TransitionZero

From Vision to Voltage

Open Source Modelling of the ASEAN Power Grid with TZ-APG

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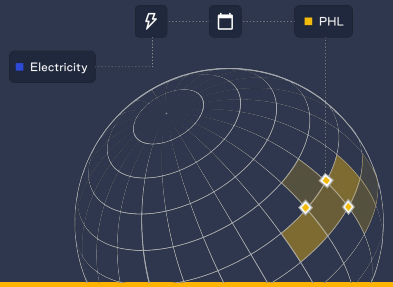

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TL;DR

Executive summary of TZ-APG v1

TZ-APG study at a glance (1)

Motivation

TZ-APG is an open source power systems model built on PyPSA, covering 10 Southeast Asian countries, with a focus on regional transmission.

It was developed to address emerging questions on regional grid connectivity that are not yet covered or fully dissected in existing literature, such as:

- Country-level impact of different grid expansion pathways
- Role of a regional grid in fostering renewable energy and curbing fossil fuels
- Identification of “green” transmission corridors
- Newly proposed bilateral interconnectors and their potential effect on broader regional connectivity

The **ultimate goal of TZ-APG is to provide better, more transparent data and energy systems analytics** into how regional grid development - and the various pathways to it - could play out for each country and stakeholder.

Design

10
ASEAN COUNTRIES

4
GRID SCENARIOS

- 2023-2035 modelling horizon
- 2-hour block temporal representation
- Best-in-class spatial resolution, 24-node model (at least one per country)
- Optimisation of capacity expansion and operation of power plants, storage, and transmission to meet electricity demands and national policy targets at least cost
- “Live” model built on PyPSA. New iterations ongoing to answer emerging policy and investment questions

TZ-APG study at a glance (2)

Insights from TZ-APG v1

The first iteration of the TZ-APG model yielded some notable insights:

1. New grid capacity can trigger structural and operational shifts in ASEAN's power system, as resources can be shared and utilised more efficiently. With regional grid development, ASEAN could cut down 8% of future generation capacity in 2035, mostly from storage and gas, compared to the BAU scenario.

2. Gas development in Vietnam and the Philippines could be sensitive to higher electricity imports, indicating the long-term benefits of interconnector investments.

3. ASEAN's Brunei-Indonesia-Malaysia-Philippines Power Integration Project (BIMP-PIP) deserves regional attention, as it could facilitate the "green" transmission corridor from Kalimantan to Sabah and Luzon.

4. Malaysia has the geostrategic and resource potential to become the new electricity trading hub of ASEAN.

5. Singapore's import diversification strategy can be cost-effective, but the subsea interconnectors to Cambodia and Vietnam could face low utilisation rates.

6. Given the high prevalence of fossil fuel generators in ASEAN, regional grid integration must be accompanied by a common framework for green electricity tracking to avoid carbon leakage risks and uneven climate impacts on power exporting communities.

Future applications

TZ-APG is a **tool,** not a master plan.

The model will be continuously updated to support system planning decisions across the region and within countries.

This includes improvements in **input data, constraints, modelling horizons, grid scenarios**, and others.

UP NEXT

State of play

Introduction to the ASEAN Power Grid (APG) and the current state of cross-border transmission and trade in Southeast Asia

APG - A fragmented grid with growth potential

Bilateral, unidirectional transmission dominates existing cross-border power exchange

3.6%

Share of Southeast Asia's electricity demand being met by cross-border power supply (excl. trade with China)

8/10

Number of ASEAN member states with cross-border power trading activity, but at varying volumes

7.7GW

Existing transmission interconnection capacity between ASEAN member states

Source: International Energy Agency, ASEAN Centre for Energy

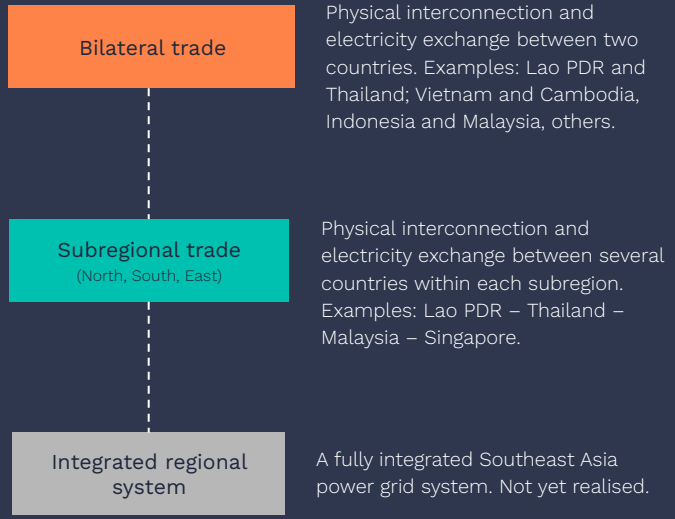
Key features

- Cross-border electricity trade in Southeast Asia started in the 1970s, growing in the 2010s as regional electricity demand growth saw countries tap into neighbouring energy sources that are cost-efficient and complementary to their resources and usage patterns.
- **The Greater Mekong Subregion remains the heart of regional power exchange**. Lao PDR is the largest net exporter. Other prominent beneficiaries include Thailand and Cambodia, where 12-17% of annual domestic demand is met by electricity imports.
- **Bilateral transactions dominate the regional trading landscape.** It was only in 2018 that the first multilateral power flow was realised, under a pilot scheme between the governments of Lao PDR, Thailand, and Malaysia.
- Currently, cross-border transmission lines are mostly unidirectional and disconnected from the local grids. They generally deliver electricity from export-dedicated power plants, backed by long-term power offtake agreements.
- ASEAN's grid network has thus remained fragmented and **cross-border trade, albeit deepening, has had limited impact in enhancing national grids and regional grid integration.**

APG: An ongoing, 27-year journey from concept to market reality

- ASEAN member states have long harboured plans for a regionally interconnected power system. In 1997, the APG was first initiated in the ASEAN Vision 2020, establishing the foundation for regional interconnection planning and cooperation.
- The APG was envisioned to evolve in phases, from bilateral trade to subregional trade, and eventually to a fully integrated regional system. However, actual progress has fallen short of the initial ambition.
- The blueprint for the APG interconnection infrastructure is presented in the **ASEAN Interconnection Masterplan Study** (AIMS), which is endorsed by the member states.
- To date, three versions of the AIMS have been released. The studies evaluate the potential savings of increased cross-border transmission and power trading, including in helping the region integrate more renewables.
- The AIMS also put forward a shortlist of interconnection projects to guide regional focus and investment. The third and most-recent iteration, **AIMS III** (2021, updated in 2022), identified 18 interconnection projects with capacity totalling up to 33GW by 2040.

Planned stages of ASEAN power market integration



Regional cooperation that's slow but steady

Planning, investment, testing, and now market development

1997

Proposed at the 2nd ASEAN Information Summit

Proposal to connect the power grids all of the various ASEAN Member States was first established.

1999-2004

Planning activities under the AIMS I

The first ASEAN Interconnection Masterplan Study (AIMS I) was completed in 2003, which proposed a regional grid network and identified potential savings in investment and operating costs from regional interconnections.

2009-2024

APG Memorandum of Understanding signed

The APG MOU was signed in 2007, and entered into force in 2009. It was valid for 15 years until March 2024.

The AIMS II and AIMS III were developed in this period to account for changes in economic situation, electricity demand, energy requirement, as well as the increasing focus on RE integration.

2014-2026

Piloting multilateral trade

In 2014, the Lao - Thailand - Malaysia - Singapore Power Integration Project (LTMS-PIP) was the first multilateral power trading scheme initiated in ASEAN.

Progressing in stages, the first electricity flow that crossed through all four countries was eventually registered in June 2022. Valid until 2026, the trading capacity is set at 200MW.

In 2023, the Brunei Darussalam - Indonesia - Malaysia - Philippines Power Integration Project (BIMP-PIP) was launched. Feasibility studies on cross-border electricity trade among the four countries underway.

Present

Renewal of APG MOU

An enhanced MOU and TOR is expected by end-2024.

Phase 3 of the AIMS III

Critical frameworks, market design requirements, technical standards and grid codes will need to be developed in the coming years.

There are 18 interconnectors within the region's focus

Source: ASEAN Center for Energy, AIMS III Study, Singapore Energy Market Authority

As listed in AIMS III

	Link	Existing capacity (MW)	Target cap. (MW) by 2040	Status
1	Malaysia (Peninsular) - Singapore	1,050	1,050	Existing
2	Thailand – Malaysia (Peninsular)	300	1,155	Existing
3	Malaysia (Sarawak) – (Peninsular)	-	727	Planned
4	Malaysia (Peninsular) – Indonesia (Sumatera)	-	2,124	Planned
5	Indonesia (Batam) - Singapore	-	3,400	Planned
6	Malaysia (Sarawak) – Indonesia (West Kalimantan)	230	641	Existing
7	Philippines – Malaysia (Sabah)	-	179	Planned
8	Malaysia (Sarawak) – (Sabah) – Brunei a. Sarawak – Brunei b. Sarawak – Sabah	100	71 177	Planned Existing
9	Thailand – Lao PDR	5,427	5,427	Existing

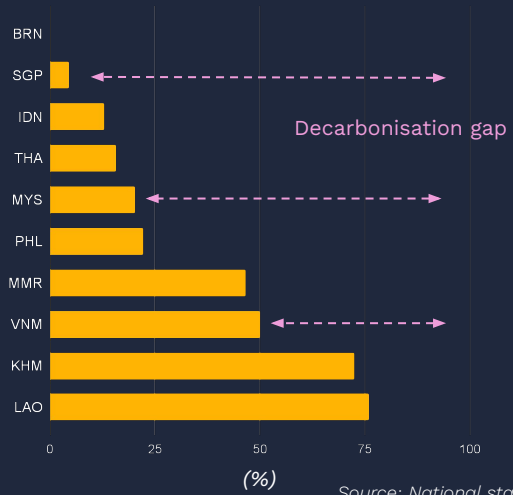
	Link	Existing capacity (MW)	Target cap. (MW) by 2040	Status
10	Lao PDR - Vietnam	570	5,000	Existing
11	Thailand - Myanmar	-	1,104	Planned
12	Vietnam - Cambodia	400	1,312	Existing
13	Lao PDR - Cambodia	300	579	Existing
14	Thailand - Cambodia	240	1,370	Existing
15	Malaysia (East Sabah) – Indonesia (North Kalimantan)	-	159	Planned
16	Singapore – Indonesia (Sumatera)	-	1,133	Planned
17	Lao PDR - Myanmar	30	609	Existing
18	Indonesia inter-island Java – Kalimantan Sumatera - Jawa	-	424 10,000	Planned

New drivers for grid investment are emerging

New priorities put spotlight on long-distance, cross-border electricity transmission

Drivers	Description
Nine out of 10 ASEAN economies have committed to achieve **net zero emissions** by or around 2050 or 2060	The conventional pathway of importing fossil fuels for localised power generation is being revisited, with more consideration given to electricity transmission and import from neighbouring markets.
Fast-growing demand for **clean electricity**	Member states are competing for big-ticket foreign investments with hard requirements for low-carbon electricity access.
Diversification as a new dimension of **energy security**	Countries are tapping into indigenous RE resources and enhancing power import capacity, to mitigate risks of imported fuel cost volatility and supply disruptions.
Export opportunities for RE resource-rich areas	Countries (even regions within a country) with abundant renewable energy are motivated to capitalise on their endowed resources, and export to willing buyers.

RE share in annual generation mix (%), 2022



Source: National statistics

However, political and social buy-in require better data and transparency

TransitionZero's APG model addresses pressing questions about regional grid planning

1 **Grid vs Fossil Fuel infrastructure**

Can a regional grid help reduce coal and gas infrastructure build-out and use?

2 **Country-level impact**

What are the net gains to each country under different regional interconnection scenarios?

3 **Green grid targets**

Which transmission corridors can be the most catalytic for regional decarbonisation?

4 **Grid and renewables promotion**

Can a regional grid foster higher renewable penetration and economics?

5 **Singapore links**

If realised, can these subsea cables be leveraged for broader regional impact?

6 Are interconnectors a core asset as we enter an era of accelerated technological change and new policy priorities?

About TZ-APG v1

An overview of the model's inputs, key constraints and modelled scenarios

24 nodes to represent the APG in an open source model framework

High-level representation of power dispatch, the regional grid and transmission corridors

Source: TransitionZero

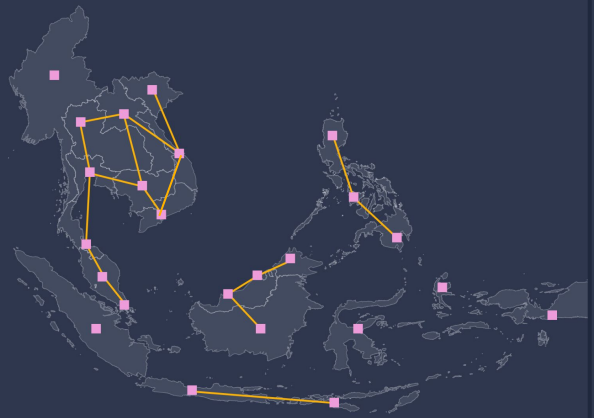
- 2023-2035, where modelled results are presented for 2035
- 2-hour block temporal representation
- Best-in-class spatial resolution, 24-node model (at least one per country)
- Optimisation of capacity expansion and operation of power plants, storage, and transmission to meet electricity demands and national policy targets at least cost
- "Live" model built with PyPSA. New iterations ongoing to answer emerging policy and investment questions

Four modelled interconnection scenarios

Testing scenarios around transmission build out in the ASEAN

BAU + Enhanced BAU

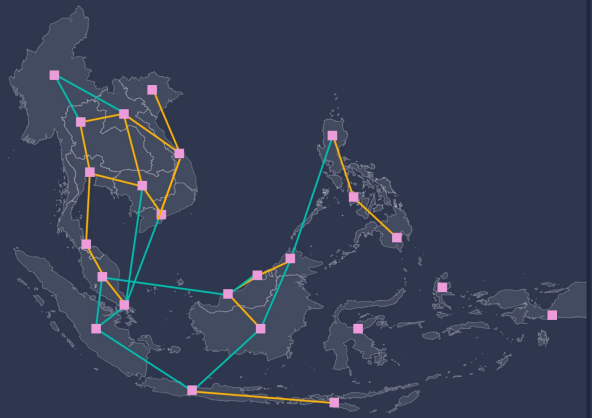
SCENARIO 1 Existing transmission at current capacity



SCENARIO 2 Existing transmission at enhanced capacity

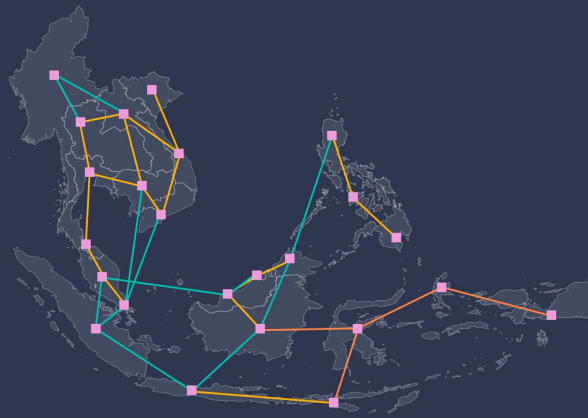
Regional Interconnection

SCENARIO 3 Existing transmission and the remainder of AIMS3 18 interconnectors, and Singapore direct links to Cambodia and Vietnam



Indonesia Super Grid

SCENARIO 4 Scenario 3 and additional transmission: 4 inter-island Indonesian links

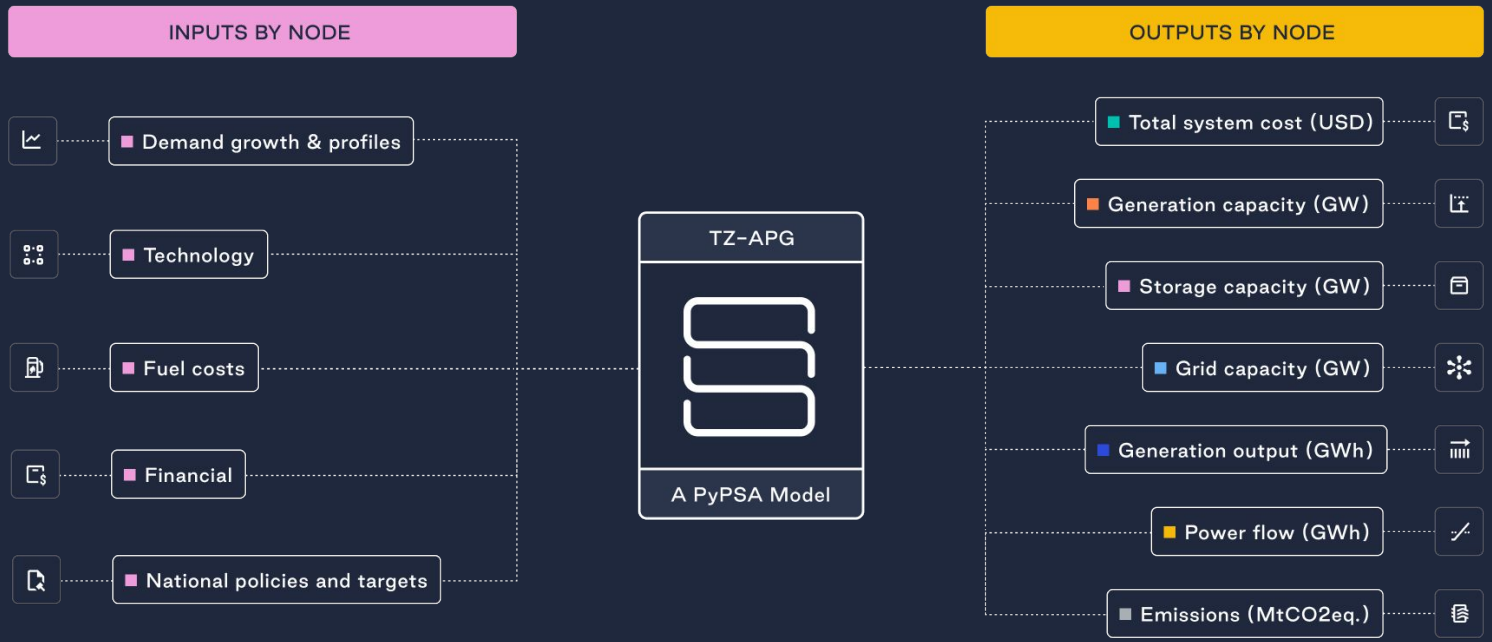


Source: TransitionZero

Full details and methodology are available in the Technical Annex.

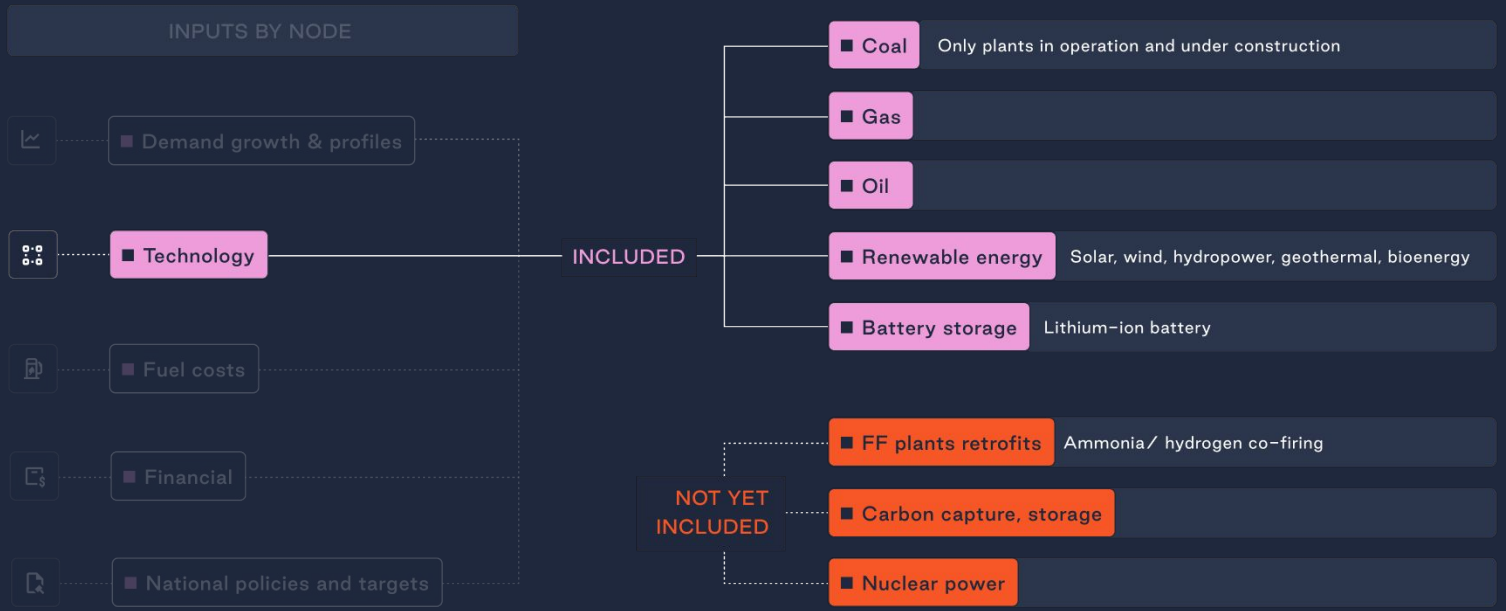
What goes in... and comes out

Validated data supports modelled outputs



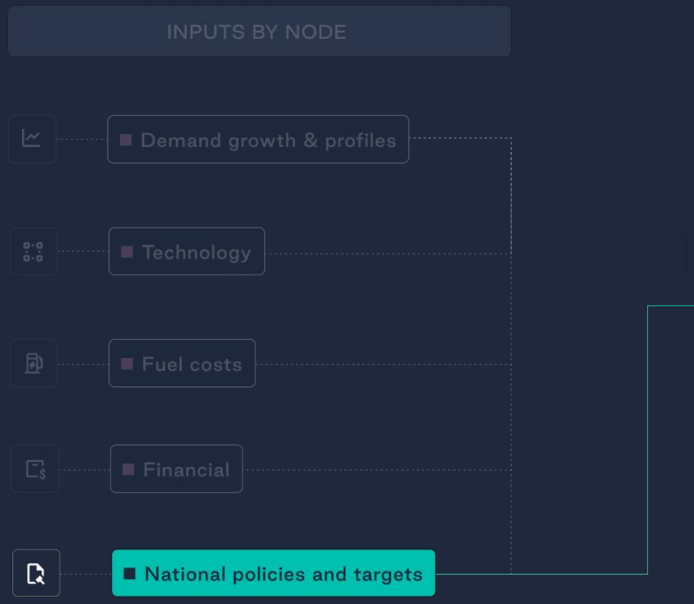
The model utilises a conservative technology palette

Our model currently works with technology choices common in ASEAN markets



... and reflects national policy constraints

In all scenarios, system development is driven by select national targets, and a least-cost outcome



	NATIONAL TARGET	TARGET YEAR
Brunei	30% solar capacity share	2035
Indonesia	31% RE generation share	2030
	Emissions target (290MtCO2eq)	2030
Cambodia	Hydro, solar, coal, gas capacity target	2030
Laos PDR	Hydro capacity target (13GW)	2030
Myanmar	RE, coal capacity target	2030
Malaysia	40% RE capacity share	2035
Philippines	35% RE generation share	2030
Singapore	Solar capacity target (2GWp)	2030
	Emissions target (60MtCO2eq)	2030
Thailand	35% RE generation share	2037
Vietnam	Wind capacity target; coal peak target	2030

Capacity target Generation target Emissions target

Regional & thematic highlights

What the modelled outputs from TZ-APG v1 tell us about ASEAN's power system in 2035

The price tag of regional grid development could be hefty

But investments should be considered for long-term returns and rewards

Total transmission upgrades and investment costs by scenario, in USD billion

SCENARIO 2

Enhanced BAU

57

USD billion

SCENARIO 3

Regional Interconnection

122

USD billion

SCENARIO 4

Indonesia Super Grid

124

USD billion

New grid capacity can trigger structural & operational shifts in the region's power system

Resources can be shared and utilised more efficiently

System requirements

▼ 27-37 GW

or up to 8% reduction in total system capacity required compared to BAU scenario

- ▼ 22-25 GW — up to 36% reduction in storage capacity
- ▼ 4-9 GW — 3-7% reduction in gas capacity
- ▼ 1-4 GW — up to 3% reduction in hydro capacity

Fleet economics

Changes in capacity factors of key generation sources compared to BAU scenario

- ▲ 0.6 pp — increase in avg. CF ... of coal plants
- ▲ 0.8 pp — ... of gas plants
- ▲ 3.5 pp — ... of hydro plants

Emissions impact

▼ 0.4-0.9%

Emissions reduction potential in year 2035

System cost impact

(incl. all generation capex 2023-2035, and opex for 2035)

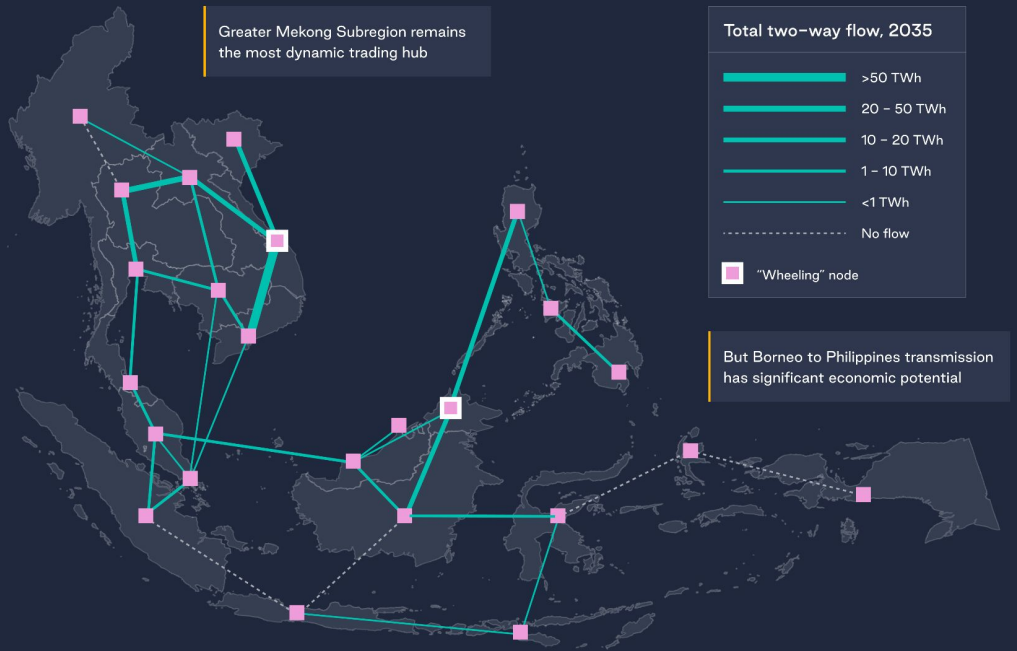
▼ 0.8-2.3%

System cost savings potential in year 2035

What the model shows

- Scenarios with more regional transmission available see a **decline in the buildout of new storage, gas, and hydropower capacity**, indicating potential capex savings.
- Regional grid integration fosters an optimal operation/economics of power assets, which is reflected in upticks in utilisation rates of **coal, gas, hydro, geothermal**, and **bioenergy generators** as power systems get more connected.
- The overall growth of solar and wind power is similar across the modelled scenarios, emphasizing the complementarity of these technologies with more dynamic grid capacity.
- Driven by a least-cost outcome, TZ-APG v1 shows that there could be **system cost savings** of up to 2.3% compared to BAU scenario. **Emissions savings** by year 2035 are limited to 0.9%; improving this performance would require adjustments to the dispatch assumptions of FF generators, and cost profile of brown power, among others.

Two main hubs hold the biggest potential for transmission



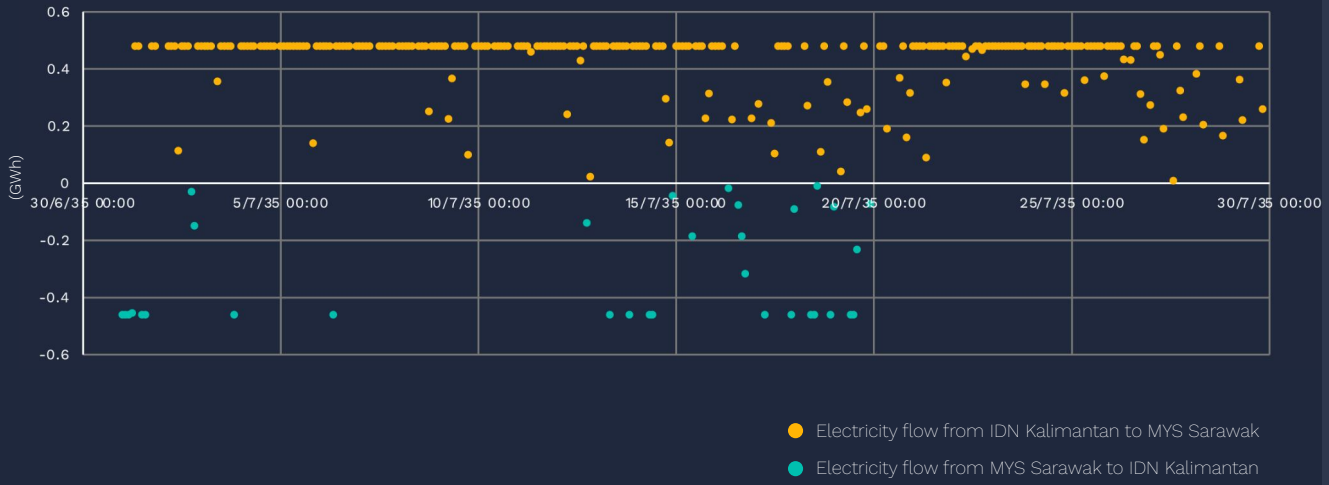
What the model shows

80% of the region's electricity trade observed in six key routes

Route	Two-way flow, 2035 (TWh) in "IDN Super Grid" scenario
VNM Central - South	81.0
LAO – VNM Central	49.4
LAO – THA North	33.6
MYS Sabah – PHL Luzon	19.7
IDN Kalimantan – MYS Sabah	18.1
THA Central - North	13.4

Partners can benefit from complementary resources and usage patterns

Electricity exchange simulation between IDN Kalimantan and MYS Sarawak (GWh) at 2-hour intervals in July 2035



What the model shows

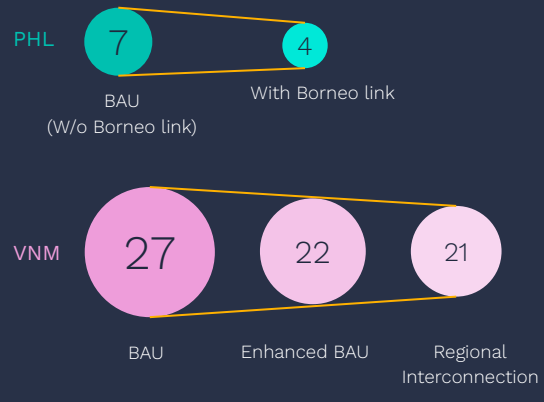
- While the majority of cross-border exchange in the region is unidirectional, there are also instances of two-way flow where partners have complementary differences in seasonal, time-of-day demand and resource availability.
- This relationship is observed in two-way cross-border exchanges between the following nodes:
  - **MYS Sarawak** and **IDN Kalimantan**: While the former is the main exporter throughout the year, MYS Sarawak becomes the importer, although in small amounts, in the months July, November and December.
  - **KHM** and **VNM South**: Exports from KHM are most observed in the months from July to October, while VNM South exports on a sustained basis, in small amounts, throughout the year.

Grid or Gas?

Transmission could outcompete gas assets in Vietnam and the Philippines

Trade flows between nodes

Gas capacity by grid scenario (GW), 2035



Lao to Vietnam power flow

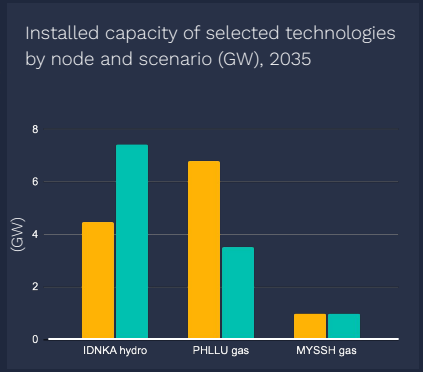
Borneo to PHL Luzon power flow

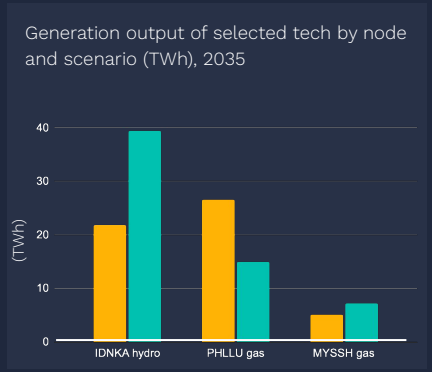
What the model shows

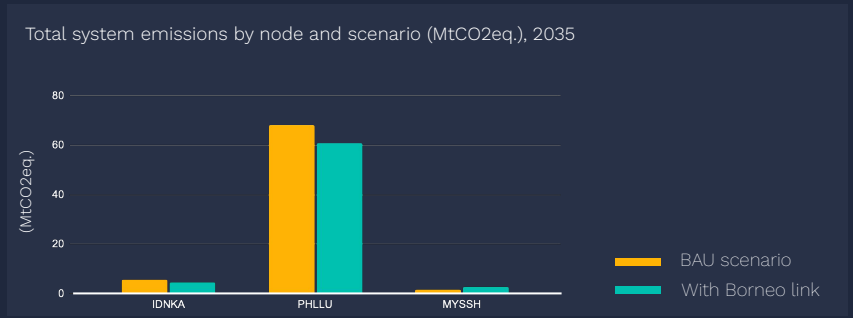
- VNM and PHL could be the main beneficiaries of gas “avoidance” resulting from better regional interconnectivity. **The build-out of gas in these countries appears sensitive to grid enhancement and expansion**.
- With grid links to Borneo, **PHL Luzon** reduces the need for new gas capacity by 48% compared to BAU scenario. Coal power generation in the country could also slide by 2%.
- Transmission grid upgrades in **VNM** could reduce investment needs for new gas generators. Higher import capacity from LAO to carry electricity to the two load centres in the North and South could reduce gas buildout in the country by up to 20%.

The green lane

Kalimantan – Sabah – Luzon a potential decarbonisation corridor





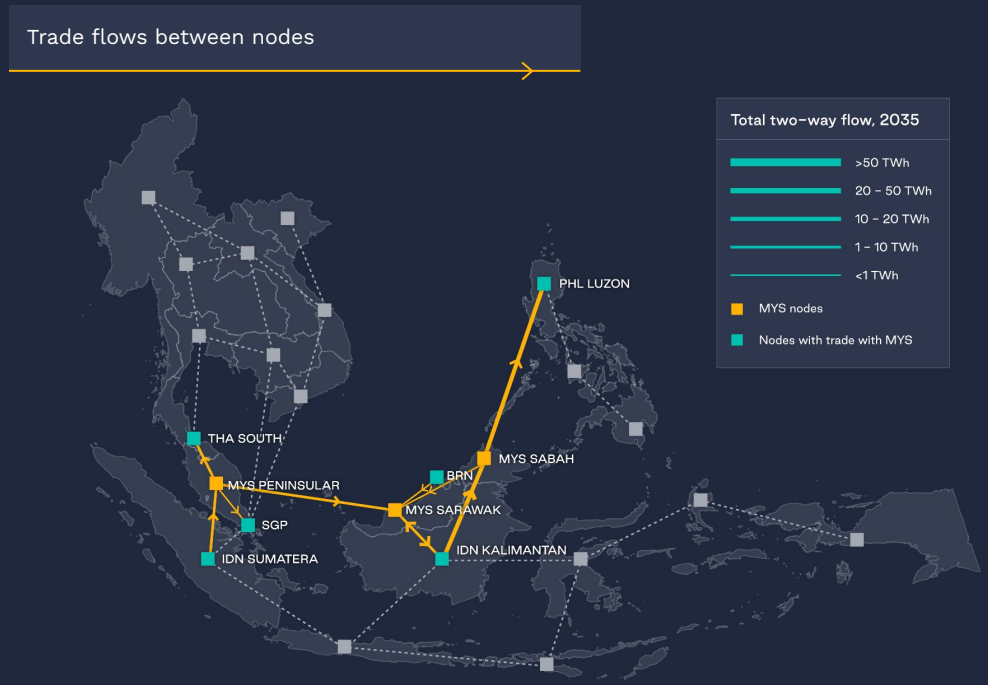


What the model shows

- Grid connectivity and electricity trade between IDN Kalimantan, MYS Sabah, and PHL Luzon could bring about **net positive climate benefits**.
  - **IDN Kalimantan** could tap its hydropower resources for export revenues.
  - **MYS Sabah** plays an important role as trade facilitator, “wheeling” clean electricity from IDN Kalimantan to PHL Luzon.
  - **PHL Luzon** imports clean power and contains gas capacity development by 48% compared to a no-import scenario.
- **This finding supports ASEAN’s second multilateral initiative, the Brunei - Indonesia - Malaysia - Indonesia Power Integration Project (BIMP-PIP)**, which was recently launched by member states in 2023.

Malaysia the new trading platform

ENEGEM kick-off makes sense



What the model shows

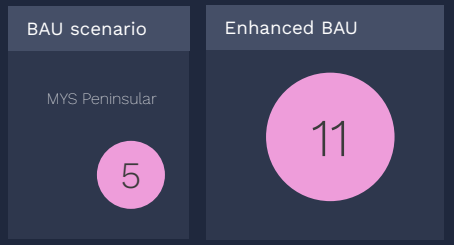
- Malaysia could further capitalise on its geostrategic location and resources to facilitate multilateral cross-border trade in the region
  - Two-way trade with **IDN**, including imports from Sumatera and two-way exchange with Kalimantan.
  - **MYS Sabah** plays key role as carrier of clean electricity from IDN Kalimantan to **PHL** Luzon
  - Exports to **SGP** are observed in all scenarios, though actual volume is sensitive to SGP's access to new exporters, such as IDN Sumatera
  - Exports to **THA** in steady volumes throughout all scenarios
- The recent establishment of the Energy Exchange (**ENEGEM**), a centralised platform to enable green electricity sales to neighbouring countries, is a step in the right direction. It is designed to foster **grid-to-grid connection and export**, initially to SGP and THA.

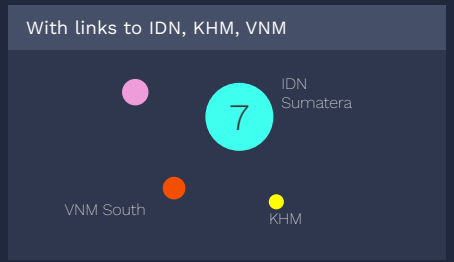
Singapore imports diversified

Every partner counts

Trade flows between nodes

Singapore's import volume by partner and scenario (TWh), 2035



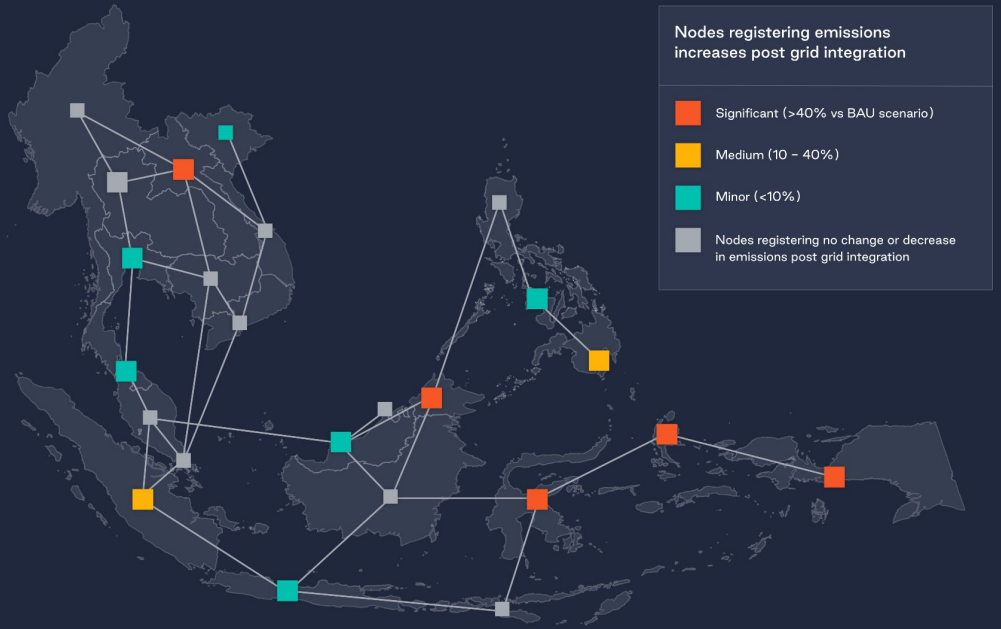


What the model shows

- SGP must rely on power imports to meet growing demand and decarbonisation targets.
- Proposed interconnection with partners such as **IDN Sumatera, KHM, VNM** could divert importing demand away from **MYS Peninsular.**
- Imports from **KHM** and **VNM** even though registered, are modest in volume, and the subsea interconnectors appear to have no impact on multilateral trade (i.e. only transmit electrons to SGP for final consumption).

Tackling uneven impacts

Carbon “leakage” risk as the grid is saturated with fossil generators



What the model shows

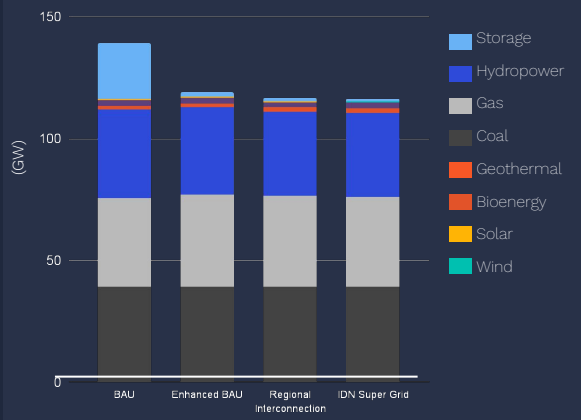
- Not all nodes register neutral or positive climate impacts from regional grid integration in the modelled year 2035.
- This occurs because the model, currently configured to aim for a least-cost outcome and current policy targets, would choose to optimise coal and gas plants in operation.
- In practice, the question of carbon “leakage” risk is not new when it comes to grid integration and cross-border electricity trade. As demand for “green electricity” rises, the traceability of imported power will become crucial.
- ASEAN countries have diverse priorities and some will focus on efforts to mitigate carbon leakage risk and foster “green” cross-border trade. Future model iterations could explore the nodes that could be most positively affected by changed technology assumptions (e.g. dispatch constraints on FF generators, higher RE build-out).

Country deep dives

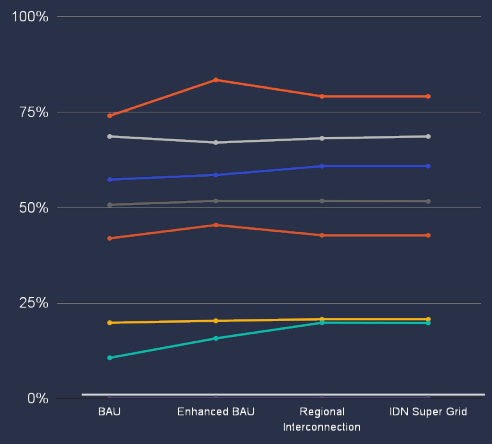
A closer look at how national power systems fare under different grid pathways under TZ-APG v1

Indonesia: FF dispatch constraints could be a game changer

Indonesia's capacity mix by scenario (GW), 2035



Capacity factor by technology by scenario (%), 2035



Emissions impact

▲1.5-1.7%

Emissions increase risk in year 2035 compared to BAU scenario

System cost impact

▼1.6% to ▲0.3 %

System cost reduction/increase in year 2035 compared to BAU scenario

(incl. all generation capex 2023-2035, and opex for 2035)

What the model shows

- Grid expansion has the most visible impact on IDN's **storage capacity**. Compared to the BAU scenario, IDN's storage capacity would be reduced by 91-95% under any of the three grid development pathways modelled through 2035. The rest of the capacity mix remains largely unchanged across the grid scenarios.
- IDN's generation mix sees a slight change in the share of each technology under each grid scenario.
- Even though modest in size (202MW) and only built in IDN Sulawesi, the **wind fleet** sees improved performance under the three grid expansion scenarios, as the model optimises clean sources to meet national emissions targets.
- Total system cost reduction is highest (-1.6%) under the IDN Super Grid scenario.
- In this cost optimisation model, grid expansion might lead to upticks in emissions for IDN, as coal and gas plants' increased outputs are not fully offset by clean sources. This suggests the potential role of FF dispatch constraints for improved emissions outcomes in IDN.

Indonesia: Cross-border prevails over intra-island trade

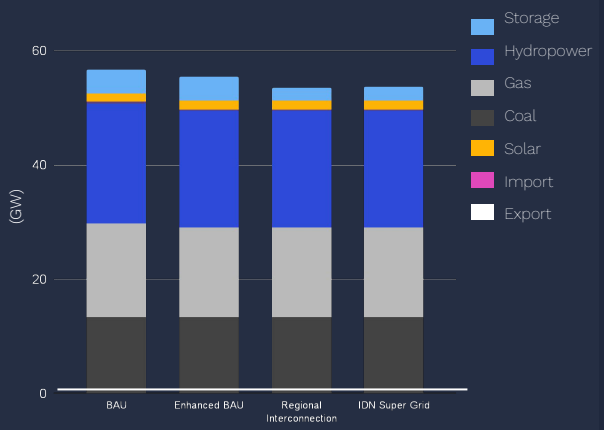
Trade flows between nodes: IDN Super Grid scenario

What the model shows

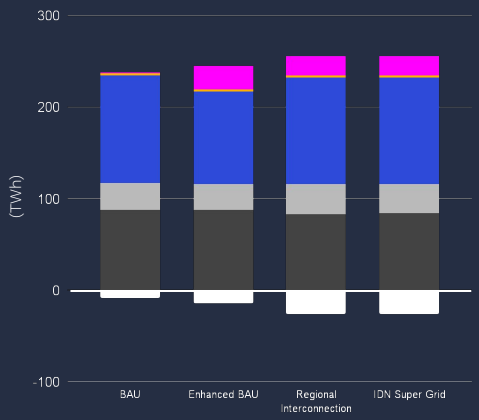
- Even with inter-island transmission lines established, **power trade between IDN's main islands remains very modest**, at less than 2TWh in year 2035. The only routes with traffic are:
  - **Nusa Tenggara and Jawa** (two-way trade observed, but in negligible amount)
  - **Nusa Tenggara to Sulawesi** (one-way, limited)
  - **Kalimantan to Sulawesi** (one-way, largest)
- This suggests that each island has adequate supply for self-sufficiency, including of brown sources, with system cost optimised and IDN still able to meet its 2030 emissions target.
- Meanwhile, the model shows **notable export potential for IDN generators**:
  - **IDN Kalimantan** to **PHL Luzon** (via **MYS Sabah**)
  - **IDN Sumatera** to **SGP**
  - **IDN Sumatera** to **MYS Peninsular**

Malaysia: Hydropower economics and gas leakage

Malaysia's capacity mix by scenario (GW), 2035



Malaysia's generation mix by scenario (TWh), 2035



Emissions impact

▼1.0–3.5%

Emissions reduction in year 2035 compared to BAU scenario

System cost impact

▼2%

System cost savings in year 2035 compared to BAU scenario

(incl. all generation capex 2023-2035, and opex for 2035)

What the model shows

- Grid expansion could help MYS reduce its **storage** and **gas capacity**, by up to 40% and 5%, respectively, compared to the BAU scenario.
- **Hydropower** becomes the largest source of power in MYS in the modelled year 2035, and regional grid integration gives a boost to its utilisation compared to the BAU or Enhanced BAU scenarios.
- The uptick in **gas output** post-grid integration, mostly observed in MYS Sabah and MYS Peninsular. suggests the important role of "green electricity" tracking in managing carbon leakage risk in export countries such as MYS.
- **System cost savings** potential is estimated at 2% compared to the BAU scenario.
- At the national level, MYS registers a n**et positive emissions impact** under any grid development scenario.

Malaysia: A regional trading platform

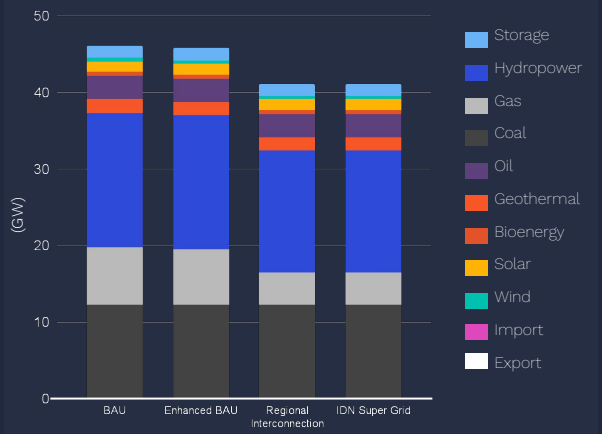
Trade flows between nodes, Scenarios Regional Interconnection and IDN Super Grid

What the model shows

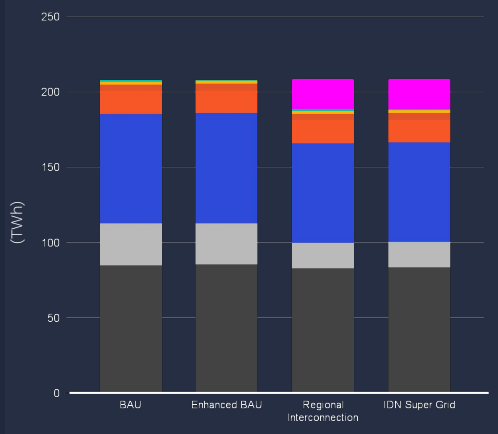
- MYS could further capitalise on its geostrategic location, resources and facilitate multilateral cross-border trade in region
  - Two-way trade with **IDN**, including imports from Sumatera and two-way exchange with Kalimantan.
  - **MYS Sabah** plays key role as carrier of clean electricity from IDN Kalimantan to **PHL** Luzon
  - Exports to **SGP** are observed in all scenarios, though actual volume sensitive to SGP's access to new exporting sources, such as IDN Sumatera
  - Exports to **THA** in steady volumes throughout all scenarios
- The recent establishment of the Energy Exchange (**ENEGEM**), a centralised platform to enable green electricity sales to neighbouring countries, is a step in the right direction. It is designed to foster **grid-to-grid connection and export,** initially to SGP and THA.

Philippines: Gas sensitivity

Philippines' capacity mix by scenario (GW), 2035



Philippines' generation mix by scenario (TWh), 2035



Emissions impact

▼ 0.4-6.1%

Emissions reduction in year 2035 compared to BAU scenario

System cost impact

▼ 0.5-7.9%

System cost savings in year 2035 compared to BAU scenario

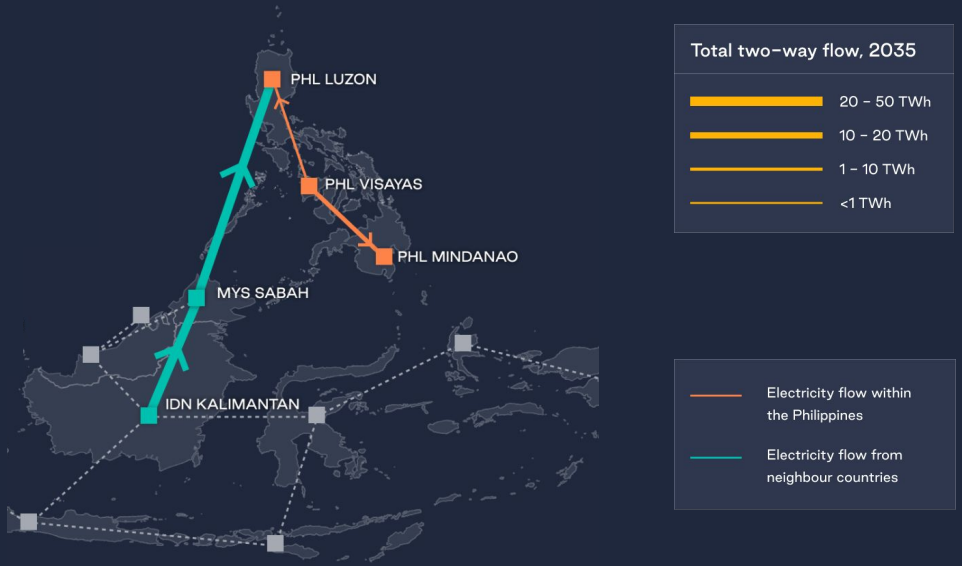
(incl. all generation capex 2023-2035, and opex for 2035)

What the model shows

- Currently an isolated system, PHL's power system does not register notable structural or performance change if existing transmission between the three grid regions Luzon, Visayas, and Mindanao is strengthened (under "Enhanced BAU" scenario).
- However, once grid connection is allowed with Borneo island (last two scenarios), PHL's build-out of gas and hydropower capacity instantly drops by 44% and 9%, respectively, compared to a no-connectivity scenario. This is due to favourable cost and emissions profiles of imported electricity.
- With regional grid integration, PHL could cut down system cost by 7.9% compared to a no-connectivity scenario, while emissions savings potential is also registered by up to 6.1%.

Philippines: The merits of the BIMP-PIP

Trade flows between nodes, Scenarios Regional Interconnection and IDN Super Grid

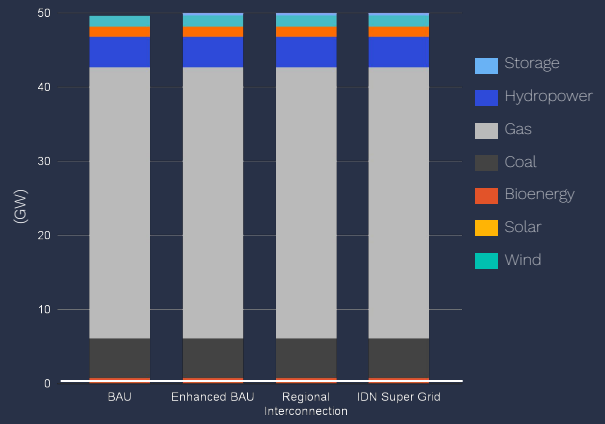


What the model shows

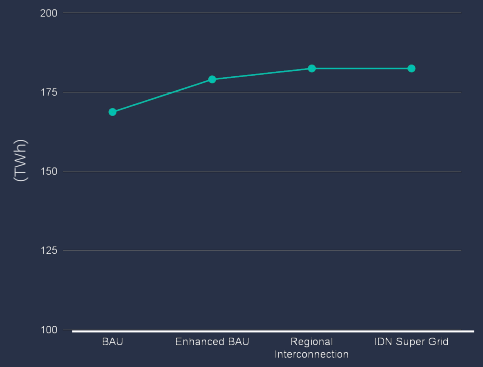
- Within PHL, the transmission route between Visayas and Mindanao sees the most traffic, with the latter being the distinct exporter under all scenarios.
- PHL's gateway to the regional power system is Borneo island via Malaysia, with Sabah playing a key role as the "carrier" of hydropower electricity sourced from IDN Kalimantan.
- This finding highlights the decarbonisation impact of a multilateral trading scheme between IDN, MYS and PHL, which the member states are currently pursuing under the Brunei – Indonesia – Malaysia – Philippines Power Integration Project (BIMP-PIP).

Thailand: Regional competition hits

Thailand's capacity mix by scenario (GW), 2035



Thailand's gas power output by scenario (TWh), 2035



Note: y-axis is truncated

Emissions impact

▲ 0.8–3.6%

Emissions increase risk in year 2035 compared to BAU scenario

System cost impact

▲ less than 0.01%

System cost increase in year 2035 compared to BAU scenario

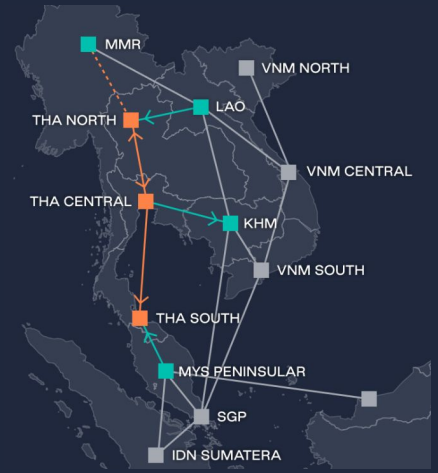
(incl. all generation capex 2023-2035, and opex for 2035)

What the model shows

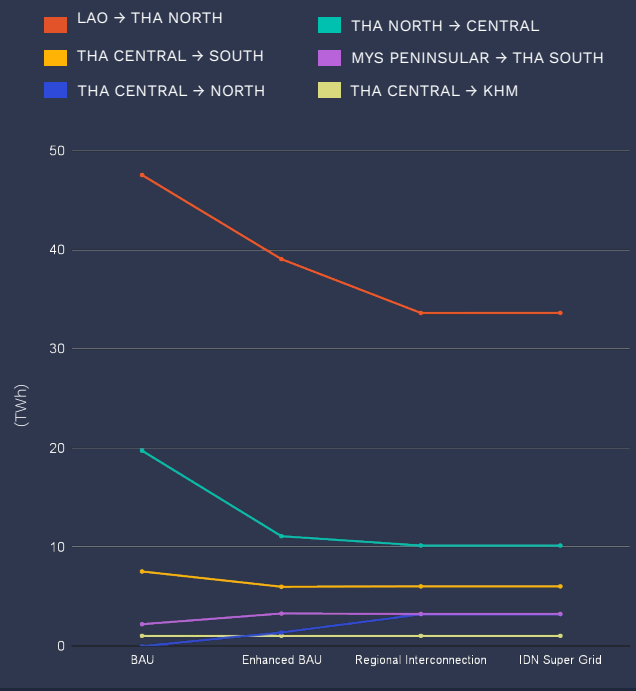
- THA's capacity mix remains almost unchanged across the grid scenarios, except for **storage capacity**. Unlike other countries, THA observes an expansion, albeit modest, in storage capacity as regional grid integration improves.
- **Gas** continues to occupy the lion's share of THA's generation mix. Notably, gas output trends upward in the three grid expansion scenarios, making up for lost imports that are being diverted away from THA in favour of VNM (see next slide).
- As a result, THA registers increased emissions across the three grid expansion scenarios.
- Note that the model has yet to meet THA's policy target of reaching 36% renewable penetration (capacity share) in year 2037, as the modelling period stops at 2035. Future model iteration will expand to 2040 or 2050 to explore the implementation and impact of this target.

Thailand: Power rerouted

Trade flows between nodes, Scenarios Regional Interconnection and IDN Super Grid



Trading volume between nodes by scenario (TWh), 2035

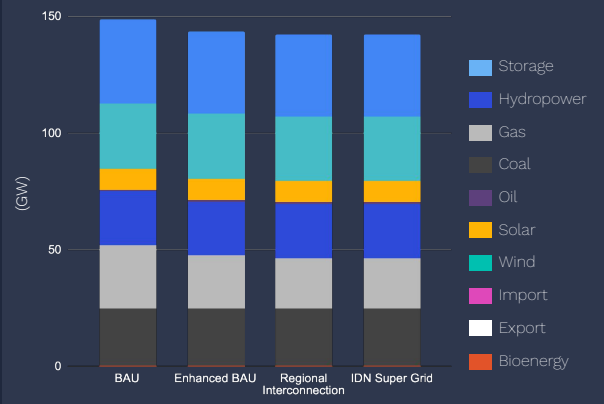


What the model shows

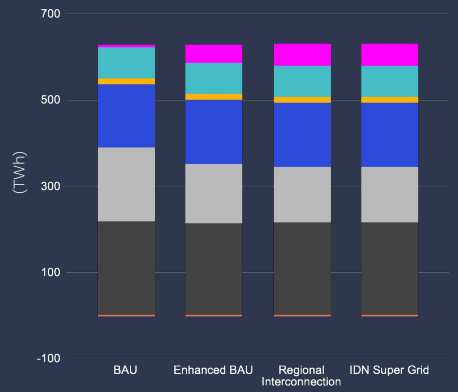
- At present, THA already has grid connections and power trade with neighbouring LAO, KHM, and MYS Peninsular. However, with grid expansion taking place in nearby markets, THA's power system is impacted as a result.
- The drop in imports from LAO results in increased transmission from THA Central to North. THA North, previously a "wheeling" node for imported electricity, also reduces transmission to the load centre in THA Central.
- **This is a grid-to-grid integration simulation**. In practice, as most export-dedicated LAO power plants may not be fully connected to the national grid and are bound by long-term contracts to export to THA, the trade diversion to VNM would be less straightforward.

Vietnam: Gas sensitivity

Vietnam's capacity mix by scenario (GW), 2035



Vietnam's generation mix by scenario (TWh), 2035



Emissions impact

▼5.3-5.6%

Emissions reduction in year 2035 compared to BAU scenario

System cost impact

▼2.4-3.0%

System cost savings in year 2035 compared to BAU scenario

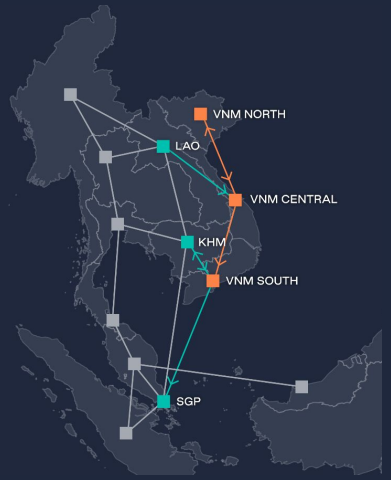
(incl. all generation capex 2023-2035, and opex for 2035)

What the model shows

- VNM's capacity mix registers a notable **drop in gas capacity** as grid connectivity with LAO deepens. VNM, particularly the North and South regions, could cut down gas build-out by 17-21% compared to the BAU scenario with more imports enabled from neighbouring LAO.
- With an ambitious target for variable renewables such as wind and solar, VNM's needs for **storage capacity is significant** (35-36GW) and the highest in ASEAN, in the modelled year 2035.
- Overall, with higher imports and avoided investments in gas, VNM could register system cost savings compared to the BAU scenario. It also stands to benefit from increased climate benefits as a result of further regional grid integration.

Vietnam: Heavy traffic

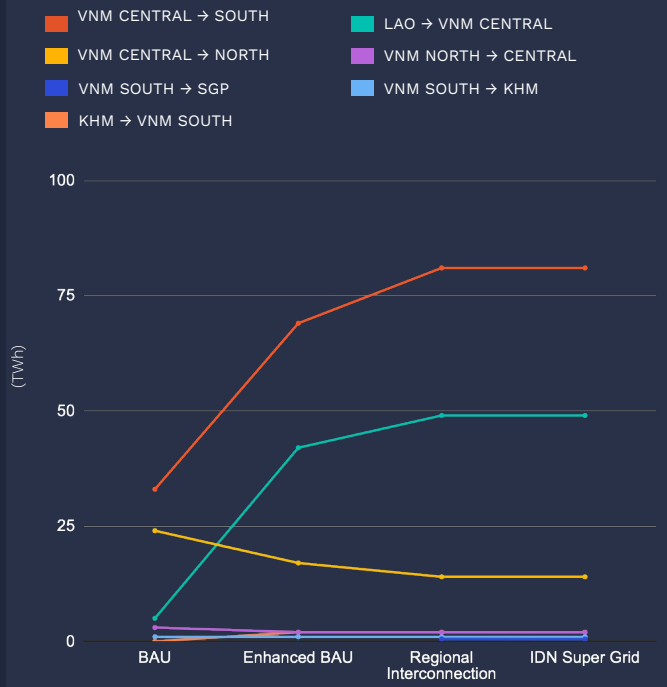
Trade flows between nodes, Scenarios Regional Interconnection and IDN Super Grid



Electricity flow within Vietnam

Electricity flow with neighbour countries

Trading volume between select nodes by scenario (TWh),2035



What the model shows

- With the main load centres in the North and South, and renewables sources concentrated in the Central node, **domestic transmission** lines are heavily in use.
- Imports from LAO are optimised by the model, mostly to serve VNM South. The optimal import capacity (5.3-6.5GW) by the modelled year 2035 aligns with the G2G MOU of reaching 5-8GW transmission capacity by 2030.
- Two-way trade with KHM remains stable across the grid scenarios and reflects resource complementarity between the two countries.
- Even though modest in export volume (<1TWh in year 2035), the model still shows the economic case of exporting power to SGP from VNM South.

Policy and user guidance

Reflections on TZ-APG modelling

TZ-APG model is a tool

There is an opportunity to use TZ-APG modelling infrastructure and layer the results to offer complete and strategic insights to facilitate transmission planning and investment in Southeast Asia

1

Impact assessment of new grid or import capacity on a country's power system and performance outlook

TZ-APG enables sensitivity analysis of different input parameters. The ability to test for dynamic transmission and import capacity would be of particular relevance to countries where local governments are advancing transmission investments and import approvals.

2

Assessment of the "green" credentials of a transmission candidate

TZ-APG can support global initiatives focused on financing "green" grid infrastructure by modelling the prospects of a transmission candidate in facilitating renewable energy flows between chosen nodes.

3

Examining electricity and transmission cost options

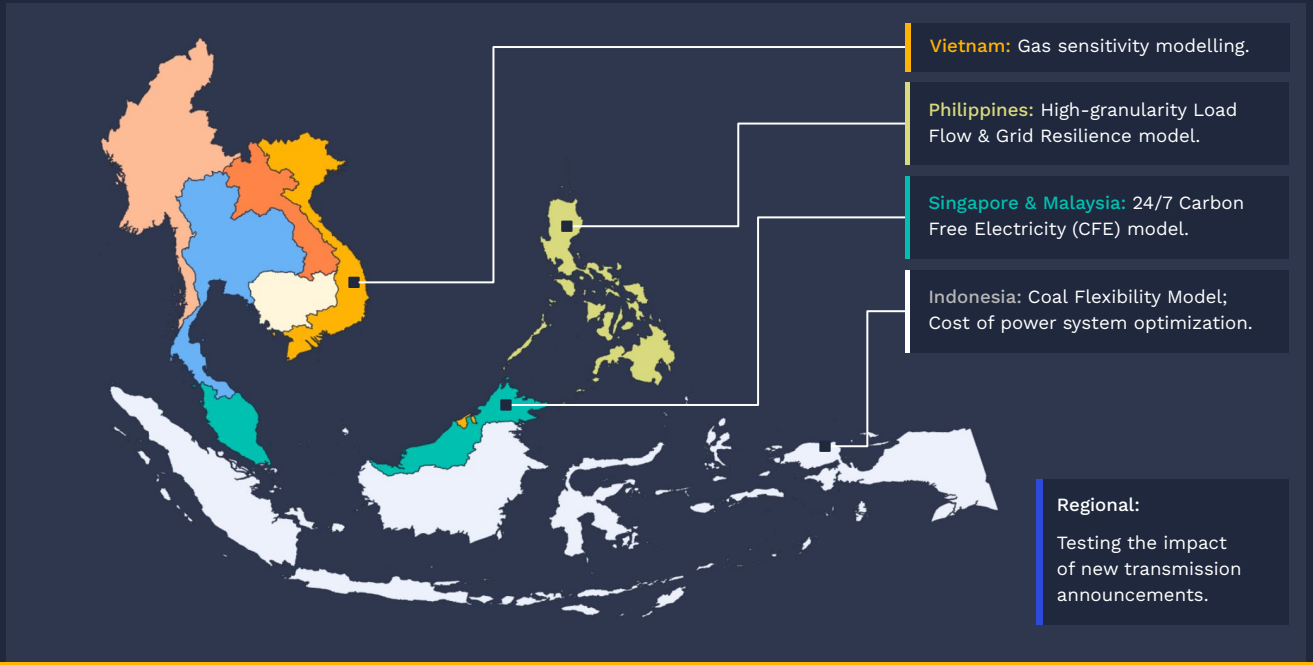
With further iterations, the costs of electricity export, wheeling, and import can be better represented to provide insights on the financial implications of regional interconnection.

Next steps

Our roadmap for TZ-APG

Work in progress

Projects built on top of the TZ-APG are underway, making us well-positioned to answer emerging questions on systems planning across the region and within countries



- TZ-APG is a base model with ASEAN coverage, enabling national and subnational model iterations.
- The model set-up is flexible and scalable, able to incorporate new data inputs, constraints, and other configurations.
- This will allow us to simulate the impact of new and existing policies or investments that we're sure to see in the region.

This is just the beginning

TZ-APG is a *live, open source model* with new runs planned within the next 6-9 months

New iterations, improvements	Description	Type of improvement
NZE 2040/2050 outcome	Extend modelling horison to 2040/2050, and model for a net zero emissions outcome	Modelling horizon, Constraints setting
Adjusted FF plants operating parameters	Constrain the dispatch of coal or gas assets to test the penetration ability of RE. Example: coal flexibility assessment	Constraints setting
Demand sensitivity modelling	Test more dynamic demand growth scenarios and investigate impact on system development	Input data
Improved RE potentials and profiles data	More robust, granular solar and wind potentials and profiles data (nodal, sub-nodal level)	Input data
Improved RE cost data	More robust, granular, and updated LCOEs for renewable technologies (country-specific)	Input data

Get started with TZ-APG v1

Visit transitionzero.org to download the package

The .ZIP package includes seven files

TZ-APG v1 PyPSA model files in .nc format

- `tz-apg-v1_scenario-bau.nc`
  unidata network file for the Business-As-Usual (BAU) scenario, featuring 31 existing interconnector and transmission routes with no expansion allowable.
- `tz-apg-v1_scenario-ebau.nc`
  unidata network file for the Enhanced Business-As-Usual (EBAU) scenario, featuring 31 existing interconnectors and allowing their expansion
- `tz-apg-v1_scenario-regi.nc:`
  unidata network file for the Regional Interconnection (REGI) scenario, featuring 54 existing and proposed interconnectors
- `tz-apg-v1_scenario-isg.nc:`
  unidata network file for the Indonesia Super Grid (ISG) scenario, featuring 62 existing and proposed interconnectors

`tz-agp-v1_inputs.csv`
excel tables containing all the model inputs by scenario used in TZ-APG v.1.

`tz-agp-v1_results.csv`
excel tables containing all the model results used in TZ-APG v1 and analysed in the “From Vision to Voltage” report.

`tz-apg_technical-annex.pdf`
A pre-print article that explains the methodology and data sources in detail.

DOWNLOAD

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Attribution

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