SECTION 3

IDENTIFYING ASEAN'S TIPPING POINTS BY SECTOR

This section presents analyses on the six prioritized sectors in ASEAN discussed in Section 2. In each sector analysis, the report seeks to answer the following questions:

Global sector context

- What is the **global context** of how this sector will decarbonize?
- What are the **core low-carbon solutions** that will drive decarbonization?

Geographic sector context

- How is the **sectoral transition progressing** at **ASEAN level**?
- Are there **opportunities or challenges** specific to the region?

Solution status

- What is the **current status** of the core solution being adopted at ASEAN level?
- Is it only **in development**, or being adopted in **niche markets**, or starting to break into **mass market**?

Tipping point status

- How close are we to a **tipping point**, to help the solution break into mass market?
- What are the **key gaps** to be addressed to trigger one?

Tipping point calculation & levers

- What is the **comparison** of the **current** and **potential future costs** of the **low-carbon solution** versus **the incumbent**?

Target conditions progress to trigger tipping point

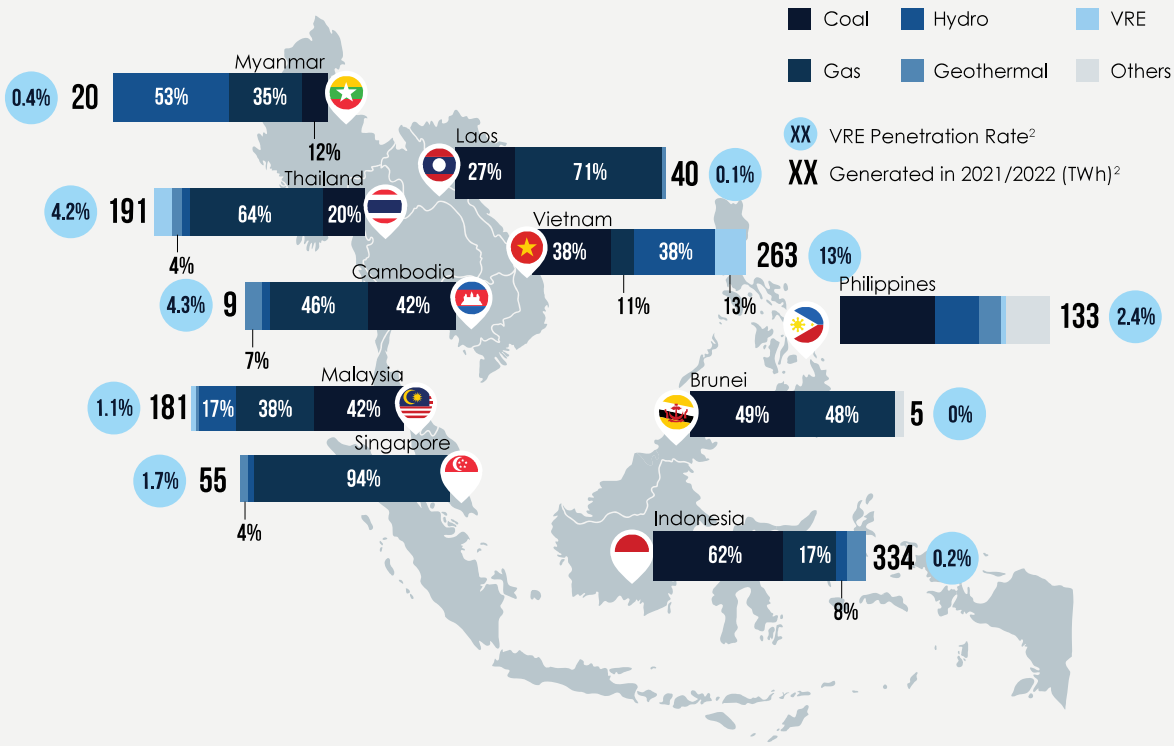
- What is **the current** and **potential future** status of the **tipping point conditions** (affordability, attractiveness, and accessibility)?

POWER: SOLAR & STORAGE

25% OF TOTAL ASEAN GHG EMISSIONS 2020

SECTORAL & GEOGRAPHICAL CONTEXT

- **Globally, renewables has experienced a large ramp-up in deployment**. In 2022, solar and wind accounted for 85% of new generation capacity from renewables. Solar and wind together made up 12% of global electricity generation in 2022.[1]
- **ASEAN is still one of the most coal reliant regions in the world**. 45% of power comes from coal, with Vietnam, Indonesia, the Philippines, Malaysia, and Cambodia get 50+% of power from coal. Only 4% of power is served by variable renewable energy (VRE), that is solar and wind, with 3% coming from solar.[2]
- **Growth in ASEAN has not been balanced with renewable energy sources.** Clean electricity, which represents 30-40% of newly installed capacity, is not keeping pace with demand increase (5% annually since 2016).[3]
- **Differing circumstances across grid nodes.** The Philippines and Indonesia have different grid nodes with different situations, making it harder to shift to renewables. Other localized barriers also exist, such as ease of doing business (e.g., Laos & Cambodia).



Our analysis will focus on solar (and solar + storage) as tipping points, considering the lower wind potential in ASEAN overall. Due to differing solar deployment and enabling policy environment, we have classified[4] the ASEAN countries into two groups:

STRONGER ENABLING POLICY ENVIRONMENT → **WEAKER ENABLING POLICY ENVIRONMENT**

Group 1

Countries with higher solar deployment (>1.5 GW), stronger enabling policy environment, more mature market (lower risk), and more ambitious VRE planning in its PDP* (by 2030)

Group 2

Countries with lower solar deployment (<500 MW), weaker enabling policy environment, less mature market (higher risk), less ambitious VRE planning in its PDP* (by 2030)

Notes: [1] Systemiq (2023), The Breakthrough Effect: How to Trigger a Cascade of Tipping Points to Accelerate the Net Zero Transition. [2] Our World in Data (n.d.), Electricity production by source. [3] ASEAN Centre for Energy (2022), The 7th ASEAN Energy Outlook 2020–2050. [4] Adapted from Asian Development Bank, Bloomberg Philanthropies, ClimateWorks Foundation, Sustainable Energy for All (2023), Renewable Energy Manufacturing: Opportunities for Southeast Asia. *) Power development plan.

SOLUTION STATUS IN ASEAN

Solution status stages: ● *Solution development* › ● *Niche market* › ● *Mass market*

Solar

NICHE TO MASS MARKET

- **Only 3% of power in ASEAN is generated from solar.**[2] Vietnam is leading the charge with 10%, one of the leaders globally. The rest of ASEAN is still lagging: Thailand at 2.6%, the Philippines at 1.6%, and most ASEAN countries at below 1%, compared to leading countries such as China (4.8%), India (5.1%), Australia (13%) and Chile (17.4%).
- **For countries with higher barriers, issues range from technological costs, regulatory processes, and power market structure.** Although there have been several advancements in procurement process and technology cost reduction, more improvements are needed to kickstart solar adoption.

Solar + Storage

NICHE MARKET

- **Energy storage deployment in ASEAN is still in a very early stage** but is expected to reach 1,175 GW in 2050 (1.5°C scenario with 100% RE generation).[5]
- Countries such as Thailand and Vietnam have **incorporated solar + battery storage solutions** into their **long-term electricity plans**, but there has not been any significant progress in project execution. Other countries are looking into system-level storage such as pumped storage (Indonesia, the Philippines).[6]
- **Battery manufacturing is already present and growing** fast in Thailand and Vietnam, with Indonesia and Malaysia also following suit.[7]

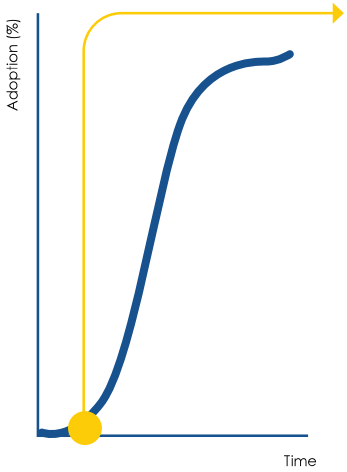
TIPPING POINT AND ADOPTION RATE STATUS

Legend: ⬚ *Focus of tipping points* ✓ *Mostly reached* ○ *Reached in certain cases* – *Not reached*

Tipping point status

	GROUP 1	GROUP 2	INDONESIA*	COMPARISON TO...	STATUS/REASONING
TIPPING POINT 1 LCOE of solar < **new** coal/gas	✓	⬚ ○	⬚ ○	• **New Coal (Group 2)** • **New CCGT (Indonesia)**	• **Has been reached for Group 1 and could already be achieved in Group 2** under certain cases. • **For Indonesia**, since there is already a coal moratorium, **T.P. 1 will be compared to new CCGT**.
TIPPING POINT 2 LCOE solar + storage < **new** coal/gas	○	○	○	• **New Gas (CCGT)**	• **T.P. 2‡ against new CCGT could already be reached** in countries who do not have domestic gas production (or price cap), and when international gas price fluctuation is apparent.
TIPPING POINT 3 LCOE of solar < **existing** coal/gas	✓	⬚ ○	⬚ –	• **Existing Coal**	• **T.P. 3 has been reached for Group 1 and could be reached in Group 2** except for Indonesia (domestic coal price cap). T.P.3 can link with **carbon financing for accelerated coal closure.**
TIPPING POINT 4 LCOE solar + storage < **existing** coal/gas	○	–	–	• **Existing Gas (CCGT)**	• **T.P. 4 could be reached in certain case, and is currently only relevant for, for Group 1 who has high VRE penetration** (particularly Vietnam, with 13% VRE, and Thailand who has high gas shares).

Current adoption status



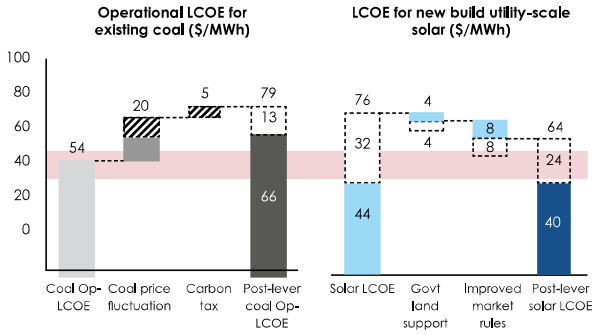
Even though most of the tipping points have been reached, ASEAN's 3% VRE penetration means solar (+storage) is in its early stages of the adoption curve. There are other **key barriers/levers to reach tipping points outside of affordability: attractiveness, and availability, which covers:**

- **Streamlining power purchase agreement (PPA) and procurement process** by using auctions. This can reduce overhead & land costs.
- **Restructuring of existing power generation market structure.** Countries are locked in to long-term/ fixed take-or-pay PPAs for legacy coal power plants.
- **Ensuring project proponents receive benefits** from carbon revenue, to enable lower levelized cost of electricity (LCOE).
- **Investing in grid infrastructure** to reduce interconnection costs for new solar + storage.
- **Increasing the price for coal,** either through carbon tax or removing domestic price caps/subsidies (especially in Indonesia).
- **Implementing strict pollution regulation** for coal plants, increasing their operational costs.
- **Exploring the possibility of direct-PPA and power wheeling**.

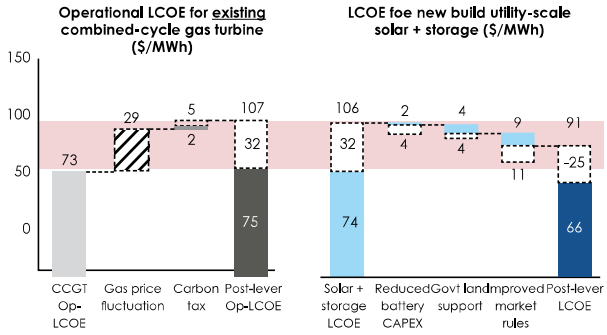
Notes: CCGT = Combined cycle gas turbine power plant. [5] IRENA (2022), Renewable Energy Outlook for ASEAN. [6] Country analysis from respective power development plan, Systemiq analysis. [7] ADB et al. (2023), Renewable Energy Manufacturing: Opportunities for Southeast Asia. *) Country with domestic coal and gas price cap. †) Coal moratorium in place. ‡) Solar + storage (4-hour duration, sized at 40% of solar capacity).

COUNTRY GROUP 1: VIETNAM, THAILAND, PHILIPPINES, MALAYSIA

TIPPING POINT 3



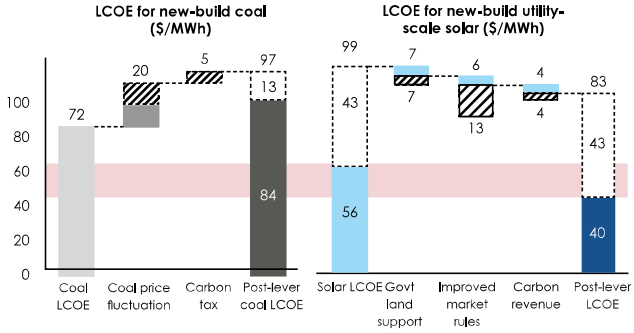
TIPPING POINT 4



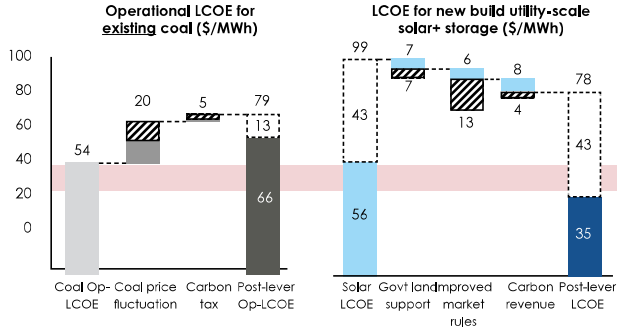
- **Replacing coal would be a priority for Group 1 since new solar LCOE can already undercut the marginal cost of existing coal.** This can be done without the need to couple solar with storage as existing flexibility is typically adequate to provide balancing at <5% VRE penetration (Phase 1 of VRE integration[8]), except for Vietnam (13% VRE penetration).
- **Solar + storage LCOE is already within range of tipping point against existing CCGT.** To push VRE penetration further, countries will need to couple solar with storage to balance the output and provide more system flexibility. However, this will only be relevant at a later stage when VRE penetration has reached >10% (Phase 3).

COUNTRY GROUP 2: CAMBODIA, LAOS, MYANMAR

TIPPING POINT 1



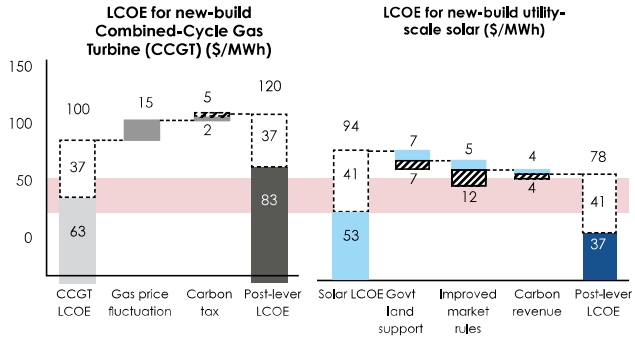
TIPPING POINT 3



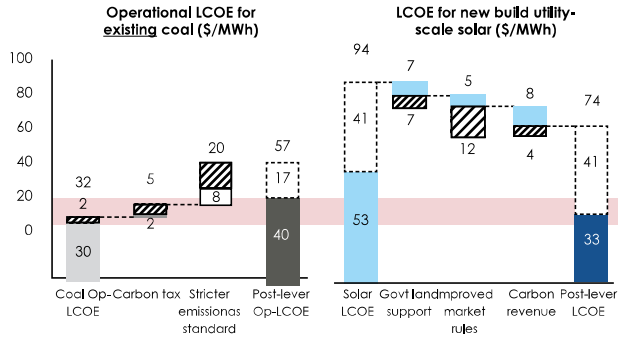
- **T.P. 1 may have already been reached in Group 2 although not without a range of uncertainty**. This is due to higher market uncertainty, conditions for investment, and inherently lower solar irradiation. That said, solar can already be cost-competitive with support from the government, such as land provision and improved market rules (auction certainty).
- **T.P. 3 can also be brought forward further by accessing carbon financing** from coupling renewable buildout with coal closure**, thus further improving solar's cost-competitiveness.
- **Since most Group 2 countries have a major share of hydropower (~40%) and are still in the Phase 1 of VRE integration[8]**, no additional system flexibility via energy storage is technically required.

COUNTRY GROUP 2 W/ DOMESTIC PRICE CAP: INDONESIA

TIPPING POINT 1



TIPPING POINT 3



Fossil fuel LCOE *Solar-only / Solar + Storage LCOE* *Range of cost* *Additional but uncertain change* *Range of tipping point*

- **The artificially low domestic price cap for coal ($70/ton) and gas prices (~$6/MMBtu) makes it difficult for solar to compete on a level playing field.** Moreover, Indonesia currently has many barriers for solar deployment, including: overcapacity in some regions, inflexible power system due to rigid PPAs, inefficienct procurement, poor market rules and inconsistent regulation.
- **Removing these barriers is therefore imperative to bring forward solar's tipping points in Indonesia.** These could include: gradual removal of implicit subsidies (e.g., from domestic price cap), improving market rules and regulation, supporting land provision, and deploying solar through competitive auctions. Carbon financing** from coupling renewable buildout with coal closure can also bring forward the tipping point faster.

Notes: LCOE of new-build solar and solar + storage are calculated using NREL's 2021 Annual Technology Baseline (ATB), which can be accessed at https://atb.nrel.gov/. LCOE of new-build and operating LCOE (marginal cost) of existing thermal power plants (i.e., ultra super-critical coal-fired power plant, combined-cycle gas turbine, and open-cycle gas turbine) are calculated using IESR's LCOE calculator, https://energycost.id/, with inputs from Lazard's (2023), Levelized Cost of Energy Analysis, Version 16.0, for global comparison and IESR (2023). Making Energy Transition Succeed: A 2023's Update on The Levelized Cost of Electricity and Levelized Cost of Storage in Indonesia, for ASEAN assumption. [8] Based on IEA's six phases of VRE integration [IEA (2018), System Integration of Renewables], where Phase 1: VRE has no noticeable impact on the system (<5% VRE penetration), Phase 2: VRE has a minor to moderate impact on system operation (5-10% VRE penetration), Phase 3: VRE generation determines the operation pattern of the system (10-25% VRE penetration), and Phase 4: The system experiences periods where VRE makes up almost all generation (may begin above 20% VRE penetration for less flexible grids; often above 30% for more developed grids). No countries have reached Phase 5 or 6 as of 2022 yet and hence will not be detailed here (see here for more details); **) Carbon revenue from accelerated coal closure uses $10-$15/tCO2e carbon pricing,, 0.9 tCO2e/MWh coal plant emissions intensity, and 0.3 tCO2e/MWh grid emissions intensity for the avoidance calculation.

FOR OTHER ASEAN COUNTRIES

For Singapore and Brunei: These city states might be better inclined to import VRE or hydro from neighboring countries (e.g., Malaysia/Indonesia), and become the market that triggers the inflection point of solar (+storage) adoption in ASEAN countries.

COUNTRY GROUP 1:

ENABLING CONDITIONS TO TRIGGER TIPPING POINT	PROGRESS
AFFORDABILITY • **Relevant tipping points at current VRE penetration (in highlight):** *[T.P. 1] LCOE solar < new coal/gas;* *[T.P. 2] LCOE solar + storage < new coal/gas;* **[T.P. 3] LCOE solar < existing coal/gas;** **[T.P. 4] LCOE solar + storage < existing coal/gas.** • **Reduced battery price for solar + storage.** • **Increased cost of running fossil-fuel power plants** (e.g., import tariffs for coal or gas).	✓ **[T.P. 3]: Solar LCOE in Group 1 can already undercut existing coal generation** (at $44-76/MWh vs. $54-79/MWh, respectively). ✓ **[T.P. 4]: Solar + Storage's** (4-h duration, 40% PV capacity) **LCOE** ($74-106/MWh) **in Group 1 is already close to tipping point with existing CCGT** ($73-107/MWh), driven in part by fluctuating natural gas price. It may reach parity by pulling a few levers such as reduced battery energy storage CAPEX, land support, or improved market rules. ✓ **Plans in investments for battery manufacturing has been seen across ASEAN** (e.g., LG, CATL, and REPT in Indonesia; VinES in Vietnam). ✓ **Coal import tariffs**, which is being considered in Vietnam, may accelerate tipping point being reached. **Key actions to accelerate progress:** ❑ **Policy adjustment:** Set ambitious VRE deployment target to make the full use of solar's tipping points to go net zero. ❑ **Procurement adjustment:** Utilize large-scale solar auctions to further bring down the cost of solar/solar+storage.
ATTRACTIVENESS • **Sufficient flexibility in the system** to manage the intermittency and variability of solar and wind. • **Fossil-fuel PPA lock-in is solved.** Utilities can renegotiate/restructure existing PPA deals. • **Ensured demand from large-scale/-volume projects.** This can be achieved from dedicated renewable auctions or mass procurement from industrial parks/large private sector players.	✓ **Existing system flexibility** (e.g., gas or hydro) **in Group 1 are capable to provide required balancing** given that VRE integration in ASEAN is mostly still in Phase 1 (<5%), except for Vietnam. Vietnam (13% VRE) is currently facing grid and solar curtailment issues due to the unpredictable growth of solar from its previous feed-in tariff program and extreme drought rendering its hydropower resources low). ✗ **While technical flexibility is often adequate, contractual inflexibility of long-term PPAs caused the system to be 'rigid'.** Renegotiating rigid coal/gas PPAs can unlock more flexibility in the system. However, no progress is seen yet. ✓ **Large solar demand** (in gigawatt-scale) **has generally been available in Group 1, although is declining in Vietnam** (due to grid and curtailment issues). **Malaysia and Philippines have used large-scale reverse auction** for its procurement instead. **Key actions to accelerate progress:** ❑ **Policy adjustments:** Plan for flexibility needs in the power system (toward net zero); Streamline rigid PPA renegotiation to unlock more system flexibility. ❑ **Procurement adjustment:** Take the full benefit of the price discovery effect of reverse auction-based procurement.
ACCESSIBILITY • **Availability of Direct PPA or Power Wheeling** to increase access to more solar projects to support industrial decarbonization. • **Build-out and improvement of existing electricity networks** to increase renewables penetration to the grid. • **Development of interconnectivity between ASEAN** countries is key to increase accessibility to countries with lower renewable resources.	✓ **Countries like Philippines and Vietnam have explored schemes like direct PPA and power wheeling** for both large-scale and distributed solar deployment. Thailand is exploring similar schemes. ✓ **All four countries have expressed plans to improve their grid infrastructure in their power development plans (PDP).** ✓ **Interconnectivity between neighbouring ASEAN** is still under development, and increasing importance of environmental attributes of renewable energy might become barrier. **Key actions to accelerate progress:** ❑ **Investment for grid:** Foreign direct investments to further develop grid ability for increased renewable penetration. ❑ **Infrastructure advancement:** New technology investment to improve grid connectivity and energy access.

Legend: ✓ Progress is moving well ✓ Progress is mixed ✗ Progress is not happening (or happening far too slowly)

Notes: Tipping point enabling condition's rating guide: Affordability: Green – Parity achieved, Amber: Parity could be achieved with the help of levers before 2030, Red: Parity might only be achieved after 2030. Attractiveness & Accessibility: Green – No barrier to tipping point, Amber – Currently impeding tipping point but strong progress underway, Red – Currently impeding tipping point with limited progress to date.

[8] Phase 4 of IEA's six phases of VRE integration, IEA (2018), System Integration of Renewables.

COUNTRY GROUP 2:

ENABLING CONDITIONS TO TRIGGER TIPPING POINT

PROGRESS

AFFORDABILITY

- **Relevant tipping points at current VRE penetration (in highlight):**

  [T.P. 1] LCOE solar < new coal/gas;

  [T.P. 2] LCOE solar + storage < new coal/gas;

  [T.P. 3] LCOE solar < existing coal/gas;

  [T.P. 4] LCOE solar + storage < existing coal/gas.
- **Reduced battery price for solar + storage.**
- **Increased cost of running fossil-fuel power plants** (e.g., import tariffs for coal or gas).

✓ **[T.P. 1]: Solar LCOE in Group 2** ($56-99/MWh) **could already undercut the LCOE of new-build coal ($72/MWh),** although not without a wide range of uncertainty.[9] For Indonesia, this has not been reached due to its domestic price cap that in effect is a major subsidy for coal power. Against CCGT, however, it can already tip (also w/ range).

✓ **[T.P. 3]: Similarly, solar LCOE has almost reached cost parity with existing coal for Group 2** (except Indonesia).

✓ **Investment plans in downstream battery manufacturing are in place in Indonesia** (LG, CATL, RPET).

✓ **Increased price for coal/gas due to international market volatility is likely** although does not seem so for Indonesia at least in the mid-term (3 years ahead).

Key actions to accelerate progress:

- ❑ **Policy adjustment:** Plan a gradual phase down of fossil fuel subsidies to create a level playing field for renewables. Accelerated coal phase out financing will also help.
- ❑ **Market design adjustment:** Improve market rules/design by creating market certainty, fair allocation of risks for long-term PPAs (investment), and clear & consistent regulation.

ATTRACTIVENESS

- **Sufficient flexibility in the system** to manage the intermittency and variability of solar and wind.
- **Fossil-fuel PPA lock-in is solved.** Utilities can renegotiate/restructure existing PPA deals.
- **Addressed system overcapacity** in some countries, such as Indonesia and Laos, to make room for VRE.
- **Ensured demand from large-scale/-volume projects.** This can be achieved from dedicated renewable auctions or mass procurement from industrial parks/large private sector players.

✓ **Existing system flexibility in Group 2 countries are generally capable to provide required balancing** given that VRE penetration in Group 2 is still below 1%, except Cambodia.

✗ Despite having technical flexibility, **contractual inflexibility of long-term PPAs often causes the system to be 'rigid'.** No progress to renegotiate/ restructure PPA is seen yet.

✓ **In Indonesia and Laos, the point above is exacerbated by overcapacity.** Indonesia is currently working on early coal retirement, in part to circumvent its overcapacity.

✗ **Current auction method in Group 2 are generally sporadic and one-off** with huge sunk cost risk for project developers.

Key actions to accelerate progress:

- ❑ **Policy adjustment:** Streamlining national coal phase-out strategy to enable VRE-led transition toward net zero (including streamlining rigid coal PPA renegotiation to enable higher system flexibility).
- ❑ **Procurement adjustment:** Develop gigawatt-scale solar pipelines and design large-scale solar auction to bring down 'local' solar LCOEs through economies of scale.

ACCESSIBILITY

- **Availability of Direct PPA or Power Wheeling** to increase access to project developer.
- **Build out and improvement of existing electricity networks** to increase renewables penetration to the grid.
- **Development of interconnectivity between ASEAN** countries is key to increase accessibility to countries with lower renewable resources.

✗ **Some countries in Group 2 still have not made power wheeling available, nor direct PPA** (due to its electricity law).

✓ **Several countries must still prioritize investments in T&D** to improve reliability in certain areas before improving major grids to enable renewable penetration.

✓ **Interconnectivity in ASEAN is still under development,** and it is planned that 20 GW to be dedicated for interconnectivity purposes[11]. However, environmental attributes of renewable energy might become barrier.

Key actions to accelerate progress:

- ❑ **Policy adjustments:** Enable power wheeling to increase accessibility to renewable energy.
- ❑ **Transmission infrastructure investment:** Invest in improving transmission lines.
- ❑ **Interconnectivity improvement:** Accelerate interconnection execution to accelerate renewable buildout.

Legend: ✓ Progress is moving well ✓ Progress is mixed ✗ Progress is not happening (or happening far too slowly)

Notes: Tipping point enabling condition's rating guide: Affordability: Green – Parity achieved, Amber: Parity could be achieved with the help of levers before 2030, Red: Parity might only be achieved after 2030. Attractiveness & Accessibility: Green – No barrier to tipping point, Amber – Currently impeding tipping point but strong progress underway, Red – Currently impeding tipping point with limited progress to date.

[9] Myanmar's political landscape are the business barriers. Laos's regulatory framework and planning are still lagging compared to other ASEAN countries. [10] SEADS (2023), Building the ASEAN Power Grid: Opportunities and Challenges.