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PUBLIC REPORT

Transitioning Coal-Fired Power in Malaysia

Coal-fired power plant (CFPP) early retirement and repurposing strategies

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Abbreviations

Abbreviation	Description
BAU	Business as Usual
BESS	Battery Energy Storage System
CFPP	Coal-fired Power Plant
CAPEX	Capital Expenditure
CO_2	Carbon Dioxide
DCF	Discounted Cash Flow
IRR	Internal Rate of Return
JT	Just Transition
NGFS	Network for Greening the Financial System
NPV	Net Present Value
OPEX	Operational Expenditure
P&L	Profit and Loss
PPA	Power Purchase Agreement
RE	Renewable Energy
Solar PV	Solar Photovoltaic
UEL	Useful Economic Life

Contents

Purpose of this report

This report aims to provide a clear, actionable, and replicable framework for stakeholders in Malaysia to assess and implement coal-fired power plant (CFPP) transitions. It outlines a step-by-step approach to prioritising, evaluating, and implementing transition pathways for CFPPs in Malaysia.

It draws on publicly available data to demonstrate how CFPP transitions could be evaluated, including an illustrative case study of a representative plant to highlight the financial, policy, and just transition dimensions that must be addressed to achieve a successful phase-out.

It should be noted that while plant-level confidential data was not accessible, we have based our analysis on published sources. If full plant-level data were available, it may have improved the accuracy and detail of the assessments undertaken. Nevertheless, key conclusion from this work are unlikely to change, for example:

- The economic fundamentals driving the transition in Malaysia are unlikely to change – utility scale solar PV is already the least-cost option, despite the need for additional flexibility and storage
- Emerging options like ammonia co-firing remain costly and are unlikely to offer cost competitive decarbonised options in the future
- Carbon pricing would create additional cost pressures on coal, further shifting the economics in favour of renewables

This report draws from the findings of a more detailed study conducted for the UK FCDO in Malaysia.

Making the case for accelerating Malaysia’s coal phase out

Key takeaways for policymakers and coal asset owners to consider:

Accelerating coal phase out and investing in technologies e.g. solar PV and battery energy storage would drive substantial carbon savings

By speeding up the phase-out of coal, Malaysia can cut carbon emissions and meet its net-zero target by 2050. Policymakers should act quickly, as faster transition means bigger carbon savings. Switching to solar power and battery storage can help accelerate this shift. However, funding this change must consider the potential loss of revenue from existing power agreements.

Policy reforms are necessary to manage early coal retirement

To support the coal phase-out and renewable energy integration, Malaysia will need to make changes to its power markets. This includes removing coal subsidies, introducing carbon pricing, and providing more incentives for renewable investments. These changes will ease the financial burden on plant owners, improve energy security, and help achieve the country’s climate goals.

Just transition principles should be accounted for in energy transition strategies

Policymakers should prioritise worker retraining, especially for coal sites transitioning to technologies like solar PV, which may need fewer onsite workers. However, investing in a domestic solar supply chain — covering manufacturing, installation, and maintenance — could create significant economic opportunities. The transition to cleaner technologies should also include measures to protect community cohesion and reduce the risk of unemployment and economic challenges.

Carbon taxes could make coal less viable, accelerating the shift to solar PV and energy storage solutions

Malaysia plans to introduce a carbon tax, although details on sector coverage and pricing are still being defined. This tax could significantly impact the power sector. If coal plant owners cannot pass the cost onto consumers, they may face lower profits, stranded assets, and need to retire plants early. However, if the cost is passed on due to power purchase agreements (PPAs), power tariffs in Malaysia could rise. In contrast, solar power presents a cheaper and cleaner alternative. As the carbon tax makes coal less competitive, it strengthens the case for solar and energy storage. Policymakers should prioritise these technologies for a cost-effective transition away from coal.

Section 1

Malaysia's energy transition

Malaysia’s energy transition context

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As Malaysia works towards its climate goals, phasing out coal-fired power plants (CFPPs) is a key challenge. With a target to reach net-zero emissions by 2050 and 70% renewable energy capacity, the country is exploring pathways for an early and sustainable coal phase-out.

Current energy mix

- **Installed capacity:** 38% natural gas, 34% coal, 27% RE, 1% diesel.
- **Grid stability:** Peninsular Malaysia has a healthy reserve margin (22-36%), but Sabah faces greater disruptions and instability
- **Solar PV growth:** Solar PV has been growing but faces challenges like lack of financing options, and the need for grid upgrades

Infrastructure

- Peninsular Malaysia holds the **majority of CFPP capacity**, while Sabah and Sarawak rely more on gas and hydropower
- **Absence of interconnection** between grids in these regions limits the potential for balancing supply, demand, and RE integration

Policy

- **Subsidies:** The government subsidises energy prices, keeping electricity tariffs among the lowest in the region. While this benefits consumers in the short term, it also exposes Malaysia’s public finances to the volatility of global fossil fuel markets
- **Energy security:** As a net importer of coal and facing shrinking natural gas reserves, Malaysia’s energy security could be at risk

Challenges for the transition

- **Grid constraints:** Targeted technical upgrades needed to support higher solar PV and variable RE integration. Key priorities include expanding transmission capacity, enhancing flexibility with energy storage systems and demand side response, and modernising the grid through smart technologies
- **Financial support:** Developers need more support for RE projects
- **Just transition**: Ensuring CFPP workers and affected communities are supported through the transition

Source: IRENA Malaysia Energy Transition Outlook

Section 2

A policy framework for CFPP transition in Malaysia

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Policy framework for coal transition and RE deployment

To develop actionable and country-specific recommendations, it is essential to evaluate the enabling environment that supports or hinders the coal-to-renewables transition.

A — Policy and market readiness

- Are national goals aligned with coal phase-out timelines?
- Do electricity markets support RE investment?
- Are carbon pricing or subsidy reforms needed?
- Are permitting and policy barriers addressed?

B — Financing and investment

- What financial barriers exist for renewables and storage?
- Can transition finance support early retirement of thermal generation assets?
- What incentives reduce upfront capital costs for renewables?
- Which international funds can be utilised?

C — Grid and system planning

- What technical upgrades are requirement to facilitate a higher penetration of renewables?
- Where are the technical constraints?
- How is demand-side flexibility encouraged?
- Which other types of flexibility can be utilised?

D — Just transition

- Which workers/communities are most affected?
- What retraining or upskilling is needed?
- How can job creation be maximised?
- How are decisions ensuring inclusive and equitable outcomes?

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Policy actions to support Malaysia’s coal transition

The following recommendations relate to the policy framework and are tailored to Malaysia’s context, supporting a just and cost-effective transition away from coal.

A Policy and market readiness

- Strengthen policies to phase out coal in **Peninsular Malaysia**, where most coal capacity is concentrated
- Reconsider **coal subsidies and explore carbon pricing** to disincentivise continued CFPP operation
- Address **high upfront Energy Storage Systems (ESS) costs** through regulatory frameworks and innovative financing mechanisms

B Financing and investment

- Explore and adapt **international models** for coal plant retirement (e.g. refinancing, transition finance mechanisms)
- Create markets that **reward flexibility and clean energy** while penalising inflexible fossil assets
- Conduct further studies to assess the **cost-effectiveness and viability of retirement pathways**

C Grid and system planning

- Promote **large-scale adoption of ESS** through targeted policies and incentives
- Explore opportunities for **interconnection**
- Encourage **demand-side flexibility**, system planning, and integration of new technologies
- Address **technical grid constraints**, particularly in Sabah and Peninsular Malaysia

D Just transition

- Integrate **just transition planning early** to support affected workers and communities
- Develop **training and certification** for solar and BESS roles
- Support **local job creation** through solar supply chain development

Section 3

A site-specific framework for CFPP transition in Malaysia

Steps for assessing CFPP transition pathways

There are several options for transitioning coal-fired power plants (CFPPs). The Carbon Trust has developed a structured approach to help navigate key considerations and trade-offs to assess which solutions may be most suitable for a specific CFPP.

1

Prioritise CFPPs for transition

Use a multi-criteria analysis (MCA) to evaluate a portfolio of CFPPs based on their energy security, cost, socioeconomic and environmental impacts

2

Identify viable transition scenarios*

Assess the technical and economic feasibility of transition options in the Malaysian context such as retrofits, conversion to different technologies, or replacement with renewable energy

3

Evaluate site-specific factors

Consider the CFPP site characteristics such as its technical attributes, resource availability, site suitability for transition options and the expected impact on the grid

4

High-level financial analysis

Compare costs and benefits e.g. NPVs, levelized costs of energy, CAPEX, cost savings and potential revenues of different transition scenarios, while considering carbon pricing sensitivities

5

Assess just transition implications

Evaluate workforce exposure, retraining and employment opportunities, and regional economic diversification potential

**Transition scenarios provide alternative pathways for CFPPs to transition to low-carbon operations, beyond the typical "Business as Usual" (BAU) approach. These scenarios aim to explore innovative and feasible decarbonisation strategies while maintaining energy security and economic viability.*

Step 1: Prioritise CFPPs for transition (1/3)

The Multi Criteria Analysis (MCA) prioritises plants based on four key dimensions and ensures that plants selected for early retirement:

(i) will have the **least impact on the security of supply**,
(ii) are the costliest or **least financially viable** to operate ,
(iii) are **most environmentally damaging**,
(iv) and have the **smallest socioeconomic impact** in terms of livelihood generation and community contribution**.**

The MCA enables policymakers or asset-owners to make balanced, evidence-based decisions that align with national decarbonisation goals while minimising trade-offs. To ensure that both regional and plant-level considerations are captured in the MCA, a set of four scores were developed to help frame the interconnections between the energy system, policy, economic and social dimensions of the coal transition:

Energy Security Score

Indicates how important a plant is to maintain the power system security of supply in the future. CFPPs that play a significant role in the power generation mix should not be prioritised for transition.

Financial Viability Score

Indicates how costly it is to continue operating the CFPP. The more costly it is, the greater the likelihood that the owner might be willing to explore transition options.

Environment Score

Indicates how damaging the plant is in terms of contribution to emissions and air pollution. The greater damage it causes to the environment, the higher the priority it should be to transition the plant.

Just Transition Score

Indicates the quality of life of those directly affected by the CFPP's continued operations. Plants responsible for significant livelihoods should not be prioritised for transition.

Step 1: Prioritise CFPPs for transition (2/3)

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Across the four dimensions, the MCA is divided into two components to assess (i) the country context in terms of its degree of readiness to enable a transition to clean energy, and (ii) plant-specific characteristics and operating conditions. This approach connects the feasibility of early plant retirements with national transition readiness, ensuring that the shift is both technically viable and supported by comprehensive policy and market frameworks.

Energy security

- Forecasted share of coal generation in total power generation
- Forecasted share of coal capacity in total power capacity
- Forecasted adjusted power excess capacity
- Ambition of national coal phase out commitments
- Ambition of renewable energy policy plans
- Role of gas in the energy mix
- CFPP efficiency
- CFPP size
- CFPP utilisation rate

Financial viability

- Exposure of coal assets to competition
- Level of market support for renewable energy
- Presence of coal sector subsidies
- Amount of equity/return guaranteed for CFPP owners
- National debt levels
- CFPP variable operating and maintenance costs
- CFPP utilisation rate

Environment

- Contribution of power sector emissions to national emissions
- Strength of environmental regulations
- Evidence of enforcement of penalties for environmental breaches
- CFPP carbon intensity of operations
- CFPP air pollution

Socioeconomic

- Government budget allocation for just transition
- Policies set to support affected workers and communities
- Access to education and retraining for green jobs
- Importance of coal to the economy (coal rent as % of GDP)
- Number of direct workers in the CFPP

Key: Country-level factor (blue) | Plant-level indicator (green)

Step 1: Prioritise CFPPs for transition (3/3)

The MCA integrates both regional-level and plant-level factors to inform how CFPPs are ranked for transition. An example of how the scoring is conducted is provided below.

a) **A qualitative assessment is carried out to determine the country's "readiness" across each dimension.** This assessment indicates the level of importance each dimension should have within the MCA framework and informs the allocation of weightings.

b) **Each plant-level indicator under the energy security, financial viability, environment and socioeconomic dimension is assigned a value between 0-1** based on pre-defined rules and thresholds. The scoring thresholds are developed based on the fleet characteristics of the region and can be adjusted to different geographies to account for their local context.

c) **The average of the total Security, Cost, Environment and Socioeconomic scores are taken to derive the Total Plant Score,** which is used to inform the final ranking of the CFPPs.

Example scoring rules for CFPP utilisation rate (Energy security dimension)

Plant Level Indicator	Criteria	Value	Energy Security Readiness Assessment		
			High	Medium	Low
Utilisation	Low utilisation	0 ≤ x ≤ 40%	0	0.5	1
	Medium utilisation	40% < x ≤ 60%	0.5	1	0.5
	High utilisation	>60%	1	0	0

- **The MCA prioritises differently based on the plant's power utilisation rate,** depending on the country-level readiness assessment, which looks at energy security plans and the role of coal in the future power generation mix.
- **Plants with high utilisation should only be prioritised when the energy transition readiness assessment notes a high level of energy security readiness** in future policy and a low level of coal in the forecasted generation mix so as minimise disruption to energy security.
- **Based on this assessment, coal is expected to play a role of low importance** in Malaysia's future power generation mix alongside **high energy security readiness** through policy. Hence, plants with high utilisation levels are prioritised, followed by plants with medium utilisation as this is not expected to compromise energy security given the large current role of natural gas in flexibility provision.

Step 2: Identify viable transition scenarios (1/2)

Transition scenarios provide alternative pathways for CFPPs to shift toward low-carbon operations, compared to a "Business as Usual" (BAU) approach. These scenarios aim to explore innovative decarbonisation strategies that maintain energy security while promoting investment opportunities. By evaluating various options, asset owners can identify the most cost-effective, balanced solutions suited to site conditions.

BAU

- **BAU:** no changes to current CFPP operations; continue as per usual (used as a baseline).

Retire

- **Retire and mothball**: CFPP is deactivated but remains structurally intact. CFPP can be reactivated for use in future if needed.
- **Retire and decommission:** CFPP is retired, dismantled, and site is remediated.

Retrofit

- **Run flexibly:** Retrofit to reduce generation and provide system balancing and flexibility services.
- **Carbon Capture and Storage (CCS):** Retrofit with CCS technology to capture carbon emissions from coal combustion.
- **Ammonia co-firing:** Retrofit to co-fire coal with ammonia.
- **Biomass co-firing:** Retrofit to co-fire coal with local biomass feedstocks (could also explore full conversion).

Convert

- **Synchronous condenser:** Retire CFPP and convert induction generators to synchronous condensers for grid stability services.
- **Small modular reactor (SMR) (nuclear):** Retire CFPP and convert turbines and steam cycles with SMR technology.
- **Advanced geothermal:** Retire CFPP and convert equipment to support geothermal power generation.

Repurpose

- **Solar PV:** Retire CFPP and build a solar PV plant on existing site.
- **Onshore wind:** Retire CFPP and build an onshore wind plant on existing site.
- **Gas and green hydrogen:** Retire CFPP and build a CCGT plant to co-fire natural gas and green hydrogen.
- **Energy storage*:** Retire CFPP and build a standalone battery/thermal energy storage facility on existing site.

** Energy storage can be paired with other options such as solar PV*

Step 2: Identify viable transition scenarios (2/2)

The transition scenarios are evaluated according to the following criteria on a Red-Amber-Green (RAG) scale, from the perspective of Malaysia's national energy context. This approach enables a clear and comparative assessment of each option's feasibility and impact - helping decision-makers quickly identify which pathways align best with Malaysia's energy goals, environmental priorities, and economic realities.

Criteria	Red	Amber	Green
Technology readiness- proof of use in the Malaysia / deployment of technologies at scale.	**Immature technology** globally and with **very little usage** in Malaysia.	**Some level of maturity** globally, and with **some usage** in Malaysia.	**Relative matured technology** globally and with a **high degree** of usage in Malaysia
Economic viability - The expected new capital expenditure from the option versus the overall cost savings generated from repurposing and re-using existing infrastructure, equipment	**Large upfront investment** required. **Low cost savings- Requires mostly / all new equipment –** no/limited option to retain/re-use existing equipment/infrastructures – may need government support	**Some upfront investment** required. **Medium cost savings - Some equipment re-used and/or workforce retained –** new transmission grid infrastructure might need to be built.	**Minimal upfront capex** required. **High cost savings - Majority of equipment and workforce retained –** existing transmission infrastructure reused / no new cables.
Environmental impact – expected emissions profile of the option.	Lifecycle emissions reduction potential is **significantly less** than the BAU option	Lifecycle emissions reduction potential is **comparable** to BAU option .	Lifecycle Emission reduction potential **is significantly greater than the BAU option**
Job creation – opportunities to retain workers through skills transfer or retraining and/or new employment.	**Majority of current workforce** needs retraining/reskilling.	**Some of current workforce** can be retained with reskilling/retraining.	**Majority of the current workforce** can be retained with **little to no** retraining/reskilling.

Step 3: Evaluate site-specific factors

Following the shortlist of suitable transition scenarios identified for Malaysia's national energy context, the next step is to assess how well each scenario aligns with specific plant or site conditions. This involves evaluating technical, environmental, and operational compatibility to determine which scenarios are most feasible and effective for individual sites.

By comparing the ideal conditions required for each scenario against the characteristics of a given plant, this step helps ensure that the recommended transitions are not only nationally relevant but also practical at the site-level, minimising the risk of stranded assets or suboptimal investments.

Plant profile

- A CFPP's age, size, and efficiency serve as key indicators for assessing the cost-effectiveness, remaining operational life, and emissions reduction potential of various transition scenarios

RE availability

- The RE availability and replacement capacity potential of the CFPP site and how readily accessible and usable it is

Site suitability

- Attractiveness of the site in relation to the transition scenario option, considering space, surface type, vegetation, land use, etc.

Expected costs of replacement capacity

- The expected costs based on the type and size of potential replacement capacity of the CFPP

Type of available infrastructure

- Availability of roads/transport networks for build out of new replacement options
- Size of existing grid connections. Other existing reusable infrastructure

Stakeholder preferences (socio-economic)

- Presence of stakeholder (e.g. communities) preferences for CFPP or alternative transition scenarios

Expected impact on the grid

- The impact of applying the transition scenario to the selected CFPP in terms of its effects on network stability.

Step 4: High-level financial analysis

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After identifying feasible transition scenarios and assessing site-level suitability, a high-level financial analysis is conducted to compare the BAU trajectory with the shortlisted transition pathways. This analysis helps evaluate the cost implications of each option, highlighting which scenarios are financially sustainable and which may present greater risks.

1 Scenario development

Financial assumptions are established based on plant-specific data (considering key metrics like OPEX, CAPEX and expected revenue). In absence of plant-specific data, secondary research from similar markets, e.g. Southeast Asia markets can be used.

2 Discounted cashflow valuation

Assess the BAU financial performance of CFPPs by using a discounted cashflow (DCF) to evaluate the financial viability of continuing BAU operations without transitioning (factoring in existing PPA conditions where available).

3 Financial analysis of transition scenarios

Analyse the financial implications of key transition scenarios to determine the most financially viable solution, through analysis of DCF, net present value (NPV), internal rate of return (IRR), CAPEX costs, and avoided emissions.

4 Comparison of financial outcomes

Compare the financial outcomes of pursuing the BAU and transition scenarios in terms of lost and new revenue, new CAPEX and debt servicing, and total cost of transition scenario (including decommissioning) and just transition costs.

Step 5: Assess Just Transition Implications (1/2)

To understand the social implications of transitioning away from coal, the next step involves establishing a baseline profile of the workforce and jobs at risk - including direct, indirect, and induced employment. This includes analysing key characteristics such as worker demographics, income levels, roles, skill requirements, and the presence of social protections or benefits that may support a just transition.

By comparing these baseline characteristics to potential alternative employment opportunities under each transition scenario (e.g. Solar PV), it is possible to assess the transferability of skills and identify any gaps that may require targeted support, such as reskilling programs.

Jobs

Direct employees: those employed by the CFPP undergoing closure.

Indirect employees: those employed by industries reliant on the CFPP undergoing closure.

Induced employees: those working in industries enabled by the spending of direct workers.

1. Types of jobs at risk

- Determine the number of jobs at risk.
- Evaluate the types of jobs at risk, including roles, responsibilities, skill levels, contract types and working conditions.
- Establish worker demographics and characteristics (i.e., income level, skills, education).
- Identify disproportionally vulnerable workers (e.g. women or low-income groups).

2. Types of new transition scenario jobs

- Evaluate the types of jobs required including roles, responsibilities, skill levels, contract types and working conditions.
- Establish typical worker demographics and characteristics (i.e., income level, skills, education).

3. Assess transferability to new jobs

- Assess skills transferability of workers to new industries and accessibility of existing alternative livelihood options.
- Identify potential redundancies and skill gaps and access to skills training opportunities to support re-employment.

Step 5: Assess Just Transition Implications (2/2)

To ensure a just and inclusive energy transition, it is important to understand the social and economic resilience of workers and communities affected by coal plant closures. This step provides a framework to assess the broader community and environmental impacts of each transition scenario.

Assess socioeconomic resilience and community impacts of CFPP closure and transition scenario		
Revenue and services	**Community cohesion**	**Environment and health**
• Assess dependence of state revenue on incumbent industries. • Identify basic services to be impacted by state revenue loss and plant closure. • Identify public services provided by the polluting industry at risk. • Evaluate industry contribution to national and state revenue. • Evaluate the social spending of incumbent industries (e.g. CSR).	• Evaluate socioeconomic resilience and potential vulnerabilities of the community by collecting data on poverty rates, employment rates, income inequalities, and access to social / state benefits. • Understand community concerns and attitudes towards plant closure. • Assess likelihood of social tension, conflict, and increased gender-based violence; and strength of cultural and social ties to the displaced industry.	• Evaluate impact of plant closure on greenhouse gas emissions. • Determine impacts of plant closure on air pollution, water, land and potential for hazardous waste. • Determine any introduction of new environment, health and safety hazards.

Section 4

Applying the site-specific CFPP transition framework: A case study

Introduction to the case study

This case study aims to serve as a practical decision-support tool for policymakers, utilities, and investors by developing a transition plan for an anonymised CFPP, with the goal to:

- Demonstrate how to prioritise CFPPs for retirement based on integrated criteria.
- Evaluate realistic repurposing pathways grounded in national policy and plant-specific characteristics.
- Inform site-specific investment planning, workforce transition programmes, and renewable energy deployment strategies.

The case study applies the site-specific CFPP transition framework to (i) identify a suitable plant for early retirement, (ii) assess transition options that leverage Malaysia's natural resource potential, policy landscape, and the plant's technical characteristics, and(iii) evaluate the financial outcomes and just transition impacts associated with the selected transition pathway.

As part of this approach, the case study includes the following analysis:

Technical suitability

Assessing site specific characteristics related to solar irradiance, land availability, grid integration capacity, etc.

Cost-benefit modelling

Includes assessing CAPEX, OPEX and NPV scenarios of different transition options

Socioeconomic impact assessment

Determining impacts on employment, skills transferability and community effects

Emissions reduction potential

Estimating avoided carbon emissions across transition scenarios

Overview of the transition approach for Plant A

Plant A was selected for early retirement due to high costs and limited grid and environmental impact. Solar PV was identified as the most suitable replacement, offering low costs, emissions benefits, and alignment with Malaysia's RE goals. While on-site jobs may decline, broader solar investment could create significant employment and community benefits.

1

Prioritise CFPPs for transition

Plant A was prioritised for early retirement due to high O&M costs, moderate grid and environmental impact, and manageable workforce transition risks.

2

Identify viable transition scenarios

Solar PV is a cost-effective, proven solution for Malaysia's energy transition, with co-located battery storage enabling greater grid independence and emissions reduction.

3

Evaluate site-specific factors

Solar PV + BESS is a sustainable transition option for Plant A, offering strong technical fit, grid flexibility, and environmental benefits, despite higher upfront costs and partial capacity replacement.

4

High-level financial analysis

While all scenarios except solar PV can maintain existing capacity, solar PV is the most cost-effective and environmentally beneficial option—profitable through its UEL and aligned with Malaysia's low-carbon goals—while ammonia, gas, and biomass face higher costs and limited emissions benefits.

5

Assess just transition implications

Solar PV was identified as the most suitable transition for Plant A. While repowering the site would require fewer on-site workers, broader investment in Malaysia's solar supply chain could create thousands of new jobs. Many roles are transferable, some require upskilling, and the shift supports local employment, better health outcomes, and long-term sustainability aligned with national RE goals.

Characteristics of Plant A

Plant A was prioritised for early retirement due to economic, operational, and social factors. **High O&M** costs made it less viable long-term. It has **medium utilisation rates** so its retirement would have minimal impact on grid reliability. The plant employs **few direct workers**, easing workforce impacts. Its moderate emissions and location with average air quality, alongside existing environmental policies in Malaysia, also supports a smoother environmental transition.

Plant Characteristics

Installed capacity (MW)	600MW
Age as of 2025 (years)	< 10 years
Capacity factor (%)	50%
Efficiency (%)	35%
Coal type	Lignite

Site Characteristics

Site suitability, RE & infrastructure availability

- 700,000 m², flat land, near the coast (access to water for cooling). Limited infrastructure (single-lane sub-road), may hinder solar and BESS equipment transportation.
- Strong solar irradiance levels, nearby biomass from palm oil waste, infrastructure for ammonia and hydrogen under development.

Stakeholder preferences

- Agriculture-based economy (palm oil), low population density, job creation from ammonia not a priority.
- State unemployment 2-4%, limited influence of energy project job creation on community preferences.

Energy demand and supply in region

- Region's energy supply capacity is 6,000MW, majority from large hydropower, providing grid flexibility.
- Estimated 10% increase in energy demand by 2025, driven by industrial, commercial, and residential sectors.

Transition scenario results for Malaysia according to its national context

The transition scenario analysis for Malaysia shows that solar PV is commercially viable with low implementation costs and significant potential to reduce emissions. To maximise solar use and reduce grid dependency, co-locating solar PV with battery energy storage is recommended. This allows excess energy during peak sunlight to be stored and used during high-demand periods.

		Total Score	Technology readiness	Economic viability	Environmental impact	Job creation	
Good choice	Repurpose: Solar PV	2.75					*Options that are low carbon, likely to be the most attractive and viable today often with well known or mature technologies.*
	Convert: Synchronous condenser	2.00					
	Repurpose: Battery energy storage	1.75					
Contingency plan	Retrofit: Biomass co-firing	2.25					*Options that are potentially feasible, lower carbon and provide a stable Plan B but may not be as commercially attractive.*
	Retrofit: Run flexibly	2.25					
	Retrofit: CCS	2.00					
"Big bet"	Convert: SMR (nuclear)	2.00					*A more futuristic / ambitious option to explore that may not be the best option today but could be viable in the future.*
	Convert: Advanced geothermal	1.75					
	Repurpose: Gas and green hydrogen	1.50					
	Retrofit: Ammonia co-firing	1.50					

A limitation of solar PV co-located with battery storage is the space required, as replacing capacity like-for-like could be constrained by space. It's essential to assess the feasibility of installing PV panels over larger areas to ensure economic viability, while also considering the high cost of battery storage.

Note: Maximum score that can be achieved is 3.00

Recommended transition scenario for Plant A

The findings below presents the overall assessment of the highest-scoring transition scenarios for Plant A, classified as either a "Good choice" or a "Contingency plan."

SITE SUITABILITY & RE AVAILABILITY

The site is ideal for solar PV, with **enough space and good solar irradiance**, enabling up to 74 MW of solar capacity, including battery storage. There is also potential to scale solar or other renewables in nearby areas to enhance supply.

The close proximity to **palm oil plantations offers a potential biomass supply**; however, the sustainability of this source must be carefully evaluated to ensure it qualifies as a truly low-carbon option.

ENERGY DEMAND & GRID FLEXIBILITY

The region's **high reserve margin and ample hydropower capacity offer flexibility**, allowing Solar PV + BESS to integrate smoothly with the grid.

The region's **growth is expected to be large**, and biomass co-firing could meet this demand.

COST CONSIDERATIONS

While **Solar PV+BESS has higher upfront costs** compared to biomass or ammonia co-firing for equivalent capacity replacement, the **environmental benefits and alignment with grid flexibility** make it a future-focused investment.

Retrofitting for **biomass co-firing is more cost-effective than ammonia and gas, but still involves significant upfront costs**. Biomass co-firing remains expensive in the long term and may not be economically viable after 2030.

ENVIRONMENTAL & STAKEHOLDER PREFERENCES

With moderate air quality, Solar + BESS offers **minimal environmental impact** and **aligns with regional socio-economic goals**.

Biomass co-firing emissions reduction is **uncertain if the biomass is not sourced sustainably**. Air quality indicators such as PM may increase, but SO2 decreases with biomass co-firing as compared to coal.

Good choice: Retire and repurpose site - Solar PV+BESS

Contingency plan: Biomass co-firing

Replacement capacity by transition scenario

Replacing Plant A's installed capacity could be done by switching to other fuels, but this would not be a credible way to cut carbon emissions. It would also miss out on the bigger benefits of using more renewable energy—like cheaper, local power, new jobs, and growing local industries.

Transition scenario	Installed capacity (MW)	Generating capacity (MWh/year)	Capacity factor (%)	Expected useful economic life*
BAU	600	2,100,000 - 2,628,000	40-50%	40
Solar PV	74	103,718	16%	25
Biomass co-firing	600	2,522,880	50%	40
Ammonia co-firing	600	2,628,000	50%	40
Natural gas and hydrogen	600	2,995,920	57%	50

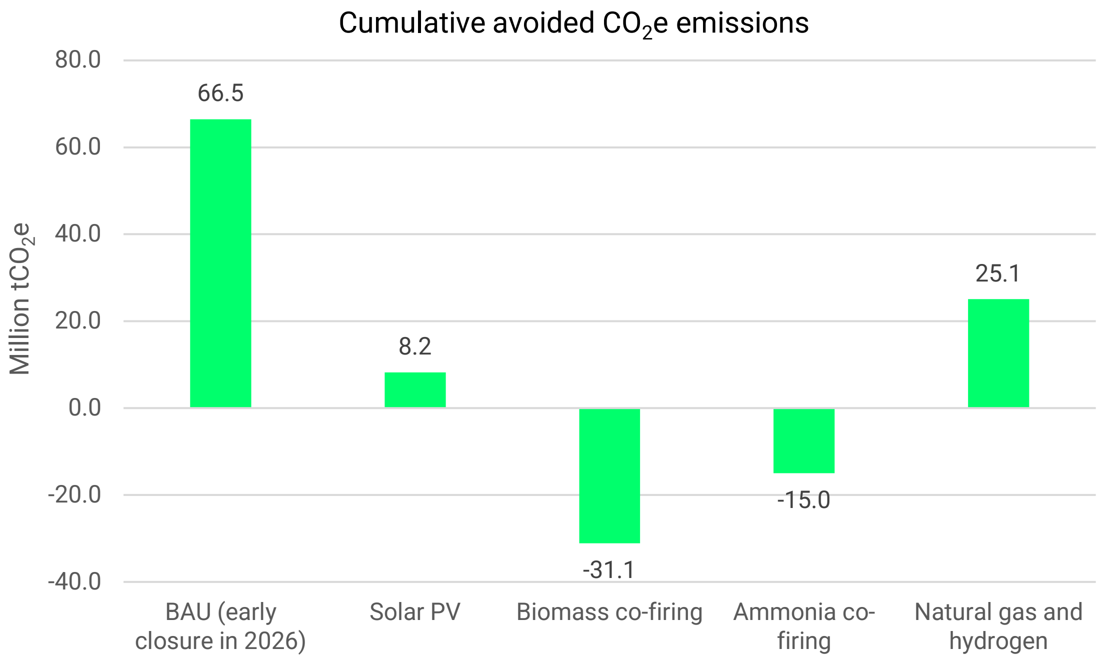
Key insights

- Most transition options can maintain the current power output at the same site, except for solar, which would require significantly more land to match existing capacity.
- However, a simple like-for-like replacement of thermal plants would limit the broader benefits of a renewable-based power system for Malaysia.
- Biomass and ammonia co-firing can deliver similar output (with some efficiency losses), while natural gas and hydrogen could generate even more due to their higher capacity factors.

**Note: This represents the expected useful economic life; however, the introduction of carbon taxes could impact the lifespan of thermal plants.*

Comparing avoided emissions across transition scenarios

Retiring Plant A early (as early as 2026) could avoid 66.5 million tCO_2e, based on a 40-year operating life. This would significantly cut Malaysia's emissions and benefit the health and wellbeing of nearby communities.



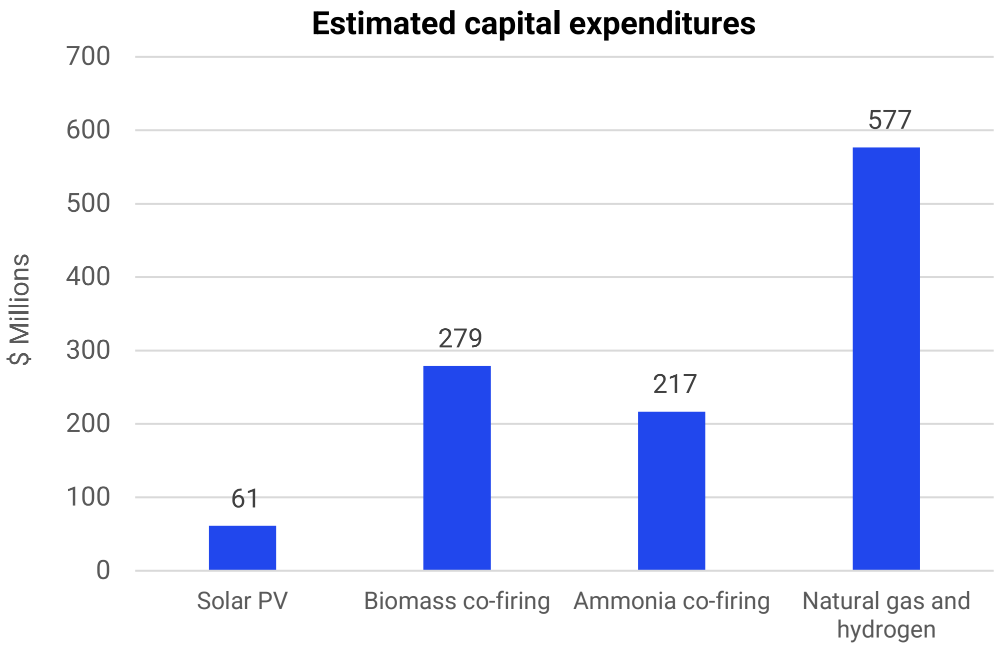
Key insights

- Solar power offers strong emissions reductions, even when adjusted for its share of capacity.
- Biomass co-firing* and ammonia co-firing show negative emissions savings because their carbon impact is close to coal, and extending plant life for co-firing could increase total emissions.
- A 20% mix of green hydrogen with natural gas shows better results, as hydrogen produces no emissions when burned and natural gas is cleaner than coal.

**This analysis focused solely on the direct emissions from biomass sources and does not account for its carbon-neutral potential arising from plants absorbing CO_2 during their lifetime. It also assumes a transition year in 2026.*

Capital expenditure by transition scenario

Retrofitting Plant A to use biomass, ammonia, or hydrogen would be expensive due to high fuel and upgrade costs. However, reusing existing infrastructure like boilers, turbines, and grid connections could help reduce some of these costs.



Key insights

- Switching to natural gas and hydrogen is the most expensive option, as it would require major upgrades, including a new gas turbine system and other plant changes.
- Retrofitting for biomass or ammonia co-firing is also costly, needing upgrades to boilers, control systems, fuel handling, and safety systems.
- Solar PV is the most affordable transition option due to lower construction costs, though this doesn't account for decommissioning and site preparation, which would still be needed.

Source: Enlit (2024). Coal to gas a bridge to sustainability; N. Henkel (2023). Five Reasons Why Power Plant Owners Should Consider Repurposing Their Assets; IRENA (2013). Biomass Co-firing Technology Brief.

Potential impact of carbon tax

Malaysia is expected to implement a carbon tax by 2025 on iron, steel and energy industries. This signals a structural shift in how the power sector might be regulated. For CFPPs, especially the younger plants, this introduces uncertainty around cost competitiveness, returns, and transition planning.

Possible implications to Plant A

In the absence of a carbon tax, Plant A could remain financially viable and continue operating until 2045 or the end of its useful economic life (estimated around 2059) without intervention.

Depending on PPA conditions / cost recovering mechanisms, carbon pricing could significantly erode net income margins over time, influencing reinvestment or refinancing decisions.

Once its PPA ends, Plant A may no longer be insulated from carbon costs, exposing it to lower profits, especially as capacity factors decrease with age.

Key questions for plant owners on carbon pricing

- How will carbon pricing be designed (e.g. pricing level, facility eligibility, timelines, etc.)?
- Will existing PPAs condition be maintained or renegotiated in the context of new carbon regulations?
- How will revenues from carbon pricing be used (e.g. for just transition support, investment in low-carbon infrastructure or RE deployment)?
- Will carbon pricing accelerate fuel switching, early retirement or lead to stranded asset risks (and how will complementary policy be used to prioritise one over the other)?

How carbon pricing is introduced will shape the long-term outlook for Plant A. It will affect retirement timelines, investment signals, and the pace of Malaysia's energy system transformation.

Socio-economic assessment of Solar PV

As solar PV was identified as the most suitable transition option for Plant A based on technical and financial analysis, its socioeconomic impacts were assessed. It supports a just transition, with positive effects on local job creation, alternative livelihoods, and environmental and health outcomes. This transition also aligns with Malaysia's renewable energy targets.

Alternative Livelihoods

Roles like project developers, financial analysts, and administrative positions can easily transition to solar jobs. Some positions, such as mechanics and installers, may have temporary employment depending on project cycles. The workforce size may be smaller due to the simpler operational requirements of solar projects.

Potential for redundances

Certain roles among mechanics, installers and repairers may face redundancies as the direct skills required may not transfer as easily to solar-related roles. Welders, cutters, solderers and brazers may also face challenges.

Effort required for re-skilling

Power plant operators and engineering roles will require moderate upskilling to adapt to solar specific technologies. Technical certifications and specialised training programmes will be important for roles in solar installation and maintenance.

Environment & Health

For most roles, the transition to solar PV maintains high employment quality in terms of worker safety though some workers may find the transition involves manual labour in some cases. There will be positive impacts on health of workers moving to the new role as solar emits no or low emissions.

Impact on community (i.e. relocation of workers and impact on community ties; indirect and induced job creation/economic diversification)

Likely to have a positive impact on the community, as many workers can transition to solar jobs without relocating which can preserve community ties.

Long-term sustainability (i.e. is the transition scenario expected to create long-lasting jobs or is just an interim solution that is likely to be replaced)

High long-term sustainability as this transition scenario aligns with Malaysia's target of increasing its RE mix that largely comprises of solar. This should maintain local job creation and economic benefits.

Conclusion

The case study demonstrates that transitioning Plant A to Solar PV with BESS offers a technically, economically, and socially viable route, supporting Malaysia's broader goals for clean energy, emissions reduction, and a just transition. Key conclusions drawn from the case study include:

Technical suitability

Solar PV + BESS is technically feasible for Plant A due to favourable solar irradiance and sufficient site space.

This transition scenario improves energy resilience by enabling storage during peak production and supply during peak demand.

Cost-benefit modelling

Solar PV is cost-competitive, and the only transition scenario with positive NPV over the project lifecycle.

This option is also aligned with the anticipated carbon tax introduction in Malaysia and would avoid exposure to fossil fuel cost volatility (if the carbon tax impacts the power sector).

Socioeconomic impact assessment

Most workforce impacts from transitioning a CFPP to Solar PV + BESS are manageable, with moderate upskilling requirements for roles in solar energy.

Emissions reduction potential

Early retirement of Plant A could save up to 66.5 million tonnes of CO_2, and the transition to Solar PV + BESS reduces air pollutants, improving local health and environment quality.

Limitations of Solar PV + BESS:

- Space constraints require careful land use planning, however opportunities exist for scaling distributed renewables in nearby locations. It will be important to invest in Malaysia's regional RE development to further strengthen the country's energy security.
- Battery costs remain a challenge, however there is a strong potential for cost reductions over time through technology advancements.

The Carbon Trust is a company limited by guarantee and registered in England and Wales under company number 4190230 with its registered office at Level 5, Arbor, 255 Blackfriars Road, London SE1 9AX, UK.