Overview of ASEAN regional/RE grid integration analysis

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System Integration of Renewables
Consultation Workshop, Bangkok, 20 June 2019
IEA

Outline

- Overview of ASEAN and regional/RE integration
  - ASEAN power grid
  - Integration of renewbles and flexibility options
  - Background and key objectives of the ASEAN RE grid integration project
- Approach to assess the value of cross-border interconnection and RE in ASEAN
  - Modelling approach, scenarios and main assumptions
- Key findings
  - The value of multilateral power trade in ASEAN
  - The benefits of expanding cross-border interconnectors
- Summary and next steps

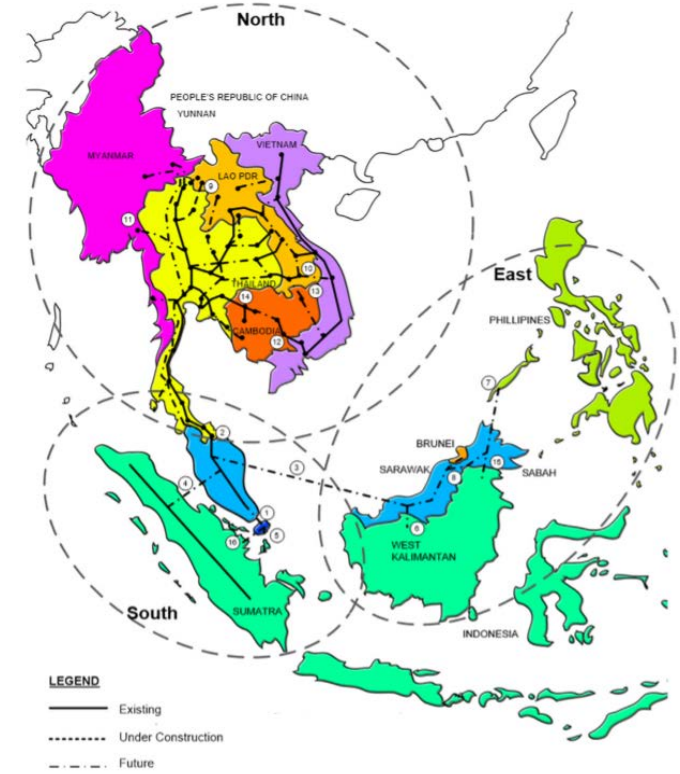
Overview of ASEAN and regional/RE integration

ASEAN power grid

Integration of renewables

Background and objectives

ASEAN power grid

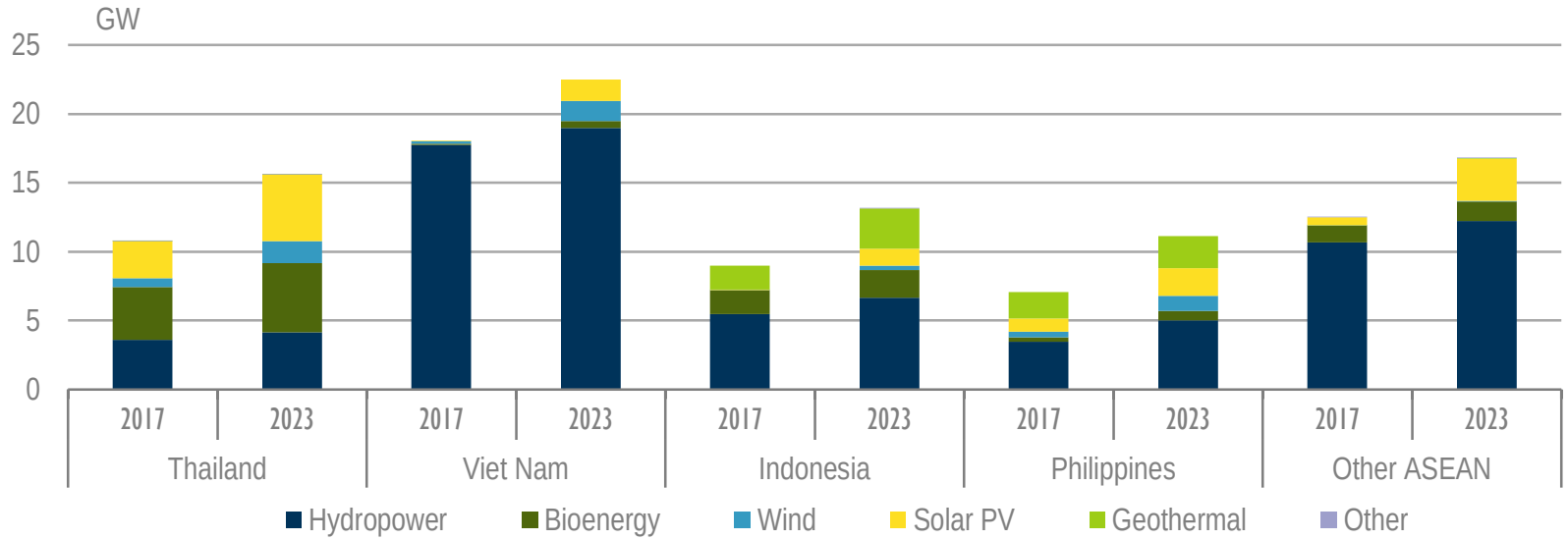


- Ensure regional security by promoting the effective utilisation and resource sharing for common regional benefit.
- Facilitate cross-border electricity trading
  - reliable, efficient, and economical operations
  - effective utilisation of resources across geographical locations
- Enable the integration of higher share of VRE sources in the ASEAN power system
  - A target of 23% RE share by 2025

The ASEAN Power Grid is an ambitious project that aims to interconnect the power systems in the region. It is a road to multilateral power trade that enables the integration of renewables

ASEAN renewable capacity to grow over a third by 2023

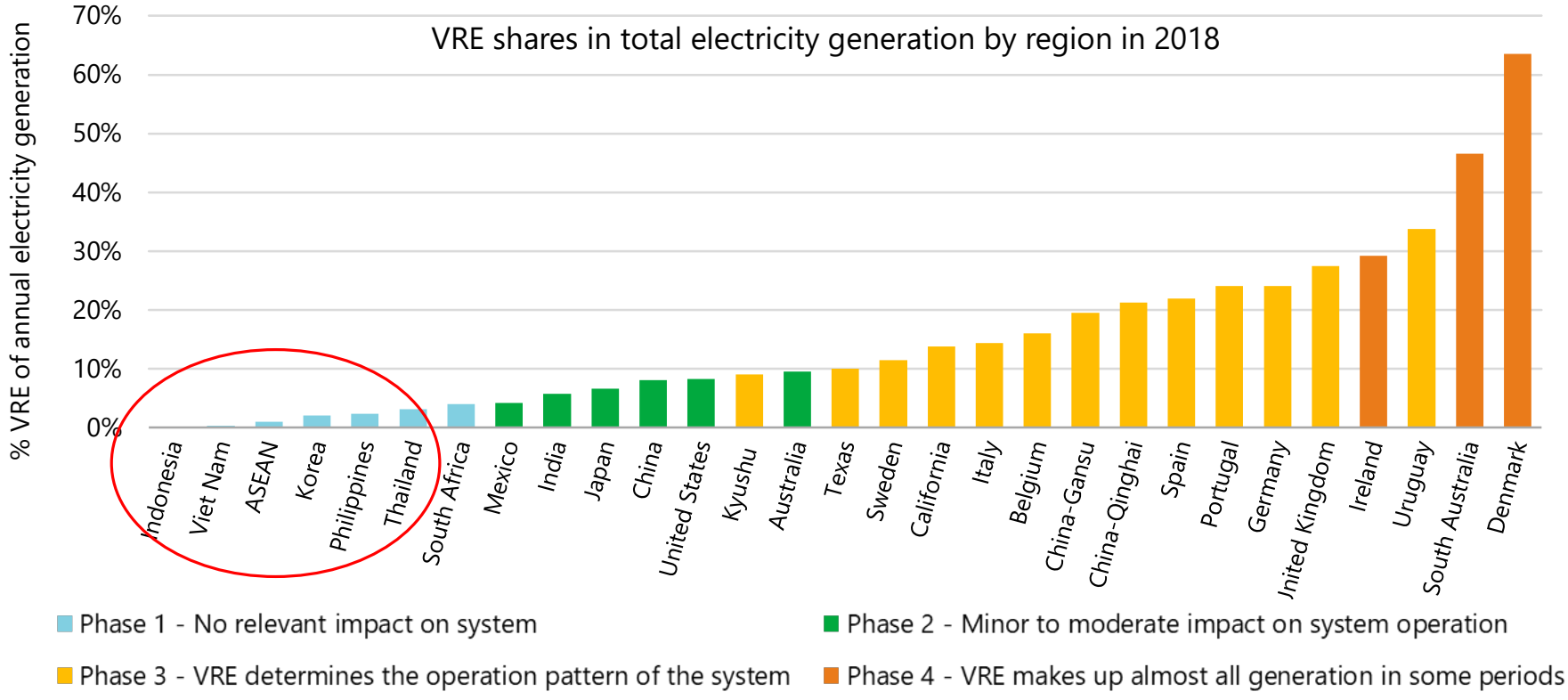
ASEAN cumulative renewable capacity, 2017 and 2023



The growth of solar and wind raises system integration challenges. ASEAN power grid is a key flexibility resource.

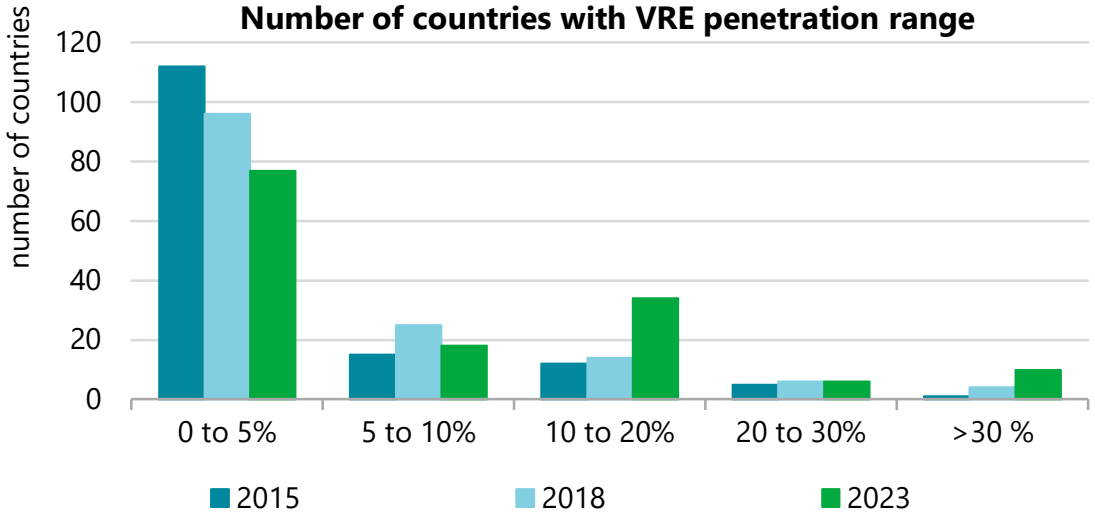
Source: Renewables 2018: : Analysis and Forecasts to 2023

System integration: different phases



Many countries/regions are still in Phase 1 and 2 of system integration but they are expected to be moving to higher phase in the coming years.

Solar and wind making strong inroads globally



Source: Status of Power System Transformation 2019

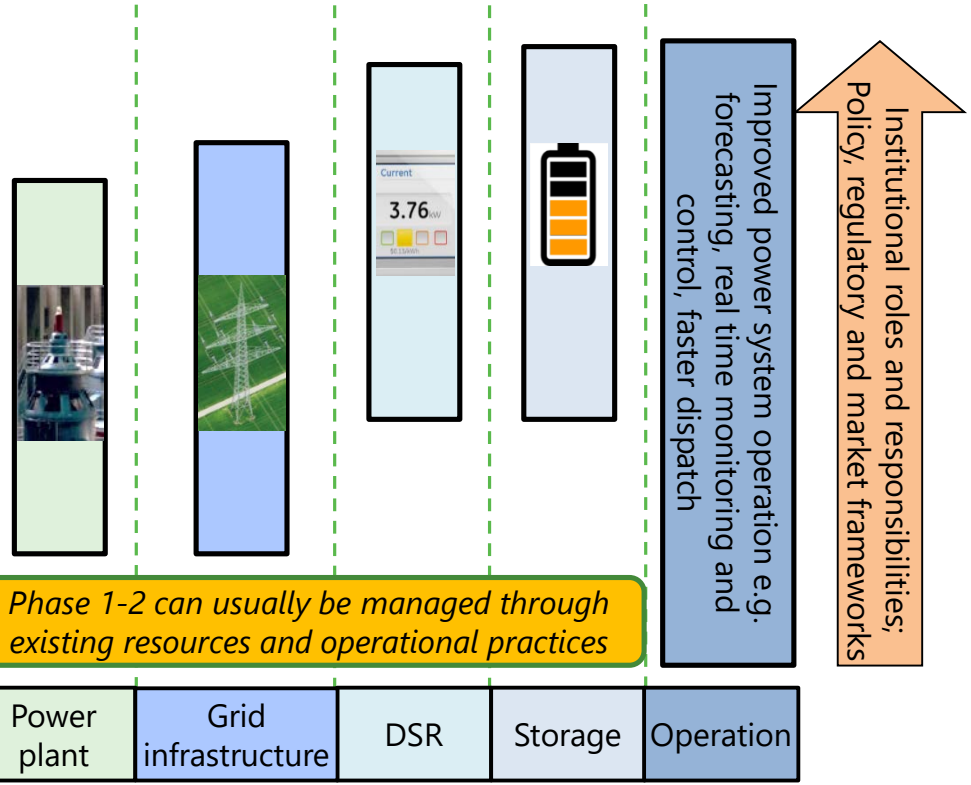
Increasing number of countries with higher VRE penetration

As the number of countries with medium-to-high shares of VRE rises significantly, it is expected that power system flexibility will become a more prominent issue in coming years

Key transition challenges and flexibility resources

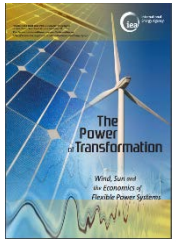
Phase 6	Need for seasonal storage and use of synthetic fuels or hydrogen
Phase 5	Coping with longer periods of surplus or deficit of energy
Phase 4	Ensuring robust power supply during periods of high VRE generation
Phase 3	Greater variability of net load; changes in power flow patterns on grids
Phase 2	Minor changes to operating patterns of existing power plants
Phase 1	

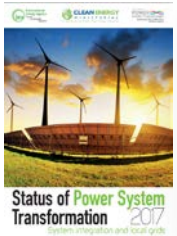
Key transition challenges

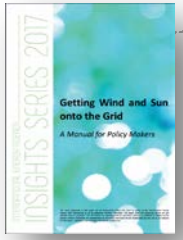


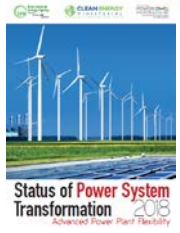
Key flexible resource examples to enable transition

IEA System Integration of RE analysis and engagement since 2014









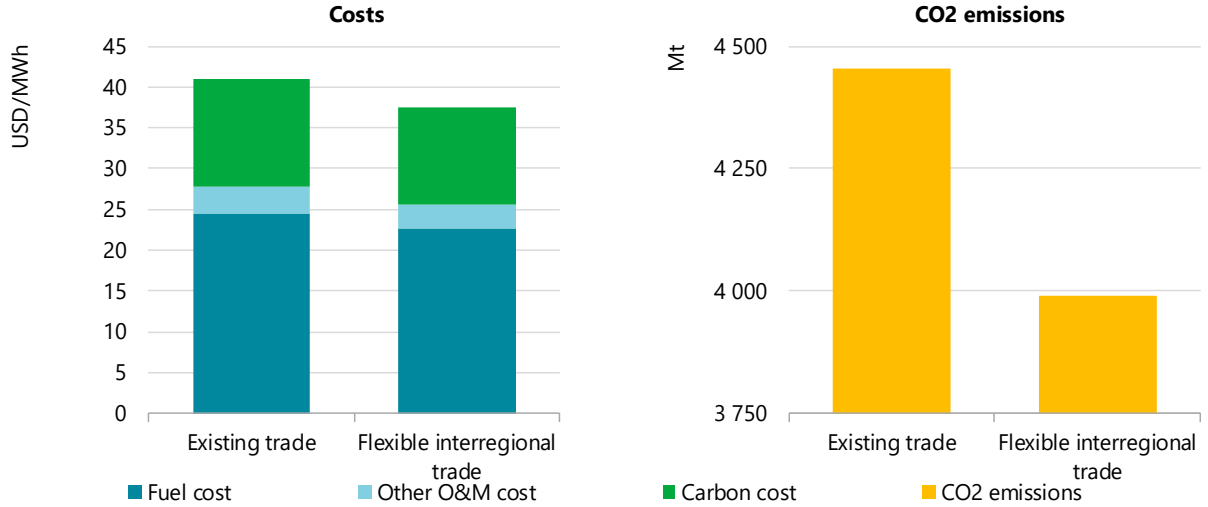
Workshops and dissemination events
Regional Latin America training (2014/15/16);
New Delhi/Bangalore (2015);
Bali Clean energy Forum (2015/17);
Beijing (2016/17); Astana (2016);
Johannesburg (2016);
New Delhi (2017); Mexico City (2017);
Jakarta (2017/2018); Manila (2017/2018);
Copenhagen (2018)

IEA System Integration analysis covered over 20 countries in the five continents. Association and partner countries have been systematically prioritized. Recent grid integration modelling study.

Electricity networks remain a critical enabler of system flexibility

- Inter-regional transmission interconnections and international coordination can yield significant economic benefits
  - *Example: IEA China Power System Transformation study (NPS scenario, 2035)*

  Potential for yearly USD 9 bn operational cost savings with inter-regional trading



Enhanced trade across regions can bring substantial cost savings and emission reductions by sharing flexibility resources more widely.

Interconnections are a main source of system flexibility

- **Security of supply**
  Interconnections between systems with different generation technology mix provide greater security of supply. Reserve capacity to ensure robust power supply can also be shared within an interconnected network.

- **Economic benefits**
  Interconnectors can achieve measurable savings in peak capacity needs. It can also provide economic benefits by allowing the cost-effective generating units within the interconnected area to be dispatched, and enabling power trade between the systems.

- **Integration of VRE resources**.
  Interconnectors enables higher levels of VRE integration by allowing the flexibility resources to be shared across a wider area. In addition, integrating VRE resources across a larger geographical area can smooth the variability of the overall VRE generation.

This study focuses on the value of interconnectors for the integration of VRE (cost and environmental impact), while maintaining the same reliability standard and efficiency in the use of assets.

Background and objectives of the ASEAN RE integration project

Background

- Supporting Thailand's 2019 ASEAN Chairmanship which aims to accelerate the development of the ASEAN Power Grid (APG)
- Build on the detailed study on Thailand RE grid integration assessment

Key objectives of ASEAN RE grid integration analysis

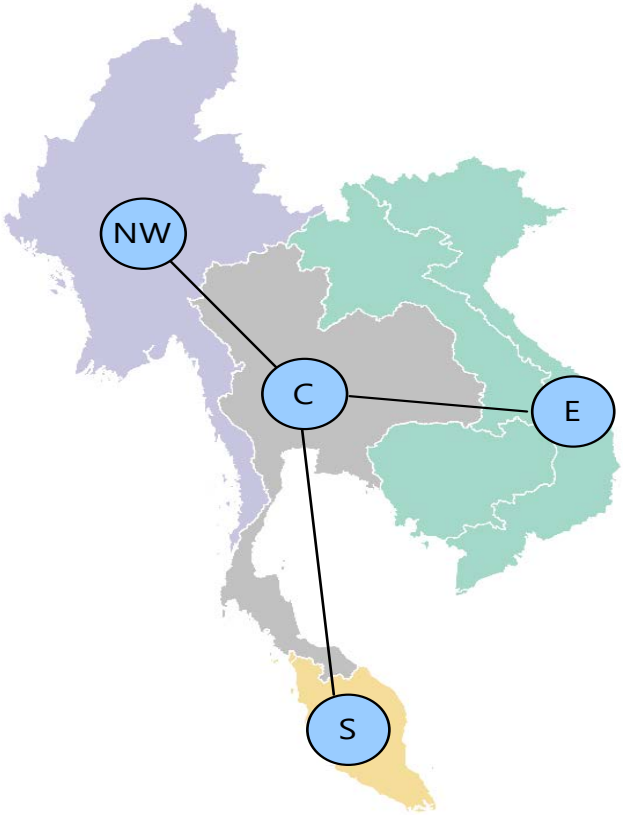
- Assess the value of the regional integration to accommodate growing share of RE
  - Benefits of multilateral power trading and cross-border interconnectors
  - Economic, operational, environmental and policy-related considerations
- Analyse the impact and value of flexibility technologies for the ASEAN power grid
  - Cross-border interconnectors and DSM

Approach to assess the value of cross-border interconnection and renewables in ASEAN

Modelling approach

Scenarios and key assumptions

Method to assess the value of cross-border interconnection

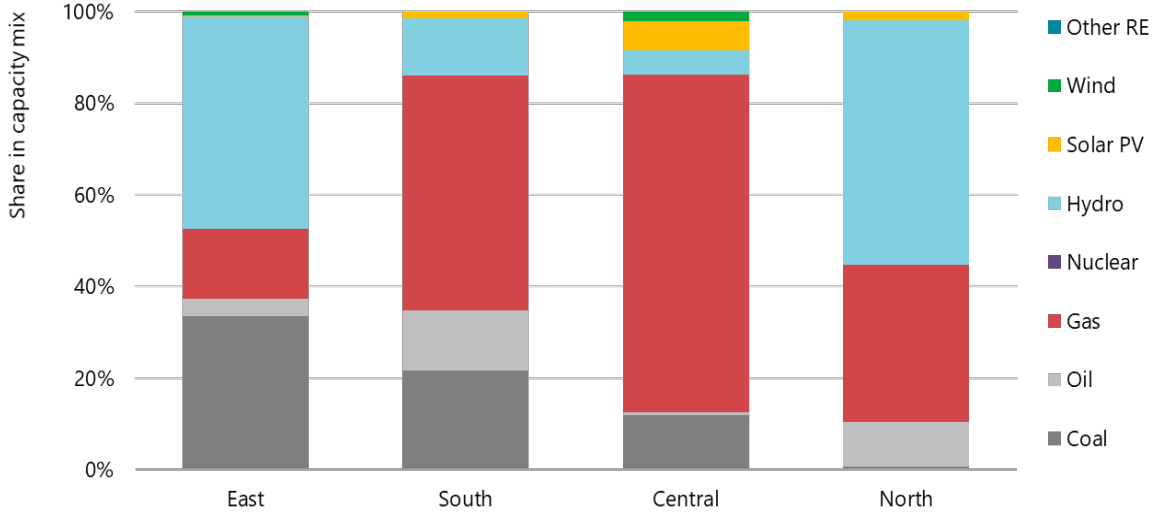


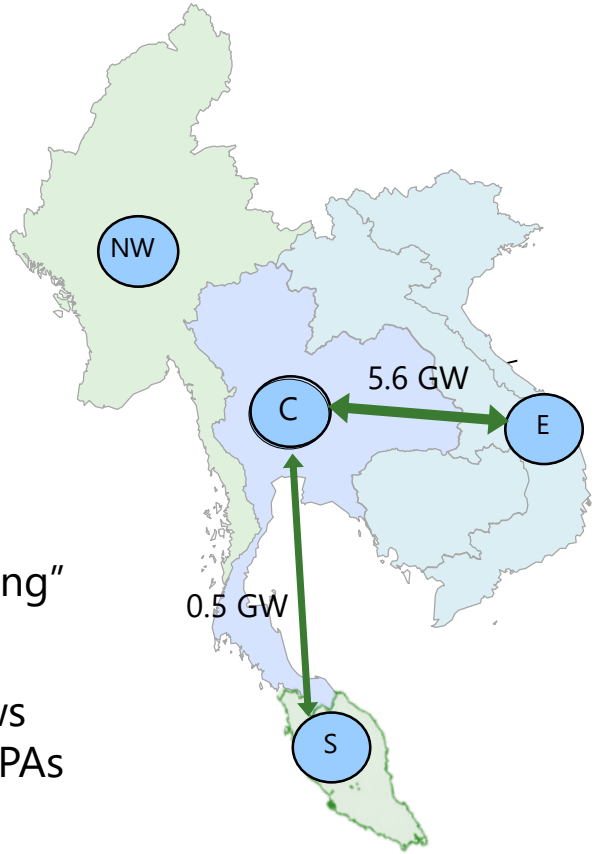
*** Indonesia, Philippines and Brunei are not taken into consideration due to limited resources and availability of data.*

Quantitative analysis to assess the value of APG cross-border in accommodating the growing share of VRE

- Hourly production cost modelling of ASEAN's future power system in 2035
  - represent important characteristics of power system with increasing share of VRE
- Four selected transmission zones with high-level cross-border transmission connections.**
  - **Central** (Thailand); **East** (Cambodia, Lao PDR and Viet Nam); **Northwest** (Myanmar); **South** (Malaysia and Singapore)
- These locations possess a number of existing interconnectors but mostly are limited to bilateral trade with PPA

Existing generation capacity and interconnectors





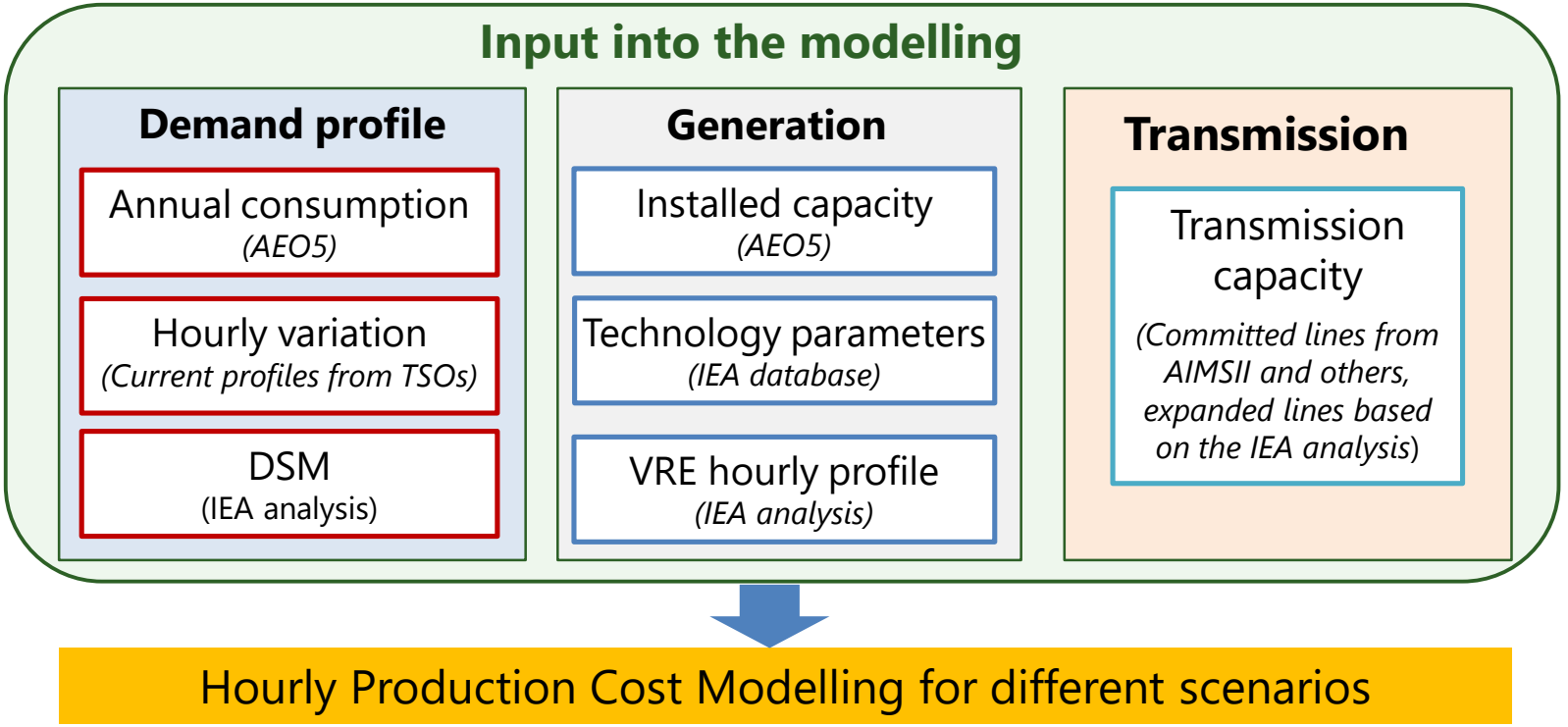
- Existing and committed interconnectors are treated as "existing"
- Modelled as line-by-line basis
- In the scenarios which assume bilateral trade, the power flows of interconnectors built for power import/export based on PPAs are constrained

Scenarios for the analysis

No.	Scenario	Key criteria			
		Cross-border transmission grid	*Cross-border trading arrangement*	*DSM*	*Share of VRE*
1	**Base**	Existing	Bilateral (PPA)	No	**12%** (AEO5)
2	**Base – high VRE**	Existing	Bilateral (PPA)	No	**20%**
3	**Multilateral trade (MPT)**	Existing	Multilateral	No	**12%** (AEO5)
4	**MPT – high VRE**	Existing	Multilateral	No	**20%**
5	**Expanded interconnectors**	Expanded	Multilateral	No	**20%**
6	**DSM**	Expanded	Multilateral	Yes	**20%**

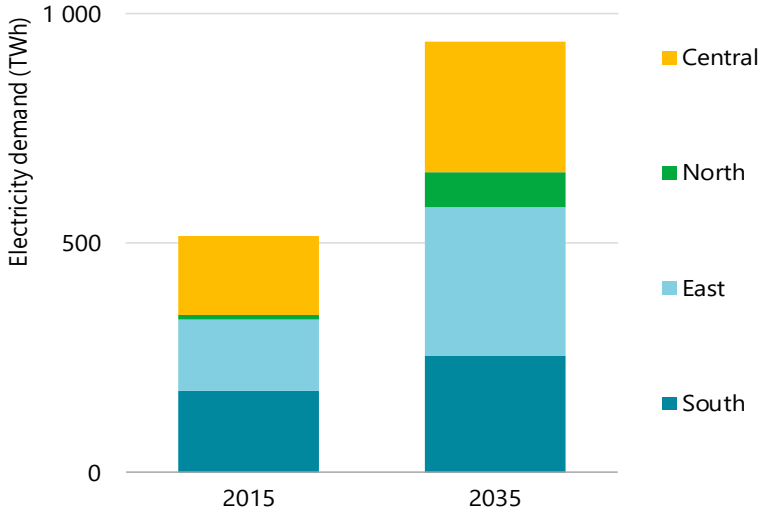
- **Base:** Constrained utilisation of interconnectors based on existing situation (PPA and bilateral trade)
- **Multilateral trade:** Usage of interconnectors is fully optimised
- **Expanded interconnectors:** Assess and optimising expansion candidates
- **DSM:** the value of efficient cooling appliances and improved flexibility through digitalization

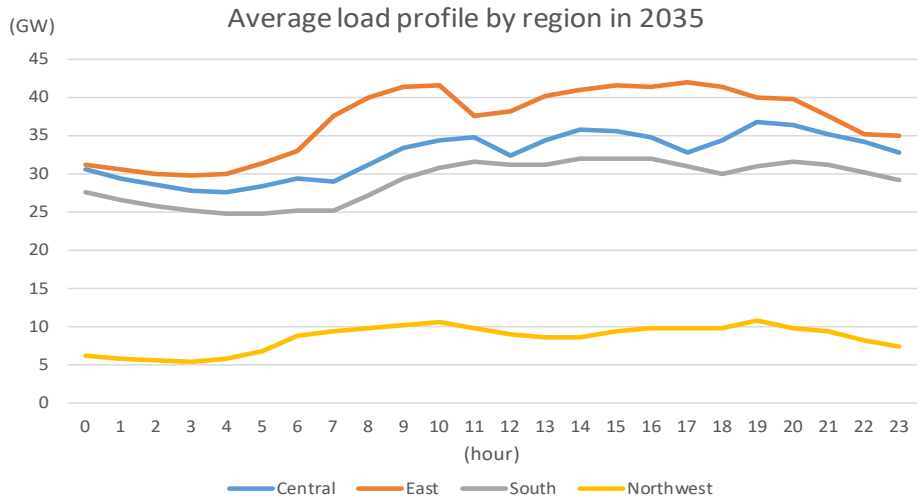
Overview of the modelling approach



Referring to the 5th ASEAN Energy Outlook (AEO5) for scenarios and input parameters as well as additional IEA analysis and assumptions

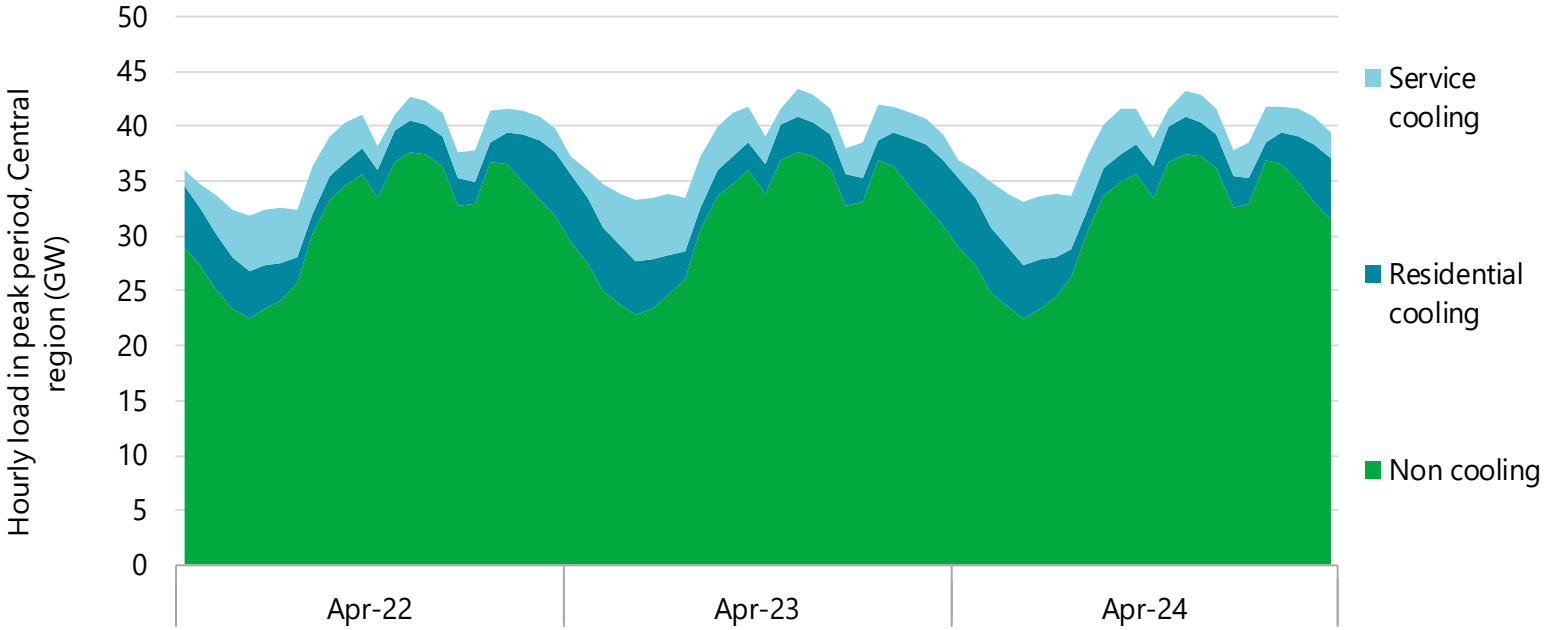
Estimating future electricity demand in 2035





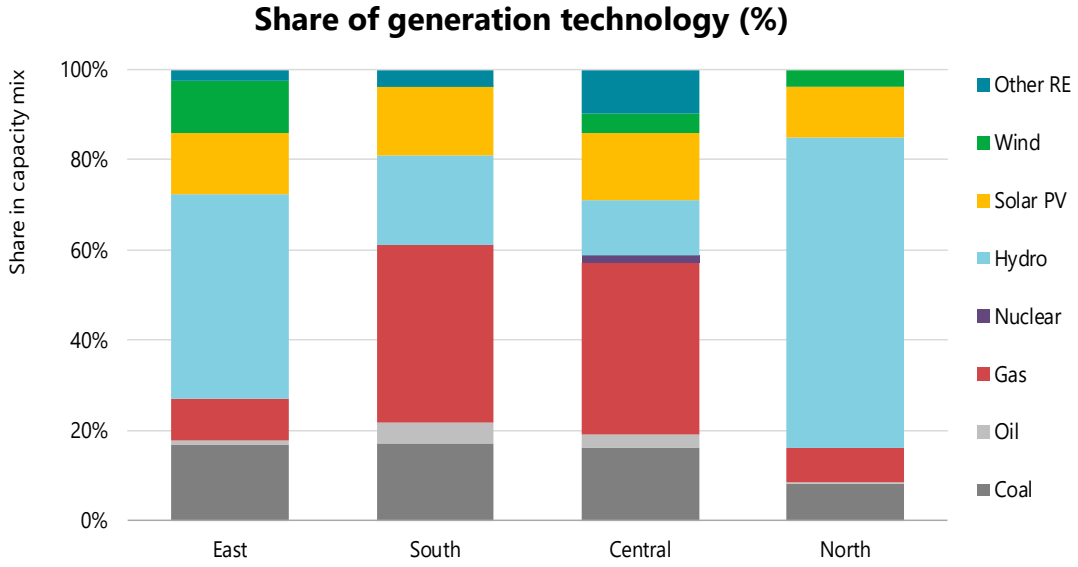
- Electricity demand in 2035 is based on the ASEAN Progressive Scenario (APS) in AEO5
  - with additional consideration for cooling sector.
- More than 80% increase compared to 2015, projected top-down driven by economic and population growth, considering efficiency improvement policies
- Cooling load is explicitly modelled: derived from IEA "Future of Cooling" work (2017)

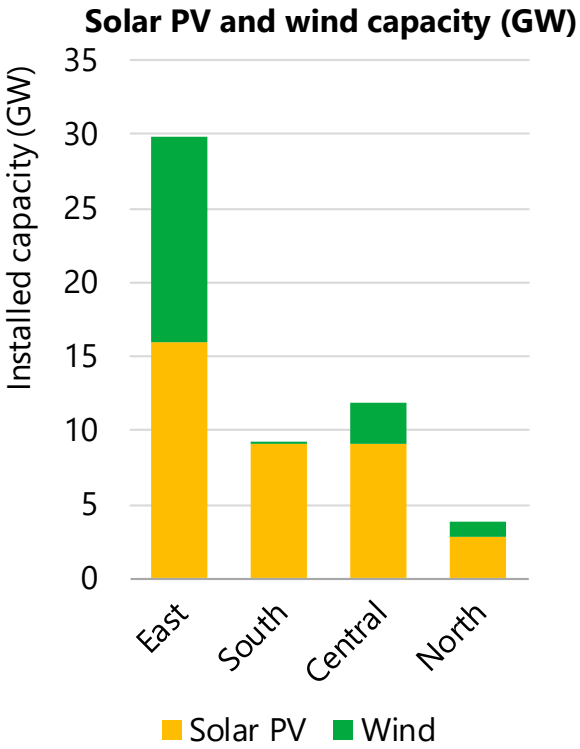
Demand response of estimated cooling load



Cooling load of each region is estimated bottom-up based on available data, so that the impact of demand side management can be measured

Electricity generation capacity in 2035

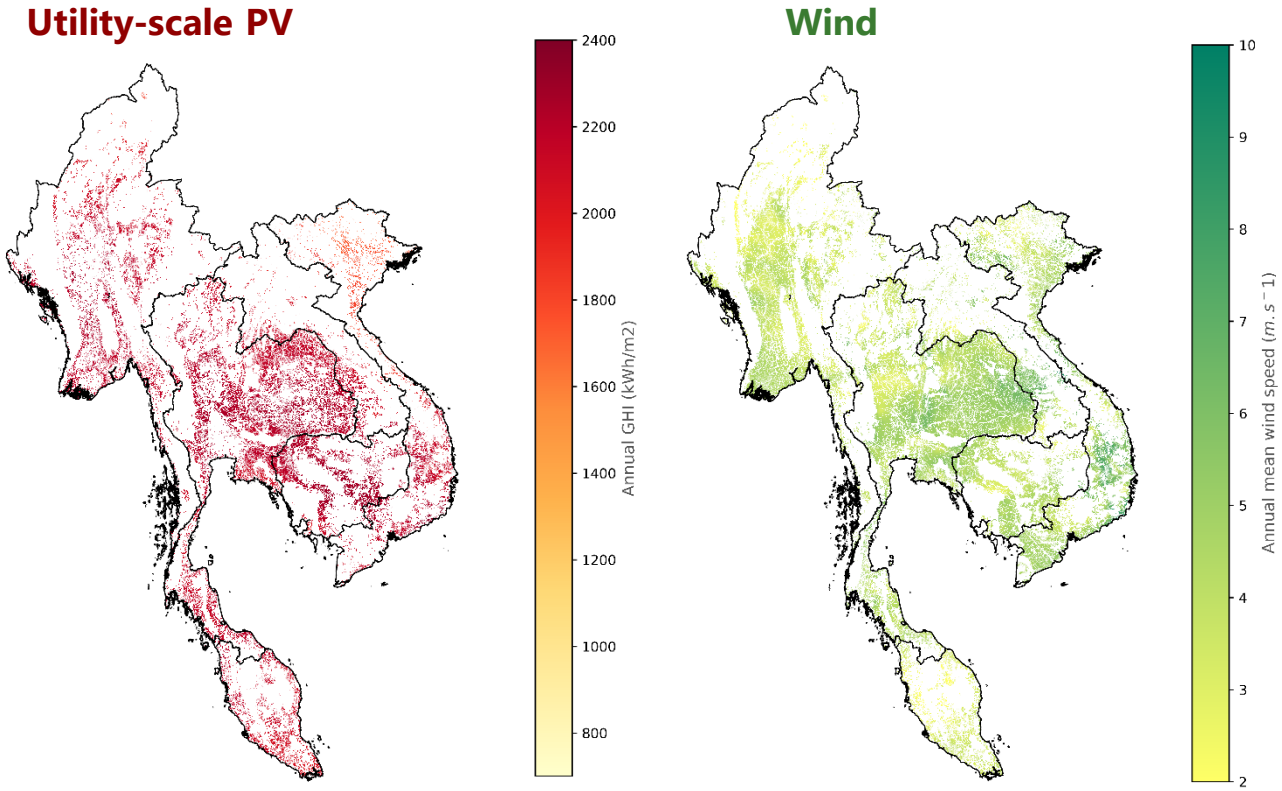




- Based on the 2035 generation capacity mix in AEO5
- VRE penetration of around 10% in generation mix in the APS scenario

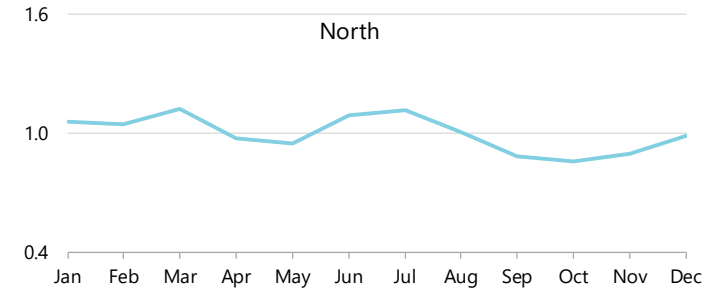
Generation capacity in 2035 refers to the 5th ASEAN Energy Outlook (AEO)

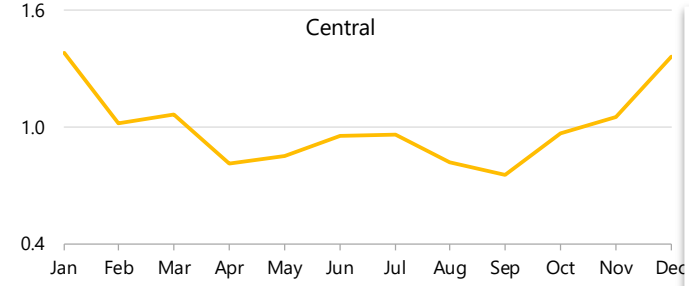
Solar and wind resource potential in different regions

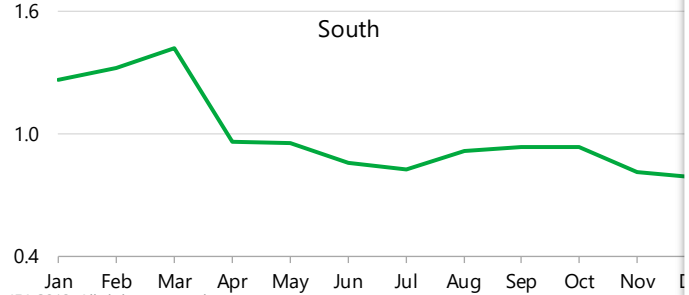


More than 6,000/12,000 sites for solar PV and wind power plants are selected based on key factors such as resource potential, proximity to the grid, non-protected areas, population density

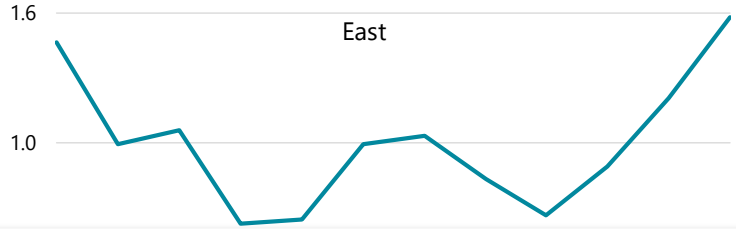
Interconnectors can help reducing seasonal variability

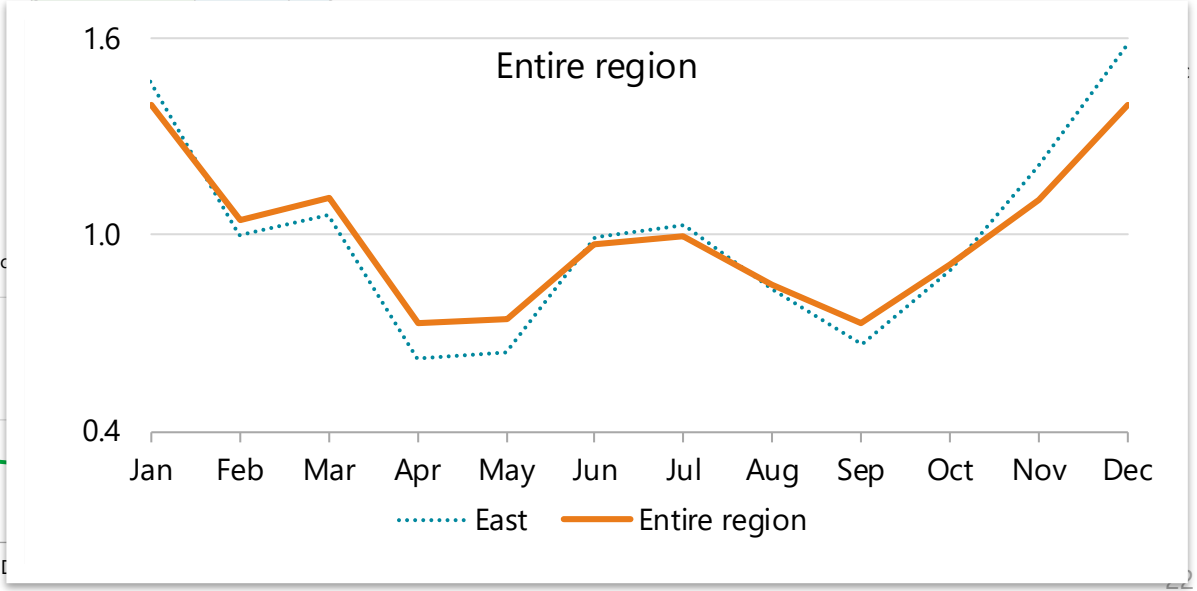






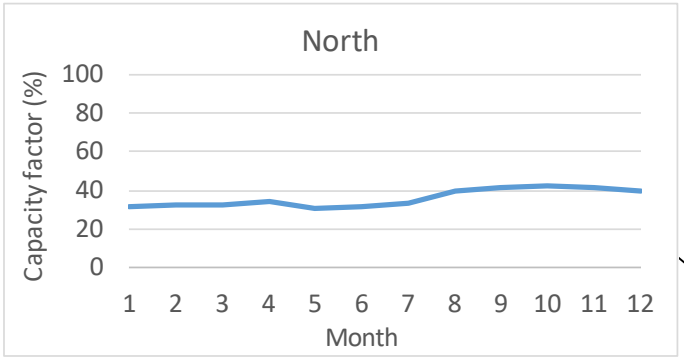
VRE generation per month

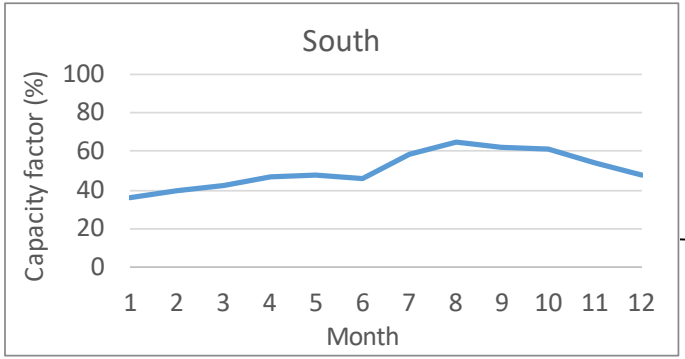


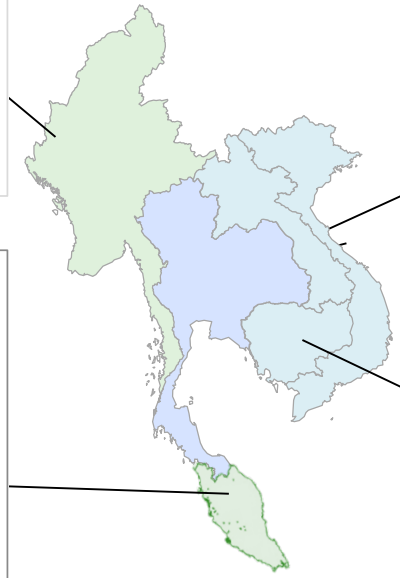


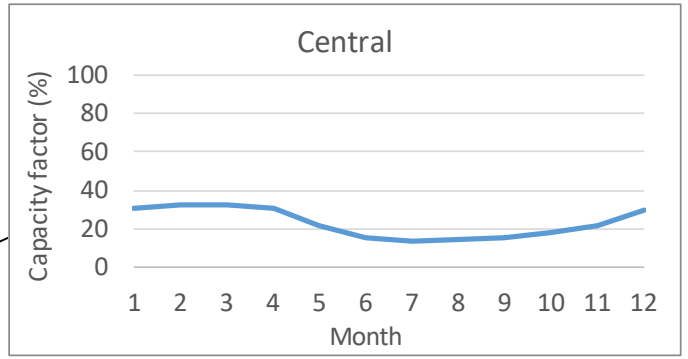
Interconnectors can also balance seasonal variability in hydro

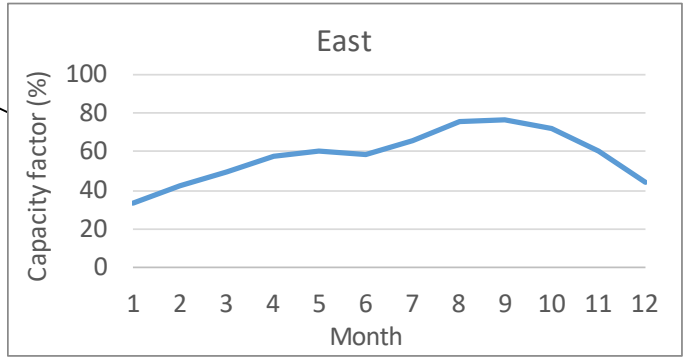
Hydro generation per month











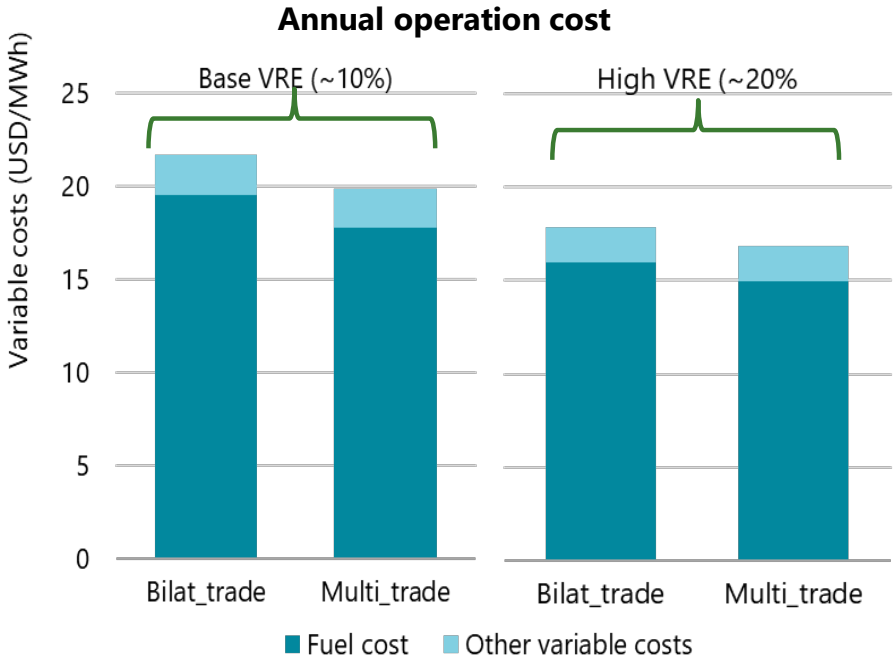
Note: VRE generations are calculated based on the generation capacities in the 5th ASEAN Energy Outlook

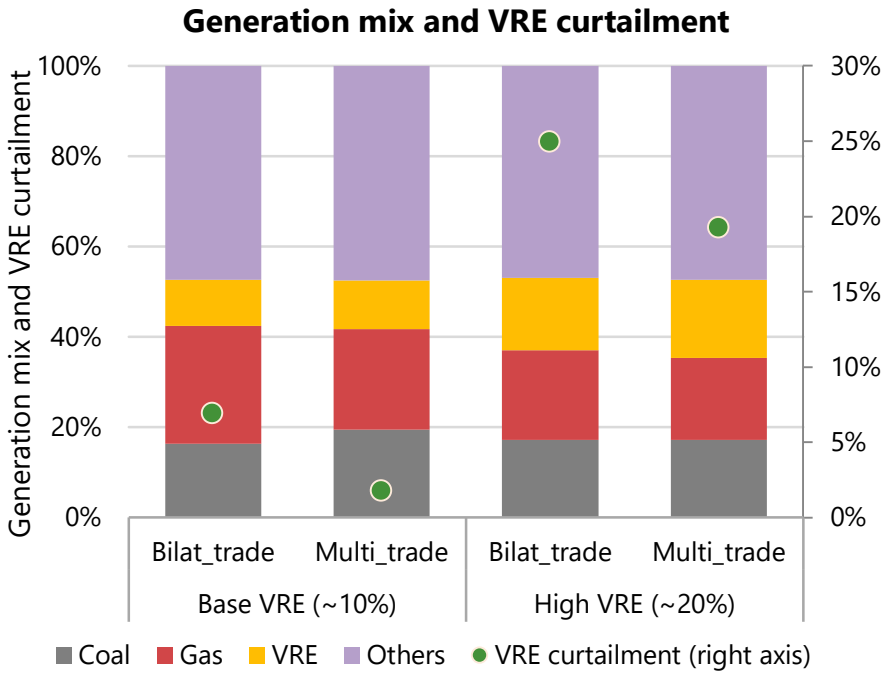
Key findings

Potential value of multilateral power trade in ASEAN

Benefits of expanding cross-border interconnectors

Economic benefits of cross-border multilateral trade

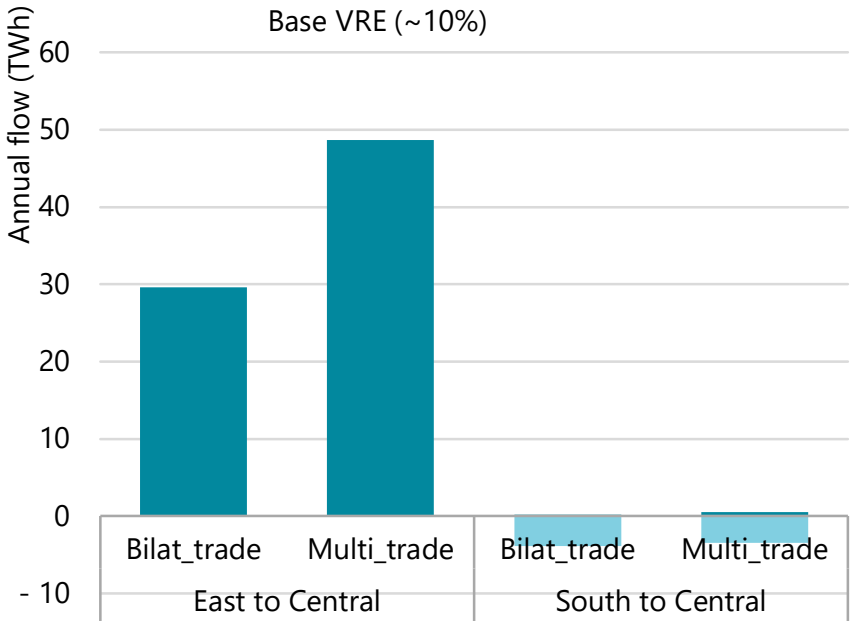




Operational cost savings of USD 1-2 billion per year

Multilateral trade based on the existing cross-border interconnectors can reduce the overall operational costs of the ASEAN power sector, largely by accommodating more VRE (less curtailment)

Inter-regional flows as a result of multilateral cross-border trade

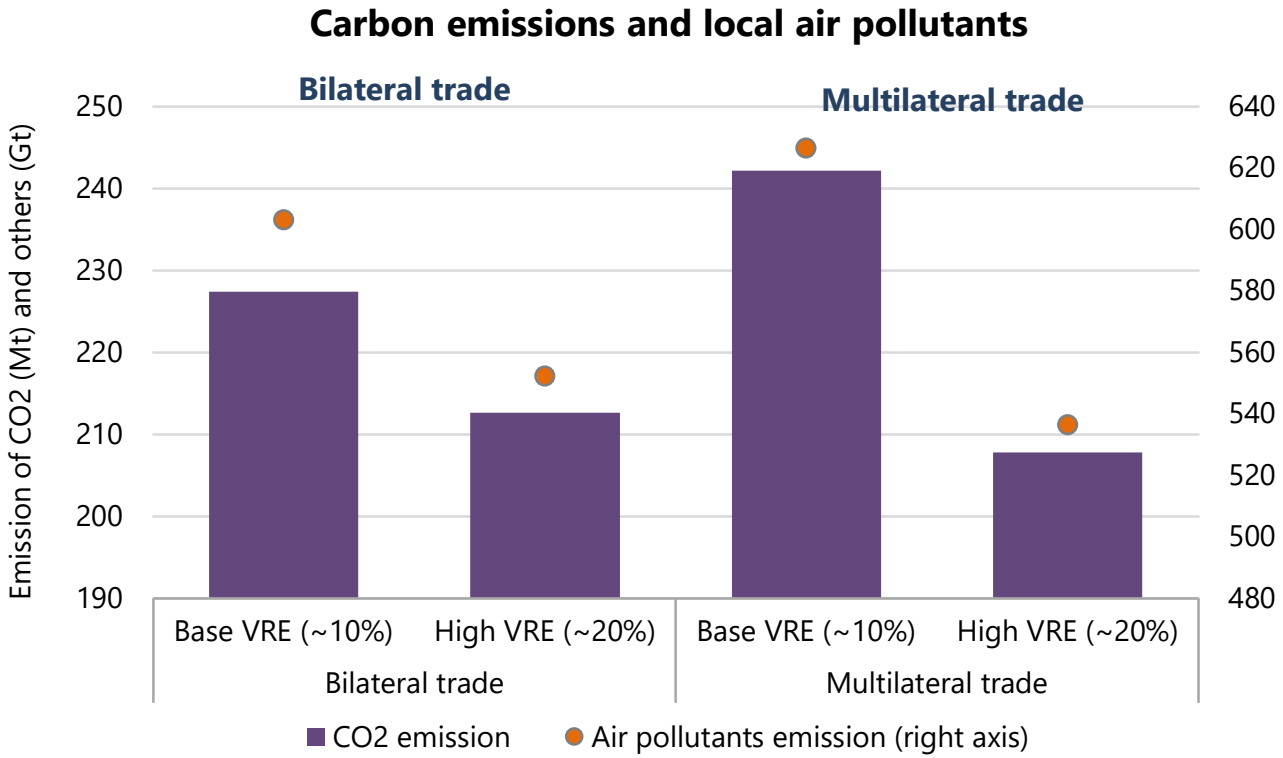


- Multilateral trade allows for a more cost-effective utilisation of the existing cross-border interconnectors,
- Allowing greater electricity flows from regions with lower generation costs, particularly hydro and VRE generation in the eastern region (Cambodia, Lao PDR and Viet Nam

* Note there is no flow between North and Central n the model at present since there is no interconnection at present

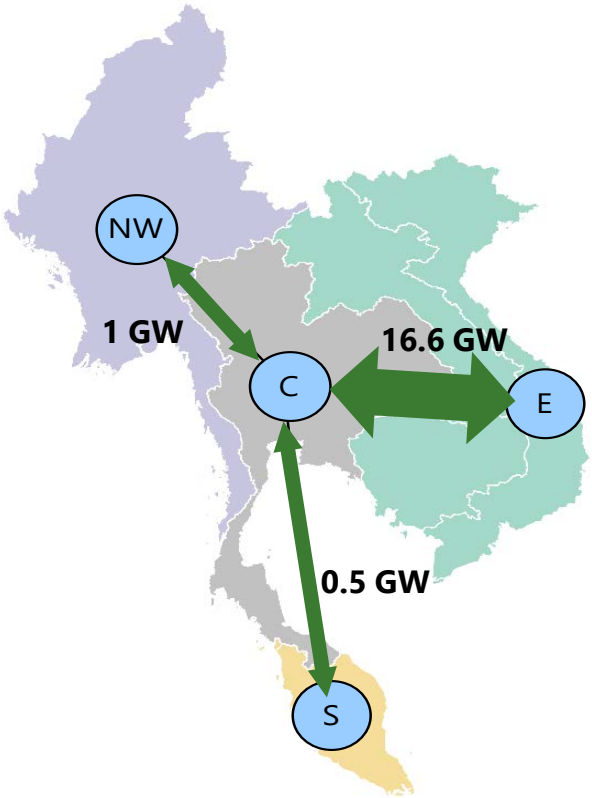
Multilateral trade allows for a more cost-effective utilisation of the existing cross-border interconnectors

Environmental benefits from higher VRE penetration



Accommodating more VRE helps to reduce environmental impacts from the power system in ASEAN.

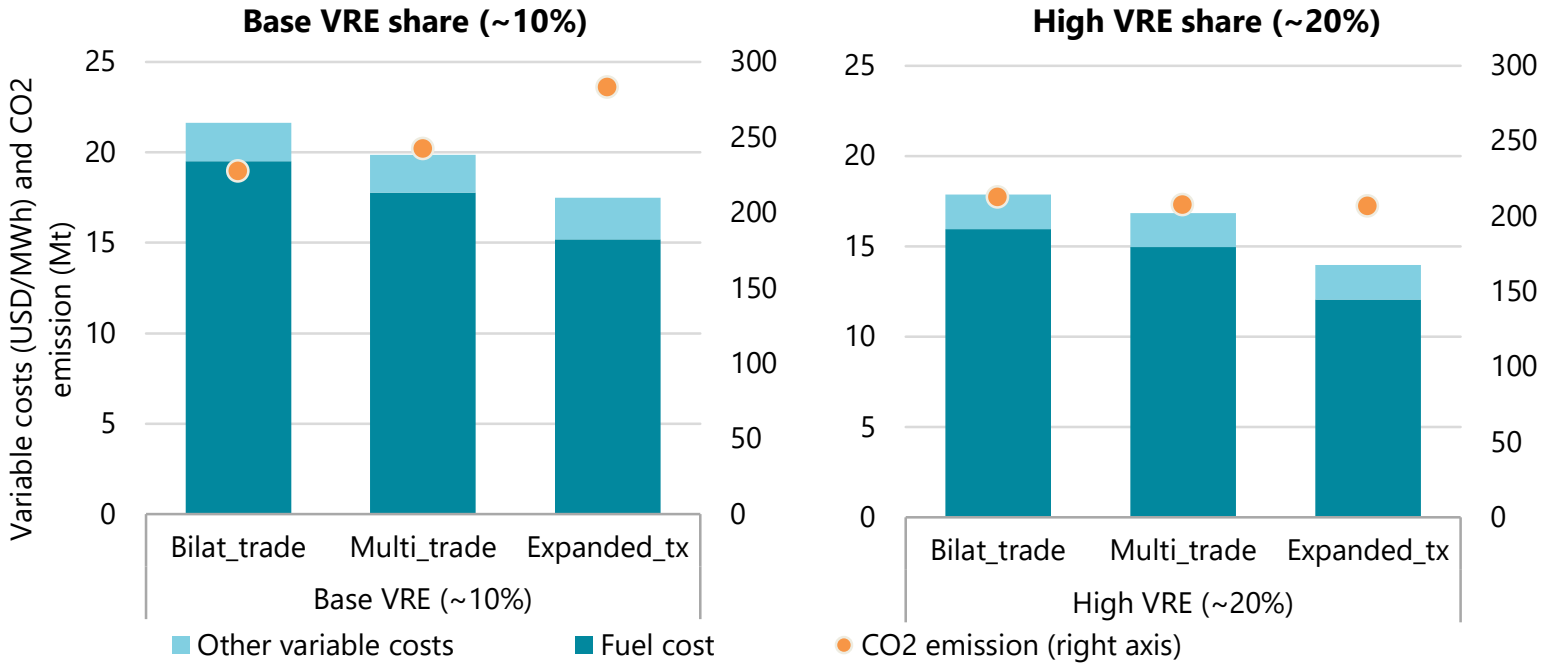
Expansion of cross-border Interconnectors in ASEAN



- Additional capacity of cross-border interconnector are selected through the cost optimisation process
  - Based the generation capacity and demand in each region
- 11GW of cross-border interconnectors are added
  - estimated investment cost of USD 16 billion
- Most are between east and central
  - Sharing low-cost generation resource (i.e. RE) in the eastern region

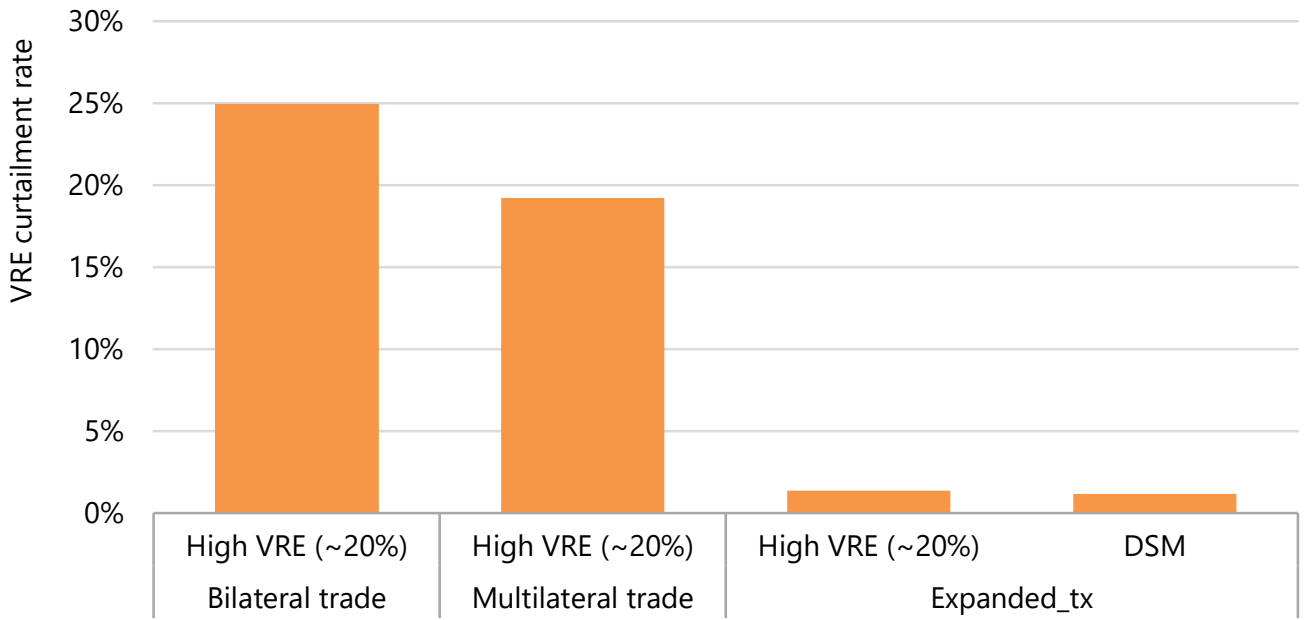
Additional interconnectors are selected based on the operational cost optimisation process, which results in 11 GW of expansion, most of which between eastern and central region.

The value of expanding cross-border interconnectors to accommodate VRE



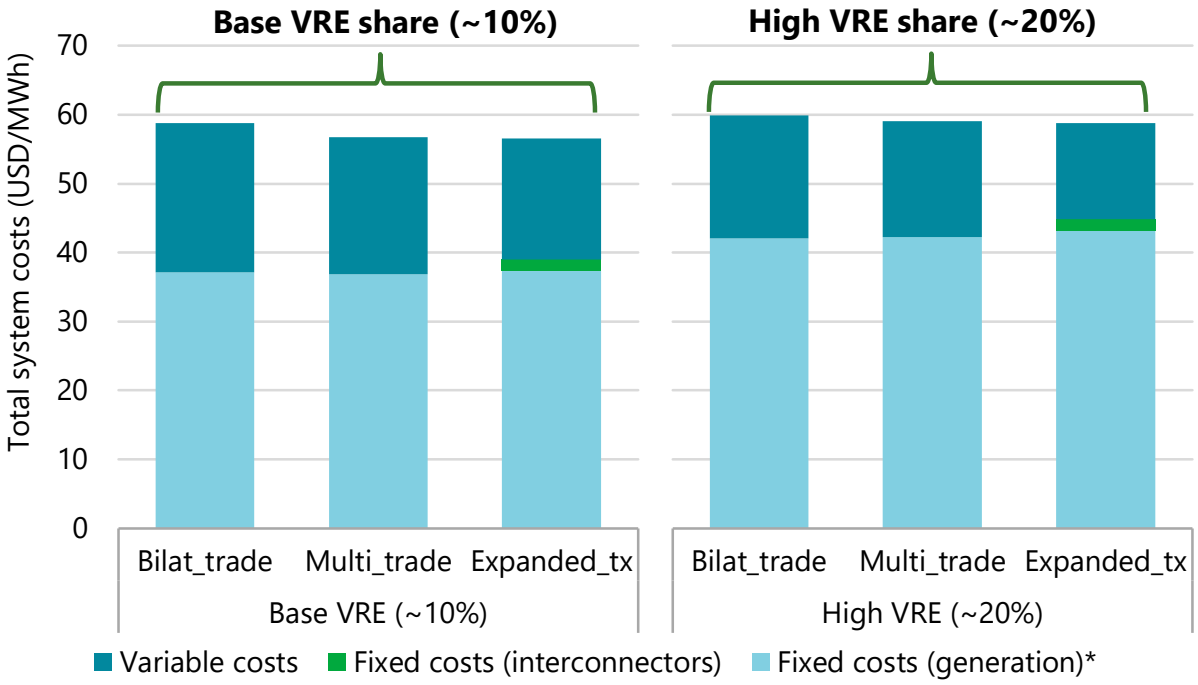
Expanding interconnectors can further reduce operational costs. It enables the integration of higher share of VRE that provides economic and environmental benefits, even without externality costs.

The value of expanding cross-border interconnectors to accommodate VRE



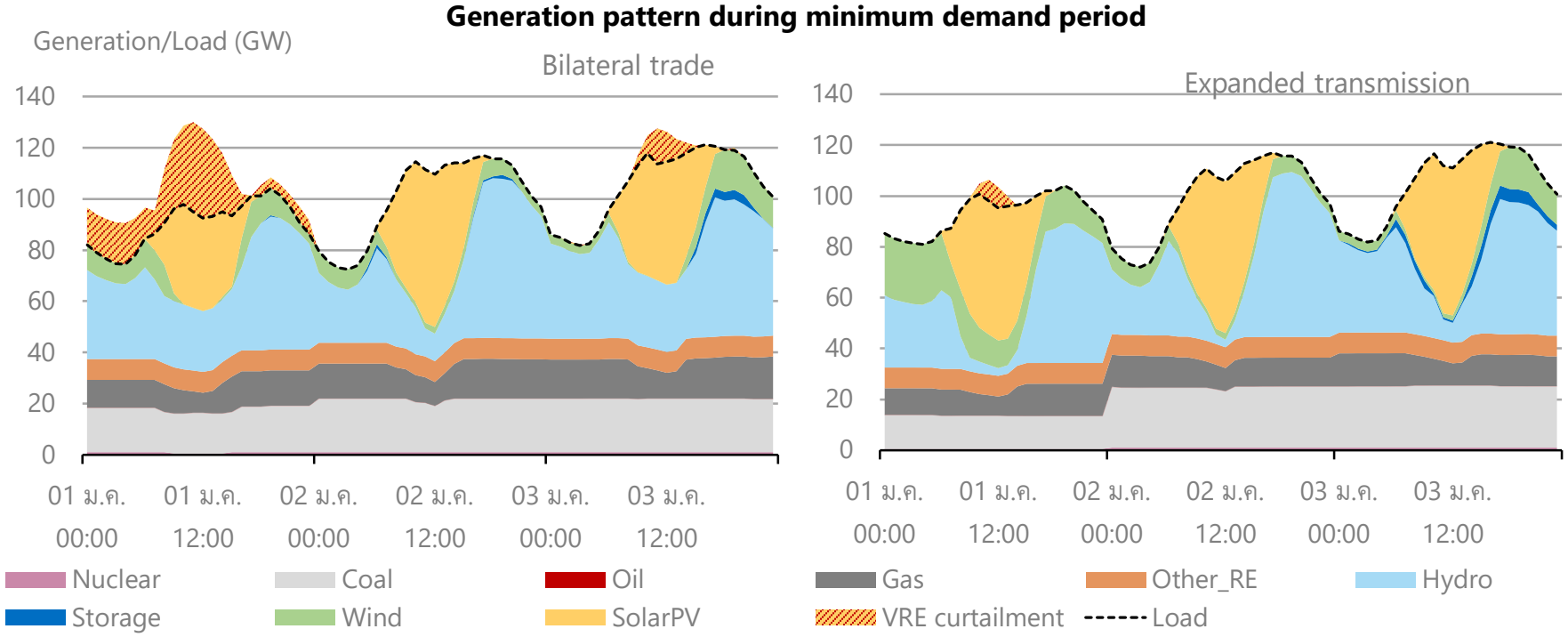
Expanding interconnectors reduce VRE curtailment and enable the integration of higher share of VRE

Total system costs with the expansion of interconnectors



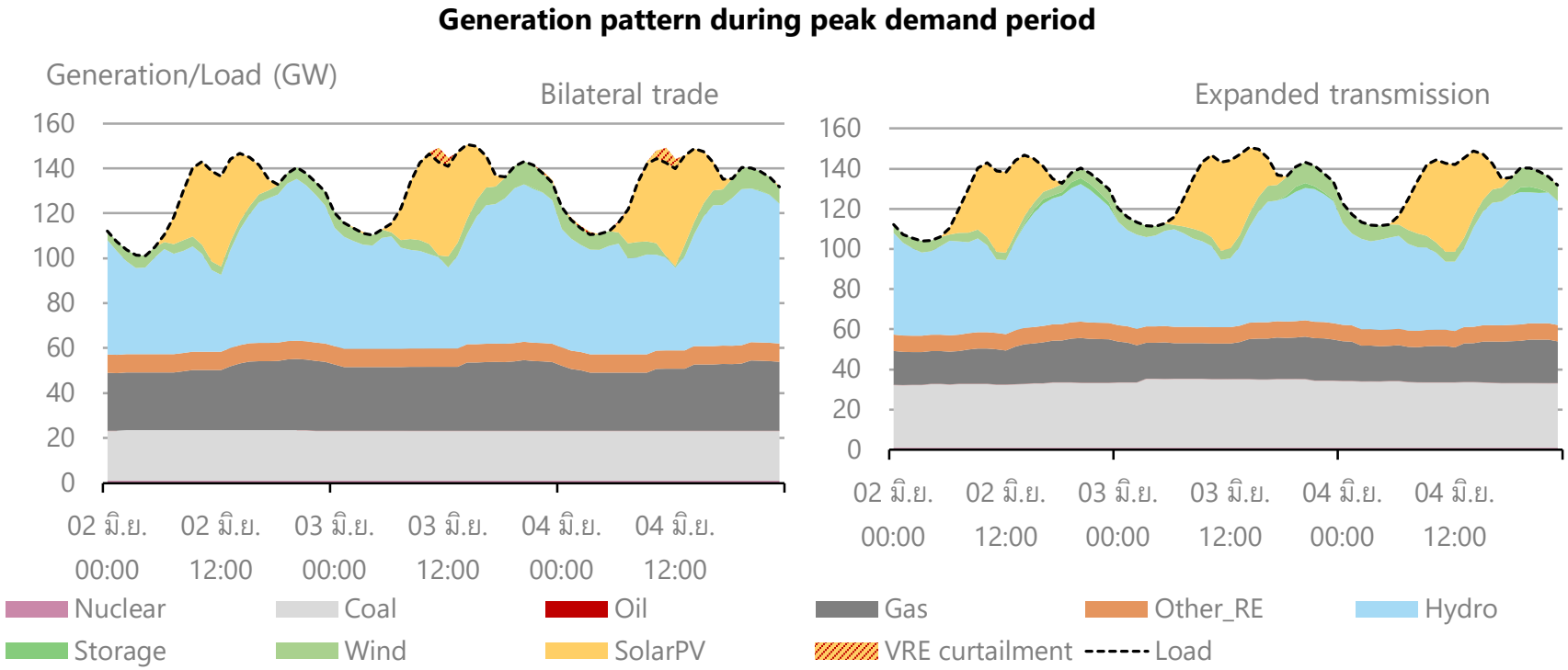
Well-balanced solution is necessary to ensure affordable, stable and clean electricity supply. Interconnectors coupled with higher share of VRE can be a strong option.

Cross-border interconnections provide operational flexibility



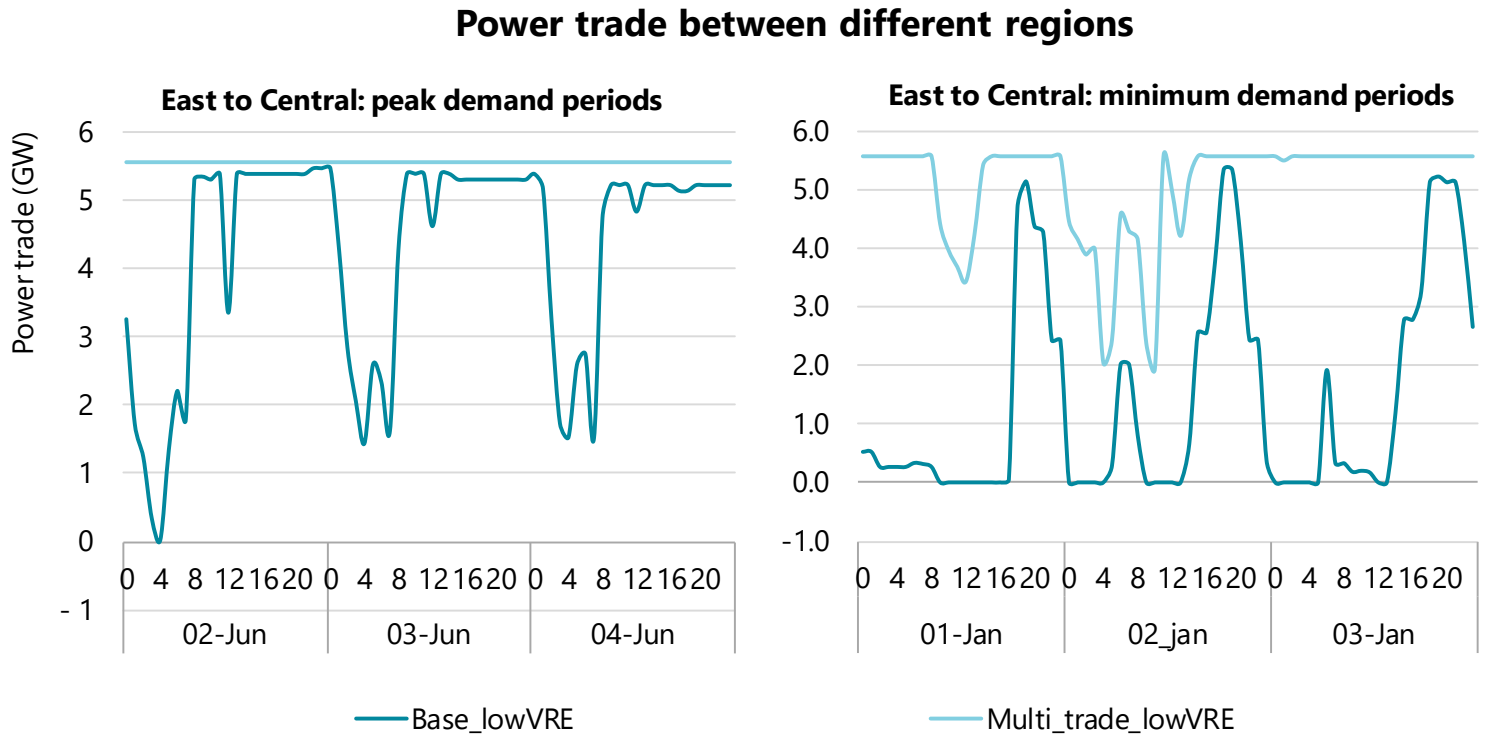
Cross-border interconnectors with multilateral trade reduces VRE curtailment, particularly during low-demand and high VRE generation periods

Cross-border interconnections provide operational flexibility



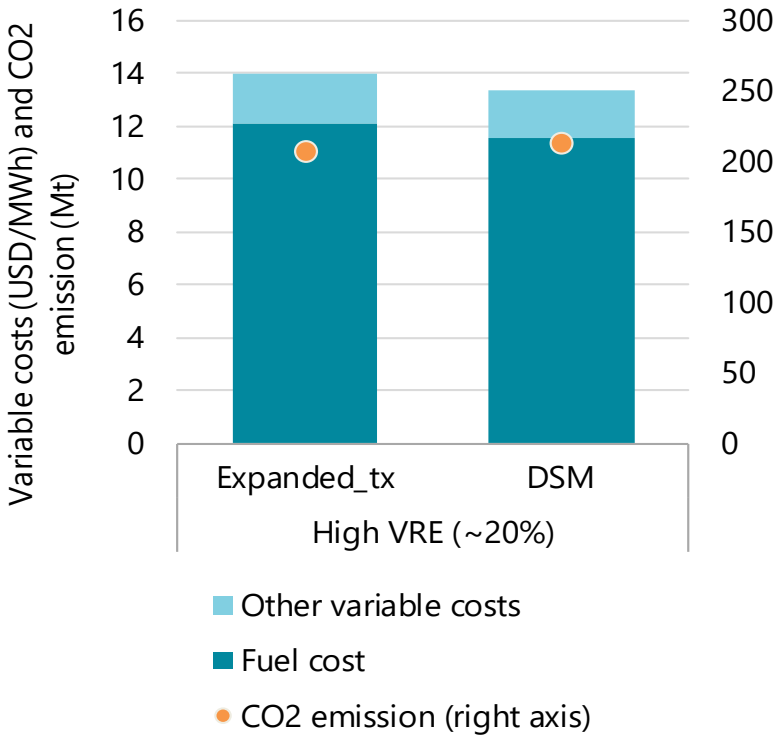
The maximum load day sees significantly more hydro generation. Expanded transmission eliminates some VRE curtailment, as well as reducing the role of gas in the energy mix

Economic exchange during abundant VRE



For multilateral trade, the power exchange is based on the cost-effectiveness. More flow eastern regions (Viet Nam and Laos) to Thailand

An economic impact of demand side management



- Efficient cooling appliances that enables flexible cooling through digitalization can replace a part of expensive generators' role to provide flexibility to the power system.
- The annual variable cost saving is around USD 0.6 billion (4-5% of total variable costs). The benefit will be higher if investment costs are considered

Demand side management options further increase the value of multilateral trade and interconnectors by reducing both operational and capital costs

Summary and next steps

Summary

- Multilateral power trade and cross-border interconnectors in ASEAN promotes the effective utilisation and resource sharing for common regional benefits
- A number of common benefits covering economic, operational and environmental aspects, which are relevant for all stakeholders
- Cross-border interconnectors enhance the flexibility of the ASEAN power sector in facilitating the increasing share of renewables, particularly solar and wind
  - Higher share of VRE can be integrated into the ASEAN power system in a cost-effective and reliable manner
- It is importance to build upon the existing efforts, both the trading arrangements and physical grid infrastructure

Next steps

- The work is ongoing and final outcomes will be delivered at AMEM in Sept 2019
  - Assess the role of flexibility options, particularly DSM in the cooling sector, in
- Provide input into AIMS III and AEO6, which can integrate this initial phase of ASEAN RE integration analysis
  - Sharing resources and approach to address key challenges in the analysis
- Possible extension to cover more AMS countries with a more detailed analysis to identify priority areas to enhance system flexibility and improve policy design
  - Different energy mix scenarios with supply and demand alternatives covering AMS
  - Assess the value of different cross-border interconnection options under different trade models

Next steps

Scenario	Tx	Cross border trade	DSM	VRE share	Current status and next steps
Base case	Existing	PPA only	No	11%	**Last round of results**
Multi Trade	Existing	Multilateral	No		**Last round of results**
Expanded Tx	Expanded	Multilateral	No		**Last round of results**
Higher VRE	Existing	PPA only	No	21%	**Last round of results**
VRE + Trade	Existing	Multilateral	No		**Last round of results**
VRE+ Tx	Existing	Multilateral	No		**Last round of results**
VRE +DSM	Expanded	Multilateral	Yes		**On going**

Key challenges and assumptions

Key challenges	Approach / assumptions
Detailed split of hydro type, future gas technologies, utility/rooftop PV is unknown	• Assume the split based on existing plants and 60/40 split for utility/rooftop
Operational constraints of hydro depending on river systems are hard to represent	• Assume seasonal flows for run-of-river, and an annual constraint as well as a minimum daily constraint based on the seasonal flows for large reservoirs
Limited access to demand profile data in some countries	• Apply current hourly profile for a year or a typical day. • Obtain actual load profiles from member countries

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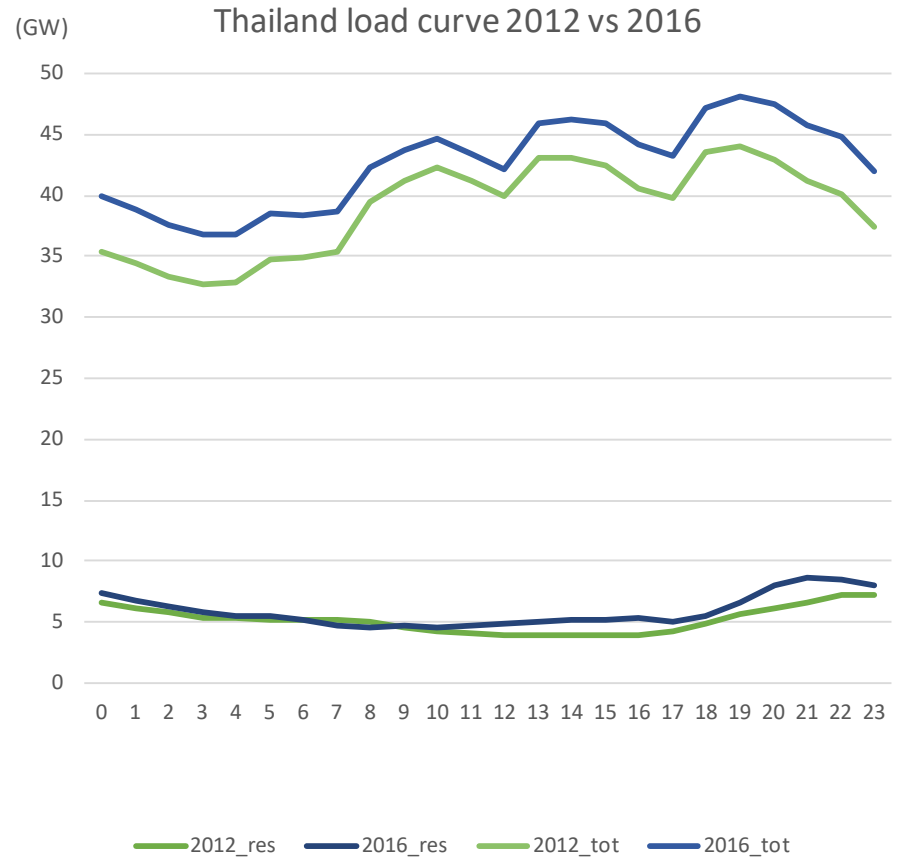
Outline

- Overview of ASEAN power grid
- Background and key objectives of ASEAN RE grid integration
- **Approach to assess the value of cross-border interconnection in ASEAN**
  - Modelling approach
  - Scenarios
- Key findings
  - The value of multilateral power trade in ASEAN
  - The benefits of expanding cross-border interconnectors
- Summary and next steps

Modelling the evolving load profiles



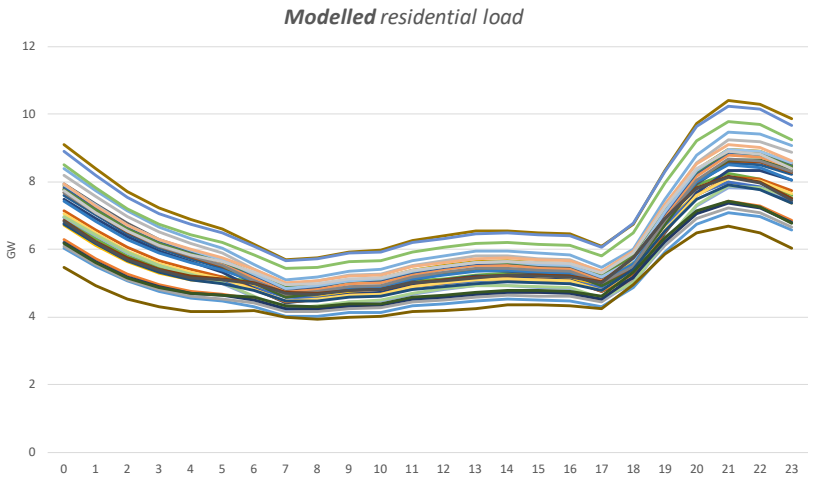
(Note) Res=residential sector load; Tot=total load. (Source: EGAT)

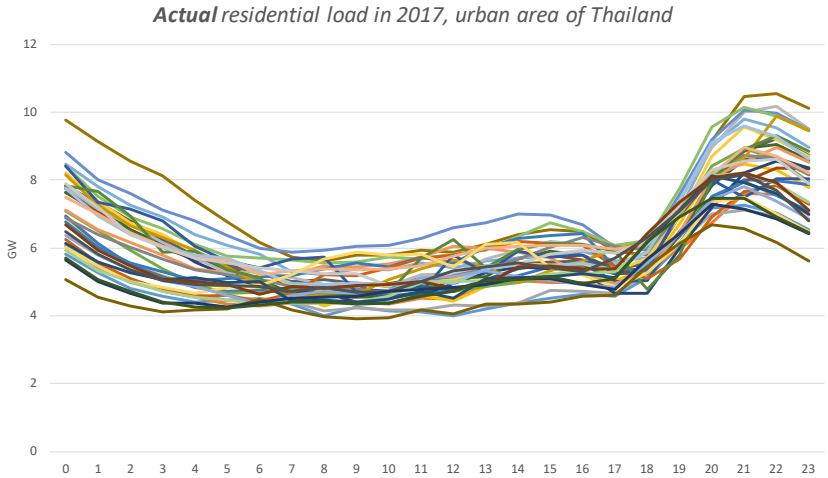
- Load shape will not be stable, and it will have impact on variable renewables integration and multilateral trade
- For example, Thailand is experiencing greater evening peak

  Potential causes:

  - Increasing evening peak load in residential sector (e.g. air conditioners to cool the room before going to bed)
  - Increasing share of service sector demand (e.g. restaurants and hotels have peak in evening)
- The potential change of future load profile will be considered in the next step of the analysis, if **sufficient data is available**

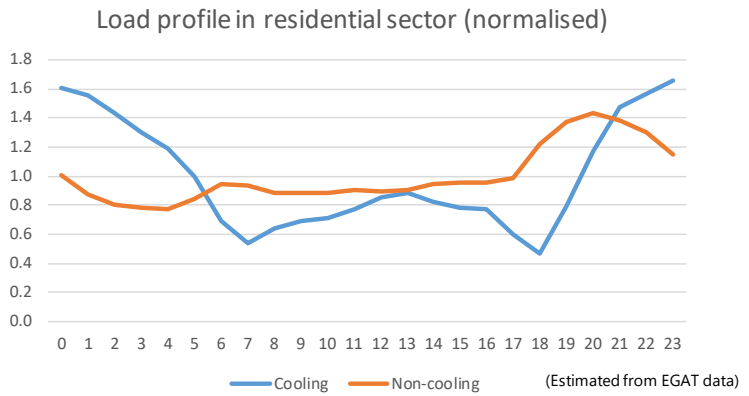
Model validation for residential sector load profile





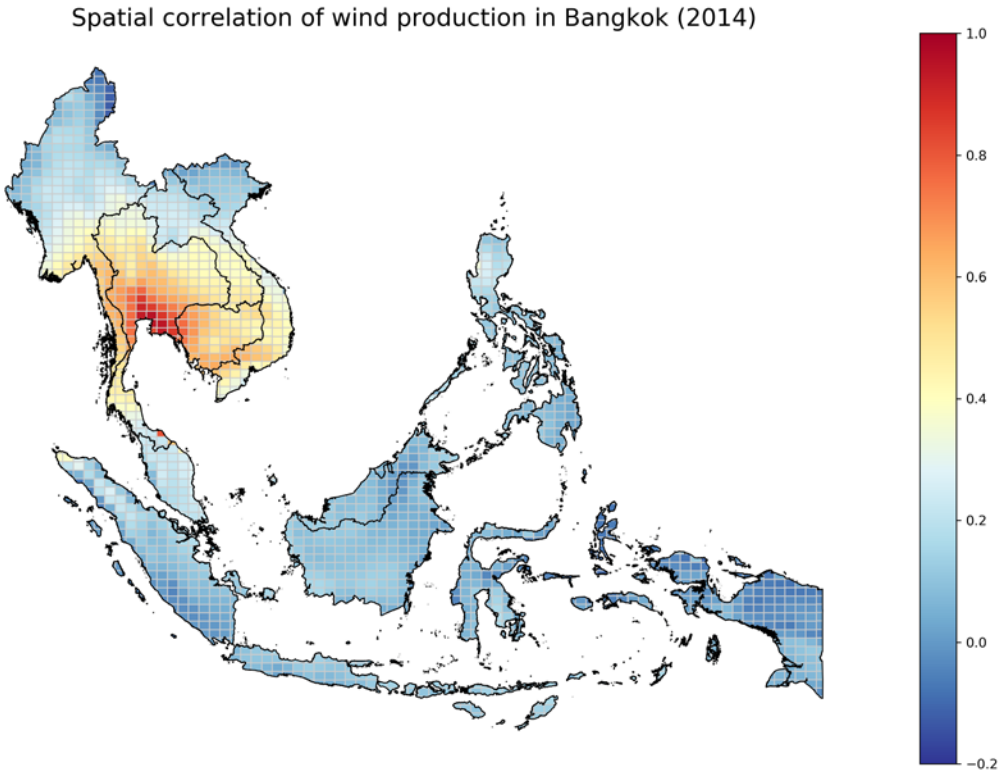
(Source: MEA, 2017)

- Modelling residential sector load as a sum of cooling load and non-cooling load
  - Consumption for cooling is estimated with temperature/humidity correlation
  - Non-cooling load is estimated to be constant across seasons
- The model was validated against typical days in 2017



(Estimated from EGAT data)

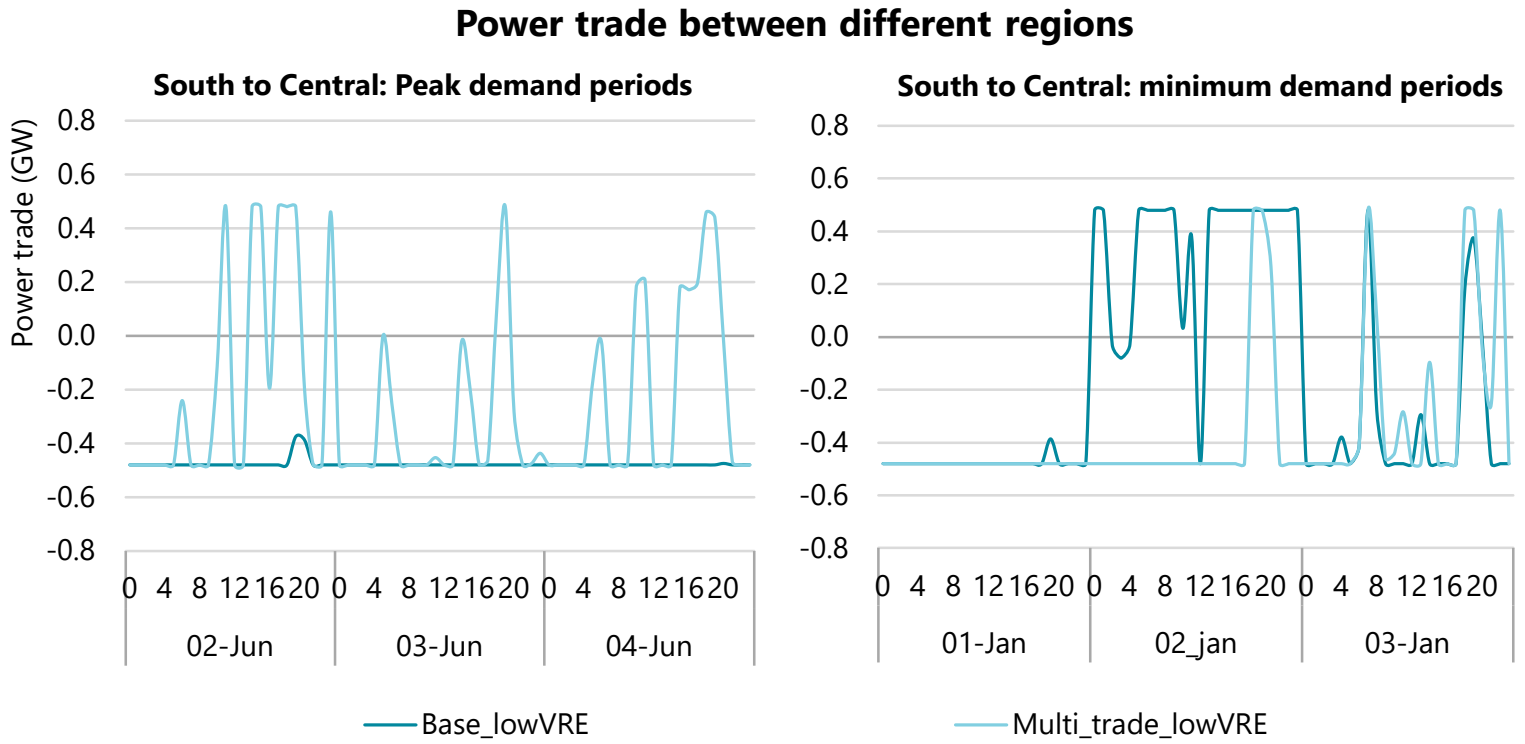
Simulation of hourly generation indicates potential benefits of APG



Source: Renewable Ninja with Vestas V90 2.0 MW, 2019

- Hourly solar and wind generation in the region is simulated, assuming the current weather conditions
- Correlation coefficient between wind generation in different places is calculated (e.g. Bangkok and other places: left)
- **Wind profiles in the Mekong region can have a complementarity** in generating electricity

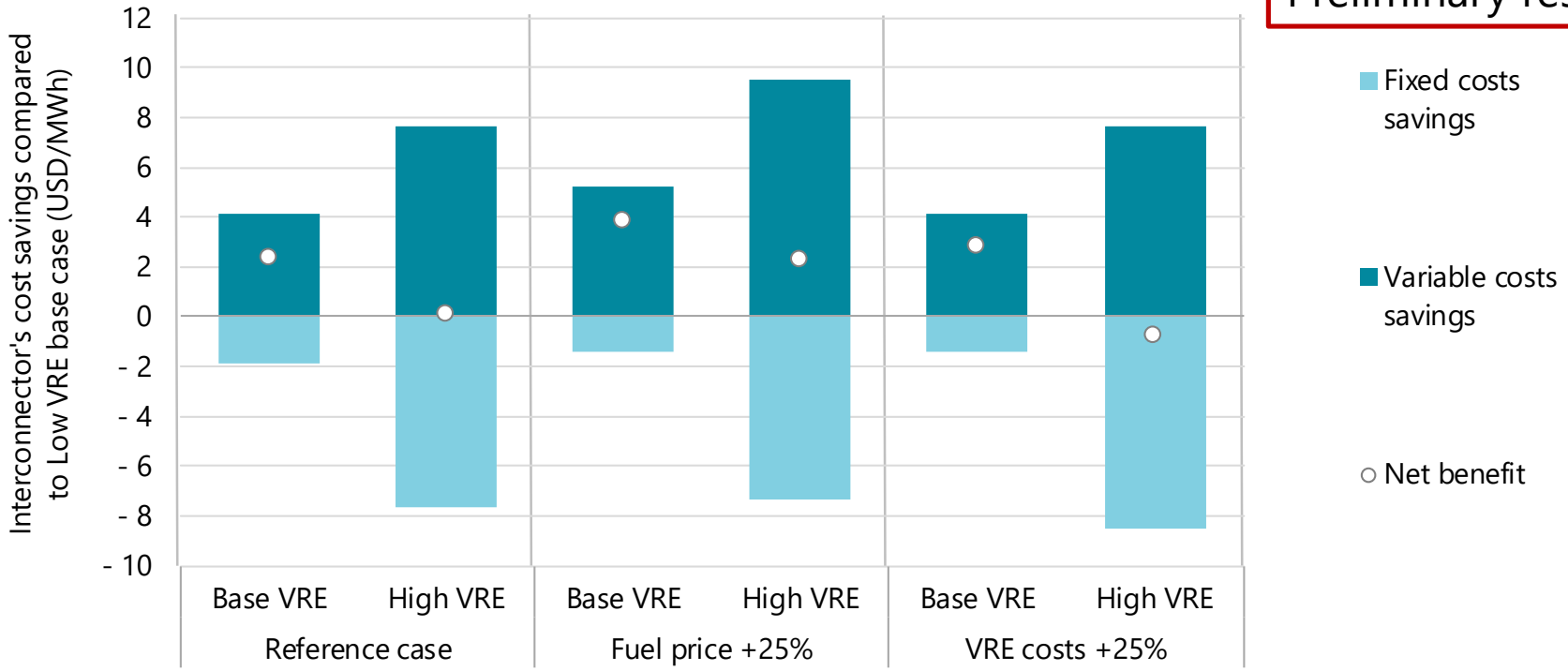
Economic exchange during abundant VRE



Fluctuating trade pattern may indicate interconnectors between South and Central are enabling the import from East to Central

Uncertainty in fuel prices and technology costs

Preliminary results



The results are not without uncertainty, particularly on the future fuel prices and technology costs.