BESS services, such as energy arbitrage and ancillary services, from which storage facilities can benefit financially. Energy arbitrage means storing energy when electricity prices are low and releasing it when they are high, while ancillary services include providing system backup and maintaining grid stability through peak demand reduction. Generators can provide these services to the utility as the grid operator and receive market-based payment under the TPA framework. This distributes grid development responsibility from the utilities to other power market participants. Moreover, targeting cross-border trading under this framework can increase competition among power producers, which may potentially lower the costs.

Holistic system-wide planning and policies are important for supporting the ramping up of solar and facilitating it with grid flexibility, to be on track for a net zero target by 2050. The establishment of a National Decarbonisation Committee is a positive step towards adopting a more holistic approach to ensure secure and affordable electricity nationwide, advancing the transition to clean energy.

Securing the future

Advancing solar goals can bolster Malaysia's energy affordability and security

64% fall in utility-scale solar cost in Malaysia between 2016 to 2021 demonstrated the possibility to further accelerate solar growth.

Malaysia's substantial solar potential is an advantage for transitioning away from fossil fuels. This is further supported by the country's long-standing policies that encourage solar adoption and affordability of solar technology. The existing NETR (National Energy Transition Roadmap) target, which prioritises solar as the primary renewable source, can play a role in balancing electricity reliability and sustainability. However, by quadrupling solar power generation by 2035 to align with the IRENA pathway, Malaysia can also bolster energy security and introduce affordability benefits to the power sector transition.

Peninsular Malaysia's twin demand peaks demonstrate that solar power is the feasible option for Malaysia to transition away from fossil fuels. Solar intermittency can be challenging to address, especially with the conventional grid infrastructure, but complementing solar with hydropower and adopting battery storage at scale can be the solution to ensure power supply meets the demand. Before battery storage becomes vital to maintaining grid stability, Malaysia can expand its solar deployment and further harness its solar potential.

With the falling utility-scale solar generation costs in Malaysia, there are opportunities to reach the country's power sector net zero ambitions faster. Holistic system-wide planning can support the country in accelerating its clean energy transition, paving the way for it to reap the benefits of less exposure to fuel price volatility risks and lower the possibility of becoming a net power generation fuel importer.

Supporting Materials

Methodology

Regional electricity demand estimates for 2021-2023

The electricity demand for Peninsular Malaysia, Sabah and Sarawak from 2021 to 2023 is estimated by calculating each region's demand share in the respective years, derived from electricity demand data from eStatistik, against Malaysia's total electricity demand from Ember's Electricity Data Explorer.

The Compound Annual Growth Rate (CAGR) is calculated to analyse the changes in Peninsular Malaysia and Sarawak's demand shares from 2010 to 2020. Peninsular Malaysia's demand share shows a decreasing pattern (-1.5% year-on-year) while Sarawak's is increasing over the years (+13% year-on-year). Sabah's demand share is relatively constant, using an average of 4% demand share.

NETR's electricity generation estimates

The estimated generation volume of the NETR target in 2035 is derived from the 2035 capacity target outlined in the NETR report multiplied by capacity factors from some studies and full day and year operating hours.

Bioenergy and hydro capacity factors (60% for both) are taken from Peninsular Malaysia Outlook 2019. A capacity factor for gas power plants of 60% is used while the capacity factor for coal is 67.5% obtained from the average of two studies, Columbia University and Universiti Tenaga Nasional. Recognising that solar technologies keep advancing over the years, a 20% capacity factor is included in the calculation.

Net electricity demand estimates

Net electricity demand is the peak hourly demand minus the average hourly solar generation for 2023. For each scenario of increased solar penetration, increased solar generation is determined by adjusting the actual solar generation in 2023 according to the desired penetration level. For instance, if the actual solar generation in 2023 corresponds to a 5% solar penetration, then to estimate the solar generation for a 20% penetration limit scenario, multiply the actual solar generation by a factor of four.

Fossil fuel, solar generation costs and electricity tariff estimates

Ember analyses the comparison of solar and fossil fuel generation costs. The potential electricity tariff with solar power replacing fossil fuels is also estimated and compared with the actual electricity tariff in 2024.

The coal and gas generation costs of Peninsular Malaysia are obtained by adding the base tariff with the surcharges and rebates applicable to non-domestic customers between 2015 and 2023. The solar generation costs come from the lowest auction rates with a 30-50 MW capacity size range. An exchange rate of USD 0.21 per Malaysian Ringgit (MYR) is used across the years to present a comparable analysis.

To estimate the solar-dominant electricity tariff in Peninsular Malaysia, existing retail, transmission, and distribution costs are added to solar generation costs, assuming no significant grid upgrades are needed to accommodate solar between those years.

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Cover image

Solar panels to provide power supply on the island of Semporna, Sabah, Malaysia.

Credit: Muslianshah Masrie / Alamy Stock Photo