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Target-based energy transitions in the electricity systems of Southeast Asia: A comparative study of Indonesia, the Philippines, and Vietnam

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A B S T R A C T

Three emerging Southeast Asian economies, Indonesia, the Philippines, and Vietnam, exhibit similar socio-economic development and reliance on coal for electricity generation. Yet, the countries have set different energy targets, indicating different energy transition pathways. This study aims to understand what kinds of energy transitions are implied by these targets and how these targets may lead to different transitions in electricity systems by analysing electricity mix evolution and decarbonisation pathways across the case countries. A decarbonisation pathway framework is applied to account for the decline of fossil fuels and the growth of low-carbon sources in the analysis. Initially used for analysing historical data, the framework is applied to target data of emerging economies by complementing it with target interpolation and scenario construction. Target interpolation is functions are used to generate annual projection data, while scenario construction is functions are used to explore future pathways indicated by countries' targets and policies. Our results show heterogeneity in decarbonisation pathways among the case countries despite their similar levels of economic development and geographic locations. The analysis also highlights the crucial role of rapidly growing demand, as increased renewable energy deployment does not necessarily lead to decarbonisation of electricity systems. This study offers methodological contributions by expanding framework applicability to future target data of emerging economies. It also provides theoretical contributions in understanding transition dynamics under growing electricity demand and policy implications for energy planning in Indonesia, the Philippines, and Vietnam, with potential applicability to other emerging economies with similar conditions.

1. Introduction

In climate change mitigation, targets serve as regulatory tools that enable the implementation of regulatory instruments [1] and can elicit broader consent and agreement on the future to be achieved [2]. Such functions can be observed in the 1.5–2 °C climate target of the Paris Agreement. Following the Agreement, the target has led to climate policies in various countries worldwide, led corporate-level initiatives to reduce emissions, and fuelled social movements for climate action [3]. Energy transition, as part of climate change mitigation, also sees targets as tools to legitimise and normalise interventions [4].

Energy targets can be defined as "numerical end results" [1] established to guide energy-related policies. These targets are typically set by governments or other actors to achieve specific levels of energy production or consumption [5]. They can pertain to specific sectors, such as electricity, heating, cooling, and transportation, or to the overall energy sector. Additionally, targets often specify a time frame or deadline for accomplishing the objective. Energy targets are commonly set for renewable energy deployment [5] or energy efficiency improvements [6,7]. They can be established at different levels, including local [8], national [9] or even supranational [10]. It is important to distinguish between targets and goals, aims, or objectives as targets are more strictly defined and serve as concrete benchmarks for measuring progress [1].

Previous studies and reports have used energy targets in several analytical ways across both developed and developing countries contexts. One group of studies treats targets as implementation goals and examines the measures needed to achieve them. These include simulation analysis of energy targets in North African countries [11], scenario modelling of renewable energy targets in Ghana [12], analysis of the components required to achieve Egypt's 2035 energy plan [13], and optimisation of renewable energy deployment to achieve energy targets in Indonesia [14]. A second group investigates target achievability through probability assessment, applied to China energy targets [15], evaluation of policy effectiveness, applied to EU member states [16] and

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Australia [17], and feasibility analysis, with a case study from China [18]. A third group uses targets as planning or assessment benchmarks, either by proposing financially achievable renewable energy targets in Ghana through energy modelling [19], assessing the impacts of energy target implementation on the EU's electricity sector [20] or on power plant portfolios in Indonesia [21], or incorporating targets into outlook scenarios to find optimised pathways towards electricity system decarbonisation [22,23].

Across these approaches, targets are generally used as goals, inputs, constraints, benchmarks, or endpoints. While these approaches are useful for investigating the feasibility, optimisation, costs, and emissions of electricity system decarbonisation, they often do not explicitly assess the types of energy transitions implied by achieving the targets themselves. Understanding the transitions that the targets aim to achieve is important because increasing renewable energy deployment does not always lead to decarbonisation of the entire energy system, particularly under rapidly growing demand conditions [24]. It means that targets that seem to significantly increase the share of renewable energy in electricity generation may not actually result in transitions that lead to decarbonisation.

This study aims to understand the energy transitions implied by national energy targets, if achieved. It also aims to examine how different energy targets may lead to varying levels of decarbonisation progress. The focus is on electricity systems in developing and emerging economies, arguing that understanding energy targets in the context of the future energy transition is particularly crucial for countries with rapidly growing electricity demand, which may lead to higher emissions. This study applies an energy transition framework developed by Suzuki et al. [25], which distinguishes energy transition states based on low-carbon and fossil fuel deployment in electricity systems. This framework enables explicit interpretation of the energy transition states implied by national energy targets and helps assess whether, if achieved, the targets would yield transition states associated with decarbonisation. Energy targets are regarded as regulatory tools, and it is presumed that countries will allocate sufficient resources to meet them. This paper examines transitions in electricity systems through the evolution of the electricity mix and decarbonisation pathways.

A case study is conducted on three Southeast Asian countries, namely Indonesia, the Philippines, and Vietnam. Southeast Asia is selected because the region has very rapid economic [26] and electricity demand [27] growth with a high dependence on coal-fuelled electricity. The growth is expected to continue, leading to a 35% increase in CO2 emissions by 2035 [22], further hindering global efforts to mitigate climate change. Meanwhile, the countries, accounting for almost 60% of the region's electricity systems [27], have similar development profiles and rely heavily on coal for electricity generation, but have set different targets for energy technology deployment in their electricity supply. This study asks two research questions: 1) How will the electricity mixes of Indonesia, the Philippines, and Vietnam evolve in terms of their renewable and fossil fuel shares based on the established energy targets in each country? 2) How will the power sector transition of the three countries, as reflected by their decarbonisation pathways, develop if they achieve their energy targets?

To answer the first question, interpolations are conducted on countries' energy targets to obtain annual electricity generation projections. Eight scenarios are developed by combining this generation with the projected electricity demand obtained from the same official documents. To answer the second question, the framework developed by Suzuki et al. [25], referred to hereafter as the decarbonisation pathway framework, is applied to the scenarios. The framework divides the energy transition into four phases: high-carbon substitutions, energy reductions, energy additions, and low-carbon substitutions, which enables interpretation of whether renewable electricity growth under the targets represents additional supply or contributes to the displacement of fossil-fuel electricity. While addressing the research questions, this work also demonstrates how to apply the decarbonisation pathway framework to investigate future decarbonisation pathways in developing countries, even though the framework was initially intended to track historical energy transitions in developed countries.

The results show that, despite similar socio-economic development and geographic locations, the energy targets of Indonesia, the Philippines, and Vietnam indicate different electricity-mix evolution and decarbonisation pathways. Although renewable sources are projected to account for the majority of Indonesia's electricity mix, the country is expected to stay in energy additions until 2050. On the other hand, Vietnam's more ambitious targets on renewable energy deployment and fossil-fuel decline can lead to a shift towards low-carbon substitutions. The Philippines' renewable energy target can also lead to a decline in fossil fuels, prompting low-carbon substitutions before 2030 and indicating that fossil fuel expansion is unnecessary to meet electricity demand during that period. Yet these trends depend on demand projections; higher demand projections will require renewable energy deployment beyond current targets to decarbonise the countries' electricity systems.

This study contributes by treating national energy targets not only as scenario inputs or policy constraints, but as objects of assessment that imply specific transition states of electricity systems. Empirically, scenario analysis shows that increased renewable energy deployment does not necessarily lead to decarbonisation of the electricity system. Methodologically, it demonstrates how the decarbonisation pathway framework can be applied to future target data to interpret transition states implied by national energy targets under rapidly growing electricity demand in developing and emerging economies. Theoretically, it contributes to a more nuanced understanding of transition dynamics of electricity systems in developing and emerging economies under rapidly growing electricity demand.

The rest of this paper is organised as follows. Section 2 summarises energy transition developments in Southeast Asia, outlines the socio-economic and electricity system conditions in Indonesia, the Philippines, and Vietnam, and reviews their energy target developments. Section 3 (methodology) details how the decarbonisation pathway framework is applied to explore target-based energy transitions by complementing the framework with target interpolation and scenario development. The results concerning target projections, electricity mixes, and decarbonisation pathways are presented by country in Section 4. The results of the three countries are then compared in Section 5 (analysis), followed by a discussion which highlights the strengths and limitations of the methodological development in Section 6. Finally, conclusions and policy implications are provided in Section 7.

2. Background information

2.1. Energy transition in Southeast Asia

Southeast Asia[1]'s electricity sector remains primarily reliant on fossil fuels. In 2021, coal accounted for 43% and natural gas for 28% of the electricity generation [27]. However, this does not imply a lack of historical engagement with renewable energy. Historically, hydropower has been the leading renewable energy source in the region's electricity systems [28], with Cambodia, Laos, and Vietnam having very high hydropower generation shares between 50% and 100% [27].

The current transition involves the deployment of modern renewable energy. It is fuelled by the declining cost of renewable energy technologies both globally and in the region, the adoption of emergent technologies such as floating solar photovoltaic (PV) and offshore wind turbines, the increasing demand for clean energy from multinational companies operating in the region, and the digitalisation of the power

[1] Southeast Asia refers to the ten member countries of ASEAN (Association of Southeast Asia Nations): Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

sector [29]. Policies have supported the transition and facilitated the decarbonisation of the energy system [30]. A recent example is the rapid deployment of solar power in Vietnam between 2018 and 2021, facilitated by a generous feed-in tariff (FiT), income tax exemption, and exemption from land-lease payment [31].

Despite Vietnam's successful example, the region still faces many challenges and barriers to renewable energy deployment. Some of the challenges come from economic considerations, such as the perceived high transition cost [32–34] and a lack of capital investment and competition in the energy sector [32]. Other barriers stem from regulatory authorities, including policy uncertainty [31], incomplete regulation [35], regulatory difficulties [33], and prioritisation of funding for more basic facilities [34]. The countries also face technical limitations like underprepared infrastructure [31,35] and limited institutional capacity to implement regulations [36]. Other challenges include conflicting interests among different stakeholders in the energy sector [33, 37,38] and concerns over energy supply security [34].

Amid these challenges, several studies have investigated decarbonisation pathways in the region. Some studies and reports focus on cost-optimal pathways to meet climate targets, either for Southeast Asia as a whole [22,39] or more specifically for the island of Sumatra in Indonesia [40]. Irsyad et al. [41] have used scenarios to estimate the cost of decarbonising Indonesia's power system. Two other studies focus more on the technologies required to decarbonise the region's power sector [42,43], while Tran et al. [44] investigate the required technologies to decarbonise Vietnam's power sector. Yet, like the studies discussed in Section 1, these studies have generally used targets, climate goals, or decarbonisation endpoints as inputs or constraints for scenarios. They have not explicitly interpreted the transition states implied by achieving the targets themselves.

2.2. Socio-economic development

The three countries have been experiencing continuous population growth since 1990 (Fig. 1), with Indonesia having the largest population (275 million) in 2022 [45], followed by the Philippines (115 million) and Vietnam (98 million). The Philippines and Vietnam had a similar growth rate in the early 1990s, but the Philippines' population surpassed Vietnam's in the early 2000s. Unlike population growth, the GDP per capita of the three countries shows more dynamics. Since 1990, Indonesia and the Philippines have had several declines (Fig. 1), most noticeably in the late 1990s during the Asian financial crisis, after the end of the commodity boom in 2011, and in 2020 due to the COVID-19 pandemic. Yet, the three countries show a generally positive growth trend over the last 32 years, with Vietnam experiencing the fastest growth.

The increases in population and GDP per capita are reflected in the growth of electricity demand per capita (Fig. 1). The electricity demand per capita in the three countries has been growing rapidly since 1990; in 32 years, the Philippines' demand has doubled, Indonesia's has increased by 800%, and Vietnam's electricity demand per capita has grown by 2700%. Vietnam's rapid growth has also led to the highest demand per capita growth among the three countries, reaching twice Indonesia's level and three times the Philippines in 2022. The rapid demand growth in the three countries may also be attributed to the increase in electricity access (Fig. 1), with Indonesia and Vietnam reaching 100% electrification in 2022 and the Philippines around 95%.

2.3. Electricity systems in the case study countries

Different geographical conditions result in different grid systems across the countries. Indonesia and the Philippines, both archipelago states, feature several island main grids, with minimal to no electricity trade with neighbouring countries [22]. The Indonesian grid comprises seven main systems: Sumatra, Java-Bali, Kalimantan, Sulawesi, Maluku-Papua, West Nusa Tenggara, and East Nusa Tenggara. Notably, the Java-Bali grid is the largest, representing 70% of the country's on-grid electricity in 2020 [46]. In the Philippines, the grid network is divided into three systems from north to south: Luzon, Visayas, and Mindanao, with Luzon being the largest, accounting for 70% of the total

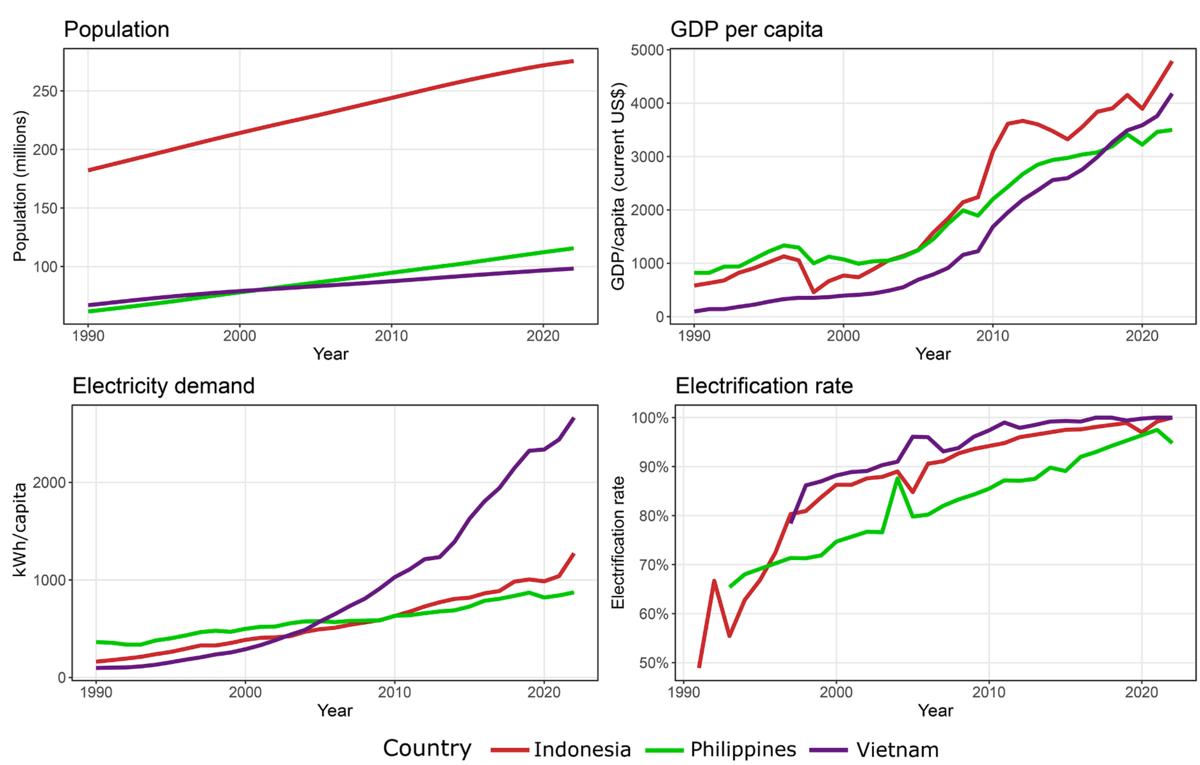

Fig. 1. Population, GDP per capita, electricity demand per capita, and electrification rate development of Indonesia, the Philippines, and Vietnam (Processed from IEA [27] and World Bank [45] data).

installed capacity [47]. Conversely, Vietnam operates an interconnected grid system, divided into northern, central, and southern regions [48], which is linked to China, Laos, and Cambodia, thereby facilitating electricity trade with its neighbours.

Electricity demand growth has been met by fossil fuels, as these countries are producers of natural gas, coal, and, to a lesser extent, crude oil [22]. However, the development of these sources differs. The share of coal in countries' electricity mixes has been increasing, reaching about 50% in 2022. The increase has been encouraged by policymakers' view of coal as a cost-effective and swift solution to satisfy the growing demand [38,49]. The role of natural gas, mainly from domestic production, has also been growing and now contributes significantly to the electricity mix. In contrast, the use of oil for electricity generation has been decreasing significantly over the past 32 years, particularly in Indonesia and the Philippines.

Similar to fossil-fuel power development, the development of renewable energy in the electricity mix also varies among the three countries (Fig. 3). Hydropower, despite the relative decline in recent years, remains the predominant renewable source, accounting for about 9% in Indonesia and the Philippines in 2022 and nearly matching coal share in Vietnam. Geothermal energy has a notable presence, accounting for 5% of Indonesia's electricity generation and 10% in the Philippines in 2022. Like hydropower, its share has been declining in the Philippines since 1990 and has not seen significant development in Indonesia. Other modern renewables, such as solar, wind, and biomass, make up smaller portions of the electricity mix in these countries, except for solar power in Vietnam, which accounted for 10% of total electricity in 2022, attributed to successful policy implementations in recent years [31].

2.4. Energy targets and their development

This paper focuses on energy targets in the electricity system at the national level; further use of the term 'energy targets' refers to electricity supply targets. This paper also includes targets derived from the primary energy target, which is seen as an "overarching" target [5]. The energy targets of the case countries are established by various governmental institutions through different policy documents. Indonesia's targets are set by the President Office as a national energy policy and the more detailed interpretation of the target is provided by the Ministry of Energy and Mineral Resources (MEMR). The Philippines' targets are established by the Department of Energy (DOE) and issued in the Philippines Energy Plan (PEP). Vietnam's targets are presented in a power development plan issued by the Prime Minister Office. Over the last decade, energy targets of these countries have undergone several changes (Table 1). Each target revision results in an increasing trend of renewable energy and a decreasing trend of coal. The countries set most of their energy targets until 2050 within a range of values.

Indonesia's energy targets currently in effect are the targets under the 2014 National Energy Policy [51], supplemented by the 2017 National Energy Plan [52], while a new draft of the National Energy Policy was released in 2024 [50]. As this is in its final stage at the time of writing of this paper, it reflects the more recent development of

Table 1
Energy target development of Indonesia, the Philippines, and Vietnam. LC refers to low-carbon, RE refers to renewable energy, and NRE refers to new and renewable energy, which includes renewables and other low-carbon technologies. The policy documents are provided with their citations.

	Policy documents	Target unit	Target year	Target		Target year	Target	
Indonesia	2024 Draft of National Energy Policy [50]	Share of primary energy mix	2030	RE	19–22%	2050	RE	44–47%
				Coal	41%		Coal	19–21%
				Gas	13–14%		Gas	17%
				Oil	22–26%		Oil	8%
				NRE	0.1–0.2%		NRE	8%
	2014 National Energy Policy [51], 2017 National Energy Plan [52]	Share of primary energy mix	2025	NRE	23%	2050	NRE	31%
				Coal	≥ 30%		Coal	≥ 25%
				Gas	≥ 22%		Gas	≥ 24%
				Oil	< 25%		Oil	< 20%
The Philippines	Philippines Energy Plan 2023–2050 [53]	Installed capacity	2050	RE	107–115 GW			
				Coal	11–15 GW			
				Gas	20–26 GW			
				Oil	4 GW			
				Other LC	4.8 GW			
	Philippines Energy Plan 2020–2040 [54]	Installed capacity	2030	RE	30 GW	2040	RE	53–81 GW
				Coal	14 GW		Coal	14 GW
				Gas	7 GW		Gas	19–24 GW
				Oil	5 GW		Oil	5 GW
	Philippines Energy Plan 2018–2040 [55]	Installed capacity	2030	RE	25–26 GW	2040	RE	40–50 GW
				Coal	18–19 GW		Coal	18–31 GW
				Gas	5 GW		Gas	18–22 GW
				Oil	2 GW		Oil	2 GW
							Other LC	0–1.2 GW
Vietnam	Power Development Plan 2021–2030 with a Vision to 2050 [56]	Installed capacity	2030	RE	81 GW	2050	RE	340–400 GW
				Coal	30 GW		Coal	0 GW
				Gas	37 GW		Gas	8 GW
				Other LC	3 GW		Other LC	94–133 GW
	Revised Power Development Plan 2011–2020 with a Vision to 2030 [57]	Installed capacity	2020	RE	20 GW	2030	RE	26 GW
				Coal	26 GW		Coal	55 GW
				Gas	9 GW		Gas	5 GW
							Nuclear	5 GW
	Power Development Plan 2011–2020 with a Vision to 2030 [58]	Installed capacity	2020	RE	19 GW	2030	RE	20 GW
				Coal	36 GW		Coal	76 GW
				Gas	12 GW		Gas	17 GW
				Nuclear	1 GW		Nuclear	10 GW

Indonesia's energy sector, such as the Just Energy Transition Partnership [59], coal power plant moratorium [60], and the country's aspiration to phase out coal in 15 years [61]. Hence, we decided to use the proposed targets in this paper.

The Philippines' energy targets underwent several changes in a relatively short period: the earlier targets were issued in 2018 [55], revised in 2020 [54], and again in 2023 [53], with the latter effectively becoming the most recent target. Aside from the energy target, the energy plan documents in every revision also contain two electricity demand projections, the "Reference" scenario, which assumes business-as-usual conditions, and the "Clean Energy" scenario, which assumes a higher level of energy efficiency. The two demand projections reflect the energy efficiency measures the Philippine government aims to achieve.

Vietnam's energy targets also underwent changes but with less frequency than the Philippines'. The earlier targets were set in 2011 [57] and revised in 2016 [58]. The most recent targets, established in 2023 [56], include ambitious targets to reduce fossil fuel use. Specifically, coal power plants are planned for phase-out and gas power plants are intended to be nearly phased out by 2050.

3. Methodology

To answer the research questions, the decarbonisation pathway framework developed by Suzuki et al. [25] was chosen as the main methodological framework. The framework is considered suitable for analysis for three reasons. First, it allows for a common categorisation of the energy transitions of the case countries and, thus, enables comparison. Second, the framework also provides a visual representation of potential decarbonization pathways. Third, it offers a comprehensive overview of the electricity system by incorporating electricity generation from fossil fuels, low-carbon sources, and renewables. Including all energy sources in the analysis is essential to investigate whether a rapid increase in renewable or low-carbon deployment would lead to the desired states of energy transitions, given the rapidly expanding electricity systems of the case countries due to the growing demand [37,38,62].

The decarbonisation pathway framework categorises decarbonisation into four states based on average annual low-carbon growth rate and fossil-fuel growth rate over a certain period (Fig. 3). High-carbon substitutions occur when fossil-fuel growth is positive while low-carbon growth is negative, energy additions occur when both fossil-fuel growth and low-carbon growth are positive, low-carbon substitutions occur when fossil-fuel growth is negative while low-carbon growth is positive, and energy reductions occur when both fossil-fuel and low-carbon growths are negative. The shifts within and between these categories over periods of time build into decarbonisation pathways, which, for G7 countries and the EU, historically moved from energy addition to low-carbon substitution [25]. The framework places greater emphasis on the evolution of all decarbonisation pathways than on the decarbonisation state of each period. It also means that the magnitude of change between periods may vary, and whether this magnitude leads to a change in the decarbonisation states of certain periods rather depends on the position of each period in relation to the others.

The framework was initially developed to investigate decarbonisation pathways using historical data; however, this paper applies it to target data reflecting future assumptions about energy transitions. Applying the framework to different data comes with challenges. The most recent targets for the case countries (Table 1) are given as ranges of values for certain years until 2050. This results in a lack of continuous data needed to operate the framework and creates uncertainty about which target values the countries will follow. The rapidly growing electricity demand introduces further uncertainties as there is a discrepancy between the total electricity generation targets and the projected electricity demand, despite both being sourced from the same documents. To overcome these challenges, the decarbonisation pathway framework is complemented by target interpolation to generate continuous data and by scenario construction to account for uncertainties in targets and projected demand.

Therefore, the approach of this paper consists of four main steps (Fig. 4). First, energy targets for Indonesia, the Philippines, and Vietnam are obtained from policy documents. These targets are converted to electricity generation when they are not expressed in terms of generation and then interpolated to produce annual electricity generation values from 2023 to 2050. It should be noted that the annual generation values are obtained by interpolating between official target years, not by forecasting from historical trends. Second, demand projections are obtained from the countries' policy documents and interpolated between available demand-projection years to generate annual demand values. Third, demand projections are combined with interpolated generation values to develop scenarios of future electricity mixes. Lastly, the annual growth in low-carbon and fossil-fuel electricity generation is calculated from the electricity mix in each scenario. The decarbonisation pathway framework is then applied, resulting in decarbonisation pathways for each scenario and answering the second research question. The remainder of this section provides a detailed explanation of each step.

3.1. Target interpolation

Before the interpolation process, energy targets from the policy documents of the case countries need to be expressed uniformly in terms of electricity generation. The process of converting targets into electricity generation varies depending on how the countries present their targets (Supplementary Note 1). The resulting energy target data are available in Supplementary Data 1. Then, to identify a suitable interpolation, the methods used to calculate electricity generation growth in countries' energy plans are examined using different growth models following Cherp et al. [63]. Exponential, logistic, linear-logistic, and Gompertz models were fitted to the historical and target data of the three countries. The fitted growth models were used only to assess possible interpolation methods. The fitting result shows that although some data points align with one or more growth models (Supplementary figure 1), many target points do not fit any of these models. It might be due to the nature of target formation, during which the governments of Indonesia, the Philippines, and Vietnam might not use specific growth models based on scientific literature or might use other growth models developed differently. For this reason, it was decided to perform interpolation by assuming linear growth between the countries' respective target years as expressed in Eq. (1).

$$EG_n = EG_{DP1} + \frac{EG_{DP2} - EG_{DP1}}{Year_{DP2} - Year_{DP1}} \times (Year_n - Year_{DP1}) \tag{1}$$

EG represents electricity generation; *DP* represents a data point, with DP2 corresponding to the target at a later time point than DP1; and *n* represents a data point between DP1 and DP2.

3.2. Electricity demand interpolation

The electricity demand projections are provided only for several specific years in the policy documents of the case countries (Supplementary Data 2). Similar to the target data, electricity demand is interpolated by assuming linear growth between data point to obtain the annual demand values for all years. Eq. (1) is also used in this interpolation, with electricity generation (*EG*) replaced by electricity demand.

3.3. Scenario construction

Scenarios are constructed based on the variations of generation and demand projections. The scenarios incorporate different assumptions based on variations in interpolated generation and demand values. There are four groups in total, with each group having two scenarios that incorporate the projected demand range (Table 2). The first scenario group, no adjustment, means the generation values are used as stated in the policy document. The scenario group comprises LDNA (lower-demand projection) and HDNA (higher-demand projection). The second group, proportional adjustment scenarios, use the same values as in the first group but the generation is matched to the demand projection by keeping the same proportion of the share of each energy source in the generation projection. This means that the share of each source is reduced proportionally when total generation exceeds projected demand, or increased proportionally when it falls short. This adjustment is justified by historical precedents in which supply and demand have always matched. The proportional adjustment scenarios also include lower (LDPA) and higher (HDPA) demand projections.

The third scenario group, fossil fuel development, and the fourth group, low-carbon development, are distinguished by how the three countries plan to deploy low-carbon sources, particularly renewables. In fossil fuel development scenarios, countries are assumed to achieve the lower end of renewable targets and obtain the remaining supply from fossil fuels. In low-carbon development scenarios, countries are assumed to meet the upper end of renewable targets and fulfil the remaining demand from fossil fuel sources. Each scenario group consists of scenarios with lower- and higher-demand projections: LDLRE and HDLRE for the third group, and LDHRE and HDHRE for the fourth group. The assumption about the remaining generation stems from findings from previous studies in which fossil fuels, particularly coal, have been used in the three countries as a “quick” option to meet increasing demand [38,49].

3.4. Decarbonisation pathways of the energy targets

Application of the decarbonisation pathway framework requires specific time periods to observe the growth of fossil fuels and low-carbon sources. Five-year periods between 2020 and 2050 are chosen to avoid the extreme variation in the growth rate typically observed in one year, while providing greater detail in comparison to ten years, for example. Decarbonisation pathways are constructed based on the growth rates of fossil fuels and low-carbon sources, calculated as the average growth rate over one period normalised to the total electricity supply (Eq. (2), developed by Vinichenko et al. [64] and also used by Suzuki et al. [25]). The first period (2020–2025) is calculated using historical data for 2020, obtained from IEA [27], and projection data for 2025.

Table 2
Summary of the eight scenarios derived from the demand projection and energy targets of Indonesia, the Philippines, and Vietnam. The ↑ sign represents a higher range, ↓ represents a lower range, CV represents generation values relative to the demand projection, NA represents no adjustment, PA represents proportional adjustment, and FF represents fossil fuels.

Scenario group	Scenarios	Abbreviation	Demand projection	Generation value
No adjustment (as stated in the policy documents)	LDNA	Lower demand, no (generation) adjustment	↓	CV, NA
	HDNA	Higher demand, no (generation) adjustment	↑	CV, NA
Proportional adjustment (generation is made to match demand)	LDPA	Lower demand, proportional (generation) adjustment	↓	CV, PA
	HDPA	Higher demand, proportional (generation) adjustment	↑	CV, PA
Fossil-fuels development	LDLRE	Lower demand, lower renewable energy	↓	Renewables: ↓, remaining demand: FF
	HDLRE	Higher demand, lower renewable energy	↑	Renewables: ↓, remaining demand: FF
Low-carbon development	LDHRE	Lower demand, higher renewable energy	↓	Renewables: ↑, remaining demand: FF
	HDHRE	Higher demand, higher renewable energy	↑	Renewables: ↑, remaining demand: FF

$$GR = \frac{(EG_{YearFinal} - EG_{YearInit}) * 2}{TES_{YearFinal} + TES_{YearInit}} \tag{2}$$

GR refers to growth or change rate, *EG* refers to electricity generation, *TES* refers to total electricity system, *YearInit* refer to the initial year of a period, and *YearFinal* refers to the final year of a period.

Renewable energy sources, including hydropower, geothermal (for Indonesia and the Philippines), solar, wind, and biomass and renewable waste (BWR), becomes the focus of the decarbonisation pathway analysis. Nuclear power and hydrogen are also included as other low-carbon technologies because they are part of countries’ targets. Yet they are not the focus of this study, as the case countries lack historical precedent in their development, and their deployment uncertainty is greater than that of renewable energy technologies. Oil is excluded because its share of electricity generation has been significantly declining across countries, and imported electricity is classified as a distinct category within the decarbonisation pathways.

4. Results

The electricity mix (Fig. 3) derived from countries’ targets through the interpolation process shows different energy source configurations for Indonesia, the Philippines, and Vietnam. There is a discrepancy between generation and demand projection as the upper range of the demand projection does not match the upper range of the total generation projection. A similar discrepancy is also observed between the lower range of demand projection and the lower range of total generation projection (Supplementary Figure 2). Scenarios are constructed from these electricity mixes, resulting in different configurations between fossil fuels and low-carbon shares in the electricity supply (Fig. 4). The electricity mixes in the scenarios are simplified as renewable sources are grouped into one category and fossil fuel sources are grouped into another category. The upper range projection in Fig. 3 corresponds to HDNA scenarios in Fig. 4, while the lower range projection in Supplementary Figure 2 corresponds to LDNA scenarios in Fig. 4. Applying the energy transition framework to each scenario results in various decarbonisation pathways for each country (Fig. 5). The results are further described by country in the rest of this section.

4.1. Indonesia

Indonesia’s electricity mixes reveal that the upper range (Fig. 5) and lower range (Supplementary Figure 2) of demand projections are closely aligned with total generation until 2030. Still, the demand projection consistently exceeds the total generation afterwards. By 2050, the gap between the two is projected to range from 135 to 180 TWh. The total generation shifts towards renewables and low-carbon sources by 2050. Coal-powered generation is projected to increase until 2030 before declining gradually while natural gas share is projected to rise steadily, and combined, they comprise 30% of the electricity mix. All renewable energy sources are projected to grow until their total share comprises around 60% of the mix, with solar power leading the expansion, followed by biomass, hydropower, and geothermal. The energy target has notably set a low deployment target for wind power, leading to a much slower growth rate than other renewables. The share of other low-carbon sources, primarily nuclear, is projected to increase gradually until 2040, after which it will accelerate.

All of Indonesia scenarios show that the cumulative shares of renewables and low-carbon sources in the electricity mix grow significantly until 2050, while the cumulative share of fossil fuels stabilises (Fig. 6). Yet the scenarios differ on when fossil fuels stop growing, as scenarios with lower demand projections (LDPA, LDHRE) indicate around 2030, while scenarios with higher demand projections (HDLRE, HDHRE) suggest after 2040. Scenarios with higher demand projections also tend to have a higher fossil fuel share, particularly the HDLRE scenario, where fossil fuels account for more than half of total generation by 2050. This is double the generation that Indonesia energy target aims to achieve. Even if the country achieves the upper level of its renewable target (HDHRE scenario), the fossil fuel share will still be higher than in the targets. On the other hand, scenarios with lower demand projections (LDPA, LDLRE, LDHRE) show a fossil fuel share similar to the country's target, with the LDHRE scenario even showing a third less fossil fuel share.

Decarbonisation pathways across Indonesia scenarios also reflect a stabilised fossil fuel share, with the fossil fuel growth rate declining between each period from 2020 to 2050 (Fig. 7A and B). However, in five scenarios, the end of the decarbonisation pathways still indicates energy additions by 2050, while the other three scenarios lead to low-carbon substitutions after 2040 (Supplementary Figure 3). The decline rate of the fossil fuel share in scenarios leading to low-carbon substitutions, as represented by the HDPA scenario (Fig. 7A), does not seem to differ significantly from that in scenarios leading to energy additions, as represented by the HDLRE scenario (Fig. 5B). The difference lies in the fossil fuel share growth in early periods (2020–2030) where the fossil fuel growth rate in the HDPA scenario is lower than that in the HDLRE scenario.

4.2. The Philippines

Although the Philippines projects its electricity demand over a range of values, the upper and lower projection ranges are comparable (Fig. 5), with the largest difference between the two demand levels being only 5 TWh. This results in a different type of discrepancy between projected demand and total generation. The upper range of the demand projection is always below the upper range of total generation, while the lower range of the projection remains below the lower range of total generation until 2040, after which it exceeds the generation projection (Supplementary Figure 2). The electricity mix projections also show a continuous increase in the gas share until 2050, reaching four to eight times the 2022 level. Coal-powered generation is projected to show little to no growth and start declining gradually. The share of renewable sources also grows rapidly, reaching around eight times the 2022 level, with wind and solar power leading this expansion. The country also plans to deploy new low-carbon technologies, especially nuclear power; however, this is only found in the upper-level projection of the energy target.

Most Philippines scenarios reflect the rapid growth of fossil fuels and renewables, as indicated by the cumulative shares of each energy source in the electricity mix (Fig. 6). Four scenarios (LDPA, HDPA, LDLRE, HDLRE) show that the fossil fuel share will decline until 2030 before increasing again, while scenarios reaching the upper level of renewable target (LDHRE, HDHRE) show another temporary decline in fossil fuel share between 2040 and 2050. The two scenarios also show fossil fuel share at around the same level as in 2022, differing significantly from the other scenarios, which indicate a significant increase up to 30%–40% of total supply share by 2050.

The differences among scenarios are reflected in their decarbonisation pathways. The LDPA scenario (Fig. 7A) shows a shift in the decarbonisation pathways, with the country remaining on low-carbon substitutions until 2030 before transitioning to energy additions, reflecting the six scenarios that indicate a temporary decline of fossil fuel share (Supplementary Figure 4). On the other hand, scenarios showing continuous growth in the fossil fuel share follow decarbonization pathways, as in the HDNA scenario (Fig. 7B), where the pathways shift only within energy additions. Despite differences in pathways and the relatively low growth of fossil fuel shares in the LDHRE and HDHRE scenarios, all scenarios indicate that the country will still be in energy additions by 2050.

4.3. Vietnam

Vietnam's upper and lower demand projections exhibit similar values until 2030, diverging thereafter to reach a 150 TWh difference by 2050 (Fig. 5). The two projection levels also relatively align with the upper and lower (Supplementary Figure 2) levels of the total generation, respectively, until 2030, and then exceed the total generation until 2050. The total generation highlights a rapid increase in renewable sources. Wind and solar power are projected to dominate growth, accounting for nearly 50% of total electricity generation by 2050. It also shows the adoption of other low-carbon technologies, primarily nuclear and hydrogen, starting in 2030, with the target of reaching one-third of total generation by 2050. In contrast, coal- and gas-powered generation is projected to rise sharply until 2030, after which it will begin to decline, reaching a zero share for coal and a 5% share for gas by 2050.

The cumulative shares of renewable and low-carbon sources increase significantly in all of Vietnam's scenarios until 2050 (Fig. 6). In contrast, the cumulative shares of fossil fuels vary across scenarios. Four scenarios (LDNA, HDNA, LDPA, and HDPA) indicate a significant decline between 2030 and 2050 in line with Vietnam's energy target. Two other scenarios (LDHRE and HDHRE) also show a decrease in the share of fossil fuels. Still, this decrease is much slighter than in the previous four scenarios, resulting in a significantly higher share than the target. The LDLRE scenario indicates a stable share from 2030 onwards, while the HDLRE scenario shows a continuous increase thereafter.

Despite the differences in fossil fuel shares across the scenarios, most of Vietnam's decarbonisation pathways indicate low-carbon substitutions after 2030, as represented by the HDPA scenario (Fig. 7A). A sharp shift from energy additions to low-carbon substitutions is observed in 2030, which leads to a very rapid decline in fossil fuel generation. The scenarios adhering to this trend include LDNA, HDNA, LDPA, LDHRE, and HDHRE (Supplementary Figure 5). In contrast, the decarbonisation pathways of HDLRE and LDLRE scenarios lead to energy additions by 2050 (Fig. 7B). A noticeable shift in the decarbonisation pathway between 2025–2030 and 2030–2035 persists but is not as sharp as in the other scenarios.

5. Analysis

This section provides a comparative analysis of the results from the case countries. The analysis focuses on the electricity mix and decarbonisation pathways, reflecting the electricity system transitions envisioned by countries' energy targets.

5.1. Electricity mixes of the scenarios

The variations in fossil fuel shares in the electricity mixes of the three countries indicate differences in fossil fuel resource availability. In terms of coal, Indonesia is one of the largest coal producers globally, and the country relies on its domestic coal for power generation (Fig. 2). This contrasts with the Philippines and Vietnam, as the two countries have seen a rise in the share of imported coal in power generation in recent years, raising the issue of energy security. Concerns over energy security in power generation can further be seen in the energy plans of the Philippines [53] and Vietnam [56], which, unlike Indonesia's energy plan [65], also include strategies to improve the utilisation of domestic energy sources for power generation. Natural gas is abundantly available in all three countries as they have not yet needed to import this resource (Fig. 2), which explains the countries' choice to increase

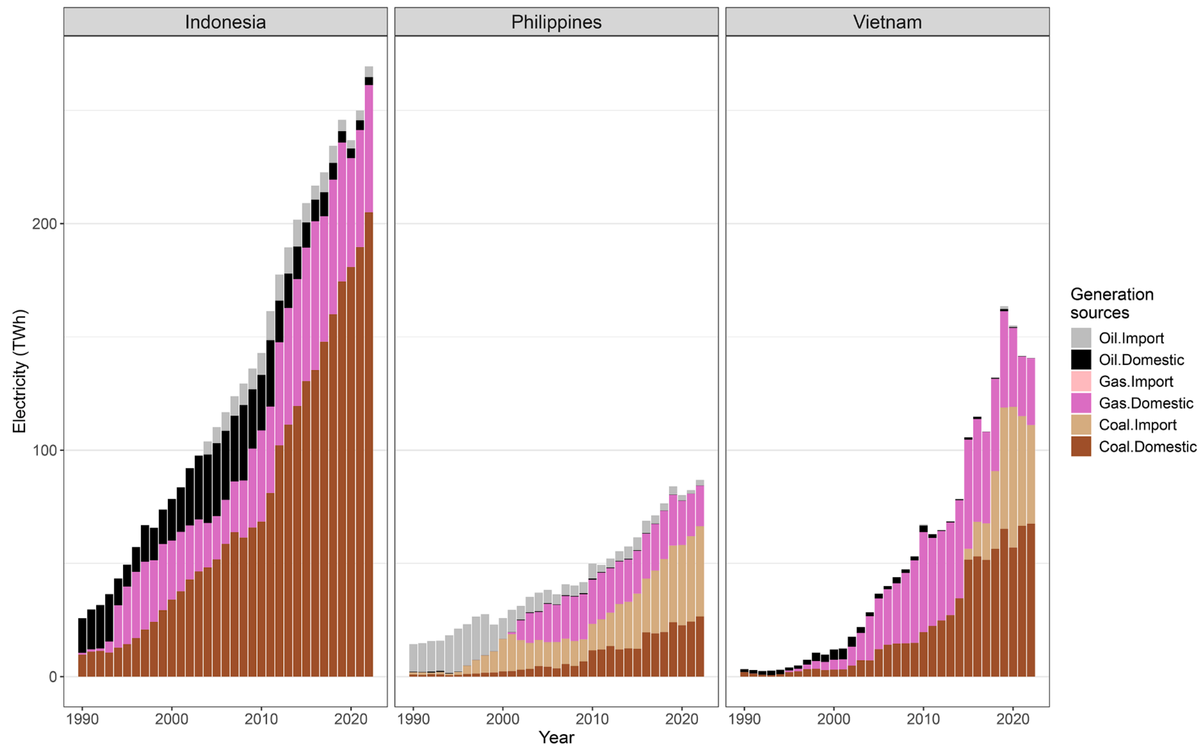

Fig. 2. Electricity generation by fossil fuel source in the three case countries, further divided into domestically produced fossil fuels (Domestic) and imported fossil fuels (Import). (Created based on IEA data [27]).

natural gas deployment in their electricity systems (Table 3).

The electricity mix results also show internal inconsistencies between energy targets and electricity demand projections, even though the data come from the same policy documents. The inconsistencies are more pronounced in the years before 2050, when projected demand usually exceeds electricity generation derived from the targets. The constructed scenarios then show how different demand projection assumptions influence the growth in the shares of energy sources, particularly fossil fuels. This influence is more pronounced for Indonesia and Vietnam than for the Philippines because the range of the Philippines' demand projection is much smaller. The fossil fuel share is generally higher in Indonesia's and Vietnam's scenarios with high-demand projections than in those with low-demand projections to cover the gap left by the demand-generation discrepancy. The scenarios assume that the countries will follow their historical tendency to rely on fossil fuels to meet increasing demand [37,62], thereby filling this discrepancy with electricity generated from fossil fuels. The implications of the discrepancy and the higher fossil fuel share in the electricity mix are more prominent in Vietnam, which has set a coal phase-out target in 2050. In the high-demand setting, Vietnam is only on track to its phase-out target in HDPA scenarios, meaning that the country needs to increase the share of renewable and low-carbon sources in its electricity system beyond the upper range of its target.

Table 3
Summary of the results of Indonesia, the Philippines, and Vietnam, with emphasis on similarities across and differences between the countries.

	Indonesia	The Philippines	Vietnam
Electricity mixes of the scenarios	• Stabilised fossil fuel growth by 2050 • Higher fossil fuel share in scenarios with higher demand projection than in scenarios with lower demand projection.	• Increasing fossil fuel share until 2050 • Yet, two scenarios with upper range of renewable target show similar fossil fuel share to 2022 level	• Rapid renewable and low-carbon growth with varied trend on fossil fuel growth • Fossil fuel phase-out in scenarios with high demand requires renewable energy growth beyond upper range of target
Decarbonisation pathways of the scenarios	• Five scenarios result in energy additions by 2050 • The scenarios show general trend of fossil fuel decline • The other result in low-carbon substitutions by 2050	• Six scenarios indicate a move from low-carbon substitutions to energy additions • Most scenarios show the country will still be in energy additions by 2050.	• Six scenarios result in low-carbon substitutions by 2050 • The scenarios show general trend of fossil fuel decline • Two other scenarios lead to energy additions by 2050

5.2. Decarbonisation pathways

Indonesia and Vietnam show different decarbonisation pathway endpoints, reflecting differences in resource availability and electricity generation targets, as discussed in Section 5.1. Vietnam's more ambitious renewable targets may also stem from its success story with solar power [31], which is not found in Indonesia. Despite these differences, the decarbonisation pathways of Indonesia and Vietnam from 2020 to 2050 follow a similar pattern. They transition from high to low fossil-fuel growth rates, accompanied by more dynamic changes in the growth rates of low-carbon sources (Fig. 5A and 5B). There is also a significant shift in the growth rate of fossil fuels between 2025–2030 and 2030–2035, though Vietnam's shift is more pronounced.

As in Indonesia, all scenarios for the Philippines suggest that the country will enter energy additions by 2050. However, the

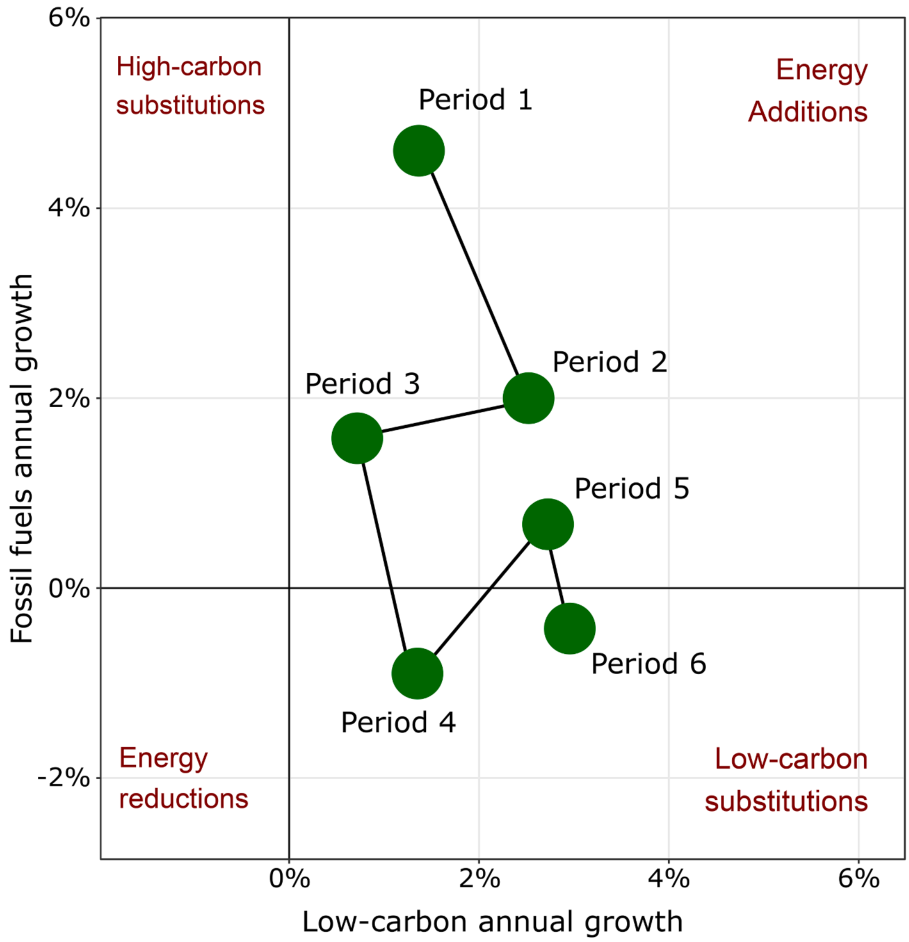

Fig. 3. An illustration of the decarbonisation pathway framework used as the main methodological framework of this paper. The lines connecting the green points represent the decarbonisation pathways. Adapted from Suzuki et al. [25].

decarbonisation pathways of the Philippines exhibit a notable distinction with the shift from low-carbon substitutions to energy additions in 2030, which is not observed in Indonesia's and Vietnam's scenarios. The Philippines' distinct pathways imply that fossil fuel growth will decline before increasing again after 2030. The absence of this trend in the LDNA and HDNA scenarios indicates that it stems from demand-generation adjustments made during scenario construction. As demand is projected to increase slowly through 2030, adjusted generation from fossil fuels is lower than in recent historical years. While there are significant concerns about the feasibility of this trend, these scenarios suggest that the Philippines may not need to increase its fossil-fuel-powered generation until at least 2030 to meet the growing electricity demand, provided the country meets its renewable energy targets. This represents a pivotal milestone in the Philippines' energy transition with enduring implications. Replacing fossil fuels with renewable energy to address rising electricity demand by 2030 could bolster confidence in renewable energy transitions, which, as demonstrated by Vietnam, might inspire more ambitious future renewable targets.

6. Discussion

This study investigates energy transition in the electricity systems through the lens of national energy targets in Indonesia, the Philippines, and Vietnam. Over the last decade, energy targets of these countries have undergone several changes (Table 1). Each target revision results in an upward trend in renewable energy and a downward trend in coal. This shift towards a higher proportion of renewable and low-carbon technologies stems from international-level announcements and commitments, such as the Just Energy Transition Partnership [59,66] for Indonesia and Vietnam and the Global Coal to Clean Power Transition Statement at COP 26 in 2021 [67] signed by the three countries. Another influence stems from domestic energy security concerns, especially in the Philippines and Vietnam, where electricity generation relies increasingly on imported energy sources [27]. Despite this similarity, the case countries have different technological choices. Indonesia coined the term "new and renewable energy" which also includes coal-bed methane, liquified coal, and gasified coal [51], raising questions about their sustainability, while the Philippines and Vietnam only consider nuclear and hydrogen as other low-carbon technologies. This difference further accentuates the different energy development that the countries aim for through their energy targets.

These targets represent future assumptions, implying uncertainty about whether they will be met within a particular timeline. This study omits this uncertainty and instead focuses on the state of energy transition in the electricity systems of the case countries. It assumes that energy targets serve as regulatory tools to place regulatory instruments [1] and guide energy-related policies [5], ultimately leading to the fulfilment of the targets. This also becomes the most fundamental assumption of this paper and influences how the state of energy transitions is observed.

Another crucial assumption is that energy targets shape energy transitions. This assumption is necessary as there has been no empirical study proving (or disproving) the causal relations between energy targets and energy transitions. Further studies may be required to resolve this assumption; however, in the current context, this study can be used to assess the transition states that energy targets aim to reach and

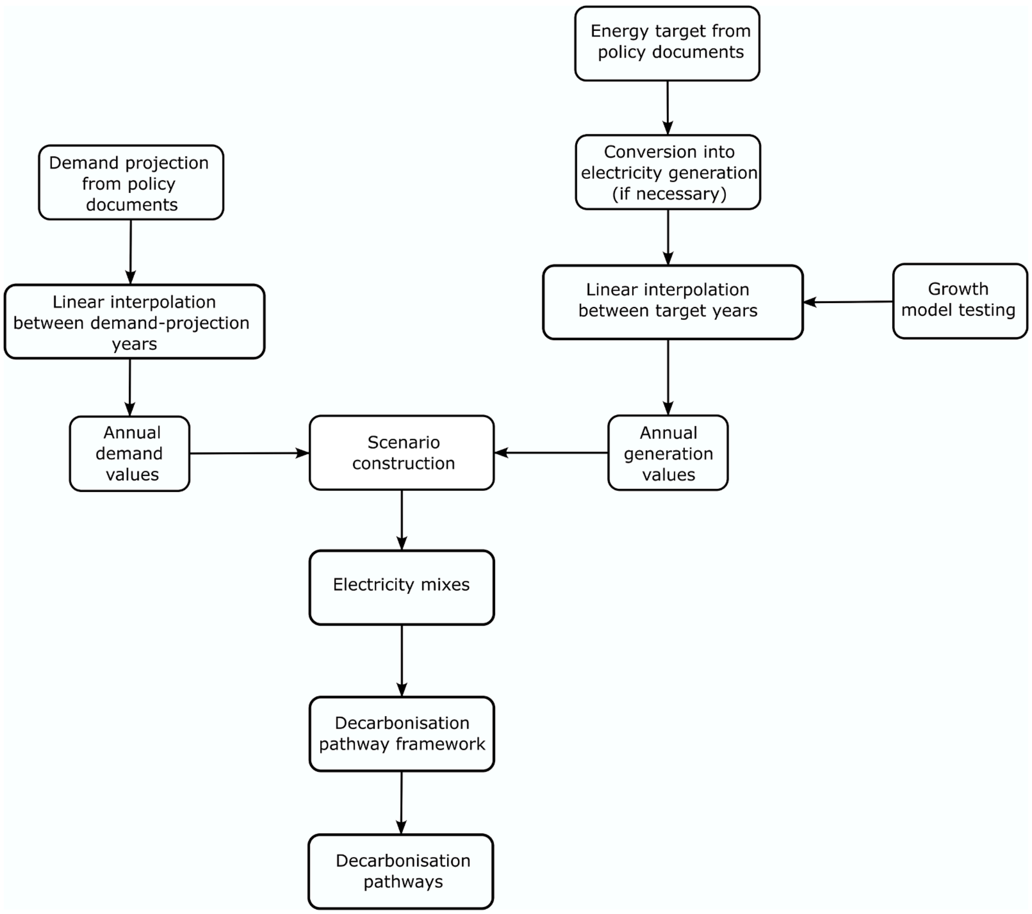

Fig. 4. Summary of the methodological approach, from processing demand and target data obtained from policy documents to building decarbonisation pathways.

whether these transition states are on track towards decarbonising the electricity system. This approach differs significantly from previous studies, in which targets are considered as one of the future alternatives [22,68], or from studies that focus on target implementation [12,14]. Analysing transition outcomes from energy targets can also serve as an alternative approach to understanding the energy transition under rapidly growing electricity demand, given the limited historical precedent for such a transition [24].

The methodological challenges arise from the different application of the Suzuki et al. [25] framework. This study applies the framework to analyse future transitions based on energy targets in developing and emerging economies, whereas the original study used it to analyse the historical transitions of developed countries. This difference leads to two complementary methodological steps: (1) target interpolation, which facilitates the application of the framework to future transitions, as energy targets are likely to be stated as ranges, and (2) scenario development, which addresses uncertainties in future assumptions, such as demand-generation imbalance. However, the challenges and additional steps to overcome them stem primarily from differences in data availability and characteristics rather than from differences in the development context of the case countries. The framework's main requirements are data on renewable energy growth and fossil fuel growth, which can be observed in both developed and developing countries. Therefore, the complementary methodological steps primarily extend the framework's application to assessing future energy transitions based on energy targets.

The use of scenarios also introduces variations in results, which differ by case country. In the electricity mix results, these variations stem from differences between the lower and higher ranges of countries' demand projections. The Philippines, which has the smallest difference among the three countries, shows less variation in the share of renewable and fossil fuel sources. Indonesia's results show greater variation than Vietnam's because Indonesia has a larger projected demand difference. The variations are also more noticeable in the fossil fuel share than in the renewable share, as the scenarios assume countries will follow their historical tendency to rely on fossil fuels, especially coal, to meet the growing electricity demand [37,38,62] if other energy sources are insufficient. This pattern may change in the future, but assuming changes to historical trends in scenarios without empirical evidence will only introduce additional uncertainty. The scenarios also introduce variations in the decarbonisation pathway results, but these variations are mainly driven by changes in electricity mixes.

Despite these variations, the results demonstrate the main novelty of this study: national energy targets are analysed not only as scenario inputs or policy constraints, but as assessment objects that imply specific transition states for electricity systems. Previous studies [12,19] and reports [22,23] have commonly used targets to define electricity system models, assess feasibility, or explore optimised decarbonisation pathways. In contrast, this study assesses decarbonisation pathways that would emerge if these targets were achieved, as well as the transition states along those pathways. This assessment is enabled by applying the decarbonisation pathway framework developed by Suzuki et al. [25] to future national targets, despite the framework's original intention for historical data. The methodological contribution of this study therefore lies in extending the framework to future cases by adding two methodological steps: 1) target interpolation, which converts discontinuous target data into annual electricity generation values, and 2) scenario construction, which combines generation values with demand projections to examine alternative supply-demand balance. Although there are some limitations, this approach provides a structured initial

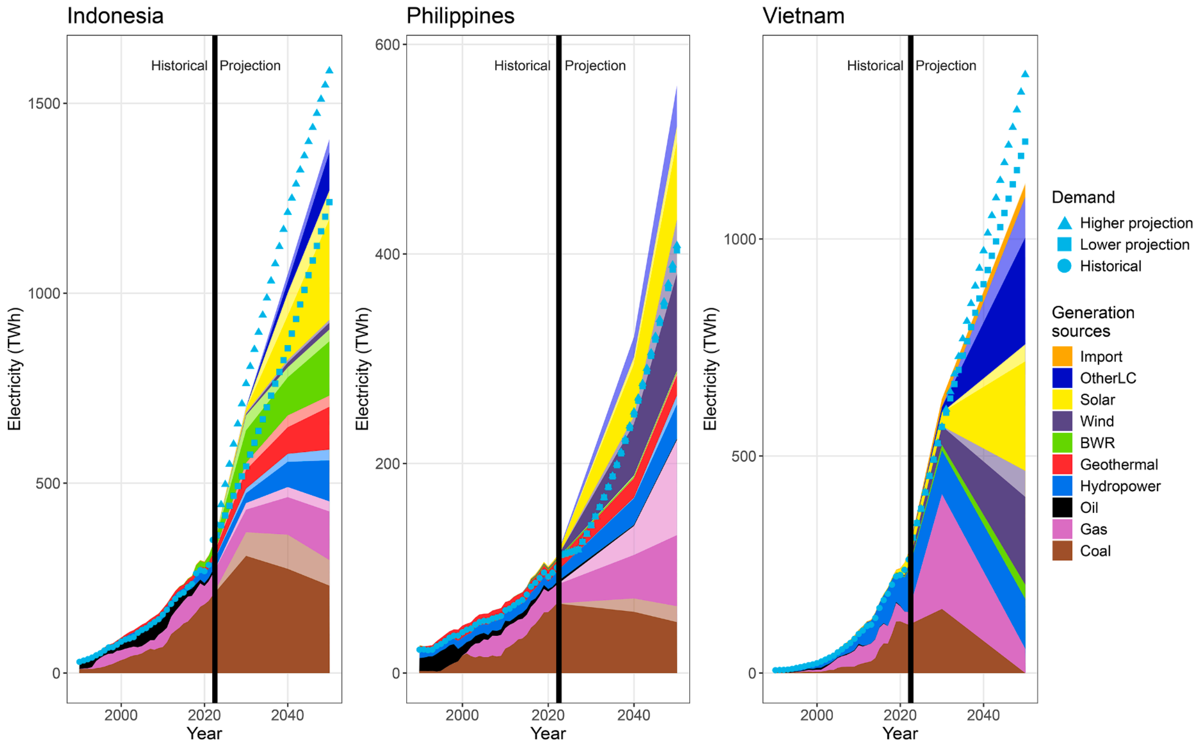

Fig. 5. Electricity generation and demand of Indonesia, the Philippines, and Vietnam 1990 – 2050 based on historical data until 2022 and thereafter projections. Both generation and demand projections are given in a range of lower and higher values. The more translucent colours on generation sources represent the higher range of generation projection. (Sources: Historical data – IEA [27]; Projection – Indonesia [50], Philippines [53], Vietnam [56]).

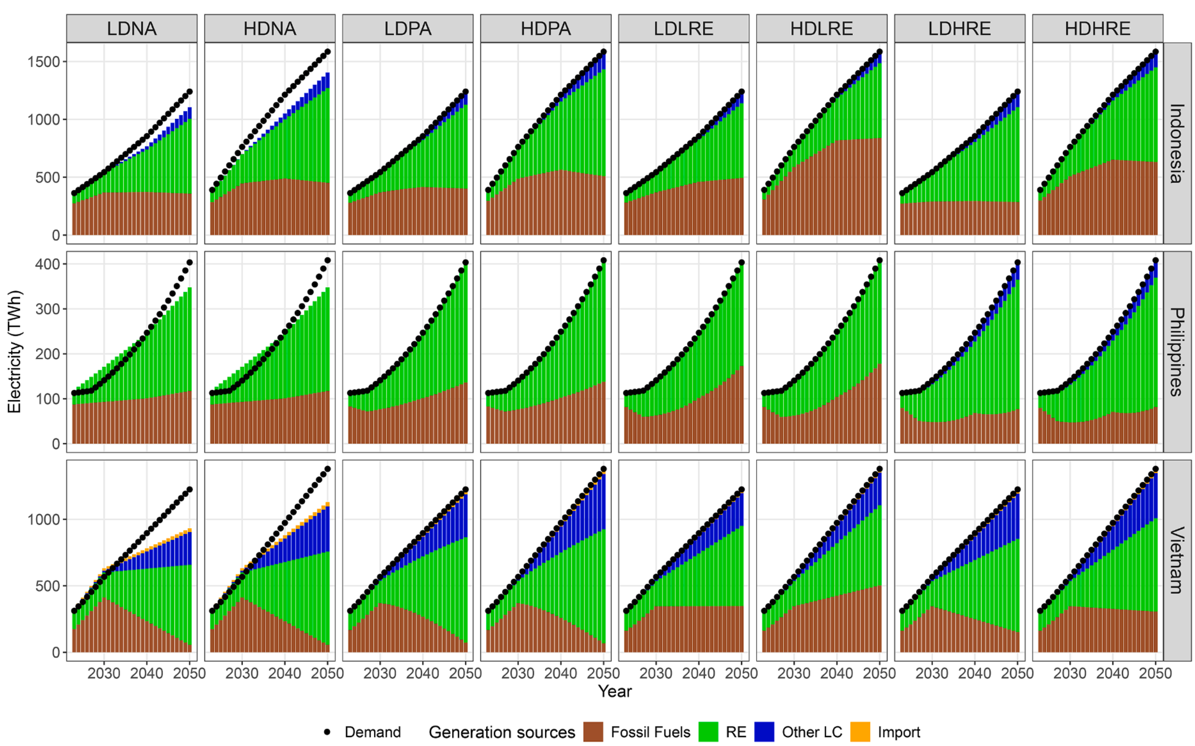

Fig. 6. Electricity generation and demand projection of Indonesia, the Philippines, and Vietnam until 2050 under eight scenarios. The generation sources are divided into four groups: fossil fuels (FossilFuels) which consist of coal and natural gas; renewable energy (RE) which includes hydropower, solar, wind, biomass & renewable waste, and geothermal (for Indonesia and the Philippines); other low-carbon sources (LC) including hydrogen and nuclear power which represent countries' aspiration to develop new low-carbon technologies; and imported electricity (Import).

assessment of how national energy targets translate into different pathways over time before more detailed analyses of feasibility, costs, optimisation, and emissions are conducted using more sophisticated energy models.

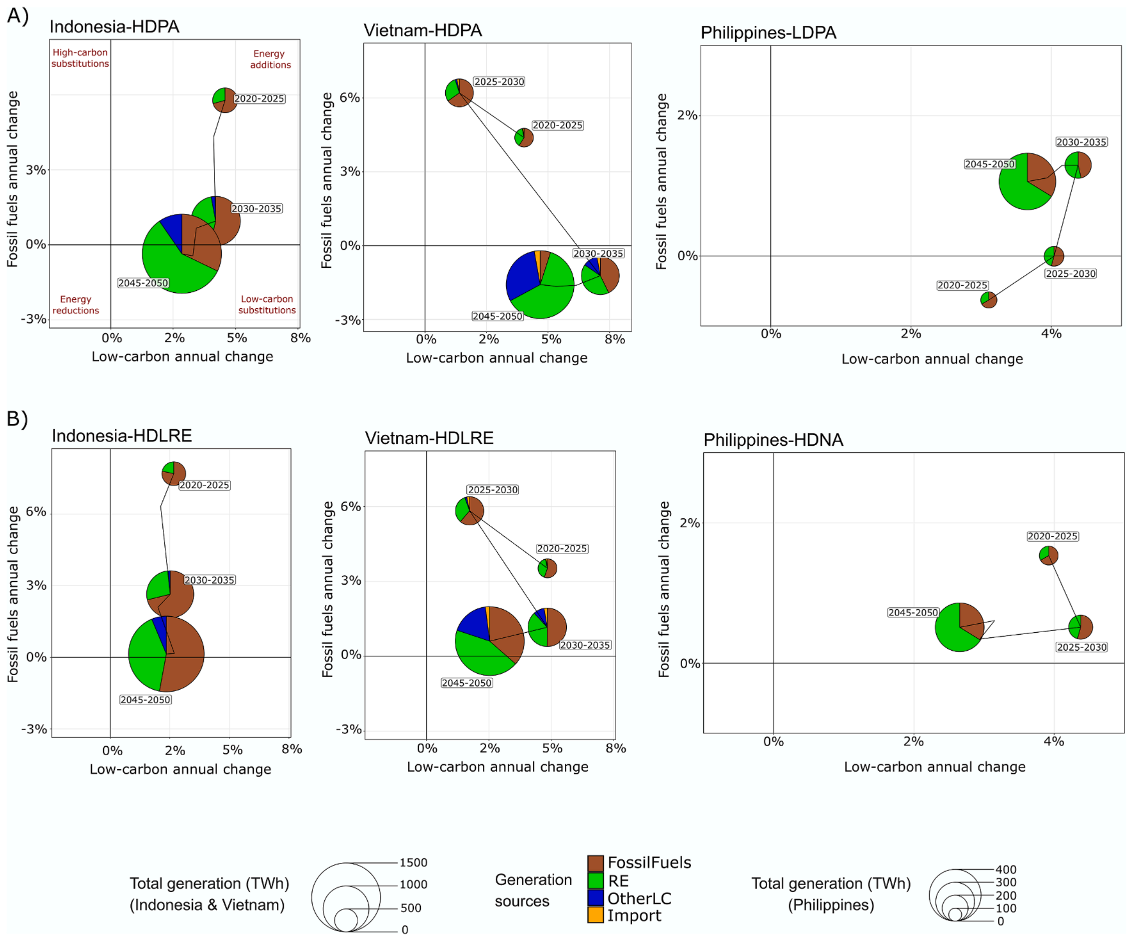

Fig. 7. Decarbonisation pathways of selected scenarios of Indonesia, the Philippines, and Vietnam. The figure is simplified to only show the pathways along with electricity mix of certain periods. Figure A shows decarbonisation pathways where each country is in a low-carbon substitution phase for at least one period, while Figure B represents scenarios in which no country enters a low-carbon substitution phase. For more complete figures of decarbonisation pathways and those for other scenarios, see Supplementary Figures 3–5.

Applying this target-focused approach yields three main insights that constitute the empirical contributions of this study. First, the study reveals that electricity demand projections and generation targets in policy documents are not always internally consistent, making target realism an important object of analysis. An example comes from Vietnam, where electricity generation from gas is to be raised nine times the 2022 level by 2030 before later being replaced by hydrogen (Fig. 5). The plan raises feasibility concerns, as developing infrastructure for gas-fired coal power plants carries a high risk of technology lock-in [69] and may shift Vietnam's dependency from coal to gas. By identifying such inconsistencies, the study shows that national targets should be assessed not only by increases in renewable energy share but also by their internal coherence and transition assumptions they reflect. Second, the study provides scenario-based evidence that increasing renewable energy targets does not necessarily reduce fossil fuel development. An example comes from Indonesia, where the fossil fuel share consistently increases across most scenarios despite its renewable energy targets, which are significantly higher than the country's historical deployment. Third, the analysis in this study further points out the crucial role of electricity demand in shaping transition outcomes. This is evident in Vietnam, where the country would need to deploy renewables beyond its current target in scenarios with high-demand projections, as the current target would not keep pace with the planned decline in the fossil fuel share.

This study also provides theoretical contributions by clarifying transition dynamics in electricity systems under rapidly growing electricity demand. The findings show that renewable energy expansion should not automatically be seen as decarbonisation, because growth in renewables may represent additional supply rather than fossil-fuel substitution when electricity demand continues to grow. It contributes to a more nuanced conceptualisation of electricity system transitions in developing and emerging economies, where decarbonisation depends not only on the pace of renewable deployment but also on whether growth in renewables is sufficient to alter fossil fuel use. In this context, electricity demand growth plays a central role in determining the transition states that national targets would lead to if achieved.

6.1. Limitations and future studies

The complementary methodological steps introduce several uncertainties and limitations to this study. The interpolation method may contribute to the discrepancy between the demand and generation values. Even though the interpolation process began with an attempt to apply various national-level energy-transition growth models, policymakers in Indonesia and Vietnam may have employed different growth models to set their energy targets and project future electricity demand. Additionally, assuming linear growth rates during interpolation may not reflect real-world renewable energy development, as wind and solar, in particular, tend to follow an S-curve trajectory [63]. The choice of growth models may directly affect calculated growth rates and electricity generation, ultimately influencing the resulting decarbonisation pathways of the case countries. Further study is necessary to understand the growth models used in the target development process in Indonesia, the Philippines, and Vietnam and to enable more accurate assessments of the decarbonisation pathways indicated by their energy targets.

The supply-demand discrepancy raises questions about scenario robustness, as the demand-generation adjustment process yields different trends across scenarios. Although Indonesia shows a consistent trend of growth in fossil fuels and renewables across its scenarios, two of the Philippines' scenarios (LDHRE, HDHRE) and three of Vietnam's scenarios (LDLRE, HDLRE, HDHRE) show markedly different trends from the other scenarios for their respective countries. Comparing the Philippines' scenarios to ERIA's energy model [70] reveals that the model's scenario featuring improved demand efficiency, more efficient power plants, and a higher contribution of renewable energy results in higher fossil fuel shares than the Philippines' LDHRE and HDHRE scenarios. A different energy model developed by EREA and DEA for Vietnam [23] also shows a significant difference in the fossil-fuel share across Vietnam's LDLRE, HDLRE, and HDHRE scenarios. These differences mainly stem from different electricity demand growth assumptions used by the ERIA model and different types of low-carbon technologies included in the EREA and DEA models. Still, the scenarios developed in this study should be used carefully and placed in the context of each country's development goals.

Target data of the case countries may also contribute to the limitations and uncertainties in two ways. The first arises from how target information from the policy documents is translated into numerical data for the decarbonisation framework, particularly for Vietnam, whose projected generation data is derived from installed capacity targets (Supplementary Note 1). The lack of information on the capacity factor assumptions used by the Vietnamese government in its policy document leads to the use of capacity factors derived from historical data. As the capacity factors tend to increase when calculated using data from more recent years (Fig. 1 of Supplementary Note 1), future electricity generation may result in higher generation than what this study calculates and the supply-demand discrepancy may not be as large as what this study shows. Further investigation is needed to understand the capacity factor assumptions used in the target formation process.

The second uncertainty arises from the general formulation process for the targets. Much like any other policy, energy targets can change rapidly. This is particularly evident in the way the Philippines revised its energy target in 2018 [55], 2020 [54], and 2023 [53]. Although these revisions may have legitimate justifications, such as the COVID-19 pandemic in 2020, they raise concerns about the realisation of the targets. Since changes in targets will affect the government's agenda, priorities, and potentially related regulations, frequent adjustments to energy targets reintroduce the challenge of policy uncertainty [31] and regulatory difficulties [33], which in turn can hinder the realisation of the targets themselves. The uncertainties surrounding the formation process and the rapid changes in the targets raise concerns about the role and significance of energy targets among energy sector policymakers, specifically whether the policymakers in the three countries view their targets as guidelines and are willing to allocate adequate resources to achieve them. Understanding the role and significance of energy targets among policymakers can help understand the credibility of targets in the energy transition and contribute to the debate on the extent to which targets should be considered in the energy transition process. Yet, these issues have not been addressed in the current energy transition literature, leaving a gap for future studies.

7. Conclusion

This study assesses the energy transitions implied by national energy targets in Indonesia, the Philippines, and Vietnam, assuming that these targets are achieved. It analyses electricity mix development and decarbonisation pathways for electricity systems based on countries' energy targets. The analysis utilises the decarbonisation pathway framework, originally designed to analyse historical transitions in developed countries, and is complemented by target interpolation and scenario construction to extend its applicability to target data from developing and emerging economies. The findings highlight the challenges of energy transition in rapidly expanding electricity systems and show the crucial role of electricity demand in determining transition outcomes. The study also shows that increasing renewable energy targets does not always lead to a reduction in the fossil fuel share of electricity supply, underscoring the need to understand the transition states implied by energy targets before conducting further analysis with more sophisticated energy models.

This study also has two main implications for the energy planning of the case countries, leading to policy implications for re-evaluating countries' electricity targets. Indonesia should consider planning for fossil-fuel reduction in its electricity supply, as increasing the share of renewable energy alone will not achieve the decarbonisation needed for the low-carbon transition of its electricity systems. The Philippines should focus more on deploying renewable energy, particularly through 2030, as many of its scenarios indicate that further expansion of fossil-fuel-based generation appears less necessary in the near future. Lastly, Vietnam should consider the feasibility of rapidly replacing fossil fuels in its electricity system with nuclear power and hydrogen, given the country's lack of historical precedent for deploying such technologies.

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CRediT authorship contribution statement

M.R. Dzikrurrokhim: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **E.O. Ahlgren:** Writing – review & editing, Supervision, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rset.2026.100152.

Data availability

Data will be made available on request.

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