Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update

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One Community for Sustainable Energy

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Disclaimer/Notice

- This "Findings of AIMS III Phase 1 and 2 Updates" version is a summary of the Report on Phase 1 – Capacity Expansion & Production Cost Simulation Modelling Updates and Phase 2 – Grid Analysis Modelling Updates, which provide the summary for the regional level.

- Country basis analysis can be referred to in the aforementioned draft reports, which can be accessed through **http://go.aseanenergy.org/AIMSIIIreportupdates** *(limited access)*.

- Extracted version of this document was reported at the 41st ASEAN Ministers on Energy Meeting (AMEM), to be held on 24-25 August 2023.

Working Mechanism and Timeline

Kick-Off Meeting
18 April 2022

→ **Data Update Consultations**
11 May – 7 June 2022

→ **Interim Meeting**
18-19 August 2022

→ **Revised Model-Consultation Meetings**
12 October – 23 November 2022

→ **Final Meeting**
9 May 2023

→ **39th HAPUA Council Meetings**
14-15 August 2023

→ **41st AMEM**
24-25 August 2023

→ **Report Dissemination**

Rationale in Updating AIMS III Phase I & II

Rationale

- **High-level directives** under the Joint Declaration Bandar Seri Begawan in 2021 to maximize the benefits of low-carbon energy resources as reliable energy sources.
- There is **a need to incorporate the recent dynamics and updates** of the national and regional power sector landscape in the AIMS III model & analysis.

Updates	Remarks
Regional update	
Changes in RE share in Installed Capacity	RE share in the total installed capacity was 33.5% in 2020 which is only a 1.5% gap from the aspirational regional RE target in installed capacity of 35% under APAEC according to ASEAN Power Updates 2021. There is a need to understand how far the progress of RE target for 2025 onwards under the current AMS PDP landscape.
National Update	
Brunei Darussalam	Plan to install 100MW of solar power plant every 5 years with the cumulative capacity targeted to be 300MW by 2035 set by Ministry of Energy together with Sustainable Energy Division (SED) and Department of Electrical Services (DES), set during the data update consultation in June 2022.
Cambodia	New national and global commitments on the climate and the environment which include maximizing the deployment of domestic renewable energy resources (RE Share 53.5% by 2040) and energy efficiency measures (equivalent 2,205 MW capacity saved), as well as excluding the development of additional coal plants and hydro dams under the PDP 2022-2040 released in March 2023
Indonesia	Significant RE increase in the total installed capacity (from around 29% to 52% by 2030 compared to the previous plan) under the new Electricity Supply Business Plan (RUPTL) 2021-2030 released in Oct 2021
Lao PDR	New solar target of 957 MW which is part of the new Lao PDR Power Generation Planning (2020-2030) shared by EdL during the data collection and consultation, received in June 2022.

The Rationale in Updating AIMS III Phase I & II (cont'd)

Updates	Remarks
National Update	
Malaysia	New solar and wind share target to increase to 40% of total installed capacity by 2035 under Malaysia Renewable Energy Roadmap released in 2021.
Myanmar	New solar and wind target, of acquiring 1770 MW and 700 MW of solar and wind installed capacity by 2030, as well as limiting the development of additional hydro dams beyond 2030 based updated generation plan submitted by Department of Electric Power Planning during the data revised model consultation, received in October 2022.
Philippines	New RE target of 35% share in the power generation mix by 2030 which comprises significant target for solar installed capacity (20 GW) and wind energy (12 GW) under the New Philippines Energy Plan 2020-2040 released in December 2021.
Singapore	New solar target to reach 1.5 GWp by 2025 and import of electricity up to 4 GW by 2035 under the Singapore Electricity Market Outlook (SEMO) released in November 2021.
Thailand	The PDP 2018 Revision 1 (2018-2037) released on 20 October 2020, aims to increase 18,696 MW of planned renewable energy from the total addition capacity of 56,431 MW by 2037. Solar is expected to deliver 9,290 MW, including floating solar of 2,725 MW, and around 1,933 MW will be developed through community-based power plants (from biomass, biogas, wastewater, and solar hybrid systems).
Vietnam	Significant expansion of wind (80 GW), solar capacity (48 GW), and solar rooftop (8GW) by 2040 which is part of the new version of PDP8 stated by EVN during the Interim Meeting on 18 August 2022.

What are we updating – Scenarios Update (1/5)

The updated study aims to adjust the “Base Case” scenario in AIMS III model based on the recent landscape. Moving forward we call this new scenario the “Updated PDP” scenario.

Categories	Base Case	Updated PDP scenario	ASEAN RE Target/ High RE Target *	Optimum RE Scenario
Scenario	**Business as Usual**	**Updated Business as Usual**	**RE Optimization to Achieve RE Target, Interconnection**	**Least Cost RE, Thermal, Interconnection**
Thermal				
Existing Plants and Retirement Schedule	Fixed	Fixed	Fixed	Fixed
Committed Plants under new PDP	Fixed	Fixed	Fixed	Fixed
Non-committed Plants under new PDP				
Coal	**Re-optimized**	**Re-optimized & limit after 2030**	Re-optimized	Re-optimized
Gas	Re-optimized	Re-optimized	Re-optimized	Re-optimized
VRE				
Existing	Fixed	Fixed	Fixed	Fixed
Committed Plants under new PDP	Fixed	Fixed	Achieving RE target in energy mix	Re-Optimized
Beyond PDP	**Maintaining VRE in mix**	**Optimized**	Achieving RE target in energy mix/ Achieving high RE Target*	Optimized
Hydro				
Existing	Fixed	Fixed	Fixed	Fixed
Under new PDP				
Committed	Fixed	Fixed	Fixed	Fixed
Non-committed	Not considered	Not considered	Not considered	Not considered
Interconnection Capacity				
Existing	Fixed	Fixed	Fixed	Fixed
Under new PDP (committed)	Fixed	Fixed	Re-Optimized	Re-Optimized
Under new PDP (Non-committed) or beyond the PDP period	Re-optimized	Re-optimized	Optimized	Optimized

What are we updating – Boundary Conditions (2/5)

Under this study update, the key consideration & boundary conditions are:

1. The updated data & parameters are **cut-off until August 2022**.
2. For expansion planning and production cost simulation, it is assumed there are **no transmission constraints** at the national level.
3. **Planning horizon is from 2020 to 2040**, divided planning horizon to **blocks of 5 years**.
4. Hourly demand pattern changes due to **PV rooftop, EV penetration, and demand side management are beyond the scope** of this study.
5. **RE resource assessment is using the previous result** under AIMS III Phase I, for the purpose of vRE Generation Profiles, however, the vRE Targets have been updated where available.
6. **Conservative approach is used** in estimating the capacity value of VRE.
7. Power plants with installed capacity under 100 MW are **lumped together**.
8. **Coal candidates are considered limited** in the expansion planning as a result of consultation with AMS. Hence, the capacity additions to meet the projected demand are largely through vRE which is Solar & Wind (optimized), Hydro (firm additions), and Gas-based units (optimized) .
9. **New and emerging technologie**s (i.e. BESS, Nuclear, Hydrogen, and others) **are NOT** considered in replacing coal.
10. **New Interconnection initiatives** such as Singapore – Cambodia, Vietnam – Singapore and others which beyond APG Interconnection Project (cut off date in September 2022) is not considered in the updated study.

What are we updating – Parameters Updated (3/5)

Updated Parameters

New RE Target	RE target are updated for all AMS
New PDP	PDP for AMS are adjusted to the newest update, to reflect the new committed power plants and retirement plans.
New Demand Projection	Demand projections for all AMS are adjusted, reflecting the current socio-economics situation post-COVID-19.
New Base Year	Base year change from 2018 to 2020
New Price Projection	New Fuel Prices Projection to consider the recent disruptions (COVID-19)

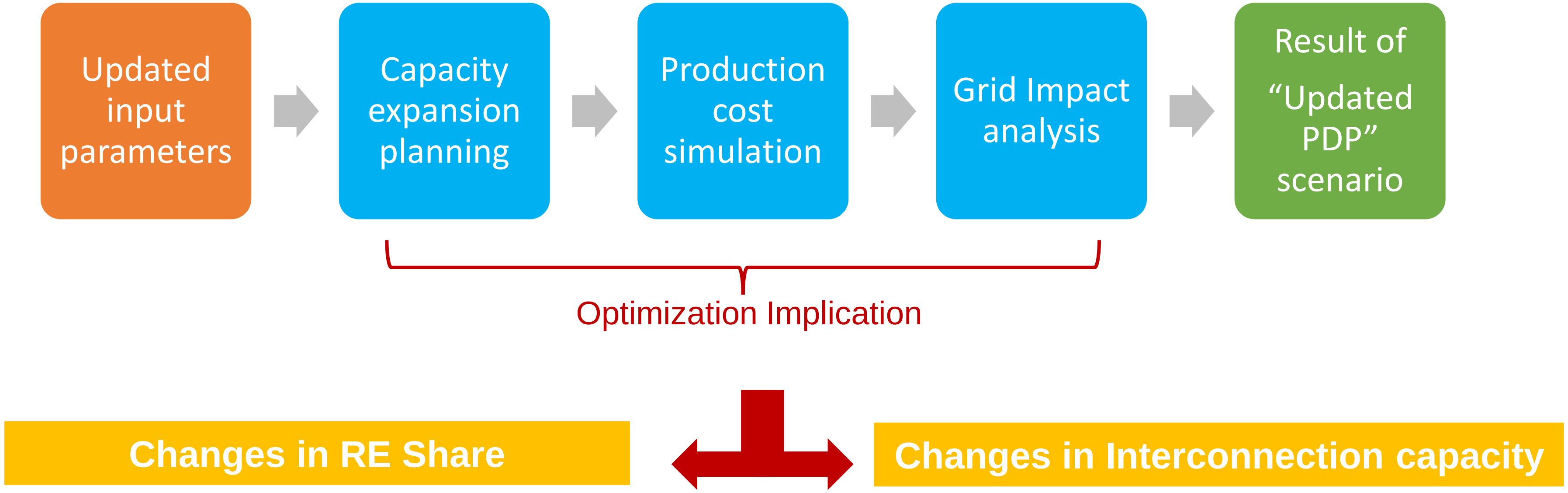
What are we updating – Parameters Updated (cont'd) (4/5)

Summary of key updated parameter in country basis:

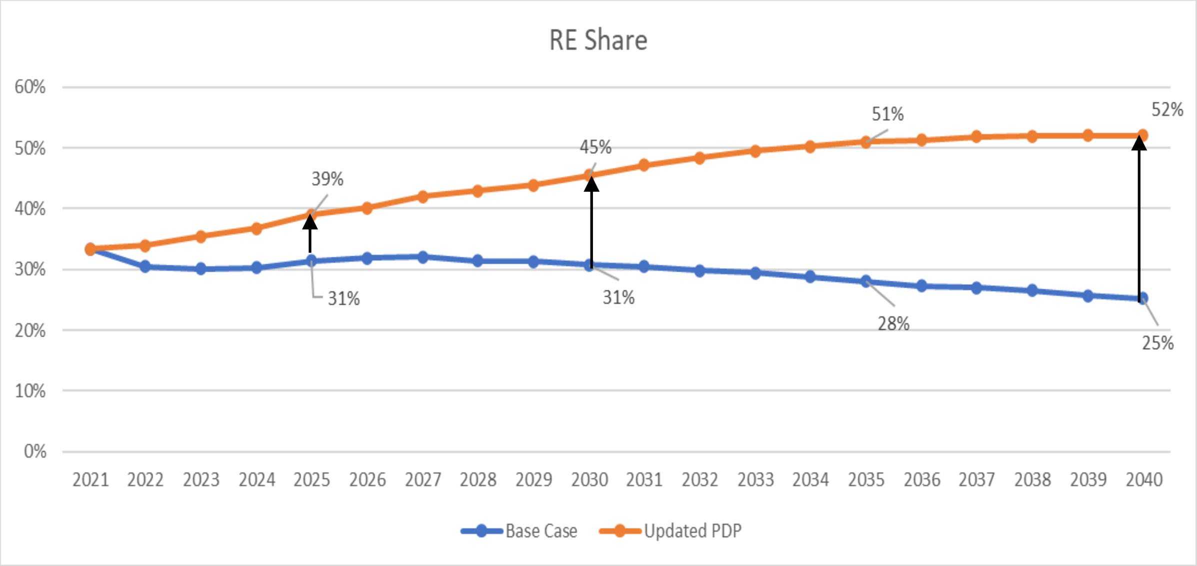
No	Parameter	BRN	CAM	IDN	LAO	MLY	MYR	PHI	SGP	THA	VNM
1.	Demand (current & projection)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2.	Current installed capacity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3.	Candidate plans	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4.	Fuel Price Projection	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5.	Hydro Generation Profiles	✗	✗	✗	✓	✗	✓	✓	✗	✗	✗
6.	vRE Target	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7.	vRE Generation profiles	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
8.	Economic Parameter	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9.	Reliability Parameter	✗	✓	✓	✗	✓	✗	✓	✓	✗	✗

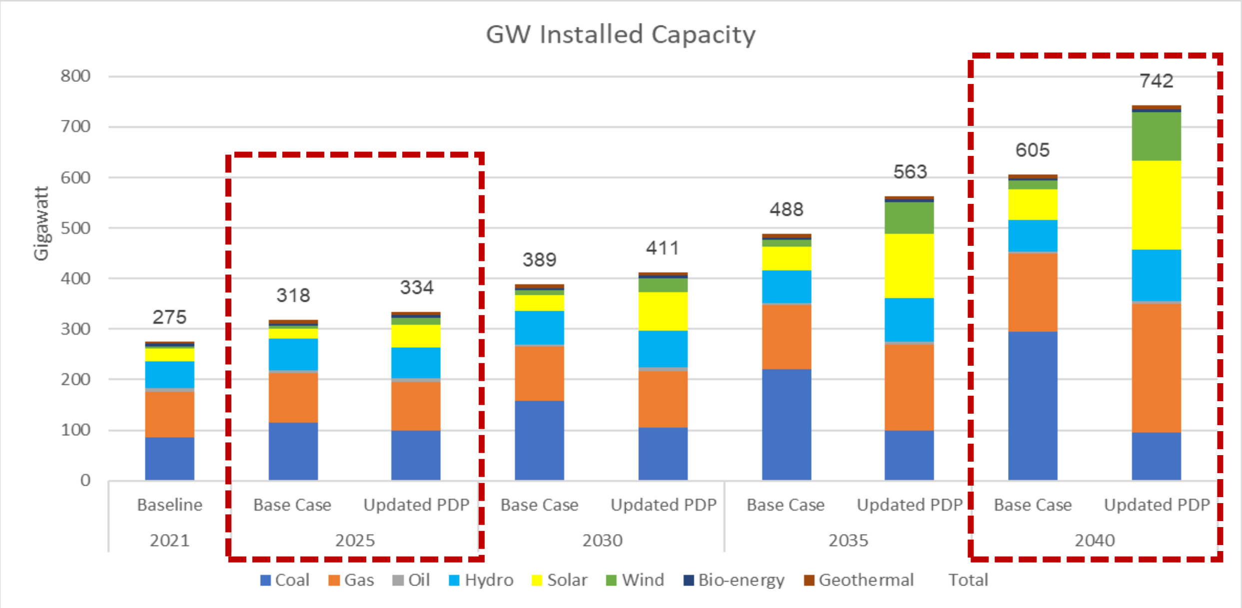
What are we updating – Implication (5/5)

- The methodology and steps of the updated study are equal to the previous AIMS III Phase I & II, only running the process for a new scenario (Updated PDP scenario) with new base year, input parameters and additional constraints.
- This re-run process will provide a new set of result which will be analyzed compared to Base Case and ASEAN RE Target Scenario of AIMS III study.
- The analysis are focused in examining the changes and differences mainly in the RE share and Interconnection Capacity of the Updated PDP scenario with previous AIMS III findings under various scenario.



Findings: Base Case vs Updated PDP Scenario – RE Share





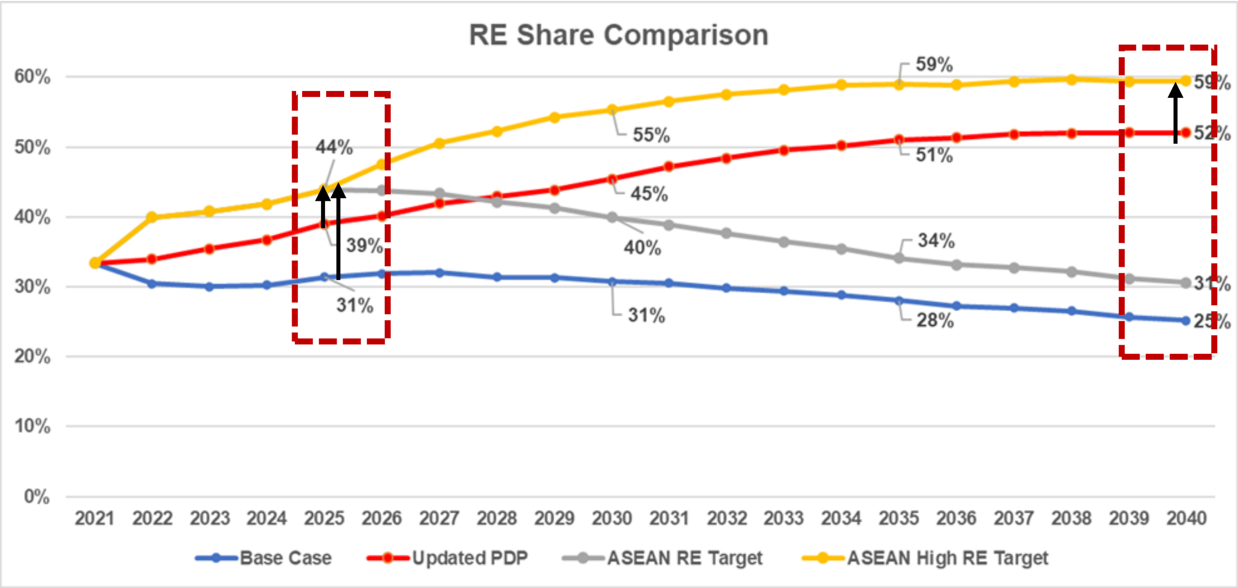
Findings

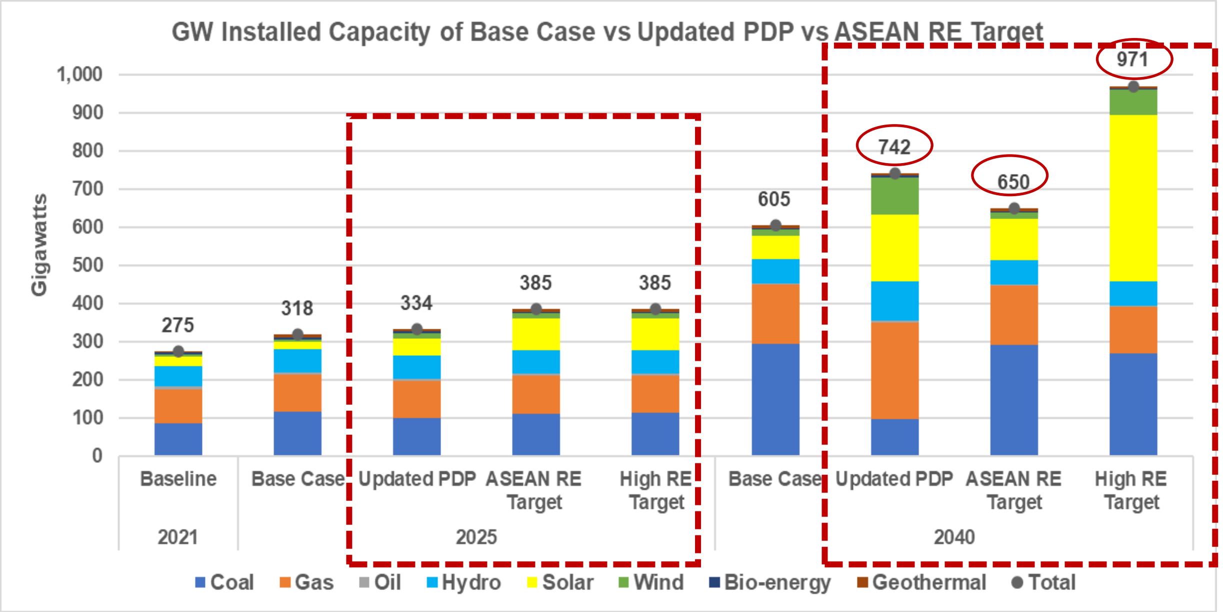
- In the Updated PDP scenario sees the RE share reaches 39% by 2025, around 8% (equivalently 30.2 GW of RE installed capacity) more than Base Case. By 2040, the RE Share comparison is more than double (25% to 52%) in Updated PDP, with approximately 234 GW of RE installed capacity difference with Base Case.
- New approach to limit coal beyond 2030 from AMS leads to lesser **coal** capacity (**around 198 GW less**) in 2040, resulting to higher share of VRE and gas, with increased around **192 GW of solar-wind** and **98 GW of gas** compared to Base Case.

Key messages:

- In 2025, there is **a slight increase** in the total capacity addition in the Updated PDP scenario compared to the base case (from solar & wind). This is due to the **higher ambition for RE under AMS PDP**.
- Beyond 2030, **the gap in total installed capacity & VRE share widens** between the Updated PDP & Base Case. This is possible due to several reasons:
    - Limited coal consideration beyond 2030 in the Updated PDP scenario
    - Beyond the AMS PDP timeframe, the VRE mix projection is optimized in the Updated PDP scenario while in Base Case is maintained to follow the previous year.

Findings: Updated PDP vs. ASEAN RE /High RE Target Scenario – RE Share





Findings:

- Under ASEAN RE Target scenario, for ASEAN to achieve RE Target of 23% by 2025, the region should reach 44% RE share in the power installed capacity. The Updated PDP results shows that the current efforts by the 10 AMS will bring the region to reach 39% RE share by 2025, only 5% less than the target in ASEAN RE Target scenario.
- Looking at 2040 horizon, the Updated PDP scenario is projected to result in 52% RE share, only have 7% less RE share from High RE target scenario (59%) if the current efforts are maintained.
- In terms of capacity, the Updated PDP results in lower VRE capacity in 2025 (36 GW less) than ASEAN RE/High RE target scenario but with more or less comparable power mix.
- While for 2040, the Updated PDP results in higher VRE capacity than ASEAN RE target (146 GW more) but lower (232 GW less) compared to Higher RE target with quite distinct mix compared to both.

Key Message:

- **AMS has a higher ambition** towards reaching the aspirational target in 2025 shown by a closer RE share gap under the Updated PDP scenario.
- AMS are **not so far off from the ambitious (hypothetical) High RE target** by 2040. This means that beyond 2025, ASEAN should consider a more ambitious regional RE target with increased focus on the various technologies for balancing the high amount of vRE possible in the system.
- The Updated PDP capacity mix by 2040 is also quite distinct compared to the ASEAN RE / High Target, with **a lower role of coal that leads to higher role of gas then followed by VRE.** To unlock a greater regional VRE utilization under APG, limitation of fossil-fuel based plants (coal and gas) beyond 2030 is necessary to provide a headroom for new emerging technology such as BESS, Hydrogen, Nuclear, etc.

Findings: Base Case vs Updated PDP Scenario – Interconnection Capacity

No	Connection	APG Status	Base Case (in MW)		Updated PDP (in MW)	
		2022	2025	2040	2025	2040
1	P. Malaysia - Singapore	525	1,050	1,050	1,050	1,050
2	Thailand - P. Malaysia	300	300	300	300	350
3	P. Malaysia - Sarawak	-	-	-	-	-
4	P.Malaysia - Sumatra	-	-	600	-	2000
5	Batam - Singapore	-	-	-	-	-
6	Sarawak - Kalimantan	230	230	230	230	830
7	Philippines - Sabah	-	-	-	-	200
8	Sarawak - Sabah - Brunei					
	Sarawak - Brunei	-	30	100	100	100
	Sabah - Sarawak	50	50	50	100	150
9	Thailand - Lao PDR*	700 (gen-tie:5,427)	700	2,000	900	1,300
10	Lao PDR - Vietnam	570 (gen-tie: 514)	200	200	570	620
11	Thailand - Myanmar	-	-	300	-	1,250
12	Vietnam - Cambodia	200	200	200	200	250
13	Lao PDR - Cambodia	200	300	300	300	500
14	Thailand - Cambodia	230	120	120	200	1000
15	Sabah - Kalimantan	-	-	-	-	200
16	Sumatra - Singapore	-	-	600	-	1,200
17	Lao PDR - Myanmar (New)	-	300	300	300	350
18	Internal Indonesia (New)					
	Java - Kalimantan	-	-	-	-	-
	Java - Sumatra	-	-	3,000	-	6,200
	Total	3,005 (7,700)	3,480	9,350	4,250	17,550

Note: Thailand-Lao PDR interconnection (9) and Lao PDR-Vietnam (10) does not include dedicated IPP exports with 5427 MW and 538 MW respectively, meanwhile in the modeling only consider grid-to-grid tie. .Meanwhile, Batam – Singapore is subsumed under Sumatra – Singapore interconnection

Findings:

- **P. Malaysia – Sumatra** : increased up to 2000 MW from 600MW by 2040, due to optimization of the model with high RE utilization in Sumatra & limited thermal in PM.
- **Sarawak – Kalimantan**: increased up to 830MW due to new demand in North Kalimantan.
- **Thailand – Myanmar** : new updated Transmission development projects in Thailand (fix)
- **Thailand – Cambodia** : new updated Transmission development projects in Thailand (fix)
- **Sumatra – Singapore**: increased to double as optimization of model suggested Sumatra to export RE to Singapore.
- **Java – Sumatra**: increased capacity to more than double, as result of optimization of the model in replacing coal with RE supply from Sumatra to Java

Key Messages:

- A **significant increase of RE commitments** in the Updated PDP scenario compared to Base Case has led to a **slight increase of interconnection capacity** in 2025 but **significantly higher** (more than doubled) by 2040. The possible reason behind this is due to beyond PDP timeframe, VRE mix for the Updated PDP scenario is re-optimized while in Base Case it is maintained to follow the previous year.

Findings: Updated PDP vs. ASEAN RE Target Scenario – Interconnection Capacity

No	Connection	APG Status	Updated PDP (in MW)		ASEAN RE Target (in MW)		High RE Target (in MW)	
		2022	2025	2040	2025	2040	2025	2040
1	P. Malaysia - Singapore	525	1,050	1,050	1,050	1,050	1,705	3,154
2	Thailand - P. Malaysia	300	300	350	300	1,043	9,937	10,300
3	P. Malaysia - Sarawak	-	-	-	64	695	-	3,152
4	P.Malaysia - Sumatra	-	-	2000	1,067	2,130	10,000	10,000
5	Batam - Singapore	-	-	-	-	-	-	-
6	Sarawak - Kalimantan	230	230	830	230	777	230	769
7	Philippines - Sabah	-	-	200	147	196	639	6,086
8	Sarawak-Sabah- Brunei							
	Sarawak - Brunei	-	100	100	62	100	540	643
	Sabah - Sarawak	50	100	150	156	177	978	2,819
9	Thailand - Lao PDR*	700 (gen-tie:5,427)	900	1,300	700	700	5,298	5,630
10	Lao PDR - Vietnam	570 (gen-tie: 538)	570	620	307	625	1,342	10,200
11	Thailand - Myanmar	-	-	1,250	919	1,262	949	1,310
12	Vietnam - Cambodia	200	200	250	328	1353	7,867	10,200
13	Lao PDR - Cambodia	200	300	500	306	625	300	820
14	Thailand - Cambodia	230	200	1000	351	1,315	7,953	10,120
15	Sabah - Kalimantan	-	-	200	158	174	1,126	4,319
16	Sumatra - Singapore	-	-	1,200	843	1,133	8,599	10,000
17	Lao PDR - Myanmar	-	300	350	306	624	758	4,606
18	Internal Indonesia							
	Java - Kalimantan	-	-	-	9	435	477	477
	Java - Sumatra	-	-	6,200	7,943	10,000	7,961	10,000
	Total	3,005 (7,700)	4,250	17,550	15,246	24,585	66,659	104,605

Disclaimer:

- Interconnection Capacity under ASEAN RE Target is based on full-optimization in both during PDP period and beyond PDP period
- Interconnection Capacity under Updated PDP is fix under new PDP and optimized under (Non-committed) or beyond the PDP period

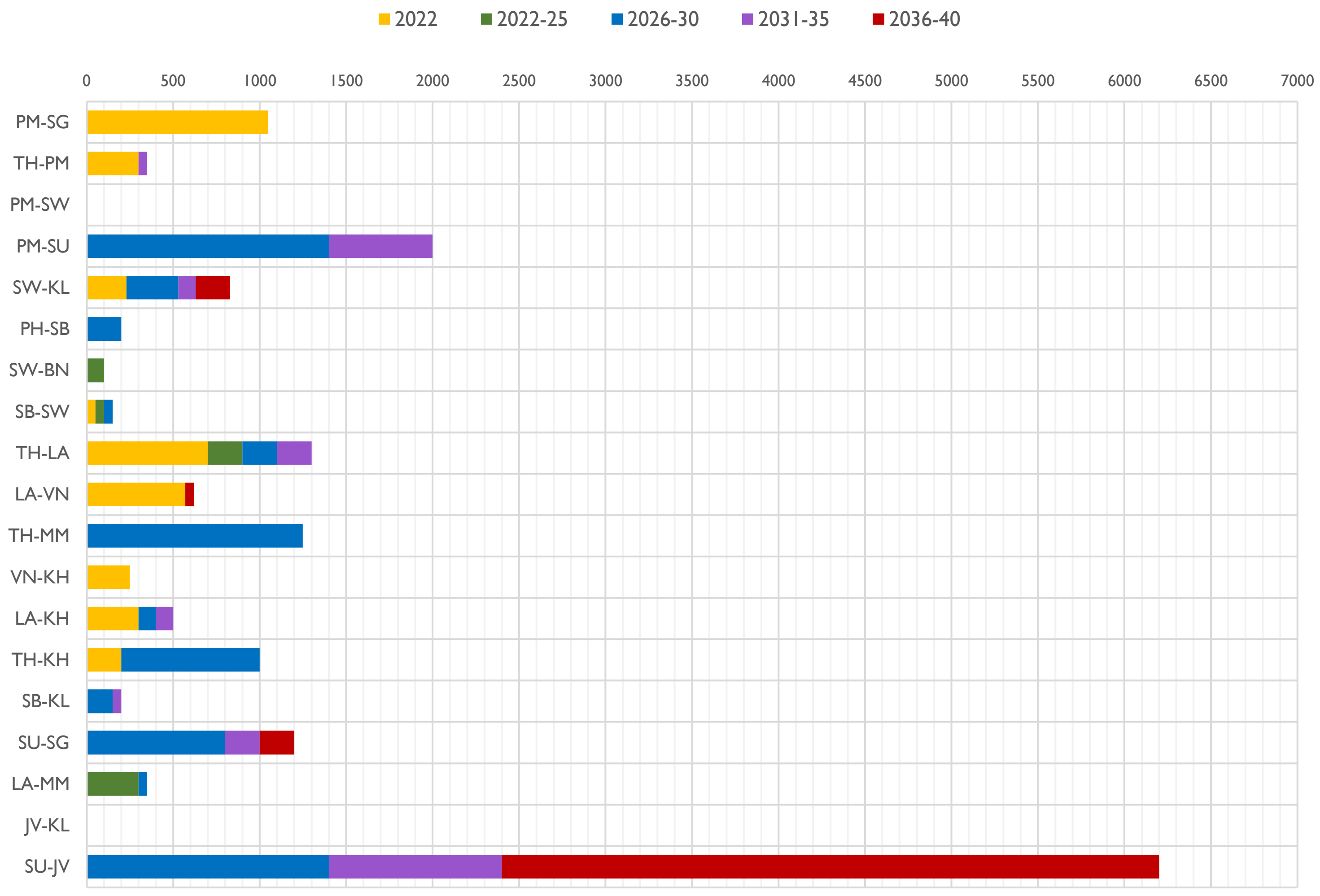
Findings:

- In 2025, the total interconnection capacity in the Updated PDP is significantly lower compared to ASEAN RE Target (4 GW compared to 15 GW). This means that to achieve the ASEAN RE target in 2025, **advancing regional interconnection is prominent.**
- By 2040, the Updated PDP and High RE Target increased their interconnection capacities of around 312% and 56%, respectively, from 2025 level. Although the actual number is very distinct between them.
- In terms of interconnection capacity, there are 12 (highlighted in yellow) out of 18 cross-border interconnections under the Updated PDP which **in line with** the recommendation from the ASEAN RE Target scenario **for the 2040 timeline.**

Key Messages:

1. The Updated PDP scenario result **confirms and validates the interconnection capacity & priorities** under the previous AIMS III Phase I Recommendation
2. Capacity projections of the Updated PDP Scenario in **2040 follows the trend of High RE target scenario despite in significantly lesser magnitude** in capacity, meaning the current national commitment of AMS **naturally leads towards to advancing the regional interconnections.**
3. The Updated PDP & ASEAN RE Target Scenario result could provide a guiding insight into low-hanging fruit interconnections & capacities until the 2025 timeframe period **but beyond that, High RE Target result could be used as a reference**.

Findings: Interconnection capacity by timeline under Updated PDP Scenario



Interconnection Capacity additions in 5-year blocks up to 2040

Findings:

- Up to 2030, the interconnection capacity addition happens mostly in Northern region (2,970 MW capacity added out of total addition around 7,470 MW)
- While beyond 2030, the addition mostly happen in Southern region region, (5,800 MW capacity added out of total addition around 6,500 MW)
- Majority of the addition is projected to occur between year of 2025-2030, with involving 14 interconnections projects.

Key Messages:

- The study updates **reaffirm the findings of priority interconnections** under previous AIMS III study
- Up to 2030,the update study results provide **a reference of the low-hanging fruit potential** of interconnection for AMS to consider. **Beyond 2030, the result should be carefully taken as indicative** potential as uncertainties are high due to AMS PDP timeframe is limited to 10 years period.
- It would be prudent to also **look in detail at the Grid Code(s) and interconnection standards** along with the market structure in the AMS being interconnected, as these factors would play a key role in ensuring that multi-lateral trade can be implemented amongst the AMS.

Note: Some interconnection capacity beyond 2030 also from commitment by AMS

Recalling AIMS III Phase 1 Findings – Role of Regional Interconnection in achieving RE Target in 2025

2025 timeframe

Base Case

- In 2025, under the Base Case, (all) renewable energies is around **31%** of the total installed capacity.
- **19.2.GW solar and 6.5GW wind** installed capacity are expected exist by 2025.
- To accommodate these needs, the existing ASEAN Interconnection Projects by Regions must be ***retained***.
- The planned ASEAN Interconnection Projects will unlock the potential of power trade up to **27,799 GWh** in the region.

Updated PDP

- In 2025, under Updated PDP, (all) renewable energies is around **39%** of the total installed capacity.
- **44.5 GW solar and 14.3 GW wind** installed capacity are expected exist by 2025.
- To accommodate these needs, the existing ASEAN Interconnection Projects by Regions must be ***retained***.
- The planned ASEAN Interconnection Projects will unlock the potential of power trade up to **31,717** GWh in the region.

ASEAN RE Target

- Under APAEC target renewable energies is around **44%** of the total installed capacity.
- 82.6 GW solar and 12.3GW wind installed capacity are expected exist by 2025.
- To accommodate these needs, the existing ASEAN Interconnection Projects by Regions must be ***upgraded***.
- The planned ASEAN Interconnection Projects will unlock the potential of power trade up to **106,713 GWh** in the region.

Key Highlights

- *For 2025 timeframe, ASEAN RE target scenario is the reference to analyse the Updated PDP result.*
- *The study update confirms that the **key message of previous AIMS III still prevails,** with only changes of the magnitude in the projection result.*
- *The Updated PDP results fit in between Base Case and ASEAN RE Target Scenario results.*
- ***This means strengthening regional interconnection to unlock greater VRE utilization is prominent to achieve the aspirational regional RE target by 2025.***

Recalling AIMS III Phase 1 Findings – Role of Regional Interconnection towards higher RE ambition beyond 2025

2040 timeframe

Updated PDP

- The updated study examines RE share of the total installed capacity is **52%** by 2040, far higher than the share under AIMS III result in ASEAN RE Target Scenario
- **17,550 MW** of the total ASEAN Interconnection Projects by Regions should be installed by 2040.

ASEAN RE Target

- The previous AIMS III study examined APAEC Target by 2040 by setting **31%** of the total installed capacity comes from RE (to reflect our base case).
- **24,585 MW** of the total ASEAN Interconnection Projects by Regions could be upgraded by 2040.

High RE Target

- The previous AIMS III study examined APAEC Target by 2040 by setting **59%** of the total installed capacity comes from RE (to reflect our base case).
- **104,605 MW** of the total ASEAN Interconnection Projects by Regions could potentially be upgraded by 2040.

Key Highlights

- *Beyond 2025, instead of ASEAN RE Target scenario, the **High RE Target scenario should be used as a reference in analysing the Updated PDP result**, as it provides a useful insight in setting higher RE ambition post APAEC Phase II.*
- *The updated study result reaffirm high-level message of the previous AIMS III study that **increasing effort in regional interconnectivity is prominen**t to massively utilized VRE potential in the region.*
- *This is confirmed by the significantly increasing interconnection capacity in 2040 due to higher RE capacity under the Updated PDP scenario **which also consistent** with previous AIMS III result under High RE Target scenario.*
- ***From here, we conclude that the current commitment of AMS: 1) brings the region on track towards achieving target by 2025 and even aiming to a higher target towards 2040 timeframe, and 2) fostering a greater collaboration to progress the establishment of ASEAN Power Grid***

Recalling AIMS III Phase 1 Findings– Prioritized Interconnections

Previous AIMS III	Updated Version
• In term of priority for implementation, several interconnections in the **Northern Region (NR)** can be identified as high priority, especially between Thailand-Lao PDR, Lao PDR – Cambodia, Lao PDR – Myanmar, Lao PDR – Vietnam, and Vietnam – Cambodia, since reflected in the Base Case, Optimum RE and ASEAN RE Target Scenario these interconnection potentially could allow high power transfer for better utilization of hydro potential of Sub Mekong region and increase VRE penetrations. • The interconnections in the **Southern Region (SR)** between Sumatra – Singapore, Sumatra – Peninsular could be prioritized to transfer surplus power. However, it was recommended that feasibility of these interconnections need to be explored in more detailed through discussions at AMS levels and feasibility studies. • The interconnections in the **Eastern Region (ER)** which could be prioritized is **Sarawak – Brunei Darussalam** transferring power from Sarawak to Brunei to feed Brunei load which reflected in the Base Case and ASEAN RE to be online prior to 2025. • The **inter-regional interconnections** via : **1) Thailand – Peninsular Malaysia (NR-SR),** capacity addition may not be significant until 2040 under the Optimum Scenario and ASEAN RE Target. **2) Peninsular - Sarawak Malaysia (SR-ER)**, the line qualified for candidate addition **only for High RE case in 2040**. Hence, feasibility of this interconnection need to be explored in more detailed through discussions at AMS levels. **3) Java-Kalimantan (SR-ER),** the line qualified for candidate addition for Optimum, ASEAN RE Target and High RE in 2030. Considering the utilization factor very low, further assessment should be followed.	• **In term of priority for implementation**, interconnections in the **Northern Region (NR)** could be used as "low hanging fruits", especially between Vietnam-Cambodia, Thailand-Myanmar and Lao PDR – Vietnam, since these interconnection are already planned and potentially create multilateral trade . • The interconnections in the **Southern Region (SR)** between Peninsular Malaysia, Sumatera and Singapore can be utilized to transfer surplus power from Indonesia to Singapore and Peninsular Malaysia especially post 2025. Furthermore, as part of the projected results from the Capacity Expansion Model, the highest interconnection suggested is between Java and Sumatera, as Java is the load center of Indonesia and replacing their coal units. • The main interconnection in **Eastern Region (ER)** which may be accorded priority may be Sabah and Kalimantan, which observe majority of capacity addition post 2025. **Sarawak to Brunei Darussalam** and **Sabah to Sarawak** interconnections are also observed to have some additions in the years prior to 2030, however, the projected capacity(s) for these is lower. • The **inter-regional interconnections** via (**Thailand – Peninsular Malaysia**) may not be feasible at the lower capacity levels and may be considered at a later stage as and when a larger capacity is envisaged/required to be built.

Recalling AIMS III Phase 2 Findings – Grid Analysis (Steady State)

Key Parameter	Previous AIMS III	Updated Version
1. Analysis, key horizon years and scenarios	• The power flow, (N-1) contingency and **short circuit analysis** • **Four horizon years (2025, 2030, 2035 and 2040).** • **Five operating scenarios** per horizon year were studied.	• The power flow and (N-1) contingency analysis • **Two horizon years 2025 and 2030.** • **Two operating scenarios were investigated**.
2. Result of flow analysis	Based on the power flow analysis, it was observed that, with adequate AMS level grid strengthening schemes as proposed, for all horizon years, the proposed interconnections are feasible.	Based on the power flow analysis, it was observed that, with adequate AMS level grid strengthening schemes as proposed, for all horizon years, the proposed interconnections are feasible.
3. Result of contingency and short circuit analysis	Based on the **(N-1) contingency analysis**, it was observed that all the interconnections are **compliant with (N-1) contingency philosophy, except Peninsular Malaysia to Singapore connection**. To make it compliant, one more circuit needs to be added for this interconnection.	• Based on the **(N-1) contingency analysis**, it was observed that all the interconnections are complaint with (N-1) contingency philosophy, except **Lao PDR to Myanmar interconnections** in the northern region and **Peninsular Malaysia to Singapore connection** in Southern region • To make Lao PDR to Myanmar interconnection compliant, it was observed that reactive power support of ~ 40MVAR on both sides of the line to transfer 350MW. To make Peninsular Malaysia – Singapore complaint, one more circuit in the existing interconnection if practically possible or another interconnection needs to be added which will facilitate 1050MW power transfer even under N-1 contingency condition.
3. Recommendation of steady state analysis	In order to facilitate the proposed cross-border power transfer for optimum utilization of resources within the ASEAN Grid, National level grid strengthening within the AMS on both sides of interconnection will be required especially in case of very high interconnection capacities	In order to facilitate the proposed cross-border power transfer for optimum utilization of resources within the ASEAN Grid, National level grid strengthening within the AMS on both sides of interconnection will be required especially in case of very high interconnection capacities.

Recalling AIMS III Phase 2 Findings – Grid Analysis (Dynamic)

Previous AIMS III	Updated Version
It is recommended to implement the Power System Stabilizers (PSS) on all the units larger than 100 MW to effectively damp the oscillations during the contingencies.	It is recommended to implement the Power System Stabilizers (PSS) on all the units larger than 100 MW to effectively damp the oscillations during the contingencies.
It is recommended to have either a special protection scheme to shed the load of around ~600MW or implement the UFLS with first stage 49Hz with 200msec delay and a minimum load shed of 600MW to bring back the frequency in Java system to acceptable range. (Specific for Java – Sumatra)	It is recommended for each AMS to adopt suitable reserve margin philosophy to take care of system contingencies and variability of renewable generation and design the appropriate back up schemes like UFLS for stable system operation. (regional recommendations).
Remarks on the Grid Analysis: • Contingency of tripping of one pole between Java and Sumatra was simulated and it was observed that Sumatra will see over frequency and Java will see the under frequency because of loss of 1500 MW. • **Beyond 2030**, in the Max VRE case and Peak load scenario, any contingency on the Lao-PDR interconnection leads to unstable inter-area oscillations which are reflected in the all AMS in northern region as Laos is highly interconnected. This limits the power transfer on the interconnections. Hence it is recommended to strengthen the 500 kV national transmission network within Lao PDR. • **Beyond 2030**, in Sumatra lot of renewable (>10GW) is getting added, mostly in Southern Sumatra. The planned evacuation infrastructure will not be sufficient to transfer such large amount of power to export points and deficit of reactive power leads to system collapse. Hence it is recommended to strengthen the transmission network in the Southern Sumatra • During peak load scenario, **beyond 2035**, loss of one circuit of Sarawak- Kalimantan (Khatulistiwa) 275 kV double circuit line, leads to other line getting highly loaded. The sustained inter-area oscillations were observed between Kalimantan (Mahakam) and rest of the AMS in the Eastern region. To mitigate this issue, national Grid network of Sabah (East to West) needs to be strengthened up to interconnection points to Sarawak and Kalimantan (Mahakam). • For all other contingencies for different operating scenarios, the system was found stable.	**Remarks on the Grid Analysis:** • In Northern peak scenario for horizon **year 2030**, there is export of surplus power available from P. Malaysia to Sumatra. Contingency of tripping of one pole between P. Malaysia and Sumatra was simulated and it was observed that P. Malaysia will see over frequency and Sumatra will see the under frequency because of loss of 700 MW. Hence it is recommended for each AMS to adopt suitable reserve margin philosophy to take care of system contingencies and variability of renewable generation and design the appropriate back up schemes like UFLS for stable system operation. • After the interconnections between the AMS, it is also important to have the coordination between the UFLS settings of the interconnected AMS • For all other contingencies for different operating scenarios, the system was found stable

High-level Messages & Way forward (1/2)

In relation to findings of RE Shares

- The Updated PDP scenario result is advisable to **be used as a reference and consideration to understand the AMS power landscape and plan towards 2040 for ASEAN to** set the next aspirational RE target post 2025 under the next APAEC Phase.

- With higher AMS ambition in pursuing RE that foster greater regional connectivity reflected in the study update, **High RE Target** scenario which is previously seemed to be a hypothetical now can be presumed to be more reachable with technological advancements in balancing the variability by considering a detailed cost assessment.

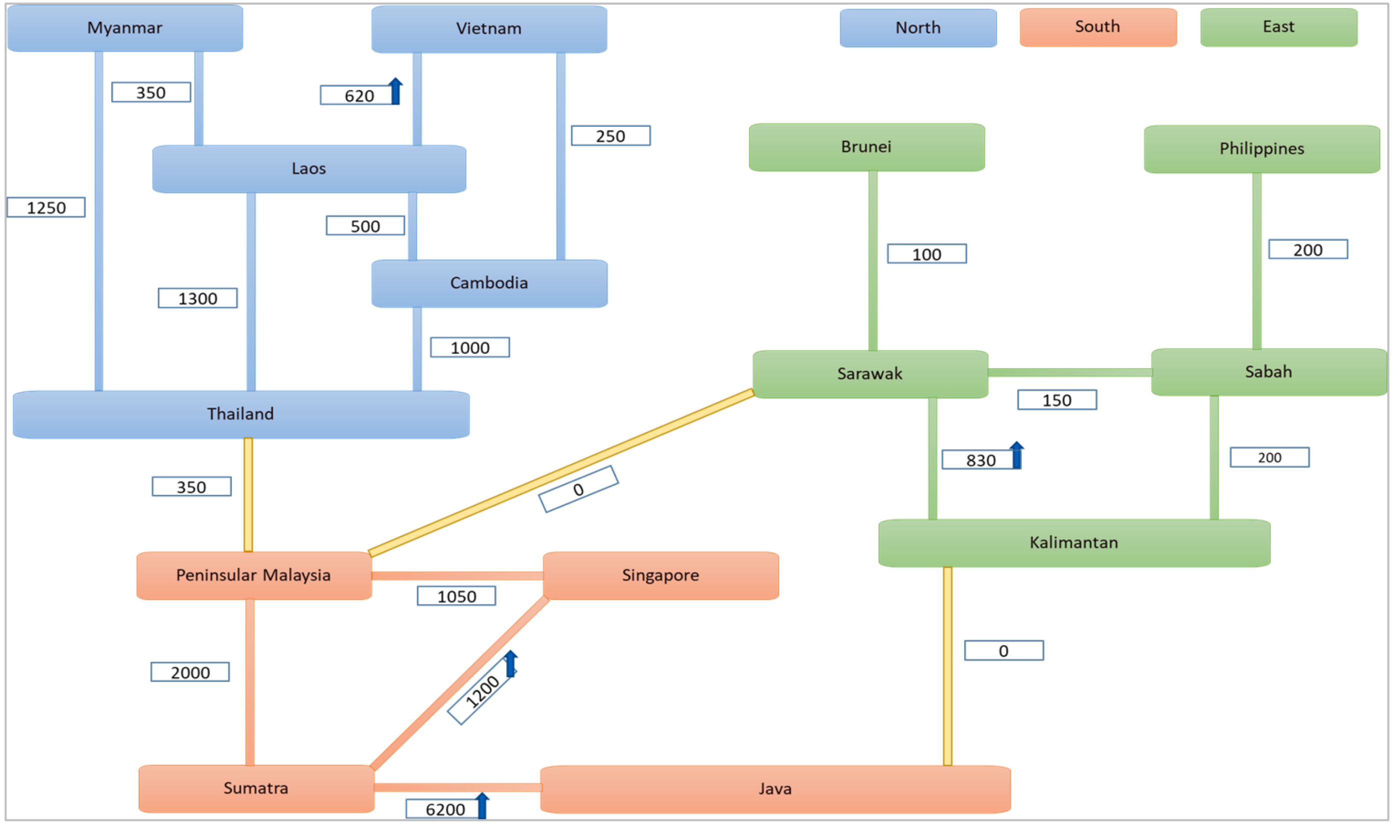
- Thus, **it is imperative for ASEAN to establish long-term RE target post 2025 with a vision towards 2040 and beyond** which can be translated as a guiding reference for setting milestones in power sector as driver for advancing ASEAN Power Grid.

- Once RE target beyond 2025 is established under the next Phase of APAEC, **it is worth considering to update AIMS III projection and reassess the relevancy of potential interconnection** the region.

RE Share Installed Capacity	2025	2030	2035	2040
AEO7 – AMS (National) Target Scenario (ATS)	37.9%	41.2%	43.9%	45.3%
AEO7 – APAEC (Regional) Pledged Scenario (APS)	**41.5%**	**47.2%**	**52.3%**	**55.2%**
AIMS III – Updated PDP	**38.5%**	**45.1%**	**50.8%**	**51.9%**
AIMS III – ASEAN RE Target	44%	40%	34%	31%
AIMS III – High RE	44.0%	**55.4%**	**59.0%**	**59.5%**

Comparison of RE Share in Installed Capacity in various scenario under ASEAN Energy Outlook & AIMS III Update. (Source: ACE)

High-level Messages & Way forward (2/2)



ASEAN Regional Level Interconnection Capacity in 2040 under Phase-I Update Scenario

In relation to findings of Interconnection Capacity

- To accurately prioritize interconnection and justify capacity addition beyond 2030, **it is recommended to periodically update the projection (every 3-5 years)** to reflect the national power development in AMS and understand possible changes of drivers in advancing regional interconnectivity to implement the APG project.
- It is imperative for AMS to initiate a more detailed analysis and formulate plans higher capacity additions in the future for prioritized interconnections.
- Thus, such a **detailed planning process is recommended to be undertaken by all AMS to ensure their readiness and identify firmer milestones** for low-hanging fruit interconnection, especially in the time horizon under 2030.

THANK YOU

Annex I – Phase I Update

Findings: Base Case vs Optimum RE vs ASEAN RE Target vs High RE – Line Utilization

S. No.	Interconnection Details	Base				Optimum				ASEAN RE Target				High RE Target			
		2025		2040		2025		2040		2025		2040		2025		2040	
		GWh	(%)	GWh	(%)	GWh	(%)	GWh	(%)	GWh	(%)	GWh	(%)	GWh	(%)	GWh	(%)
1	Thailand & Lao PDR (NR)	6,128	99.9%	6,967	39.8%	6,123	99.9%	4,321	70.5%	6,140	100.1%	4,275	69.7%	35,414	76.3%	22,049	44.7%
2	Lao PDR & Cambodia (NR)	2,506	95.3%	2,347	89.3%	2,350	89.4%	3,325	65.4%	2,649	99.1%	4,002	73.1%	2,105	80.1%	4,317	60.1%
3	Lao PDR & Myanmar (NR)	2,514	95.7%	2,567	97.7%	2,661	99.6%	4,162	77.9%	2,650	99.2%	5,179	94.6%	4,158	62.5%	17,664	43.8%
4	Lao PDR & Viet Nam (NR)	1,680	95.9%	1,722	98.3%	2,519	95.9%	4,833	92.7%	2,657	99.5%	5,182	94.7%	9,084	77.4%	34,921	39.1%
5	Viet Nam & Cambodia (NR)	1,435	81.9%	1,712	97.7%	2,587	89.5%	10,405	90.7%	2,678	92.6%	10,715	90.3%	9,994	14.5%	35,697	40.0%
6	Thailand & Myanmar (NR)	-	0.0%	168	6.4%	4,658	67.3%	2,462	25.4%	5,570	69.1%	607	5.5%	4,606	55.4%	5,029	43.8%
7	Thailand & Cambodia (NR)	25	2.4%	993	94.5%	134	4.4%	7,416	61.8%	43	1.4%	7,534	65.4%	8,133	11.7%	32,786	37.0%
8	Sumatera & Singapore (SR)	-	0.0%	5,195	98.8%	7,377	99.7%	9,685	97.4%	7,364	99.5%	9,700	97.6%	32,416	43.0%	59,988	68.5%
9	Peninsular Malaysia & Singapore (SR)	8,719	94.8%	9,046	98.3%	8,495	94.6%	8,704	96.9%	8,885	99.0%	8,698	96.9%	9,803	65.6%	16,055	58.1%
10	Sumatra to Peninsular Malaysia (SR)	-	0.0%	5,057	96.2%	9,543	98.6%	16,336	87.8%	8,827	94.6%	17,607	94.4%	54,736	62.5%	53,409	61.0%
11	Sumatera & Java (SR)	-	0.0%	25,402	96.7%	24,430	96.5%	64,039	73.1%	51,428	73.9%	65,925	75.3%	34,447	49.4%	59,852	68.3%
12	Sarawak & Brunei (ER)	262	99.8%	857	97.9%	561	98.5%	577	94.1%	516	98.1%	582	94.9%	2,921	61.8%	2,378	42.1%
13	Philippines & Sabah (ER)	-	0.0%	-	0.0%	1,111	87.4%	1,484	94.1%	1,139	89.6%	1,643	96.2%	4,268	76.1%	33,670	63.2%
14	Sabah & Kalimantan (ER)	-	0.0%	-	0.0%	1,153	82.3%	1,154	82.3%	1,127	80.4%	1,150	75.0%	4,410	44.7%	16,915	44.7%
15	Sabah & Sarawak (ER)	413	94.3%	432	98.5%	1,258	92.6%	1,075	70.1%	1,153	84.9%	975	63.6%	3,131	36.5%	18,126	73.4%
16	Sarawak & Kalimantan (ER)	1,647	81.7%	1,819	90.3%	1,398	69.4%	3,570	63.7%	1,605	79.7%	3,883	57.2%	1,193	59.2%	4,900	72.6%
17	Thailand & Peninsular Malaysia (NR-SR)	2,470	94.0%	2,408	91.6%	2,431	92.5%	7,771	76.8%	2,283	86.9%	6,934	75.7%	57,410	66.0%	67,882	75.2%
18	Java & Kalimantan (SR-ER)	-	0.0%	-	0.0%	-	0.0%	3,044	81.8%	-	0.0%	3,329	87.4%	3,542	85.1%	3,938	94.7%
19	Peninsular Malaysia & Sarawak (SR-ER)	-	0.0%	-	0.0%	-	0.0%	5,412	85.2%	-	0.0%	4,877	80.1%	-	0.0%	20,416	74.0%

Note:

- GWh is the Total Energy Flow Annually (including Forward and Reverse Flows)
- % is the percentage of Line Utilization

Note:Some interconnection capacity beyond 2030 also from commitment by AMS

Findings: Updated PDP – Line Utilization

No.	Region	Interconnection	2025				2040			
			ANNUAL Forward Flow (GWh)	ANNUAL Reverse Flow (GWh)	Line Utilization - Forward (%)	Line Utilization - Reverse (%)	ANNUAL Forward Flow (GWh)	ANNUAL Reverse Flow (GWh)	Line Utilization - Forward (%)	Line Utilization - Reverse (%)
1	Southern	Peninsular Malaysia to Singapore	8722	0	95%	0%	8807	-188	95%	-2%
2	NR-SR	Thailand to Peninsular Malaysia	99	-2385	4%	-91%	1059	-1720	34%	-56%
3	SR-ER	Peninsular Malaysia to Sarawak	0	0	0%	0%	0	0	0%	0%
4	Southern	Peninsular Malaysia to Sumatera	0	0	0%	0%	366	-16319	2%	-93%
5	Southern	Batam - Singapore*	0	0	0%	0%	0	0	0%	0%
6	Eastern	Sarawak to Kalimantan	599	-894	30%	-44%	1146	-2843	16%	-39%
7	Eastern	Philippines to Sabah	0	0	0%	0%	864	-713	49%	-41%
8	Sarawak - Sabah - Brunei									
	Eastern	Sarawak to Brunei Darussalam	844	-12	96%	-1%	823	-28	94%	-3%
	Eastern	Sabah to Sarawak	323	-315	37%	-36%	656	-363	50%	-28%
9	Northern	Thailand to Lao PDR	7	-7095	0%	-90%	2757	-3069	24%	-27%
10	Northern	Lao PDR to Vietnam	1352	-2346	27%	-47%	3053	-1929	56%	-35%
11	Northern	Thailand to Myanmar	0	0	0%	0%	1	-1883	0%	-17%
12	Northern	Vietnam to Cambodia	1	-485	0%	-22%	0	-1144	0%	-52%
13	Northern	Lao PDR to Cambodia	1825	-252	69%	-10%	3695	-75	84%	-2%
14	Northern	Thailand to Cambodia	278	-1255	16%	-72%	5824	-517	66%	-6%
15	Eastern	Sabah to Kalimantan	0	0	0%	0%	539	-679	31%	-39%
16	Southern	Sumatera to Singapore	0	0	0%	0%	10014	-65	95%	-1%
17	Northern	Lao PDR to Myanmar	2628	0	100%	0%	2187	-586	71%	-19%
18	Internal Indonesia (New)									
	SR-ER	Java to Kalimantan	0	0	0%	0%	0	0	0%	0%
	Southern	Sumatera to Java	0	0	0%	0%	15633	-15191	29%	-28%

Note:Some interconnection capacity beyond 2030 also from commitment by AMS

Findings: Production Cost & Unit Operations

Annual Total Production Costs Comparison for Milestone Study Years – ASEAN Level

Year	Phase-I Update Scenario		ASEAN RE Target Scenario	
	(Billion US$)	(US$/kWh)	(Billion US$)	(US$/kWh)
2025	54	0.040	53	0.037
2030	67	0.039	72	0.039
2035	92	0.042	93	0.041
2040	136	0.049	127	0.045

Capacity Factors Comparison for Milestone Study Years – ASEAN Level

Technology	Phase-I Update Scenario		ASEAN RE	
	2025	2040	2025	2040
Coal	73%	76%	68%	74%
Open Cycle	20%	5%	10%	6%
Combined Cycle	46%	58%	41%	40%
BIO_BASED	55%	56%	48%	38%
Oil Fired	2%	3%	6%	6%
Hydro	45%	45%	43%	46%
PUMPSTG	9%	17%	6%	14%
Geothermal	96%	93%	89%	92%
Solar	20%	18%	19%	19%
Wind	30%	33%	29%	30%

Findings:

- The total production cost under the Updated PDP Scenario is seen to increase from ~42Billion USD in 2020 to about ~136Billion USD by 2040. Consequently, the per-unit annual production costs also increase from the 2020 levels of ~4US¢/kWh to 4.9US¢/kWh by 2040 under the Phase-I update Scenario.
- Compared with the ASEAN RE Target Scenario, the present numbers are marginally on the higher side (especially for the years 2025 & 2040). This may be largely due to addition of only candidate gas-based units beyond 2030, whereby the higher fuel-cost of gas largely offsets the reductions in the production costs due to higher vRE penetration.
- The difference between coal and gas fuel price projections[1] considered in the modelling is significant, which, coupled with the fact that under the ASEAN RE Target Scenario the Coal installed capacity was significantly higher than the present Phase-I update Scenario, leads to the marginal increase in the per-unit production costs for the ASEAN System.
- This is also in spite of the mitigating factor that the total vRE Capacity under Phase-I update Scenario is higher (by 2040) than what was considered in the ASEAN RE Target Scenario, which may be displacing some thermal generation and therefore reducing the fuel costs to some extent.

SYSTEM PRODUCTION COST

4.9US¢/kWh

By 2040, up from 4.0US¢/kWh (2020 & 2025)

[1] Fuel costs are typically the largest component of the system production costs in a system.

Annex II – Phase II Update

Findings: Summary of the existing and proposed interconnection (1/ 2)

Year	Interconnection	From S/S AMS	To S/S AMS	Capacity planned as per CEP	Voltage Level	Line Length	Technology
2025	Cambodia - Vietnam	Chau Doc Cambodia	Takeo Vietnam	250MW	230kV	160km	HVAC D/C
	Lao PDR - Vietnam	Nam Mo Lao PDR	Ban Ve Vietnam	570MW	230kV	90km	HVAC D/C
	Lao PDR – Thailand	NBO and KM25 Lao PDR	Khon kean and CYP Thailand	900-1100MW	500kV	100km	2xHVAC D/C
	Cambodia - Thailand	Batambang Cambodia	Prachin Buri Thailand	200-1000MW	230kV 500KV from 2030	240km	HVAC D/C
	Lao PDR - Myanmar	M Long Lao PDR	Keng Tung Myanmar	300-350MW	230kV	240km	HVAC D/C
	Lao PDR - Cambodia	Ban Hat Lao PDR	Stung Treng Cambodia	300-400MW	230kV	85km	HVAC D/C
2030	Thailand-Myanmar	Tha-Tako Thailand	Hutgyi Myanmar	1250MW	500kV	370Km	HVAC D/C
2025	P. Malaysia - Singapore	PM – 97221 P. Malaysia	Senoko Singapore	1050	230kV	17.2km	HVAC D/C
2030	P. Malaysia - Sumatra	PM – 96211 P. Malaysia	Perawang Sumatra	1400	500kV	272km	HVDC
	Sumatra-Singapore	Paranap Sumatra	Singapore	800	250kV	350km	HVDC
	Java – Sumatra	Muara Enim Sumatra	X Bogor Java	1400	500kV	500km	HVDC

Findings: Summary of the existing and proposed interconnection (2/2)

Year	Interconnection	From S/S AMS	To S/S AMS	Capacity planned as per CEP	Voltage Level	Line Length	Technology
2025	Sarawak-Kalimantan	West Sarawak	Mambong Bengkayang	230-530	275kV	127km	HVAC D/C
	Sabah-Sarawak	1026 Sabah	Lawas Sarawak	100-150	275kV	35km	HVAC D/C
	Sarawak-Brunei	East Sarawak	Brunei	100	275kV	45km	HVAC D/C
2030	Sabah - Kalimantan	1167 Sabah	Malinas Kalimantan	150	275kV	220km	HVAC D/C
2025	Thailand – Malaysia	Khlong Ngae(Eq) Thailand	61214 P. Malaysia	300	230kV	120km	HVDC(Monopole)

Findings: Summary of stability simulation results

Contingencies (Line tripping)	Northern Maximum Load	Maximum vRE generation Scenario	Comments
2025			
Lao PDR to Thailand line	✓	✓	No Major issues observed for these simulations except the system could not survive without PSS. With the implementation of PSS on units above 100 MVA, the system becomes stable. All the simulations were then performed with PSS.
Lao PDR to Myanmar line		✓	
Lao PDR to Vietnam line	✓	✓	
Lao PDR to Cambodia line	✓		
Cambodia to Thailand line	✓		
Cambodia to Vietnam line	✓		
P. Malaysia to Thailand HVDC pole		✓	
P. Malaysia to Singapore line		✓	
Sarawak to Kalimantan line	✓	✓	
Sarawak to Brunei line		✓	
Sabah to Sarawak line		✓	
Sabah to Kalimantan line		✓	
2030			
Lao PDR to Thailand line	✓	✓	
Lao PDR to Myanmar line		✓	
Lao PDR to Vietnam line	✓		
Lao PDR to Cambodia line	✓		
Cambodia to Thailand line		✓	
Cambodia to Vietnam line	✓		
P. Malaysia to Thailand HVDC pole		✓	
P. Malaysia to Singapore line		✓	
Sumatra to P. Malaysia HVDC pole	✓	✓	System is unstable due to insufficient spinning reserve in the Sumatra system.
Sumatra to P. Malaysia HVDC pole	✓		The system is stable by using UFLS scheme along with the primary frequency response.
Sumatra to Singapore HVDC pole		✓	
Sumatra to Java HVDC pole		✓	
Sarawak to Kalimantan line		✓	
Sarawak to Brunei line		✓	
Sabah to Sarawak line		✓	
Sabah to Kalimantan line		✓	

✓	Contingency Simulated
	System Stable
	System Unstable
	System Marginally Stable

The summary of stability analysis is given below:

1. Major constraint found in the system was low frequency oscillations following clearance of the fault during the contingencies. Even the small contingency leads to growing oscillations and system becoming unstable. For different contingencies and system configurations the oscillations in the range of 0.15 to 0.2 Hz were observed. Hence all the stability simulations were performed considering Power System Stabilizers (PSS) with representative parameters on the generating units above 100 MVA. As we have assumed PSS parameters, the responses are still oscillatory. The properly tuned PSS parameters based on the tuning study will provide the clean responses. It is recommended to implement the Power System Stabilizers (PSS) on all the units larger than 100 MW to effectively damp the oscillations. PSS parameters should be derived based on the detailed PSS tuning study for individual units. The PSS should be robust to system operating conditions and should cover the range of frequencies covering inter-area modes (0.1-0.8Hz), and local modes (0.8 to 3 Hz). The PSS performance should be tested on site before putting PSS in service.

2. In Northern peak scenario for horizon year 2030, there is export of surplus power available from P. Malaysia to Sumatra. Contingency of tripping of one pole between P. Malaysia and Sumatra was simulated and it was observed that P. Malaysia will see over frequency and Sumatra will see the under frequency because of loss of 700 MW. The spinning reserve of 600 MW (Which is equivalent to largest unit size in Sumatra) was maintained in Sumatra which was lesser than the maximum import. Therefore, in this case, the primary frequency response will not be sufficient to bring the frequency back within acceptable range and the UFLS (if properly designed) will get initiated to shed around 150 MW to support frequency recovery. Hence for the loss of HVDC pole (700MW), it recommended to implement the UFLS with minimum load shed of 150MW to bring back the frequency in Sumatra system to acceptable range. It is recommended for each AMS to adopt suitable reserve margin philosophy to take care of system contingencies and variability of renewable generation and design the appropriate back up schemes like UFLS for stable system operation. After the interconnections between the AMS, it is also important to have the coordination between the UFLS settings of the interconnected AMS.

3. For all other contingencies for different operating scenarios, the system was found stable.

Findings: Recommendation of stability simulation results

In General, the following best practices need to be followed to improve system stability in view of higher renewable penetration:

1. The adequate reserves need to be maintained to support the system frequency events or compensate for the uncertainty in renewable generation. The major units connected to grid should provide the primary frequency response for faster recovery of frequency during the loss of generation/interconnection/load. The PFR functionality of the units need to be tested during the commissioning of the unit and should be part of grid code compliance tests.
2. Deployment of adequate static (Capacitor banks) and dynamic reactive power reserves (SVCs/STATCOMs) to maintain acceptable voltage profile in the system for all the operating scenarios and support voltage regulation during contingencies and avoid voltage collapse.
3. Higher penetration of renewable generation may pose different technical challenges like low SCRs, lower inertia and lower dynamic reactive power reserves. The synchronous condensers is the proven technology, which can address all the three aspects. The steam and gas units which are getting retired can be retrofitted to convert into synchronous condensers. However, system level studies are required for sizing and siting of synchronous condensers.
4. As each AMS has different Grid code and may be following different operation, connection and scheduling codes, for the smooth cross-border power transfer, the harmonization of Grid codes is required to maintain the grid performance at APG level.
5. The Wide Area Monitoring Systems (WAMS) help in monitoring and early detection of abnormal conditions, before they get converted into critical contingencies. They improve the visibility of the system and facilitate proactive measures thereby improving system stability and reliability.