RIETI Discussion Paper Series 24-E-078

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RIETI Discussion Paper Series 24-E-078

**November 2024**

# Climate Change–Energy Security Nexus in ASEAN: Quantitative text analysis using energy ministerial meeting statements *

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Abstract

The Association of Southeast Asian Nations (ASEAN) faces the urgent environmental challenge of reducing CO2 emissions from fossil fuels to limit the damage from climate change. Meanwhile, in addition to the climate change issues, ASEAN has the critical responsibility of ensuring energy security, including the need to supply stable and affordable energy. To determine how this climate change–energy security nexus has evolved in ASEAN, we examine statement documents released by the ASEAN Minister on Energy Meetings and its associated meetings. Our quantitative text analysis shows that: (1) as the discussions towards achieving carbon neutrality have progressed, the climate change issues have been increasingly highlighted, (2) the decarbonization of coal and diversification to renewable energy has received increasing attention, while energy efficiency and conservation discussions have stalled, (3) innovative technologies such as clean coal, renewable energy, and hydrogen have gained strong attention. Our analysis also finds that individual energy ministerial meetings feature different attitudes toward the climate change–energy security nexus, including in terms of their selection of energy technologies. Our study provides an opportunity to reflect on the direction that ASEAN's climate change and energy policies should take in future.

Keywords: ASEAN, energy ministerial meeting, climate change, energy security, technology.
JEL classification: Q48, Q54, Q55.



* The draft of this paper was presented at the Research Institute of Economy, Trade and Industry (RIETI) DP seminar for the paper. I would like to thank participants in the RIETI DP Seminar for their helpful comments. This paper was supported by JSPS KAKENHI Grant Number JP 23K28296. We are thankful to all the research members participating in the Yamaguchi Seminar for their helpful comments. We also give special thanks to Keola Souknilanh (IDE–JETRO) who provided helpful suggestions regarding our paper at the Society for Environmental Society and Policy Studies held on 15 September 2024.

## 1. Introduction

Climate change is now a global environmental challenge for developed and developing countries considering the emergence of serious threats such as abnormal weather and increased drought and health risk due to rising global temperatures (Intergovernmental Panel on Climate Change [IPCC] 2018). Sustainable Development Goal (SDG) 13 formulated by the United Nations (UN) requires countries to "take urgent action to combat climate change and its impacts." In December 2015, countries took a monumental step by signing the Paris Agreement at the 21st Session of the Conference of the Parties of the UN Framework Convention on Climate Change (UNFCCC). The goal of the agreement is for the countries to reduce their greenhouse gas (GHG) emissions. The Paris Agreement stipulates "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UN, 2016). The 1.5°C target requires the achievement of carbon neutrality worldwide by around the year 2050 (IPCC 2023).

All countries, including the Association of Southeast Asian Nations (ASEAN) member states (AMSs), are required to establish climate change initiatives. ASEAN is comprised 10 states: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. ASEAN has attracted attention in recent years because of its remarkable economic growth. The global share of real gross domestic product by ASEAN, 1.8% and 3.1% in 2000 and 2020, respectively, is predicted to rise to 5.8% in 2050 (Goldman Sachs 2022). With strong economic growth, the global $CO_2$ emissions by ASEAN steadily increased from 1.8% in 1990 to 5.2% in 2022 (Our World in Data). ASEAN's share is anticipated to continue to rise due to a combination of rapid economic development and population growth, heavy reliance on fossil fuels, and expanding transport networks (ASEAN Centre for Energy [ACE] 2024). In contrast, whether ASEAN's $CO_2$ emissions will peak depends on future policies to be implemented by the AMSs (International Energy Agency [IEA] 2022).

The AMSs have engaged with the climate change issues mainly in the UN arena. All the AMSs ratified the Kyoto Protocol to the UNFCCC in 1997, but they were categorized as Non-Annex I countries that were exempted from the obligation to reduce GHG emissions. Nevertheless, ASEAN has increasingly focused on climate change since the 21st century, being recognized as a highly vulnerable region to climate change (Asian Development Bank 2017; Germanwatch 2021). ASEAN has led initiatives such as the ASEAN Declaration on

Environmental Sustainability (2007), the ASEAN Working Group on Climate Change (2010), and the ASEAN Action Plan on Joint Response to Climate Change (2012) to collectively address capacity building, transfer of best practice and technology, and financial framework. Importantly, in compliance with the Paris Agreement, the AMSs submitted to the UNFCCC their nationally determined contributions (NDC), conditional and/or unconditional, concerning the 2030 target GHG emission reduction. Their NDC also mentioned required policies and plans with various aspirational levels across the AMSs (Fulton et al. 2017). Taking a step further, most of the AMSs have announced the target year of achieving net-zero GHG emissions or carbon neutrality by 2050–2065. Furthermore, ASEAN leaders annually issue the Joint Statement on Climate Change to the UNFCCC to express their collective commitments to tackle climate change. These observations indicate that ASEAN and AMSs have come to take climate change seriously.

However, according to the estimations, reducing $CO_2$ emissions dramatically in the foreseeable future is not an easy task for the AMSs (IEA 2022; Kimura et al. 2023; Phoumin et al. 2021). The reality of ASEAN is that an inexorable gap between the aspiration for green energy and fossil fuel domination exists (Shi, 2016). As the ASEAN economy rapidly grew, its energy consumption almost more than doubled from 3,569 TWh in 2000 to 7,930 TWh in 2021 (Our World in Data). The most evident increase is witnessed in Indonesia with approximately 270 million populations, from 1,164 TWh to 2,214 TWh in the same period, recording the largest energy consumption among the AMSs. Malaysia, the Philippines, Thailand, and Vietnam have also expanded their energy consumption due to an increase in per-capita consumption. Although Cambodia, the Lao PDR, and Myanmar consume less than the other AMSs, their energy consumption has gradually increased after the take-off of their economies. A study reveals that ASEAN's performance concerning climate change initiatives lags behind that of other regions, with disparity among the AMSs (Ding and Beh 2022). In any case, energy consumption in ASEAN is expected to increase continuously because of population growth and improved standard of living (ACE 2024; Sandu et al. 2019).

In terms of total primary energy supply (TPES), ASEAN is heavily dependent on fossil fuels, such as coal, oil, and natural gas, with an average share of 81.9% in 2022 (ACE 2024). Brunei Darussalam, Cambodia, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam use over 50% of their fossil fuels for energy supply (author's calculation based on the IEA). By contrast, the use of renewable energy (RE) remains less major in ASEAN, with an average share of 15.6% in 2022 (ACE 2024). The exceptions include Cambodia, Indonesia, Lao PDR, and Vietnam, which are endowed with more RE sources, such as hydropower, wind power, and geothermal energy, in their geographical locations (International Renewable Energy Agency [IRENA] 2022).

These observations have established that ASEAN must reduce its fossil fuel dependence and increase RE. Decarbonization in the AMSs requires $CO_2$ emission reduction from large $CO_2$ emitters (Lau 2022; Lau et al. 2022), namely, the power, industry, and transportation sectors, while maintaining their critical roles in the modern economy and society. Similarly, the AMSs also face the important issue of assuring energy security at the same time (Andreev et al., 2021). Energy security is defined as access to modern energy services, including a resilient energy system, with uninterrupted availability of energy sources at an affordable price (Kanchana and Unesaki 2014). The ASEAN's important agenda is still to secure sustainable economic development and reduce poverty because most AMSs have remained middle-income countries (ASEAN 2015). SDG 7 seeks to "ensure access to affordable, reliable, sustainable and modern energy for all." Energy security is also necessary for the AMSs to sustain their economic activities and people's lives, given their vulnerability to energy price hikes, energy depletion in home countries, and population growth.

This climate change–energy security nexus involving decarbonization will become more complicated in the AMSs, where fossil fuel-based energy supply occupies a large proportion in response to the rapidly growing energy demand. The ASEAN Ministers on Energy Meeting (AMEM) and its Associated Meetings have formally dealt with this difficult problem over the decades (Winanti and Hanif 2018). As we will show later in this study, the AMEM has discussed effective policies of how the AMSs can achieve decarbonization to address climate change, in addition to energy security. Interestingly, ASEAN has acknowledged the potential of developing and utilizing innovative energy technologies as the imperative tool to attain decarbonization (Vidinopoulos et al. 2020). Moreover, the AMEM has expanded to involve other surrounding countries in East Asia. This expansion has improved collective actions and cooperation to resolve the complications of the climate change–energy security nexus widely.

Accordingly, we aim to examine how ASEAN has collectively addressed the environmental challenge of climate change in relation to energy security. To scrutinize ASEAN's official intentions, we utilized the official documents of Joint Ministerial Statements and Chairman Statements released by the AMEM, ASEAN+3 Ministers on Energy Meeting (AMEM+3), and East Asia Summit Energy Ministers Meeting (EAS EMM). We aim to address our research questions of when the climate change issues emerged and how the subjects have progressed, such as decarbonization, energy efficiency and conservation (EEC), diversification of energy sources (e.g., RE and nuclear energy), and technological development. We conducted a quantitative text analysis to answer these questions. The methodology used in our study includes (1) clustering statement documents, (2) calculating the term frequency−inverse document frequency (TF−IDF) of specific subjects, and (3) counting the frequencies of collocation terms with "technology." To the best of our knowledge, our research using a text analysis method would be the first attempt to study official energy policy documents in ASEAN with a few exceptions (Taguibao 2019). We expect that our study can shed new light on the climate change−energy security nexus and provide policy implications for climate change and energy policies in ASEAN.

This paper is organized as follows. Section 2 discusses the climate change−energy security nexus in the context of ASEAN, with reference to existing academic literature. This section also reviews the role of the AMEM, AMEM+3, and EAS EMM. Section 3 explains the dataset and analytical methodology. Section 4 presents the results and advances the relevant discussion. Finally, Section 5 provides the conclusion with further research directions.

## 2. Climate Change−Energy Security Nexus

### 2.1. ASEAN's Energy Approach to Addressing Climate Change

Climate change mitigation is crucial because it lessens the impacts of climate change by preventing or reducing GHG emissions. Particularly, $CO_2$ is the most significant contributor (76%) to climate change as it is the bulk of GHG (Center for Climate and Energy Solutions). Thus, the approach from the viewpoint of energy is vital when measures are implemented to achieve a green economy (ASEAN 2023). Empirical results reveal that clean energy consumption positively impacts $CO_2$ emission reduction in the ASEAN economies (Wu et al. 2021). Therefore, energy consumption and $CO_2$ emissions are two closely related aspects of climate change.

Another reason why the climate change−energy security nexus attracts the attention of policymakers is that the regional challenges they are facing are not limited to climate change. Energy security must be considered when developing energy policies. On the one hand, the AMSs should promote energy transition from fossil fuels by decarbonizing the energy sectors by introducing RE to address climate change. On the other hand, the AMSs must secure an affordable energy supply in the region during soaring international energy prices caused by market fluctuations and several geopolitical tensions. Energy security is also indispensable for the AMSs to realize economic growth, which results in manufacturing mass production and lifestyle changes such as the spread of automobiles and home electrical appliances. Consequently, in the context of the AMSs, they are concerned that they may fail to supply affordable energy to the industry and household sectors while achieving energy transition and decarbonization.

Sustainable energy development is the key to addressing this problem. The transition to low-carbon clean energy should be promoted to ensure long-term energy security that stabilizes the energy supply and protects the environment. (1) Coal decarbonization, (2) EEC, (3) the diversification of energy supply sources including nuclear energy and RE, and (4) the use of innovative energy technologies should be considered for balancing the climate change–energy security nexus of ASEAN (Nepal et al. 2021; Safrina and Utama 2023). These factors can contribute to addressing climate change and assuring energy security.

First, reducing the $CO_2$ emissions of fossil fuels, particularly coal in the power sector, is indispensable (Overland et al. 2021). The share of electricity generated by coal in ASEAN recorded 41.9% in 2022, which was significantly larger than that of oil (1.9%) and natural gas (27.0%), though wide variations among the AMSs exist. This share is estimated to decrease slightly to 31.2% in 2050 if the historical trend without any policy interventions follows (ACE 2024). Furthermore, the total final energy consumption of coal is estimated to not decrease by 2050 because of the continued utilization by industries that are difficult to electrify (e.g., the steel industry), despite the implemented accelerated targets of each AMS (ACE 2024). Hence, achieving carbon neutrality necessitates significant efforts to decarbonize coal energy.

Second, promoting EEC can improve the energy use efficiency of the household, industry, and transportation sectors by reducing their energy consumption through changing behaviors, habits, and production processes. ASEAN sets a target aiming to reduce energy intensity by 32% in 2025 based on the 2005 level and encourages further efforts, especially in the transportation and other industry sectors (ASEAN 2020). Data show that ASEAN has achieved a 24.5% reduction in energy intensity in 2022 since 2005. A study holds that enhancing ASEAN's overall energy efficiency could considerably reduce its total energy consumption, indicating high levels of current inefficiency in the region (Adha et al. 2024).

Third, the diversification of energy sources signifies the promotion of the use of RE (e.g., bioenergy, hydropower, geothermal, solar, and wind) and nuclear energy, in addition to natural gas that emits less $CO_2$ than coal (Afifi et al. 2023). The introduction of green energy represented by RE is likely to causally decrease $CO_2$ emissions (Wu et al. 2021). Recognizing the importance of RE, ASEAN sets out an aspirational target of increasing the component of

RE to 23% by 2025 based on the 2005 level in the energy mix, including increasing the share in installed power capacity to 35% by 2025 (ASEAN 2020). According to historical data, the share of RE in TPES (excluding traditional biomass) increased to 15.6% in 2022 from 10.0% in 2005, though this increase is still significantly far from the 2025 ASEAN target. The estimation also shows that the RE share will reach only 23.3% in 2050, following the historical trend (ACE 2024). By contrast, the installed power capacity share amounted to 33.6% as of 2022 (which has almost achieved the target) and is anticipated to reach 38.0% in 2050 at the current speed (ACE 2024). However, a study argues that ASEAN must urgently transition swiftly to RE in the power sector to reach net-zero emissions by 2050 (Handayani et al. 2022).

Despite the sluggish growth of the RE share, many experts claim that the AMSs can further introduce RE in their energy mix as it could contribute to economic growth and environmental sustainability (Ilyas et al. 2024; Vidinopoulos et al. 2020). Although increasing the hydropower and geothermal energy supply is limited partly due to the geographical constraints imposed on certain AMSs, additional solar and wind power capacities could be introduced. Assuming that the regional aspirational targets in all the AMSs are achieved, estimates show that solar and wind will account for 26.5% and 32.0% of the power generation in 2050, respectively. These estimates are in contrast to 3.1% and 1.1% of the 2020 level, respectively (ACE 2024). Bioenergy, such as biofuels including bioethanol, biodiesel, and biomass, can also be an RE source that can help decrease fossil fuel dependence. For example, biofuels are estimated to reduce $CO_2$ emissions and harmful pollution in the transportation sector of the AMSs through the use of biodiesel engines (Mofijur et al. 2015).

Moreover, nuclear power can also play an important role in the AMSs in the long term, although no commercial power plants are operating presently. Not only can it provide stable and large amounts of power over a small area of land unlike RE but also emit zero $CO_2$ during power generation. The introduction of nuclear power generation demands a stringent safety management system. Nevertheless, it would be a viable decarbonization option if the AMSs could arrange a well-developed civilian nuclear system (Nepal et al. 2021).

Fourth, energy technology innovation is the key to attaining carbon neutrality toward 2050 (Afifi et al. 2023) as ASEAN advocates “accelerating energy transition and strengthening energy resilience through greater innovation and cooperation” (ASEAN 2020). Although inherent natural resources are impossible to control, man-made technology can overcome this impossibility (Lin et al. 2022). Fossil fuels, particularly coal, are predicted to remain a primary energy source in the foreseeable future. Thus, clean coal technology (CCT) that can reduce $CO_2$ emissions must be used effectively. Specifically, the carbon capture and storage (CCS) technology will allow the AMSs to continue to use fossil fuels during the increasing demand for coal (Nepal et al. 2021). Technically, CCS can capture $CO_2$ stemming from large emission sites, such as power plants and factories. This captured $CO_2$ can be utilized to enhance exploitation in oil and gas fields and produce chemical fuels (in this case, carbon dioxide capture, utilization, and storage [CCUS]). CCS is an effective tool to decarbonize the industry sector (e.g., steel and cement), where high-temperature heat is required and decarbonization by electrification is difficult.

Hydrogen, as well as ammonia as its derivative, is also a necessary clean energy option for decarbonization in the power, industry, and transportation sectors of the AMSs by substituting fossil fuels (Kimura et al. 2024; Phoumin 2021), especially when it is produced by RE (i.e., green hydrogen). From the technical and cost perspectives, electricity is difficult to generate with only hydrogen or ammonia. Thus, the immediate goal is to reduce $CO_2$ emissions from thermal power generation by mixing it with existing fossil fuels (co-firing). In the industry sector, hydrogen-reduced iron making is being experimented by using hydrogen rather than coal, without $CO_2$ emissions. Hydrogen is not used commercially for these purposes due to its high cost. Nevertheless, hydrogen technology innovation (e.g., automotive fuel cell systems) is expected to accelerate and expand the demand for hydrogen.

New energy technologies would also support the diversification of energy sources. RE has the disadvantage of intermittency that may seriously damage existing conventional electricity. Nonetheless, the technological development of reinforcing RE infrastructures, such as storage batteries, would facilitate the dissemination of RE throughout the AMSs. In terms of nuclear energy, a small modular reactor (SMR) under development will reduce obstacles for the AMSs to introduce nuclear power if its cost is decreased (Murakami and Anbumozhi 2022). Furthermore, a notable decarbonization technology in the transportation sector is electric vehicles (EVs) that run on electricity stored in batteries. Technological development is expected to help reduce vehicle prices that are more expensive gasoline-powered automobiles.

Finally, this subsection briefly surveys existing studies suggesting policy directions for ASEAN based on quantitative analyses. An energy modeling and simulation derive a realistic prediction that ASEAN will double or triple its GHG emissions compared with the business-as-usual trend because it continues to depend on fossil fuels, particularly coal (Phoumin et al. 2021). Based on this conservative prediction, the authors stress the need to invest in “cleaner fossil fuels," such as CCT and CCS, and scale up the RE share. Another simulation result shows that given the net-zero emission scenario of the ASEAN power sector by 2050, the AMSs need to immediately exploit underutilized RE potentials with energy storage for power generation (Handayani et al. 2022). This simulation also estimates that developing RE technologies is more cost-competitive than CCS. A general equilibrium analysis indicates that when the AMSs intend to fill the gap in the long-term 2°C target, clean electricity generation technologies should be the key to emission reduction in the power and energy-intensive sectors (Ruamsuke et al. 2015). In sum, these authors conclude that the effective application of clean energy (e.g., EEC and RE) and new technologies (e.g., CCS and hydrogen) are important for the decarbonization of the AMSs.

**2.2. ASEAN Ministers on Energy Meeting**

The present form of AMEM was established in 1996 with the attendance of the energy ministers of seven countries (Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam). At that period, energy security, including energy market integration (EMI), energy import diversification, and energy capacity building, was an issue because of the increased energy demand in the region. The AMEM has been composed of 10 AMSs since 1999. As a regional entity, the major objective of the AMEM is to facilitate regional energy policy cooperation and coordination among the AMSs. In recent years, although the AMEM has focused on energy security, its agenda has partly shifted to environmental impacts, sustainability, and others. The capacity and performance to execute decarbonization significantly differ between the AMSs; thus, their collective actions are required (Ding and Beh 2022).

To enhance region-wide energy cooperation, the AMEM extended beyond the framework of the 10 AMSs. In 2004, AMEM+3 was launched, consisting of 10 AMS plus 3 partner countries, namely, China, Japan, and the Republic of Korea (hereafter, South Korea). The primary motivation for establishing AMEM+3 was to deal with the energy agenda on the technology and knowledge exchange between ASEAN and the three countries. Like the ASEAN Plus Three Economic Ministers Meeting, Japan initially led the AMEM+3 in region-wide discussions about energy security through energy cooperation joint programs, anticipating increasing demand for fossil fuels in the AMSs along with rapid economic growth. Although the main topic of the AMEM+3 was energy security, Japan aimed to set out AMEM+3 as a forum in which the AMEM and China were prepared to engage with post-Kyoto Protocol negotiations on climate change (authors' interview with a former official of the Ministry of Economy, Trade and Industry, Japan). In addition to Japan, China and South Korea have also offered their energy cooperation programs to ASEAN to enhance regional energy resilience.

The EAS EMM started in 2007 with 10 AMSs, the abovementioned three partner countries, Australia, India, New Zealand, and Russia. Then, in 2011, the United States started to participate. The EAS EMM, the top-level leaders' meeting in the Asia-Pacific region, sets broader goals from economic to regional stability. The EAS EMM is expected to contribute to the goals by accommodating an energy policy that assures energy security and promotes a sustainable environment in this region. Countries possessing technological capabilities such as China, Japan, South Korea, and the United States take a leadership role in assisting environmentally friendly energy infrastructure finance and investments and facilitating up-to-date energy technology and knowledge transfers. Australia and Russia are also key players in the EAS EMM due to their abundant reserves of fossil fuel energy sources (Australia has a high potential for RE, such as solar, wind, and hydrogen).

The AMEM, AMEM+3, and EAS EMM have mainly discussed the energy security agenda since their establishment. However, they have focused on the surrounding agenda, such as decarbonization, by responding to the climate change challenge. This topic will be discussed later. Then, the following questions arise: Since when did they focus on the climate change issue in addition to the traditional energy security issue? How have the subjects of energy source diversification and technology progressed? We will examine these research questions by objectively analyzing the ministerial statements.

## 3. Dataset and Methodology

We build on the energy approach discussed in Section 2 to explore the climate change–energy security nexus in ASEAN. Based on this standpoint, this section will review the dataset gathered from statement documents published officially by the AMEM, AMEM+3, and EAS EMM. Subsequently, this section will explain the methodology to be used in the quantitative text analyses.

### 3.1. Dataset

The dataset was derived from official documents, including Joint Ministerial Statements and Chairman Statements, released by the AMEM, AMEM+3, and EAS EMM. The Chairman Statements were published only in the EAS EMM held in 2023 and 2024. These statement documents are made public after annual energy ministerial meetings that are assumed by host countries on rotating schedules. The statement documents of the AMEM, AMEM+3, and EAS EMM comprise 29 (1996−2024), 21 (2004−2024), and 18 (2007−2024) documents, respectively, totaling 68 statement documents. The AMEM statement documents from 1996 were used because its present style started in 1996 and the climate change issue did not gain much attention before the concluded Kyoto Protocol in 1997. The statement documents contain the agreements and discussions made at the AMEM and its Associated Meetings.

In the dataset, we compiled the texts of the statement documents that are readable by computer programs (we use R programming). When the texts were coded in computer programs, "noises" were eliminated rigorously as they may disturb the analytical results. First, we removed routine sentences appearing in almost all the statement documents, such as lists of ministers' and senior officials' names in attendance, opening remarks, announcements of the next meeting schedules, and acknowledgments to host countries. Next, we conducted pre-processing of corpus texts. Spaces, punctuations, and numerical values were all removed because such removals do not significantly affect quantitative text analyses that concentrate primarily on specific nominal terms. Finally, the stemming of terms in sentences was conducted to execute text analytics commands implemented in R.

After these procedures, we formulated a "document–term matrix." In this matrix, the rows and columns are composed of 68 documents and 2,511 terms, respectively. Individual matrix entries represent frequencies, indicating the number of times the terms appear in each document. As the sparsity (i.e., the ratio of 0 entry to all entries) of this document–term matrix is calculated as 86%, it is regarded as "sparse" (Imai 2017). The following analyses were conducted based on this dataset summarized as the document–term matrix.

### 3.2. Methodology

#### 3.2.1. Term frequency−inverse document frequency

A simple analytical method to measure the importance of a term is to count its frequency. The word cloud analysis is frequently utilized because it offers a visualized distribution of the term frequency in a document. However, it has the serious disadvantage of ignoring the relative importance of the term across all documents. Thus, it cannot reduce the weight of the term that frequently appears in other documents. Therefore, a frequently appearing term in other documents should be treated as having a smaller weight. To address this appropriately, we calculated TF−IDF, the statistic that measures the relative importance of a term in a particular document. By denoting a document and a term as $d$ and $w$, respectively, we define $\text{TF}-\text{IDF}(w, d)$ as follows:

$$\text{TF}-\text{IDF}(w, d) = \text{tf}(w, d) \times \text{idf}(w) \times 100$$

$\text{tf}(w, d)$ represents a term ($w$) frequency in a document ($d$). When the term does not appear in the document, $\text{tf}(w, d)$ is equal to zero. $\text{idf}(w)$ represents the inverse document frequency, defined as $\text{idf}(w) = \log \frac{N}{\text{df}(w)}$, where $N$ is the number of documents and $\text{df}(w)$ is the number of documents including $w$. Hence, as the term is used in many documents, $\text{idf}(w)$ takes a smaller value, which implies a smaller weight. By using TF−IDF in the document–term matrix, we conducted the following analyses.

### 3.2.2. *k*-means clustering

We clustered the documents from the AMEM (1996−2024), AMEM+3 (2004−2024), and EAS EMM (2007−2024), whereby we can find common trends in the clusters of categorized documents. We used the *k*-means clustering method, in which the algorithm first divides documents into appropriate *k* clusters (*k* is given) and then uses the average of the clusters. Thus, the documents were well separated through iterative calculations (Hastie et al. 2009). Consequently, we can obtain *k* groups with similar characteristics. Although it may be arbitrary, we set the number of *k* to 3.

### 3.2.3. Classification of the subjects

We concentrated on specific terms that are related to the subjects of the climate change−energy security nexus. By summing up TF−IDF of terms falling within the classification of specific subjects, we examined their trends and made comparisons between different energy ministerial meetings. To facilitate this analysis, we classified the terms into the following subjects in reference to Subsection 2.1: (1) climate change and environment, (2) energy security, and (3) technology. The simple summation of TF−IDF is executed over the terms in each classification. Specifically, (1) is related to various climate change topics, such as decarbonization, green energy transition, and environmental sustainability. Subject (2) includes "3A" (i.e., accessibility, affordability, and availability) as substantial factors for energy security (Tongsopit et al. 2016) as well as economic factors. Subject (3) considers energy innovation and technology that primarily balance (1) and (2).

Moreover, we selected terms associated with the energy approach to climate change, including decarbonization of (a) coal, use of (b) EEC, diversification of energy sources to (c)

RE and (d) nuclear energy, energy-related technologies of (e) hydrogen, and (f) EVs in the transportation sector. Table 1 shows the subjects' classification and relevant terms.

<Table 1: Subjects and Relevant Terms>

#### 3.2.4. Collocation

We counted the frequency of a collocation term of "technology" to identify the kinds of energy technologies mentioned at the energy ministerial meetings. Collocation means that a term appears adjacent to another specific term (i.e., keyword or node) in a certain span, and this former term is called a collocation term. We set the span to five, despite being arbitrary. The collocation terms we highlighted are the abovementioned terms (a)−(f). Table 1 presents the classification. The frequencies of these collocation terms will reveal the trends of energy technology development in the ASEAN region.

## 4. Results

We conducted three analyses using the text dataset of the statement documents. First, topics were searched, and energy ministerial meetings were clustered from the past to the present. Second, the trends of the subjects on the climate change−energy security nexus were followed. Third, the frequencies of the collocation terms relating to technology were counted. We attempted to answer the previously described research questions through these analyses.

### 4.1. Topic Finding and Clustering

Table 2 presents the top 10 terms in descending order of TF−IDF, which characterizes the AMEM (1996, 2010, 2015, 2020−2024), AMEM+3 (2004, 2010, 2015, 2020−2024), and EAS EMM (2007, 2010, 2015, 2020−2024). Because of space constraints in the table, we selected the year of holding the first meetings (namely, 1996, 2004, and 2007), 2010, 2015, and 2020 onward (the NDC submission deadline was 2020).

<Table 2: Term Frequency–Inverse Document Frequency>

The AMEM (2004) was interested in cooperating to secure oil distribution as it referred to the ASEAN Council on Petroleum (ASCOPE) and the Organization of the Petroleum Exporting Countries (OPEC). The AMEM (2010) dealt with environmental issues by mentioning greener economic activities. The AMEM (2015) emphasized energy cooperation projects, such as the Lao PDR−Thailand−Malaysia−Singapore Power Integration Project. Subsequently, the trend of the AMEM has dramatically changed. The AMEM (2020−2024) focused on pursuing energy transition from fossil fuels to RE. Accordingly, the AMEM invited IEA and IRENA for the first time in 2018 to accelerate RE’s introduction into ASEAN. The AMEM (2022−2023) also shed light on CCUS as a vital decarbonization technology. However, the AMEM (2024) has given some emphasis to energy security from climate change given it mentioned cross-border subsea power cable connections of energy transmission.

The AMEM+3 (2004) recognized the importance of an oil stockpile in regional energy security and made concerted efforts to form market-oriented pricing for the spot trading of oil and petroleum products. The AMEM+3 (2010, 2015) continued to make intensive discussions on the Oil Stockpiling Road Map, which was supported by Japan. Additionally, the AMEM+3 (2010) intended to advance the clean development mechanism to reduce GHG emissions and strengthen cooperation with new and RE as well. To address climate change and energy security concerns, the AMEM+3 (2015) recognized the importance of promoting civilian nuclear power based on the cooperation of professional institutions, such as the Japan Atomic Energy Agency. The AMEM+3’s efforts to promote energy transition have been strengthened further. The Cleaner Energy Future Initiative for ASEAN proposed by Japan in 2019 has been frequently mentioned at the AMEM+3 (2020−2024). In addition to Japan and South Korea, China has taken an aggressive leadership role at the AMEM+3 in recent years. Examples of China’s support include the ASEAN−China Clean Energy Cooperation Center, China–ASEAN Clean Energy Week, China Energy Technology and Economics Research Institute (CETERI), and China Renewable Energy Engineering Institute (CREEI) (CETERI and CREEI are not shown in Table 1). Moreover, the AMEM+3 (2020−2024) assumes various energy sources and technologies, such as CCUS, ammonia co-firing, solar PV, offshore wind, and EVs. In contrast, the AMEM+3 (2024) reemphasized energy security resilience exemplified by strengthening energy supply chains. It also recognized the Energy Security Forum as a significant regional collaboration platform to address price fluctuations, supply disruptions, and geopolitical risks while advancing the transition to a low-carbon economy.

The EAS EMM (2007) primarily focused on the Energy Cooperation Task Force (ECTF). The ECTF aimed to enhance energy cooperation in the fields of EEC, EMI, and biofuels for transportation and other purposes. This objective suggests that cooperation was implemented on issues related to energy security and the environment. Particularly, biofuels are expected to become a new energy source that could reduce GHG emissions despite the possible environmental disadvantages. The EAS EMM (2010) aimed at strengthening more liberalized EMI to provide affordable energy at all levels. In the context of the EAS EMM, the contribution of the Economic Research Institute for ASEAN and East Asia (ERIA) is noteworthy. ERIA is an international organization that was established by EAS member states in 2008. It has presented intellectual inputs and policy recommendations on energy issues to the EAS EMM, backed up by the Energy Research Institutes Network. The EAS EMM (2015) recognized the need to reduce fossil fuel use and GHG emissions, whereas the EAS EMM (2020−2024) accelerated efforts to transition toward carbon neutrality or net-zero emissions. New energy technologies, such as CCUS, floating solar applications, EVs, ammonia co-firing, thermal storage, and biomass in the water–energy–food nexus, also attracted the attention of the EAS EMM. However, the characteristics of the EAS EMM (2024) have changed its trend by stopping reiterating many climate change and decarbonization issues.

To add to the situation, the COVID-19 pandemic was also a critical issue at the three energy ministerial meetings in 2020. The meetings needed to consider energy security in terms of meeting an energy demand increase as the economy recovered in the post-pandemic period. Nevertheless, this pandemic shock was temporary and did not affect the trend of ASEAN emphasizing the climate change issues during the 2020s.

Lastly, we conducted the clustering analysis using the *k*-means method (*k* is set at 3) based on all 68 documents. However, the analysis failed to create a stable clustering, and the results changed depending on different random seeds. Accordingly, we conducted the same *k*-means method by applying the documents excluding the AMEM (2024), AMEM+3 (2024), and EAS EMM (2024). Such exclusion of the documents, except for that of 2024, would be justified by the previous findings as the change of that year may be heterogeneous. Table 3 shows the clustering results of the top 20 terms that characterize the individual clusters. Although the results may vary in implementing computer simulations by random seeds, we found that they are robust after performing 100 trials. Therefore, the results indicate the characteristics of the clustered meetings.

<Table 3: *k*-Means Clustering of Documents >

Cluster 1 (top-ranked terms: CLM, Mekong River, president, basin, non-OPEC, soon, amend, AEEMTRC, ASCOPE, protocol) consisted solely of the documents of the AMEM

(1996−1997). The AMEM (1996−1997) is related mainly to energy cooperation, particularly in oil distribution. These documents completely differ from the others in that they were published before the adoption of the Kyoto Protocol. Cluster 2 (top-ranked terms: minister, stream, ERIA, oil, nuclear, stockpile, biofuel, price, recognize, program) was formed by the AMEM (1998−2019), AMEM+3 (2004−2019), and EAS EMM (2007−2017). These documents discussed environmental sustainability by exploiting biofuels and RE to reduce GHG emissions. However, they were not completely focused on fossil fuel decarbonization before submitting the NDCs of the AMSs to the UNFCCC. Greater emphasis was placed on energy security cooperation such as EMI, oil stockpiling, and safe civilian nuclear management during the energy price hikes that began around 2005.

Finally, cluster 3 (top-ranked terms: transit, hydrogen, CCUS, carbon, decarbonize, stream, virtual, mobility, neutral, recovery) comprises the documents of the AMEM (2020−2023), AMEM+3 (2020−2023), and EAS EMM (2018−2023). These documents show that as the AMSs progressed toward announcing their NDCs, ASEAN and partner countries began to illustrate how they intended to decarbonize fossil fuels through energy transition by using RE, CCUS, hydrogen, and others. The documents of the AMEM (2020−2023) and AMEM+3 (2020−2023) fall into the period when the AMSs needed to implement decarbonization measures, particularly those stipulated in their NDCs. Another interesting point is that the EAS EMM (2018−2019) is also included in cluster 3. This finding suggests that the EAS EMM was ahead of the AMEM and AMEM+3 regarding the climate change discussion. In the global context, the IPCC 1.5°C Special Report was released in 2018 (IPCC 2018), and the EU approved the net-zero emission target in 2019. Arguably, because the EAS EMM includes developed countries that were sensitive to such global movements, its climate change initiatives may have begun earlier.

Therefore, the clustering analysis reveals that after around 2020, the discussions at the energy ministerial meetings involving ASEAN shifted their trend from traditional energy security to climate change issues. However, this trend may have been reversed with emphasis on energy security for the year 2024 only.

### 4.2. Trends of Specific Subjects

Figure 1 illustrates the annual time series trends of subjects (1)−(3) and (a)−(f), which are classified in Table 1, by each energy ministerial meeting. The relative importance of the subjects in the AMEM, AMEM+3, and EAS EMM was calculated by the sum of TF−IDF over relevant terms.

<Figure 1: Trends of Specific Subjects>

To begin with, we examined the subjects (1)−(3) of the climate change−energy security nexus and technology. Regarding (1) climate change and environment, the values of all three meetings remained flat at a low level before 2020 and have skyrocketed since the 2020s. Furthermore, the values of the EAS EMM tended to be higher than those of the AMEM and AMEM+3. This finding may be due to the different member-state structures between the three meetings and the EAS EMM's greater eagerness to address climate change and environmental issues than the others. Additionally, the values of the EAS EMM have already started to increase since 2018, when the interest in achieving net-zero emissions was gradually prevalent in developed countries, possibly due to the publication of the IPCC (2018). Moreover, the values of the AMEM and AMEM+3 remained low in 2018 and 2019. Thus, this difference in the timing of the increase confirms the clustering result in the previous Subsection 4.1, that is, cluster 3 includes the EAS EMM from 2018. From these analyses, the EAS EMM has led discussions about climate change and environmental issues. These discussions have been reflected at the AMEM and AMEM+3 after certain years. Despite the upward trends of the values, they suddenly declined in 2024 for all the meetings, particularly the EAS EMM.

In (2) energy security, the numerical values of the summed TF−IDF significantly indicate the concern of ASEAN with access to affordable, resilient, and stable energy sources. The values of the AMEM, and AMEM+3 in particular, demonstrated their dramatic increase in 2005 when energy prices soared as the average West Texas Intermediate (WTI) recorded 41.4 USD. This value was higher than 31.1 USD in 2003. After a temporary decline in energy prices, the average WTI reached a peak of 95.1 USD in 2011. Along with this upward pressure on energy prices, the values of the AMEM+3 and EAS EMM increased again in the early 2010s (the AMEM+3 value is larger than the EAS EMM value), whereas those of the AMEM barely increased in the same period. The values of all the meetings, particularly the AMEM+3 and EAS EMM, spiked in 2021 due to the COVID-19 pandemic. This situation indicates that energy demand would increase rapidly as the economy recovered. Subsequently, these values have remained relatively high due to energy supply instability and geopolitical risks (e.g., the war between Russia and Ukraine). The upward trend of the energy security issues was gradually formed after the repeated shocks of rising energy prices. However, despite the upward trends since the late 2010s, the AMEM and AMEM+3 values are lower than in the past.

The values of subjects (1) and (2) should be compared thoroughly considering the different criteria for selecting relevant terms. However, this comparison would give us a new perspective about the climate change−energy security nexus. Table 4 presents the average values of (1) and (2) over the AMEM, AMEM+3, and EAS EMM in 2010−2014, 2015−2019, and 2020−2024. The 2010−2014 average of (2) is 1.764, which is larger than that of (1) at 1.354. However, this relationship was reversed in 2015−2019 as the average values of (1) and (2) amounted to 1.743 and 1.132, respectively. Although the 2015−2019 average value of (2) increased to 1.762, the difference increased because that of (1) spiked to 4.239. These average values imply that the trend over the years has tilted toward the climate change issues despite exogenous shocks particularly of energy prices in individual years.

Therefore, the traditional energy security issues remain relevant, but the climate change issues currently attract increased attention in ASEAN.

<Table 4: Average Values of TF−IDF by Subjects >

In terms of (3), the 2008−2014 average value of the AMEM+3 was higher than those of the AMEM and EAS EMM. Therefore, the AMEM+3 actively worked to develop technologies that would guarantee energy security. Evidently, the values of the EAS EMM started to rise rapidly since the mid-2010s along with the increased interest in climate change and environmental issues. This upward trend was followed by the AMEM and AMEM+3 a couple of years behind. This finding suggests that the development of innovative energy technologies has been driven by the EAS EMM, which includes technologically advanced countries. Although the values of the EAS EMM were by far greater than those of the AMEM and AMEM+3 until 2022, they plunged in 2023 and 2024. Particularly, the values of the EAS EMM were reversed by those of the AMEM and AMEM+3 in 2024.

Regarding the specific subjects of decarbonization, EEC, the diversification of energy sources, and innovative technologies, (a)−(f), we can find interesting differences among (a)−(c). Regarding (a) coal, the values of the AMEM and AMEM+3 have remained large since the early 2010s. These values suggest their strong interest in coal utilization as the primary energy source to meet energy security. In contrast, the value of the EAS EMM remained low from 2007 to 2018 and increased upward in 2019. This sudden rise in the values may be due to the change in the attitude of the EAS EMM toward effective coal usage through decarbonization technologies, such as CCT, CCS, and carbon recycling. A corollary to this change is the emphasis of the East Asia Energy Forum (2018, 2019) on the ongoing role played by fossil fuels, particularly coal, in the economic development of ASEAN and East Asia. However, they have declined since 2020 (excluding 2022) and amounted to almost 0 in 2024, in contrast to the AMEM and AMEM+3. Regarding subject (b) EEC, the immediate peaks of values of the three meetings were reached around 2016−2019 (the values of the AMEM were highest in 2013, though). However, the values decreased, especially for the EAS EMM, since 2000. Subject (c) RE exhibits evident characteristics. Not only the values of the EAS EMM were consistently high on average but also those of the AMEM and AMEM+3 have been in an upward trend and caught up with that of the EAS EMM. This finding may also imply that the introduction of RE into the AMEM and AMEM+3 was influenced by the initiatives of the EAS EMM. Finally, the rough comparison of the values among (a)−(c) in the 2020s demonstrates that coal and RE have become the main targets of climate change and energy policies and that EEC has lost considerable attention.

Regarding (d) nuclear energy, it does not currently exist in Southeast Asia; thus, the AMSs paid great attention to nuclear energy. The values of the AMEM and AMEM+3 were large, with the AMEM values particularly increasing sharply in 2023 and 2024. The values of the AMEM+3 have been large due to Japan and South Korea's efforts to human training engaging with civilian nuclear management. Furthermore, the EAS EMM has not focused on nuclear energy because it may have a concern about the unrestricted proliferation of nuclear weapons. Nevertheless, nuclear energy has been gaining attention over the past few years as an effective means of diversifying energy sources in ASEAN.

Regarding (e) hydrogen, the values of the AMEM+3 and EAS EMM have become positive since 2018, and the EAS EMM recorded high values, excluding 2021. The AMEM has also been following this trend of hydrogen development since 2020. In addition, the relationship between (d) and (e) was reversed in 2021−2024, suggesting that hydrogen energy has emerged as a more realistic option to diversify energy sources in ASEAN. Furthermore, the values of (f) EVs have also increased since the late 2010s as it has been commercially popular with technology advancement in the transportation sector. The greater increase in values of the EAS EMM than those of the others indicates that it drove ASEAN's interest in EVs. Over the past few years, the values of the AMEM increased in response to the EV trend.

### 4.3. Collocation Terms with Technology

Figure 2 illustrates the trends of the collocation terms (a)−(f) with "technology." The period starts from 2007 in accordance with the launch of the EAS EMM. The frequencies are aggregated throughout the ministerial meetings. The figure illustrates several findings. First, the frequency of (a) coal increased consistently until 2015 and was the highest, excluding 2008 and 2019, among the collocation terms. Thus, the innovative technologies that enable the decarbonization of coal have been of almost great interest in addressing energy security and climate change issues. Second, although (b) EEC has continued to level off since the mid-2010s, its frequency decreased in 2023 (2) and 2024 (1). Third, the frequency of (c) RE has remained high since the late 2010s and was comparable to (a), suggesting a high expectation that RE technologies would become widespread. Finally, the frequencies of (d) nuclear energy and (e) hydrogen have been on the rise in recent years. SMR and ammonia co-firing, for example, are being developed for practical use.

<Figure 2: Collocation Terms of Technology (Time Trend)>

Next, Table 5 summarizes the frequencies of the collocation terms aggregated by the AMEM (1996−2024), AMEM+3 (2004−2024), and EAS EMM (2007−2024) to compare the technology distributions among the meetings. The total frequency of the collocation terms (509) is classified into (a) coal (232, 45.6%), (b) EEC (71, 13.9%), (c) RE (136, 26.7%), (d) nuclear energy (35, 6.9%), (e) hydrogen (34, 6.7%), and (f) EV (1, 0.2%). As confirmed in Figure 2, (a) and (c) account for almost half and a quarter of the total frequency, respectively. Another interesting finding is that the distribution of the shares of (a)−(f) differ entirely across the AMEM, AMEM+3, and EAS EMM. Specifically, (a) has the largest share in the AMEM+3 (60.5%) but has the smallest share in the EAS EMM (20.0%). In terms of the EAS EMM, the shares of (b) (20.8%) and (c) (40.8%) are larger than those of the abovementioned share of (a). Moreover, although the EAS EMM has a minimal share of (d) (2.4%), it has the highest share of (e) (16.0%) among the meetings. Thus, EAS shows the most balanced portfolio of energy technology development, not being biased toward limited particular technologies. By contrast, the AMEM+3 has the most interest in developing (d) (9.3%), being supported by Japan and South Korea. Lastly, the AMEM has relatively high shares of (a) (49.1%) and (c) (26.6%), expecting coal decarbonization and RE technologies to be the two main pillars for $CO_2$ reduction.

< Table 5: Collocation Terms of Technology (Aggregation by Meetings)>

**4.4. Summary of the Results and Discussions**

Our quantitative text analysis results are summarized as follows:

1. The energy ministerial meetings have focused more on climate change issues than traditional energy security issues since the 2020s. The findings from the analyses of clustering and trends of the subjects reveal that the EAS EMM started discussions about climate change earlier than the AMEM and AMEM+3. The growing awareness of climate change has coincided with the interest in energy technology development.
2. All the energy ministerial meetings have recognized the decarbonization of coal and diversification of energy sources to RE as important ways to reduce $CO_2$ emissions, with their interest in EEC declining. Hydrogen and EVs have also been considered as necessary technologies in recent years. However, nuclear energy is highly appreciated only in the AMEM and AMEM+3, but not in the EAS EMM.
3. The technological development of coal, EEC, and RE has been highly considered. However, a drop in the interest in EEC over the last 2 years has been observed. Nuclear energy and hydrogen have also gradually attracted attention in energy technology development. The EAS EMM has not been biased as it shows interest in various energy technologies, not only toward coal, unlike the AMEM and AMEM+3.

Hereafter, we further discuss the obtained results. First, addressing climate change does not necessarily conflict with assuring energy security. One concrete example is offshore wind power generation. This innovative RE currently has the cost disadvantage of building and maintaining facilities compared with land power generation. Nevertheless, it has a great potential to be introduced on a large scale. Thus, it is expected to help enhance energy security by supplying low-price and stable power in the future while decreasing $CO_2$ emissions without depending on fossil fuels. Moreover, building wind power generation facilities would create economic spillovers to relevant industries. ASEAN and its partner countries recognize the importance of developing energy technologies that enable such compatibility. However, attracting investments from developed countries in energy technologies, such as RE, is a challenge for the AMSs due to their limited governance and legislative ability (Vakulchuk et al. 2023). The notable effort on this problem is the formation of the Asia Zero Emission Community (AZEC), which has been promoted by Japan since January 2022 (the member countries include Japan, Australia, and the AMSs, excluding Myanmar). AZEC is expected to contribute to both the climate change and energy security issues by encouraging energy technology transfer to the AMSs through public–private initiatives and private cooperation (Ministry of Economy, Trade and Industry, Japan 2024).

Second, discussions about EEC including its technological development have stalled at the energy ministerial meetings over these years, which is open to debate. Although AMSs have enough space for EEC that intends to efficiently use energy (Adha et al. 2024), EEC alone does not seem enough to achieve the $CO_2$ emission reduction targets of their NDCs and carbon neutral goals. ASEAN understands the need to diversify energy supplies with decarbonized energy sources, especially considering many emissions from the power sector. Thus, ASEAN devotes more efforts to promote coal decarbonization and introduction of RE than further reinforcement of EEC.

Third, the attitudes of the AMEM, AMEM+3, and EAS EMM vary regarding energy policy options and technologies that should be adopted in the climate change–energy security nexus. The different emphasis on subjects at the energy ministerial meetings may be influenced by the member countries. Overall, the EAS EMM has led discussions about climate change and has influenced those in the AMEM. Because the EAS EMM includes countries in the East Asia region with different stakes, the climate change issues discussed in the region tend to be more diverse than in the AMEM and AMEM+3. For example, Japan, which domestically depends on fossil fuels, aims to develop CCT and CCUS for ASEAN's economic development. Australia has major interests in exporting not only natural resources but also hydrogen produced by RE. In contrast, the discussions of the AMEM+3 reflect the interests of China, Japan, and South Korea. Regarding energy technologies, Japan and South Korea have cooperated in the fields of EEC and nuclear energy, in which these two countries have relative technological strength. China has also established various supporting mechanisms and programs of clean energy deployment for ASEAN based on its decarbonization experience.

Finally, a question arises regarding the sudden decline in the subjects of climate change and environmental issues in 2024. One possible reason is the rising relative concern about energy security due to increased geopolitical risks. For instance, the publication of Chairman Statements, excluding Joint Ministerial Statements, at the 2023 and 2024 EAS EMMs suggests a difficulty in aggregating opinions because of conflicts between the participating countries. Additionally, because the NDC is due to be submitted in February 2025, the AMSs may be taking a wait-and-see attitude and only observe other countries' commitments to reducing GHGs. However, they are mere speculations; thus, future movements should be closely monitored.

## 5. Concluding Remarks

In this study, we explored how the climate change–energy security nexus has evolved in

ASEAN by examining joint state documents released by the AMEM and its Associated Meetings. The current challenge that ASEAN faces is to address the climate change crisis as a member of an international community and assure energy security to sustain its economic and social development. Our quantitative text analysis revealed the following. First, as the discussions towards achieving carbon neutrality have progressed in 2020, climate change issues have been increasingly highlighted. This emphasis on climate change has coincided with advances in energy technology development. Second, attention to the decarbonization of coal and diversification to RE has been reinforced, whereas the discussion on EEC has relatively stalled over the past few years. Third, innovative energy technologies, such as clean coal, RE, and hydrogen, have gained significant attention. Our analysis also revealed that the energy ministerial meetings of the AMEM, AMEM+3, and EAS EMM exhibit different attitudes toward the climate change–energy security nexus, including the selection of energy technologies. The EAS EMM, ahead of the AMEM and AMEM+3, has led the discussion on the climate change and energy technology development issues in ASEAN. Thus, our study provides an opportunity to reflect on the direction that should be taken by ASEAN's climate change and energy policies in the future.

Our study also has limitations of our study, and we set directions for further research. Our study succeeded in the objective quantitative evaluation of statement documents but ignored the contexts in which energy ministers discussed the issues. Thus, our analysis may include errors caused by the misinterpretation of contexts. Considerably, our study does not closely follow the contexts to clarify the interactions between the AMEM, AMEM+3, and EAS EMM. In addition, although the documents exhibit a degree of commitment made by energy ministers, gaps may exist between the commitments and implementations of policies. Furthermore, because our analysis lacks corroboration by anecdotes, interviews with policymakers, particularly of the chair countries, would complement our study. Such anecdotal findings may provide an answer to the sudden change in the trend of the climate change–energy security nexus in 2024.

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Table 1: Subjects and Relevant Terms

| | |
|---|---|
| (i) Energy security | accessibility, affordability, availability, economy, growth, market, price, recovery, resilience, security, stability, stockpile, supply, volatility |
| (ii) Climate change and environment | carbon, circular, clean, climate, decarbonization, ecosystem, emission, environment, GHG, fossil, green, greenhouse, methane, neutral, sustainability, transition, zero |
| (iii) Technology | innovation, technology |
| (a) Coal | CCS, CCSU, CCT, CCU, CCUS, coal, recycle |
| (b) EEC | conservation, EE, EEC, efficiency, EI, intensity |
| (c) RE | battery, biodiesel, bioenergy, bioethanol, biofuel, biomass, biomethanol, geothermal, hydropower, NRE, solar, renewable, RE, storage, wind |
| (d) Nuclear | CNE, Nuclear, reactor, SMR |
| (e) Hydrogen | ammonia, co-fire, hydrogen |
| (f) EV | EV, vehicle |

Note: CCS = carbon dioxide capture and storage, CCSU = carbon dioxide capture and storage with utilization, CCT = clean coal technology, CCU = carbon dioxide capture and utilization, CCUS = carbon dioxide capture, utilization, and storage, CNE = civilian nuclear energy, EE = energy efficiency, EEC = energy efficiency and conservation, EI = energy intensity, EV = electric vehicle, GHG = greenhouse gas, NRE = new and renewable energy, PV = Photovoltaics, RE = renewable energy, SMR = small modular reactor.

Table 2: Term Frequency–Inverse Document Frequency

AMEM

| | 1996 | | 2010 | | 2015 | | 2020 | | 2021 | | 2022 | | 2023 | | 2024 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mekong | 5.585 | USA | 2.052 | border | 1.125 | IRENA | 1.130 | transit | 1.634 | transit | 1.592 | IRENA | 1.248 | subsea | 1.803 |
| 2 | river | 5.585 | prime | 1.243 | LTMS | 0.986 | AEO | 1.035 | IRENA | 1.443 | IRENA | 1.215 | CCUS | 1.140 | interconnection | 1.798 |
| 3 | basin | 4.189 | Russia | 1.243 | cross | 0.844 | IEA | 0.932 | IEA | 1.038 | southeast | 0.849 | transit | 1.006 | APG | 1.630 |
| 4 | non-OPEC | 4.189 | greener | 0.919 | manual | 0.838 | transit | 0.905 | multilateral | 0.949 | AEO | 0.835 | APG | 0.962 | crossborder | 1.356 |
| 5 | pertaining | 2.792 | label | 0.919 | final | 0.821 | phase | 0.823 | DPS | 0.828 | CCUS | 0.740 | methan | 0.908 | DPS | 1.335 |
| 6 | amend | 2.591 | process | 0.899 | subsector | 0.672 | covid | 0.792 | award | 0.810 | IEA | 0.701 | renewable | 0.807 | cable | 1.202 |
| 7 | AEEMTRC | 2.334 | AMEM | 0.829 | SSN | 0.657 | APAEC | 0.756 | phase | 0.803 | award | 0.625 | award | 0.638 | ToR | 1.064 |
| 8 | OPEC | 2.296 | minister | 0.751 | minister | 0.621 | pandemic | 0.727 | declaration | 0.760 | phase | 0.620 | mineral | 0.621 | transit | 1.016 |
| 9 | protocol | 2.124 | partoner | 0.719 | advisory | 0.620 | multilateral | 0.706 | pursuit | 0.743 | multilateral | 0.569 | MPT | 0.606 | MPT | 0.890 |
| 10 | ASCOPE | 1.762 | procedure | 0.694 | MTPA | 0.620 | award | 0.656 | chairmanship | 0.721 | APAEC | 0.569 | declaration | 0.556 | post | 0.862 |
| | | | remark | 0.694 | pipeline | 0.617 | | | | | | | | | | |

AMEM+3

| | 2004 | | 2010 | | 2015 | | 2020 | | 2021 | | 2022 | | 2023 | | 2024 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | recognize | 2.830 | move | 1.033 | necessity | 0.936 | covid | 2.138 | virtual | 2.382 | virtual | 1.795 | CEFIA | 2.044 | transit | 1.809 |
| 2 | stockpile | 1.829 | OSRM | 0.987 | nuclear | 0.935 | pandemic | 1.570 | wind | 1.308 | just | 1.319 | transit | 1.705 | ACCECC | 1.447 |
| 3 | concert | 1.540 | earlier | 0.975 | OSRM | 0.921 | recovery | 1.549 | plus | 0.921 | transit | 1.212 | pathway | 1.301 | CEFIA | 1.054 |
| 4 | resolve | 1.540 | CDM | 0.898 | on-site | 0.910 | virtual | 1.502 | transit | 0.877 | ACCECC | 0.873 | neutral | 1.292 | pivotal | 0.868 |
| 5 | wider | 1.442 | minister | 0.879 | GHG | 0.884 | solar | 1.097 | ammonia | 0.866 | CEFIA | 0.848 | carbon | 1.076 | critical | 0.841 |
| 6 | choose | 1.338 | November | 0.846 | minister | 0.730 | CEFIA | 1.064 | CCUS | 0.765 | DSM | 0.786 | ACCECC | 1.052 | ESF | 0.782 |
| 7 | convenient | 1.338 | sufficient | 0.815 | smart | 0.701 | brought | 0.987 | Korea | 0.715 | recovery | 0.771 | ramp | 1.052 | resilience | 0.759 |
| 8 | redouble | 1.338 | context | 0.775 | amongst | 0.685 | IoT | 0.987 | CEFIA | 0.690 | PV | 0.736 | offshore | 0.818 | underscore | 0.739 |
| 9 | spot | 1.338 | NRE | 0.775 | JAEA | 0.661 | post | 0.946 | low | 0.672 | pandemic | 0.715 | vehicle | 0.780 | emphasize | 0.711 |
| 10 | circumstances | 1.282 | recent | 0.708 | model | 0.633 | PV | 0.925 | AEYA | 0.631 | scheme | 0.713 | CACEW | 0.701 | neutral | 0.711 |

Table 2: Term Frequency–Inverse Document Frequency (continued)

| EAS EMM | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | | 2010 | | 2015 | | 2020 | | 2021 | | 2022 | | 2023 | | 2024 | |
| 1 | ECTF | 3.524 | EMI | 2.292 | ERIN | 2.357 | recovery | 2.249 | transit | 2.981 | transit | 2.712 | transit | 2.862 | water | 2.133 |
| 2 | Cebu | 3.448 | ERIA | 2.218 | stream | 2.157 | WTP | 1.639 | pandemic | 1.217 | scenario | 1.918 | zero | 1.542 | food | 1.375 |
| 3 | EMM | 1.787 | stream | 1.980 | ERIA | 1.775 | CCUS | 1.467 | survey | 1.104 | neutral | 1.599 | neutral | 1.488 | cornerstone | 1.276 |
| 4 | biofuel | 1.764 | biofuel | 1.914 | benchmark | 1.314 | mobility | 1.415 | stream | 1.036 | mobility | 1.215 | net | 1.412 | heavy | 1.276 |
| 5 | declaration | 1.694 | feedstock | 1.902 | cybersecur | 1.062 | round | 1.369 | ERIA | 0.994 | pathway | 1.207 | ERIA | 1.277 | diversify | 1.102 |
| 6 | articulate | 1.379 | ECTF | 1.792 | inherent | 1.062 | ERIA | 1.141 | depart | 0.962 | architecture | 1.041 | ammonia | 0.997 | highlight | 1.073 |
| 7 | deliberate | 1.379 | make | 1.551 | lessen | 1.062 | pandemic | 1.117 | float | 0.962 | underpin | 0.945 | Australia | 0.997 | concur | 1.067 |
| 8 | format | 1.379 | liberalize | 1.528 | marker | 1.062 | transit | 1.052 | CCUS | 0.959 | carbon | 0.944 | shock | 0.969 | forward-looking | 1.067 |
| 9 | point | 1.379 | handbook | 1.309 | origin | 1.062 | covid | 1.014 | decarbnize | 0.959 | vehicle | 0.868 | scenario | 0.893 | rooftop | 1.067 |
| 10 | thereby | 1.252 | assess | 1.169 | SAEO | 1.062 | DES | 1.014 | Brunei | 0.917 | stream | 0.816 | Bali | 0.880 | thermal | 1.067 |
| | | | | | twin | 1.062 | session | 1.014 | | | | | EV | 0.880 | WEF | 1.067 |
| | | | | | | | survey | 1.014 | | | | | | | | |

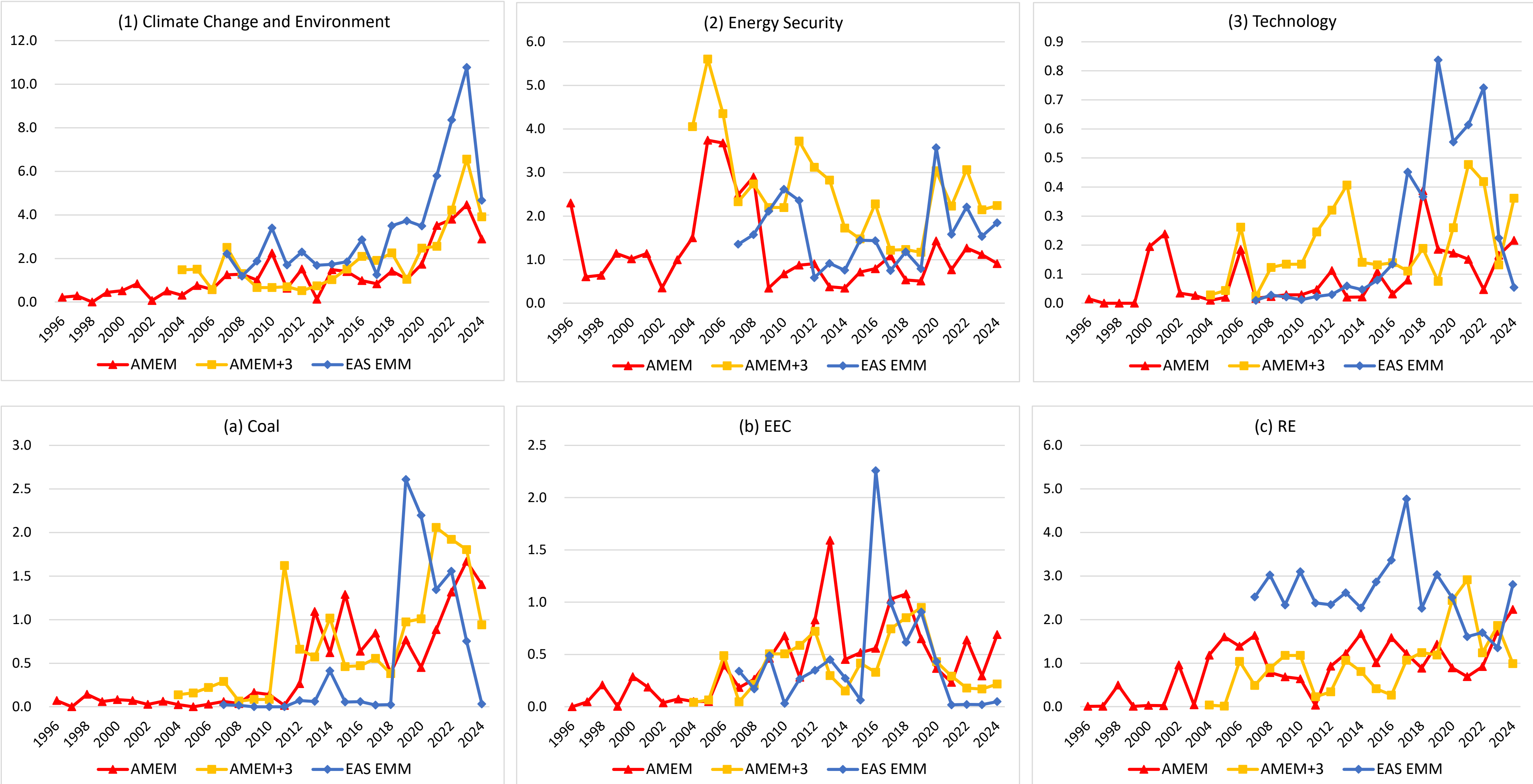
Note: ACCECC = ASEAN−China Clean Energy Cooperation Centre, AEEMTRC = ASEAN−EC Energy Management Training and Research Centre, AEO = ASEAN Energy Outlook, AERN = ASEAN Energy Regulators' Network, AEYA = ASEAN Energy Youth Awards, AMEM = ASEAN Ministers on Energy Meeting, APAEC = ASEAN Plan of Action for Energy Cooperation, APG = ASEAN Power Grid, ASCOPE = ASEAN Council on Petroleum, BIMP = Brunei Darussalam–Indonesia–Malaysia−Philippines, CACEW = China−ASEAN Clean Energy Week, CCUS = carbon capture, utilization, and storage, CDM = Clean Development Mechanism, CEFIA = Cleaner Energy Future Initiative for ASEAN, DES = distributed energy system, DPS = Dialogue Partners, DSM = demand side management, ECTF = Energy Cooperation Task Force, EMI = energy market integration, EMM = energy ministers' meeting, ERIA = Economic Research Institute for ASEAN and East Asia, ESF = Energy Security Forum, EV = electric vehicle, GHG = greenhouse gas, IEA = International Energy Agency, IoT = Internet of Things, IRENA = International Renewable Energy Agency, JAEA = Japan Atomic Energy Agency, LTMS = Lao PDR–Thailand–Malaysia–Singapore, MPT = multilateral power trading, MTPA = million tons per annum, NRE = new and renewable energy, OPEC = Organization of the Petroleum Exporting Countries, OSRM = Oil Stockpiling Road Map, PV = Photovoltaics, SAEO = Southeast Asia Energy Outlook, SSN = Sub-Sector Network, ToR = Terms of Reference , USA = United States of America, WEF = water–energy–food, WTP = willingness to pay.

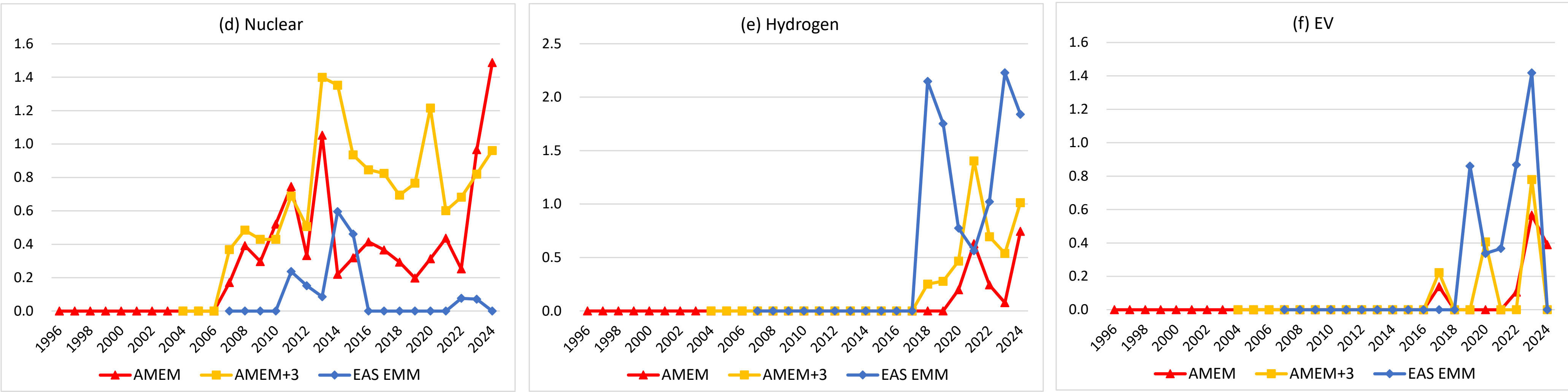
Table 3: *k*-Means Clustering of Documents

| | Cluster 1 | Cluster 2 | Cluster 3 |
|---|---|---|---|
| Documents | AMEM (1996−1997) | AMEM (1998−2019)<br>AMEM+3 (2004−2019)<br>EAS EMM (2007−2017) | AMEM (2020−2023)<br>AMEM+3 (2020−2023)<br>EAS EMM (2018−2023) |
| Top 20 terms | CLM, Mekong, river, president, basin, non-OPEC, soon, amend, AEEMTRC, ASCOPE, protocol, pertaining, satisfaction, Petro−Vietnam, signature, AEBF, OPEC, exhibit, foreign, foundation | minister, stream, ERIA, oil, nuclear, stockpile, biofuel, price, recognize, program, agree, award, ECTF, OSRM, APAEC, partner, programme, SSN, renewable, pipeline | transit, hydrogen, CCUS, carbon, decarbonize, stream, virtual, mobility, neutral, recovery, pandemic, low, IRENA, pathway, ERIA, recycling, wind, meet, CEFIA, covid |

Note: The documents of the AMEM (2024), AMEM+3 (2024), and EAS EMM (2024) are excluded.

Figure 1: Trend of Specific Subject






Note 1: The vertical axis indicates the sum of TF−IDF with respect to the terms shown in Table 1.

2: EEC = energy efficiency and conservation, EV = electric vehicle, RE = renewable energy.

Table 4: Average Values of TF−IDF by Subject

| | | (i) Climate Change and Environment | (ii) Energy Security | (iii) Technology | (a) Coal | (b) EEC | (c) RE | (d) Nuclear | (e) Hydrogen | (f) EV |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996−1999 | AMEM | 0.238 | 1.172 | 0.004 | 0.069 | 0.066 | 0.132 | 0.000 | 0.000 | 0.000 |
| | AMEM+3 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | EAS ESS | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | Average | 0.238 | 1.172 | 0.004 | 0.069 | 0.066 | 0.132 | 0.000 | 0.000 | 0.000 |
| 2000−2004 | AMEM | 0.451 | 1.002 | 0.101 | 0.054 | 0.128 | 0.448 | 0.000 | 0.000 | 0.000 |
| | AMEM+3 | 1.479 | 4.052 | 0.029 | 0.138 | 0.043 | 0.038 | 0.000 | 0.000 | 0.000 |
| | EAS ESS | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | Average | 0.965 | 2.527 | 0.065 | 0.096 | 0.085 | 0.243 | 0.000 | 0.000 | 0.000 |
| 2005−2009 | AMEM | 0.976 | 2.631 | 0.055 | 0.058 | 0.272 | 1.219 | 0.172 | 0.000 | 0.000 |
| | AMEM+3 | 1.313 | 3.444 | 0.118 | 0.164 | 0.265 | 0.722 | 0.256 | 0.000 | 0.000 |
| | EAS ESS | 1.759 | 1.680 | 0.020 | 0.014 | 0.333 | 2.625 | 0.000 | 0.000 | 0.000 |
| | Average | 1.349 | 2.585 | 0.064 | 0.079 | 0.290 | 1.522 | 0.143 | 0.000 | 0.000 |
| 2010−2014 | AMEM | 1.130 | 0.708 | 0.052 | 0.379 | 0.846 | 0.706 | 0.663 | 0.000 | 0.000 |
| | AMEM+3 | 0.660 | 2.966 | 0.277 | 0.735 | 0.529 | 0.702 | 0.756 | 0.000 | 0.000 |
| | EAS ESS | 2.272 | 1.618 | 0.031 | 0.033 | 0.275 | 2.610 | 0.119 | 0.000 | 0.000 |
| | Average | 1.354 | 1.764 | 0.120 | 0.382 | 0.550 | 1.340 | 0.512 | 0.000 | 0.000 |

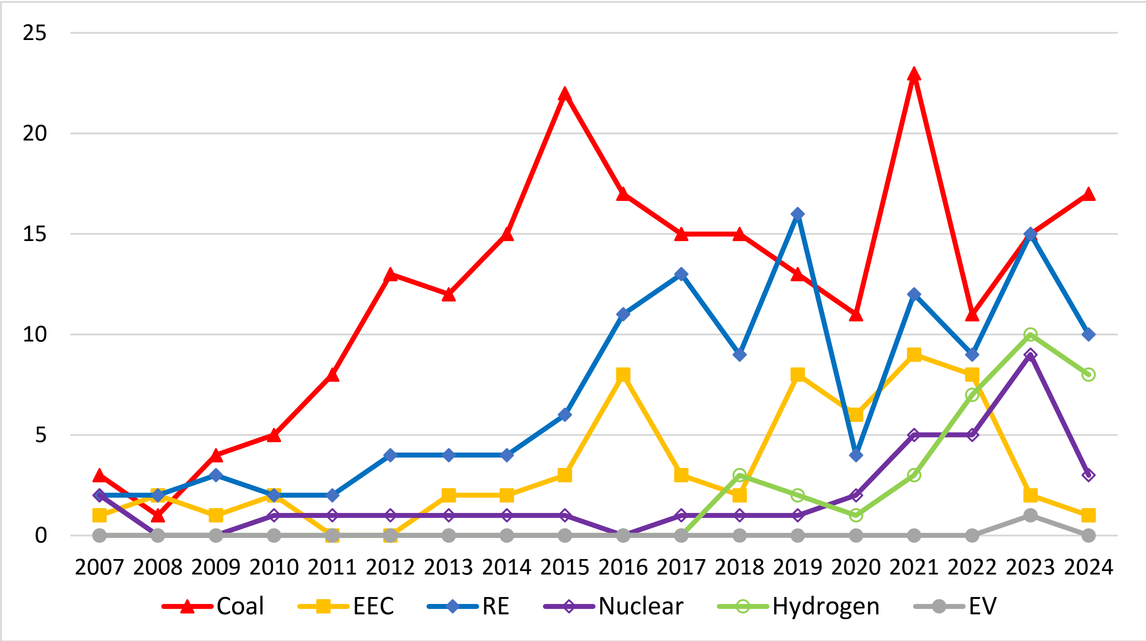
Table 4: Average Values of TF−IDF by Subject (continued)

| | | (i) | (ii) | (iii) | (a) | (b) | (c) | (d) | (e) | (f) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Climate Change and Environment | Energy Security | Technology | Coal | EEC | RE | Nuclear | Hydrogen | EV |
| 2015−2019 | AMEM | 1.226 | 0.695 | 0.126 | 0.755 | 0.728 | 1.277 | 0.322 | 0.000 | 0.028 |
| | AMEM+3 | 1.762 | 1.586 | 0.142 | 0.577 | 0.499 | 0.760 | 0.930 | 0.050 | 0.045 |
| | EAS ESS | 2.241 | 1.113 | 0.216 | 0.114 | 0.841 | 3.105 | 0.211 | 0.430 | 0.000 |
| | Average | 1.743 | 1.132 | 0.161 | 0.482 | 0.689 | 1.714 | 0.488 | 0.160 | 0.024 |
| 2020−2024 | AMEM | 2.914 | 1.019 | 0.144 | 1.018 | 0.437 | 1.135 | 0.433 | 0.230 | 0.135 |
| | AMEM+3 | 3.373 | 2.330 | 0.273 | 1.553 | 0.405 | 1.928 | 0.817 | 0.676 | 0.237 |
| | EAS ESS | 6.428 | 1.936 | 0.595 | 1.691 | 0.280 | 2.040 | 0.030 | 1.268 | 0.770 |
| | Average | 4.239 | 1.762 | 0.337 | 1.421 | 0.374 | 1.701 | 0.426 | 0.725 | 0.381 |

Note 1: “n.a.” means no data available due to the lack of samples.

2: EEC = energy efficiency and conservation, EV = electric vehicle, RE = renewable energy.

Figure 2: Frequency of Collocation Terms of Technology (Time Trend)




Note 1: The frequencies are aggregated over the AMEM, AMEM+3, and EAS EMM.

2: EEC = energy efficiency and conservation, EV = electric vehicle, RE = renewable energy.

Table 5: Collocation Terms of Technology (Aggregation by Meeting)

| | AMEM | AMEM+3 | EAS EMM | Total |
|---|---|---|---|---|
| Coal | 109 (49.1%) | 98 (60.5%) | 25 (20.0%) | 232 (45.6%) |
| EEC | 32 (14.4%) | 13 (8.0%) | 26 (20.8%) | 71 (13.9%) |
| RE | 59 (26.6%) | 26 (16.0%) | 51 (40.8%) | 136 (26.7%) |
| Nuclear | 17 (7.7%) | 15 (9.3%) | 3 (2.4%) | 35 (6.9%) |
| Hydrogen | 4 (1.8%) | 10 (6.8%) | 20 (16.0%) | 34 (6.7%) |
| EV | 1 (0.5%) | 0 (0.0%) | 0 (0.0%) | 1 (0.2%) |
| Total | 222 (100.0%) | 162 (100.0%) | 125 (100.0%) | 509 (100.0%) |

Note 1: The term frequency is aggregated by the AMEM (1996−2024), AMEM+3 (2004−2024), and EAS EMM (2007−2024), respectively.

2: Percentages in parentheses are calculated with respect to the types of technologies.