Original Article

A policy analysis of nuclear safety culture and security culture in East Asia: Examining best practices and challenges

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A B S T R A C T

This paper conducts a qualitative policy analysis of current challenges to safety culture and security culture in Southeast Asia and emerging best practices in Northeast Asia that are aimed at strengthening both cultures. It analyses lessons, including strengths and limitations, that can be derived from Northeast Asian states, given the long history of nuclear energy in South Korea, China and Japan. It identifies and examines best practices from Northeast Asia's Nuclear Security Centres of Excellence in terms of boosting nuclear security culture and their relevance for Southeast Asia. The paper accentuates the important role of the State in adopting policy and regulatory frameworks and in institutionalising nuclear education and training programmes to deepen the safety-security cultures.

Best practices in and challenges to developing a nuclear safety culture and a security culture in East Asia are examined using three frameworks of analysis (i) a comprehensive nuclear policy framework; (ii) a proactive and independent regulatory body; and (iii) holistic nuclear education and training programmes. The paper argues that Southeast Asian states interested in harnessing nuclear energy and/or utilising radioactive sources for non-power applications must develop a comprehensive policy framework on developing safety and security cultures, a proactive regulatory body, and holistic nuclear training programmes that cover both technical and human factors. Such measures are crucial in order to mitigate human errors that may lead to radiological accidents and nuclear security crises. Key lessons from Japan, South Korea and China such as best practices and challenges can inform policy recommendations for Southeast Asia in enhancing safety-security cultures.

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1. Introduction

Several Southeast Asian states aspire to include nuclear energy in their future and long-term power generation sources. The development of small modular nuclear reactors (land-based and floating) as an emerging nuclear technology is closely being monitored by several countries in the region such as the Philippines, Thailand and Indonesia. While there is no nuclear power plant yet in Southeast Asia, radioactive sources are widely used for civilian applications in medical, industrial, agricultural, and scientific research fields. Regulatory policies are being revised in several states to ensure a consistent and systematic approach to nuclear safety and security as they build up their potential nuclear power capacity. However, Southeast Asian states are facing risks due to lack of measures that will help develop and deepen their nuclear safety culture and security culture.

Meanwhile in Northeast Asia, China, Japan and South Korea have begun institutionalising lessons of past nuclear incidents, most notably the 2011 Fukushima nuclear disaster, and put more attention into identifying and rectifying human errors and complacency so as to promote a safety culture and a security culture. In fact, best practices in terms of promoting a safety culture and a security culture can be identified in Northeast Asian states. However, persistent challenges to safety culture and security culture, such as complacency, have yet to be comprehensively addressed in Northeast Asia(See. Table 1).

The paper argues that Southeast Asian states interested in harnessing nuclear energy and/or utilising radioactive sources for non-power applications must develop a comprehensive policy framework on developing safety and security cultures, a proactive regulatory body, and holistic nuclear training programmes that cover

Table 1
List of East Asian countries.

Southeast Asia/Member-States of the Association of Southeast Asian Nations (ASEAN)	Northeast Asia
Brunei	China
Cambodia	South Korea
Indonesia	North Korea
Laos	Japan
Malaysia	
Myanmar	
The Philippines	
Thailand	
Vietnam	
Singapore	

both technical and human factors. Such measures are crucial in order to mitigate human errors that may lead to radiological accidents and nuclear security crises. Key lessons from Japan, South Korea and China such as best practices and challenges can inform policy recommendations for Southeast Asia in enhancing safety-security cultures. After all, the essence of promoting cooperation is sharing of good practices among states.

2. Methodology and frameworks of analysis

2.1. Data collection

This paper conducts a qualitative policy analysis of current challenges to safety culture and security culture in Southeast Asia and emerging best practices in the broader East Asian region that are aimed at strengthening both cultures. Using the country case study approach, the paper analyses lessons, including strengths and limitations, that can be derived from Northeast Asian states, given the long history of nuclear energy in South Korea, China and Japan. It aims to examine how relevant Northeast Asia's best practices are for Southeast Asia. Country case studies from Southeast Asia are analysed to determine and evaluate the progress and challenges found in the region concerning safety culture and security culture.

The paper also identifies and examines best practices from Northeast Asia's Nuclear Security Centres of Excellence in terms of boosting nuclear security culture and their relevance for Southeast Asia. The paper accentuates the important role of the State in adopting policy and regulatory frameworks and in institutionalising nuclear education and training programmes to deepen safety-security cultures. Best practices in and challenges to developing a nuclear safety culture and a security culture in East Asia are examined using three frameworks of analysis (i) a comprehensive nuclear policy framework; (ii) a proactive and independent regulatory body; and (iii) holistic nuclear education and training programmes.

Apart from documentary analysis of official reports, presentations by national officials and related publications, the author collected research data from three expert group discussions that he convened in 2015, 2016 and 2017. Expert group discussions formed part of three policy roundtables at the S. Rajaratnam School of International Studies (RSIS), which were convened during the Singapore International Energy Week on 29 October 2015, 28 October 2016 and 27 October 2017 (For reports of the roundtable discussions: please read [1–3]. Expert group discussions involved nuclear energy experts and practitioners from selected Asia-Pacific countries and beyond, majority of them are from Southeast Asia and Northeast Asia. These experts and practitioners are present and former officials from national nuclear energy

regulatory bodies, national nuclear energy agencies, country-representatives to the ASEAN Network of Regulatory Bodies on Atomic Energy (ASEANTOM), NGOs. academic institutions, and nuclear industry. Expert group discussions facilitated policy deliberations and constructive debates among nuclear experts on post-Fukushima nuclear safety and security issues in East Asia. The objectives of the policy-oriented expert group discussions at the roundtables were:

- i. To identify and examine nuclear governance issues, national approaches, best practices and regional cooperation on civilian nuclear safety, security and radiological security;
- ii. To deliberate and evaluate ASEANTOM's capacity-building initiatives;
- iii. To discuss and assess the effectiveness of national approaches and best practices on civilian nuclear governance from nuclear-powered countries such as Japan and South Korea, particularly on safety culture and security culture;
- iv. To provide policy recommendations on and map out an agenda for strengthening nuclear safety culture and security culture in the region.

In October 2015, the author coordinated an expert group RSIS roundtable discussion entitled "Is Southeast Asia Ready for Nuclear Power?"; while in October 2016, another group discussion, the "RSIS Roundtable on Nuclear Safety and Cooperation in ASEAN" was convened. In these roundtable discussions, 12 nuclear experts from Japan, the US, Thailand, Indonesia, Malaysia, Vietnam, civil society, and the nuclear industry participated in the two roundtables and provided relevant data on the status of nuclear safety and security in East Asia. They provided their insights as they revisited the lessons of the Fukushima accident with special focus on new measures from their respective countries and associations to enhance nuclear safety and emergency preparedness and response as well as the importance of regional cooperation. Experts were also asked to tackle the burgeoning regional cooperation on nuclear energy in Southeast Asia and the efforts of ASEAN Member-States to bolster the regional culture of nuclear safety. They deliberated on the role of ASEANTOM in enhancing nuclear energy cooperation in Southeast Asia.

In October 2017, an expert group discussion was convened to get relevant data from selected East Asian states on challenges to the development of a safety culture and a security culture as well as best practices to strengthen the two cultures. Five nuclear experts and practitioners from Thailand who was directly involved in ASEANTOM's activities, Malaysia, Singapore, France, and South Korea were invited to join in the expert group discussion in Singapore entitled "RSIS Roundtable on Nuclear Safety and Security Cultures: Powering Nuclear Governance in East Asia." Key questions were sent by the author to the invited experts before the roundtable so that they could focus their presentations and deliberations on nuclear safety and security policies. The questions were: (1) What are the components of a security culture and a safety culture? (2) Why is it important for Southeast Asian countries to develop and strengthen their safety culture and security culture? (3) What is the role of the State in developing the two cultures (4) How effective are nuclear education and training programmes in Southeast Asia in strengthening the two cultures? (5) What is the role of nuclear cooperation in Southeast Asia driven by ASEANTOM? (6) How do France and South Korea enhance the two cultures through their comprehensive nuclear policy frameworks? (7) What are the best practices of their regulatory bodies? (8) How does South Korea provide license holders (operators, radiation workers and inspectors) with nuclear education and training on safety-security cultures?

2.2. Nuclear safety culture and security culture: similarities and differences

In the roundtable expert group discussion in 2016, participating nuclear experts accentuated that one important lesson from the 2011 Fukushima nuclear disaster is the need to have broader perspectives on 'unthinkable' events and unforeseen circumstances. It is necessary for nuclear staff, managers and emergency responders to be prepared for such contingencies and sudden developments. Human errors such as complacency and lack of critical thinking have been identified as key contributors to the Fukushima nuclear disaster [2,4]. Yet, as highlighted in the roundtable discussions, the nuclear industry had focused only on technological improvements, leaving out nuclear safety culture and security culture, which still need to deepen in Southeast Asia. Nuclear power and utilisation of radioactive materials for non-power applications do not merely involve technological aspects. Human aspects of nuclear safety and security should be as important as technological aspects [1,2,5].

The International Atomic Energy Agency (IAEA) defines nuclear safety culture as "the assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance." Meanwhile, nuclear security culture is defined by the IAEA as "the assembly of characteristics, attitudes, and behaviours of individuals, organisations and institutions which serves as a means to support and enhance nuclear security." These definitions highlight the importance of human factors, such as attitudes, beliefs and behaviours, in upholding nuclear safety and security [6].

Safety-security cultures cannot be instilled and cultivated overnight because three essential elements need to be developed first namely, (i) beliefs and attitudes, (ii) management systems, and (iii) behaviours. Firstly, one must have a strong belief that risks and threats do exist and therefore safety and security have to be upheld all the time. Without strong beliefs and attitudes, effective nuclear safety-security cultures will not exist. Secondly, a system of management must be put in place to impart expectations, requirements and standards for the conduct of work and training among staff and managers. Thirdly, the strength of the nuclear safety-security cultures of an organisation is observable in the behavioural patterns of its personnel which can be improved by continual learning, self-assessment, and application of best practices and lessons learnt [1,6].

As explained by a nuclear expert from Singapore in the roundtable expert group discussion, while nuclear safety culture considers the risk of **unintentional** human error that could lead to releases of hazardous substances, nuclear security places additional emphasis on **deliberate** acts (e.g., theft and smuggling of radioactive materials, sabotage of facilities) by terrorists, criminals and other malicious actors who intend to cause harm [1]. The principal shared objective of security culture and safety culture is to contain the risks resulting from the failure to manage nuclear materials and associated facilities. This objective is largely based on common principles such as critical thinking, accountable workers and managers, high priority to safety and security, two-way communication between employees and managers, learning culture, and top management commitment to safety and security. There are instances wherein the differences between safety and security requirements need to be acknowledged. On the one hand, since nuclear security deals with deliberate acts, security culture therefore requires confidentiality of information to deter malicious acts. On the other hand, safety culture encourages sharing of information due to its overriding concern for transparency [1,7]. Nonetheless, there is a good rationale for harmonisation of the two cultures: they function best when their common principles are recognised, synergised and exploited by all those involved in facilities with nuclear and radioactive materials—while also preserving each one's peculiar objectives and goals. Both cultures do have a shared main goal: to protect human lives, society, and the environment. Harmonisation entails complex negotiation, cooperation and understanding among participants, but is achievable. In this regard, seeking the common ground where safety culture and security culture overlap, co-exist and reinforce each other is imperative [8].

Table 2 demonstrates that safety culture and security culture share common elements and, therefore, approaches to promote and strengthen both cultures can overlap. It signifies opportunities to exploit synergies between the two cultures. But while nuclear safety and nuclear security share some common features, they are not the same. Table 3 presents their key differences and obviously critical areas of contention. It only shows that safety culture and security culture may at times conflict or otherwise have mutually exclusive objectives.

While there are many components of developing safety-security cultures, three of these were analysed in the expert group

Table 2
Similar/overlapping approaches to safety culture and security culture.

Approaches	Similarities
1. Legal and Regulatory Policy Framework	Both safety culture and security culture are built on a legal and regulatory policy framework, comprehensive enough to define the responsibilities of several organisations, including the role of the State.
2. Adoption of State Policy Statements	The State must also have policy statements for both cultures to set up national standards.
3. Independent and Competent Regulatory Body	Both cultures require competent and independent regulatory bodies, which have sufficient staff, funding and powers to perform their duties and the freedom to do so without undue interference.
4. Proactive and Strong Regulatory Requirements	Regulators must also set up and implement a licensing system and an inspection and enforcement system to ensure the development of a safety culture and a security culture by operators/licensees.
5. Safety culture and security culture policies by organisations	All organisations should adopt policies for both cultures, which contain the aspects of a sound management system and are provided as guidance to staff.
6. Management structures	One common key requirement is to have strong lines of authority. Both cultures need management structures that define roles, responsibilities of managers and staff, and accountability for each level of the organisation
7. Education and training	Both cultures require organisations to have sufficient financial, technical and human resources to implement safety and security requirements. Both require staff to be fully qualified. Hence, training of staff is recognised as vital to strengthen both cultures.
8. Review and Improvement	Organisations must conduct regular reviews, including self-assessment methods, of their safety and security practices and systems. All discrepancies found should be comprehensively analysed and corrected.
9. Emergency Response and preparedness	Organisations are required to develop plans to mitigate the consequences of a radiological accident. Such plans must cover both safety and security events. Safety and security representatives should learn to work together to prepare and update emergency response plans

Sources: [1]; [6—8].

Table 3
Differences in managing safety culture and security culture.

	Safety Culture	Security Culture
1. Objectives	The primary goal is to prepare for dealing with unintended acts or conditions that could lead to disruptions, breakdowns, and releases of radioactive materials from lawful and peaceful nuclear applications.	The primary goal is to prevent, detect and counteract the intentional misuse of infrastructure and materials by terrorists, criminals, or other malicious elements.
2. Responses	Responses entail engineered protection and safety management.	Responses concentrate on intelligence gathering, physical protection, vigilance, and compliance.
3. Access to facilities in case of emergency	Quick access to facilities in the event of emergency response to a safety incident is preferred but it may compromise the security of the facility and malicious actors may take advantage of it.	The introduction of delay barriers for security reasons can limit rapid access to respond to a safety event or can slow down emergency response.
4. Transparency vs Information Security	It may be desirable to identify and quantify the amounts and types of radiological or nuclear materials possessed by a facility.	Such disclosure is discouraged as it could heighten the attractiveness of the facility as a potential terrorist target.
	All individuals are requested to share information with others in an overriding concern for transparency and dialogue.	Individuals are required to protect confidential information and to share them with authorised people only.

Sources: [1]; [8]

roundtable discussion in 2017. These are a comprehensive nuclear policy framework, a proactive and independent regulator, and holistic nuclear education and training programmes [1].

2.3. A comprehensive nuclear policy framework

A key role of the State is to establish a legal and regulatory framework in order to foster an effective nuclear safety culture and a strong security culture. At the state level, there must be a policy framework on developing the two cultures. The State, through its legal and regulatory framework, has to define the (i) duties, responsibilities, and rights of various actors in the nuclear field; (ii) implementing guide for licensing nuclear facilities and radiation staff to follow; and (iii) means of regulatory control: rule making, safety evaluations, and inspections [1,6]. All nuclear-related organisations, facilities, and agencies must come up with their respective nuclear safety and security action plans and organisational policies based on the State's implementing guide. Specifically for security culture, it is necessary for the State to establish general rules for authorised access to facilities and information, with the goal of securing sensitive information, radioactive materials, facilities and transport [1,6,10].

2.4. A proactive and independent regulatory body

The establishment, implementation, and maintenance of a robust nuclear safety culture and a strong security culture are also dependent on a strong and independent regulator. The nuclear regulatory body must oversee the implementation of the policy framework, including the implementing guide, across all organisations. The 1994 Convention on Nuclear Safety and the IAEA General Safety Requirements call for the establishment of a regulatory body and the need for its independence, from the promoters of nuclear technology, such as government ministries [11]. The primary reason for having an independent regulatory body is to ensure that judgements are made and enforced without pressure from interests that may conflict with safety and security. The dynamics of the relationship between the regulator and the operator can influence the operator's safety culture and security culture either positively or negatively. In promoting safety culture as well as security culture, a regulatory body should set a good example in its own performance. That means it should establish high standards for itself, deal with operators and users of radioactive materials in a professional manner, demonstrate good judgment in its regulatory decisions, and be competent in covering both technical and human factors [12].

2.5. Holistic nuclear education and training programmes

While local and/or national cultures might influence how safety and security cultures are being developed, training and professional development are essential to the cultivation of desired norms and expected cultural behaviours in nuclear facilities. Hence, a holistic approach to nuclear education and training, which addresses human factors, is required to sustain and develop safety-security cultures [13].

The State has the responsibility to develop national education and continuous training programmes on nuclear safety and security cultures. In the context of nuclear security, nuclear security training centres and centres of excellence (COEs), as key training organisations in this area, are well placed to help strengthen security culture by broadening their activities beyond technical training and serving as a platform for knowledge sharing among regional and global experts [45]. Given the increased attention to training and the human factor in nuclear security, the establishment of a COE signifies a good practice and a strong commitment by the State to enhance nuclear security. By focusing on the human factor in securing nuclear facilities and materials, COEs serve as a mechanism for ensuring employees, managers and organisations are trained on a wide number of important nuclear security issues [14].

2.6. Hofstede model for cultural values

As the paper intends to apply the lessons from Northeast Asian countries to Southeast Asia, it is useful to briefly compare relevant national cultural aspects among these regional countries. National cultures strongly influence the development of nuclear safety-security cultures. In this regard, the papers utilises the Hofstede Insights' Six Dimensions of National Culture in comparing East Asian counties [15]. This model is one of the most comprehensive studies of how values in the workplace are influenced by culture.

The Hofstede model contains a good overview of the drivers of a national culture by analysing its six dimensions: power distance, individualism, masculinity, uncertainty avoidance, long-term orientation, and indulgence. This paper compares Northeast Asian and Southeast Asian countries using two dimensions, namely, power distance and uncertainty avoidance which may have direct reference to the development of safety-security cultures of organisations. Power distance is "*the extent to which the less powerful members of institutions and organisations within a country expect and accept that power is distributed unequally*" [15]. People in societies that have large degree of power distance accepts the hierarchical order and do not question it. Uncertainty avoidance index (UAI) is "*the degree to which the members of a society feel uncomfortable with uncertainty and ambiguity.*" People in societies with strong UAI

observe strict codes of belief and behaviour, and are intolerant of unconventional behaviour and norms [15].

It may be challenging to develop safety-security cultures in societies where power hierarchy is so entrenched that feedback mechanism between manager and employees and a questioning attitude is not highly encouraged. Open communication is essential in fostering safety-security cultures but this may be inhibited in hierarchical organisations. Furthermore, societies with a low preference for avoiding uncertainty may also find it challenging to develop both safety-security cultures. This is because preparing for uncertain and unexpected events is an important trait of safety-security cultures. Also, weak adherence to plans, rules and regulations put in place for unexpected events also indicates weak safety-security cultures. Below is the comparison among East Asian states based on analysis of Hofstede Insights(See. Table 4).

3. Key lessons and best practices from Northeast Asia

Given the long history of nuclear energy in South Korea, China and Japan and their robust expertise in operating and regulating NPPs, several key lessons and best practices in terms of developing a nuclear safety culture and a security culture can be derived from these countries and emulated to other regional countries. Moreover, these countries have institutionalised the lessons of past nuclear incidents, particularly the need to strengthen a safety culture and a security culture of employees, managers, and organisations that are involved in the nuclear industry. These lessons together with best practices are examined using three frameworks of analysis (i) a comprehensive nuclear policy framework; (ii) a proactive and independent regulatory body; and (iii) holistic nuclear education and training programmes. One important reason why lessons from Northeast Asia may also be relevant for Southeast Asia is the training assistance being provided by China, Japan, and South Korea to Southeast Asian states interested in tapping nuclear

energy in the future [16]. There is also a commercial driver for 'exporting' safety culture and security culture [17] as they are also potential suppliers of nuclear technology and NPPs for several Southeast Asian states.

3.1. A comprehensive nuclear policy framework

One key lesson from Northeast Asia is the importance of developing a comprehensive nuclear policy framework on safety-security cultures. Such policy framework provides nuclear operators and facilities with a set of legal procedures and goals concerning safety culture and security culture. The South Korean model provides this best practice. As comprehensively discussed by a South Korean nuclear training practitioner in the 2017 expert group discussion, South Korea's nuclear policy framework covers not just the technical aspects of nuclear safety and security but also the development of right mindsets and attitudes of the operators of nuclear facilities and licensees for radioactive sources. In 2001, the South Korean government issued the *Nuclear Safety Charter*, which codifies top-level philosophy and principles, including the promotion of a nuclear safety culture in all nuclear-related organisations and facilities [1].

Meanwhile, the concept of security culture was developed much later due to lack of attention given to it in the past. Nonetheless, to demonstrate the national commitment on promoting a security culture, the regulatory body Nuclear Safety and Security Commission (NSSC) issued the *Nuclear Security Culture Implementing Guide* in 2013. It explains the importance of human factors and leadership in nuclear security and interactions between safety culture and security culture. The implementing guide is intended for regulatory bodies, organisations, institutions and individuals involved in activities utilising nuclear energy or other radioactive materials. Consequently, all nuclear-related organisations, facilities, and agencies in South Korea have established their respective nuclear

Table 4
Comparison of national cultures of selected states in East Asia.

Countries	Power Distance Index	Uncertainty Avoidance Index
Northeast Asia		
1. Japan	(Score 54) Japan is a borderline hierarchical society. All the decisions should be confirmed by each hierarchical layer and finally by the top management in Tokyo. But there is no one top guy who makes decision like in more hierarchical societies.	(Score 98) Japan is among the most uncertainty avoiding countries. Due to natural disasters that frequently hit the country, Japanese people always make themselves prepare for any unexpected incidents through risk analysis, emergency plans and precautionary measures.
2. South Korea	(Score 60) South Korea is a slightly hierarchical society. Centralisation is tolerated with subordinates are expected to be told what to do by a benevolent boss.	(Score 85) South Korea has high Uncertainty Avoidance. There is need for rigid rules, precision and punctuality are the norms. Innovation may be resisted while security is a key component in individual motivation.
3. China	(Score 80) The subordinate-superior relationship tends to be polarized. Individuals are influenced by formal authority and sanctions	(Score 30) The Chinese can tolerate ambiguity. Hence, following rules and laws may be flexible depending on the actual situation.
Southeast Asia		
4. Indonesia	(Score 78) Indonesia is a very hierarchical society. Power is centralised and managers expect the obedience of their employees who need be told what to do and when. Managers take full control and are respected for their position. Communication is indirect and negative feedback hidden.	(Score 48) Indonesians have a low preference for avoiding uncertainty. They prefer preserving work place and relationship harmony so nobody wants to convey bad or negative news or feedback to colleagues.
5. Malaysia	(Score 100) Malaysia has a very high power distance score. Hierarchy in an organisation reflects inherent inequalities. With centralised hierarchy, employees expect to be told what to do by benevolent leaders. Challenges to the leadership are not well-received.	(Score 36) Malaysians have a very low preference for avoiding uncertainty. They maintain a more relaxed attitude in which practice counts more than principles and deviance from the norm is more easily tolerated.
6. The Philippines	(Score 94) The Philippines is also a very highly hierarchical society with centralisation of power and power inequality as acceptable realities. Employees expect to receive orders on what they need to do,	(Score 44) With low preference for uncertainty avoidance, deviance from the norm is more easily tolerated while strict adherence to rules is not highly expected. In the absence of rigid rules, innovation may emerge.
7. Vietnam	(Score 70) Challenges to the leadership are not acceptable in Vietnam. Power is highly centralised.	(Score 30) Vietnamese people also maintain a low preference for avoiding uncertainty. There is no strict adherence to regulations but innovation is expected.
8. Thailand	(Score 64) Employees show loyalty, respect and deference for their superiors. Information flow is through the chain of command and controlled.	(Score 64) In order to minimise or reduce this level of uncertainty, strict rules, laws, policies, and regulations are adopted and implemented. Thais tend to control everything to avoid unexpected events.

Source: [15].

security action plans and organisational policies based on the government's security culture implementing guide [1,18].

In China, the National Nuclear Safety Agency issued the *Policy Statement on Nuclear Safety Culture* in 2014 and subsequently promulgated the *Integrated Management System Manual for Nuclear and Radiation Safety Regulation*. Both contain the characteristics of a good nuclear safety culture that must be upheld by China's nuclear industry [4]. Similarly, Japan has developed a comprehensive policy framework on cultivating and enhancing safety culture and security culture. The Japan Atomic Energy Commission (JAEC) promulgated the *Basic Policy for Strengthening Nuclear Security* in 2011, requiring all organisations responsible for maintaining nuclear security to give due priority to the development of their nuclear security culture so as to ensure its effective implementation within their facilities. The *Rules for Installation and Operation of Nuclear Facilities* was revised to include the new requirement for nuclear operators to promote nuclear security culture in their facilities.

A 2012 investigation report on the Fukushima nuclear disaster from Japan's National Diet (parliament) concluded that the lack of safety culture was among the major causes of the nuclear accident. In this regard, learning from the lessons of the Fukushima disaster, the Nuclear Regulation Agency (NRA) issued the *Policy Statement on Nuclear Safety Culture* in 2015. It contains the code of conduct for fostering nuclear safety culture and requires (1) priority to safety, (2) decision-making taking into account the risks, (3) developing a questioning attitude, (4) harmonisation with nuclear security, (5) fostering, sustaining and strengthening safety culture, (6) maintaining high level of expertise and organisational learning, (7) effective communication, and (8) rigorous and prudent decisions and agile actions [19].

As a result of these policy reforms, nuclear operators and relevant facilities have initiated activities to maintain and improve their safety culture and security culture among their staff. Operators and facilities have developed their own internal guidelines based on the NRA's codes and rules as well as trainings on safety and security cultures for their staff and senior management [20,25].

A top-down policy approach to foster safety and security cultures are evident in the Northeast Asian examples with the adoption of the State's policy frameworks and guidelines by licensees into their own internal safety and security plans. While national policy frameworks and licensees' internal rules and procedures are important in strengthening safety culture and security culture in facilities, there must be an enforcement monitoring mechanism to ensure compliance and detect potential gaps. This is the role of the regulatory body.

3.2. A proactive and independent regulatory body

A proactive and independent regulatory body is indeed essential in overseeing the development of a safety culture and a security culture. Being proactive and independent entails having the regulatory power to fully monitor, assess and demand strict compliance of policy frameworks by licensees without any pressure from stakeholders with conflict of interest. Learning from previous accidents is a critical factor for having a regulator that can institutionalise safety-security cultures. For instance, based on the lessons of the Fukushima accident, Japan established an independent nuclear regulatory body, an achievement recognised by a team of IAEA experts in 2016 [4,44]. Moreover, the NRA has also included safety culture and security culture assessments in its regular inspections of facilities to identify symptoms of weakening safety-security cultures [21]. In South Korea, the regulatory oversight scope has been widened to cover human and organisational issues since 2013. This was triggered by the cover-up by

the plant manager of a station blackout incident at Kori NPP and the falsification of safety documents for NPP components in 2012 [22]. As highlighted in the 2019 expert group discussion, the South Korean regulator NSSC concluded that the operator did not strictly follow safety regulations and that the concealment showed the lack of a safety culture and strong leadership and management. Learning from the past incidents, NSSC has become more proactive in ensuring that a safety culture is observed in all nuclear facilities. The NSSC conducts periodic safety reviews, which cover safety culture assessment, every 10 years for all nuclear installations as mandated by the current legal framework. Safety culture assessment is held every 2 years for each NPP on a voluntary basis [1].

A proactive and independent regulatory body should also need to be a good example in maintaining a safety culture and a security culture. This requires raising its capability to promote safety culture and security culture among its staff. This is a positive influence that it can impart to other nuclear facilities and operators. For instance, in order to set itself as a good example in its performance, the NRA Japan developed the "*Code of Conduct on Nuclear Security Culture*" for its own staff in 2015. The Code of Conduct advances (1) awareness of a threat, (2) harmonisation with nuclear safety, (3) initiative of senior management, (4) education and self-improvement, and (5) protection of information and communication [15]. The NRA has also recognised that it needs an objective evaluation of the safety culture and security culture among its own staff. Being the regulatory body, it must be a good model to all organisations that it regulates. As such, the NRA requested the IAEA to send a nuclear security review mission in 2015 and a nuclear safety review mission in 2016, helping the NRA identify gaps and areas for further improvement [23]; [4].

In South Korea, to buttress the regulatory oversight on safety culture, the Korea Institute on Nuclear Safety (KINS), which serves as a technical support agency of NSSC for nuclear safety, launched a research project in 2013 on the development of the NSSC's regulatory infrastructure for safety culture oversight. This project examined the appropriate oversight model, methodology, inspection guides, education and training programmes for NSSC inspectors, and legal and institutional frameworks on which oversight activities should be based on [1,22]. Meanwhile, KINAC, which serves as a technical support agency of NSSC for security and safeguards, conducted preliminary studies on the development of a nuclear security culture. The outcome of these studies is the *Nuclear Security Culture Implementing Guide* that is used by licensees in developing their internal security plans [1].

To effectively promote safety culture and security culture, the regulatory body should have innovative and proactive engagements with relevant stakeholders. For example, the NRA Japan and South Korea's NSSC-KINS/KINAC regularly conduct safety-security culture briefings for top executives of nuclear facilities and operators to ensure that they can encourage their employees to always uphold nuclear safety and security [1,20]. In addition, the NRA Japan also created educational videos on nuclear security culture in order to deepen the understanding of various stakeholders [24].

Japanese and South Korean experiences vividly demonstrate it is crucial for a national regulatory body to proactively promote safety culture and security culture. This can be done through proactive awareness-raising activities such as regular dialogues, briefings and engagements with nuclear operators and licensees. Even educational video materials from the regulatory body can help licensees advance safety and security awareness among their managers and personnel.

Table 5
Centres of excellence on nuclear security in Northeast Asia.

Country	Centre of excellence	Supervising government agency	Year of establishment	Areas of specialisation	Primary activities
China	State Nuclear Security Technology Center (SNSTC)	China Atomic Energy Agency (CAEA)	2015	Nuclear Security	Provides nuclear security education, training and certification activities
Japan	Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN)	Japan Atomic Energy Agency (JAEA)	2010	Nuclear security, nonproliferation, safeguards	Offers capacity-building assistance, technical support to government; conducts policy research; shares best practices with other nuclear security officials from Asian countries
South Korea	International Nuclear Security Academy (INSA)	Korea Institute of Nuclear Nonproliferation and Control (KINAC)	2014	Nuclear security, non-proliferation, export controls	Provides education and training programmes, R&D activities, and capacity-building assistance to emerging countries in Asia

Source: [45].

3.3. Education and training through centres of excellence

Another notable best practice in Northeast Asia is the establishment of Centres of Excellence (COEs) which provide holistic education and training programmes on nuclear security and even safety. Promoting security culture has become more prominent in their training efforts as nuclear security managers seek to understand how they can assess and strengthen the human factor within their organisation [45]. In Northeast Asia, one visible outcome of the Nuclear Security Summits (2010—16) was the creation of three COEs: Japan's Integrated Support Center for Nuclear Non-Proliferation and Nuclear Security (ISCN); South Korea's International Nuclear Non-Proliferation and Security Academy (INSA); and China's State Nuclear Security Technology Center (SNSTC). State-run COEs represent the strong political commitment of the three Northeast Asian states to enhance their nuclear security governance, including security culture. Table 5 enumerates the COEs established in China, Japan and South Korea, together with their respective supervising government bodies, areas of specialisation and their primary activities relevant to nuclear security culture.

At the national level, COEs play an active role in helping each country maintain the security of its nuclear materials and facilities [17]. To complement their technical trainings, COEs regularly provide training courses, workshops and exercises on security culture to operators, regulators, radiation workers, and law enforcers, among others. They also assess the level of security culture awareness among the stakeholders and identify gaps in belief and attitude, leadership behavior, employee behavior and operation system. For instance, SNSTC has made agreements with Chinese nuclear facilities to provide technical support in improving their nuclear security capability, including security culture [17]. In South Korea, apart from its domestic training programmes, INSA-KINAC conducts annual nuclear security culture awareness surveys to determine potential gaps in the security culture and the efficacy of its training and campaign activities. The annual survey results show that the nuclear security awareness rate among those who are involved in nuclear and radiological-related activities has increased from 64.1 percent in 2010 to 85.3 percent in 2015 [1].

At the regional level, another effective role of the COEs revolves around spreading security culture awareness in the broader East Asian region, sharing of expertise and best practices among neighboring states, and capacity-building for nuclear newcomers and developing states in the region. COEs generously co-host regional/international training courses and workshops on nuclear security culture, benefitting nuclear professionals and officials from East Asian states [17]. For instance, Japan's ISCN and South Korea's INSA are much more focused on regional capacity-building in East Asia. Since its establishment in 2010, ISCN has already trained more than 700 experts on various nuclear security issues, including security culture [25]. Meanwhile, in 2017 alone, INSA offered 16 international and regional training courses on nuclear security and non-proliferation for 198 participants from nuclear newcomer countries, including East Asian countries [26].

As another example of good practice, COEs of Northeast Asia enhance their regional role by deepening their cooperation with each other. By collaborating, they create a more integrated institutional framework on regional nuclear security. Such collaboration reinforces nuclear governance and the development of nuclear safety-security cultures in the region through knowledge transfer, capacity-building, cost-sharing, and workshops that bring together international and regional experts. INSA and ISCN already cooperate on education and training through sharing of training plans, exchanging lecturers, sharing of good practices, and having observers sit in on each other's courses [17]. Cooperation among the SNSTC, ISCN and INSA is already occurring, enabling the COEs to utilise limited funding and resources more efficiently and leverage on a wider pool of regional expertise. Such cooperation should be deepened, broadened and expanded to other countries of East Asia.

4. Relevance of Northeast Asia's best practices for Southeast Asia: issues and recommendations

In developing a safety culture and a security culture, Southeast Asian states may consider the aforesaid lessons and best practices from Japan, South Korea and China, which have long and robust expertise in nuclear power and regularly provide training assistance to Southeast Asia. Northeast Asian states have been viewed as key nuclear vendors while Southeast Asia is seen as a potential market for nuclear technology.

Why do Southeast Asian states need to develop a nuclear safety culture and a security culture? In view of Southeast Asia's growing energy needs, some Southeast Asian states are also exploring the option of nuclear energy for power generation. Indonesia, Malaysia,
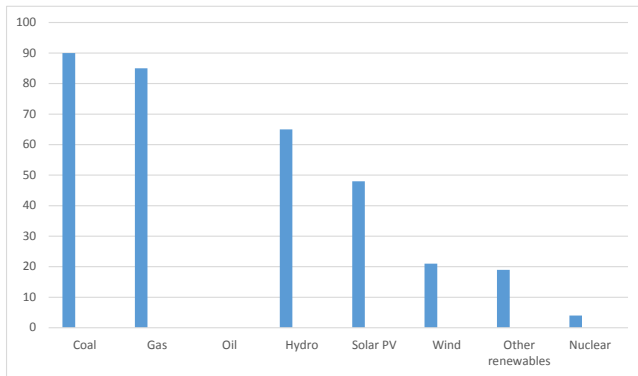
(in gigawatts/GW)

Fig. 1. Electricity generation capacity by energy sources in Southeast Asia by 2040. Source: IEA. 2017. Fig. 1 shows the projected amount of electricity (in GW) to be generated by each energy source in ASEAN by 2040.

the Philippines and Thailand have been identified as frontrunners[2] to establish civilian nuclear power programs in the region, due to their more advanced regulatory and legal frameworks, nuclear energy infrastructure and human resources development programmes ([2] While their governments have not yet taken a strong commitment to nuclear energy or an official decision, they have pre-determined 2030 to 2035 as a target to commence harnessing nuclear energy [43]. By 2040, 4 GW of nuclear power will be generated in the region [27] (see Fig. 1).

Despite the absence of NPPs in Southeast Asia, why should Southeast Asian states develop and deepen a safety culture and a security culture? As noted by nuclear experts in the 2017 expert group discussion, radioactive sources are widely used for civilian applications in medical, industrial, agricultural, and scientific research fields. If national and regional commitments to nuclear security are weak, radioactive material can be accidentally leaked, stolen and used for malicious purposes, or released indiscriminately by non-state actors/terrorists through 'dirty bombs'. Hence, the security of radiological material, a subset of nuclear security, must be enhanced. According to the latest *Global Incidents and Trafficking Database* prepared by the James Martin Center for Nonproliferation Studies (CNS), there were 870 reported incidents involving radioactive materials (theft, missing, leaked, smuggled etc) from 51 countries between 2013 and 2017. Four of such incidents were reported in Southeast Asia [28] (see Fig. 2).

In the Philippines, a moisture density gauge equipment containing radioactive materials was reported missing by private licensee engaged in soil testing in a province near Manila in September 2018. The nuclear regulatory body warned the public that the device could potentially emit harmful radiation rays if the device is handled improperly [29]. In August 2018, an industrial device containing radioactive material was reported to have gone missing in Malaysia. Owned by a private company, the device disappeared while it was being transported outside the capital Kuala Lumpur. There were concerns over the possibility that it might fall into the hands of terrorist and use it as a "dirty bomb" [30]. It was not the first time that a radioactive device has gone missing in Malaysia as the police have recorded no less than 20 cases involving radioactive and nuclear materials which have "gone missing" over recent years. Malaysia's regulatory body had found abandoned

radioactive materials with unclear origins and purpose in recent cases [31]. In Thailand, in an assessment study made by Ref. [32] on the security of radioactive sources in the country's hospitals, they found that hospital staff handling radioactive sources did not clearly understand the nuclear security law. Meanwhile in Vietnam, a former head of the nuclear regulatory body, Dr Vuong Huu Tan claimed that national culture may create limitations in the development of safety culture. The Vietnamese are in favor of personal emotions rather than the "rules in working". He said that "*as an agricultural country, most people working in the industrial zones come from rural areas with habits and practices of agricultural production that limit the formation of industrial working style and sense for compliance with labor rules*" [33].

Clearly, one major shortcoming of nuclear energy governance in Southeast Asia is weak nuclear security culture and safety culture, highlighting the importance of human factors, such as attitudes, beliefs and behaviours. Nuclear power and utilisation of radioactive material for non-power applications do not merely involve technological aspects. Human errors such as complacency and the lack of critical thinking play a role in most reported incidents, including cases of loss and theft of radioactive materials.

What are the existing challenges to the development of a safety culture and a security culture in the region? How can lessons and best practices from Northeast Asia be applied in Southeast Asia? The recommendations put forward in this section are based on qualitative research data and evidence derived from expert group discussions at the three policy roundtables in October 2015, October 2016 and October 2017, as explained in the methodology section of this article. Examples of empirical evidence from various countries in Southeast Asia are clearly discussed in this section. The recommendations are also based on policy analysis of official reports from the IAEA as well as published insights of officials from national regulatory bodies and national nuclear energy agencies in Southeast Asia.

4.1. Fragmented policy frameworks on safety culture and security culture

As seen in China, Japan and South Korea, policy frameworks, in the form of national guidelines and policy statements, were issued to standardise norms and behaviours that licensees need to follow in order to strengthen their safety culture and security culture. In Southeast Asia, Indonesia appears to have the most significant progress in the region in terms of promoting safety culture and security culture. The Indonesian National Nuclear Regulatory
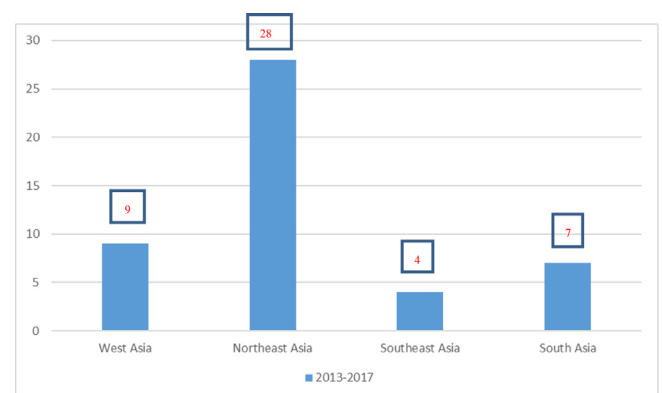

Fig. 2. Number of reported incidents involving radioactive materials in Asia by region, 2013–2017. Source: [28]. Incidents include losses, thefts and smuggling of radioactive materials.

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[2] Vietnam initially decided to build two NPPs but in 2016, its government cancelled the project due to funding and preparation concerns.

Agency (BAPETEN) prepared a safety culture guide for licensees based on existing government regulations on safety and security of radioactive sources [34]. Indonesia also developed a security culture policy framework primarily based on IAEA's nuclear security series guidance on security culture and a national regulation on physical protection of nuclear materials and facilities In order to systematically promote security culture and establish guidelines, the government established the Centre for Security Culture and Assessment (CSCA) in 2014, a vivid indication of Indonesia's improving nuclear policy framework and how it prioritises the development of a strong security culture ([2,35].

Nuclear experts highlighted in the expert group roundtable discussion in 2017 that in other Southeast Asian countries, policy frameworks on safety culture and security culture remain fragmented or even non-existent [1]. In Vietnam, for instance, there are no policies related to building and developing a culture of safety and security, even within its own nuclear regulatory agency [33,36]. More importantly, the proposed amendments to the country's atomic energy law do not clearly show how a safety culture and a security culture are to be developed or promoted in the regulatory body and licensees' organisations [37].

In Malaysia, the *Atomic Energy Licensing Regulations of 2010, Sub-Regulations 15(8)* requires "the licensee or the employer to provide appropriate training, retraining and facilities for updating the skills and knowledge of their workers". The Atomic Energy Licensing Board, which serves as Malaysia's regulatory body, recognises that regulatory clarity is still needed in order to ensure a consistent approach to developing safety-security cultures. The regulatory body therefore intends to clarify its safety-security culture definitions and characteristics; update its guidelines on licensees' self-assessments of their safety-security cultures; and elucidate the regulatory body's oversight role and the role of the licensees [1].

While most of the Southeast Asian states have legal and regulatory frameworks on nuclear energy/radioactive material, one evident gap is the lack of policy regulations on safety-security cultures. A 2018 meeting on nuclear security and safeguard project by the Forum for Nuclear Cooperation in Asia produced a listing of declared plans and methods by selected ASEAN Member States to develop nuclear security culture.

How do selected ASEAN Member States plan to foster security culture?

1. **In Indonesia**, the CSCA/BATAN introduced the concept and terms of nuclear security culture to all stakeholders by conducting self-assessment on nuclear security culture in a local radioactive source facility in 2018. CSCA also plans to develop nuclear security practical pocket book by 2019. The pocketbook will identify the roles of individual/managers to enhance nuclear security culture at nuclear facilities. Two national universities also developed curriculum on nuclear security culture for their MSc programme in nuclear security in 2017/2018. Meanwhile, three International Nuclear Security Education Network (INSEN) member-universities in the country will collaborate in establishing a research centre on nuclear security issues in 2019. Indonesia widely shared its experience in conducting self-assessment of nuclear security culture at its three research reactors, through a report submitted to IAEA.
2. **In Malaysia,** authorities held the following: the National Workshop on Nuclear Security Culture and Self-Assessment in October 2017; Train the Trainers Workshop on Nuclear Security Culture and Self-Assessment in November 2017; and Seminar for Senior Managers on Nuclear Security Culture and National Workshop on Nuclear Security Culture in March 2017. Malaysia also shared its experience in conducting self-assessment of nuclear security culture at a local hospital in Kuala Lumpur,

through a report submitted to the IAEA. Subsequently, an IAEA's expert mission to support and review nuclear security culture self-assessment visited Malaysia in March 2018.

3. **In Vietnam**, the regulatory body conducted a project on "Nuclear security foundation and self-assessment methodology" in 2016. Under this project, self-assessment questionnaires were distributed to nuclear and radiation facilities
4. **In the Philippines**, the regulatory body incorporated nuclear security culture in all security trainings for licensees/users of radioactive sources.
5. **In Thailand,** there have continuous trainings and stakeholder communications on security culture for licensees. Regulations and guidelines on the promotion of a security culture were revised under the new Nuclear Energy for Peace Act (Forum for Nuclear Cooperation in Asia, 2018).

This listing of empirical evidence (plans and activities) as to how selected ASEAN states attempt to deeply institutionalise a security culture provides an impetus for this article to recommend the need for most of these states to come up with a comprehensive nuclear policy on a safety culture and a security culture. With the exception of Indonesia, most of the Southeast Asian countries have yet to develop policy frameworks on the promotion and development of a safety culture and a security culture. Without policy frameworks from the State, it would be challenging for licensees and users of radioactive and nuclear materials to develop their safety and security plans that foster a safety culture and a security culture.

4.2. The need to strengthen the capacity of regulatory bodies

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Independence of Regulatory Agencies

Independent: China (CAEA), Indonesia (BAPETEN), Japan (NRA), ROK (NSSC), Singapore (NEA)

Semi-Independent*: Malaysia (AELB), Thailand (OAP), Vietnam (VARANS)

*The regulatory agency is attached with a government agency or ministry to which a nuclear promotion agency belongs

Not Independent: Philippines (PNRI)

As highlighted in our expert group discussions, in terms of regulatory independence, with the exception of Indonesian and Singaporean regulatory bodies, most of nuclear regulatory agencies in Southeat Asia are considered as semi-independent or having no independence. This is because most of these agencies remain attached to other agencies that promote the utilisation of radioactive material and nuclear energy. Some of the regulatory bodies are even users of radioactive material [1,3]. There is no clear separation of promotional and regulatory activities within the same regulatory body. One reason why regulatory independence is not being pursued is that some states consider close inter-agency cooperation, involving all concerned ministries and regulatory bodies, as far more important at this stage than having an independent regulator as they carefully study the introduction of nuclear power in the future [38]. Independent monitoring and inspections are a powerful tool for raising standards of security culture and safety culture and instilling professional discipline among licensees.

But beyond the issue of independence is the lack of human resource capacity hampering the development of safety culture and

security culture even in regulatory bodies. With no clear national direction on the future of nuclear energy, not many universities have established a specific programme on nuclear sciences and nuclear engineering [3,43]. In Vietnam, for instance, the regulatory body and other nuclear research agencies lack the necessary skilled human resources including experts on organisational culture. It requires competent experts with the necessary educational background in behavioral and social sciences and a specialisation in nuclear technology and operation, human and organisational factors, and safety culture assessment [39]. An IAEA peer-review mission in 2014 also found no evidence demonstrating a systematic approach for introducing a safety culture and a security culture (i.e. checklists, reports, inspections, action plans, outreach activities, etc.) by the Vietnamese regulatory body [37]. As brought out in the expert roundtable discussions, across Southeast Asia, key challenges to nuclear safety and security include the lack of funding support to implement capacity-building projects, varying degrees of knowledge and expertise among ASEAN member States, lack of well-trained staff and infrastructure, and weak commitment from policymakers down to the technical staff [1,2]. All of which may have an impact on how nuclear safety-security culture is cultivated in Southeast Asia. Some Southeast Asian countries, such as Malaysia, the Philippines, Vietnam, Indonesia, and Thailand, have more advanced technical expertise and their regulatory bodies can still organise workshops on safety-security cultures for their licensees, despite limited human resources. However, there are also a few states in the region, such as Myanmar, Laos and Cambodia, that have less organised regulatory body infrastructure and capacity [1]. This capacity gap in the region can be filled in by regional cooperation and capacity building assistance among Southeast Asian states.

4.3. Enhancing regional cooperation

In Southeast Asia, the ASEAN Network of Regulatory Bodies on Atomic Energy (ASEANTOM) has been facilitating regional cooperation on civilian nuclear energy capacity-building among Southeast Asian countries. Since its first meeting in 2013, ASEANTOM has been addressing key challenges to nuclear safety and security mentioned earlier. ASEANTOM facilitates sharing of best practices and experiences, helping Southeast Asian countries in enhancing their regulatory frameworks, and capacity building through training courses and technical collaboration with other international organisations such as the IAEA and European Commission. In order to address varying degrees of human resource capacity in Southeast Asia, ASEANTOM conducts expert missions/exchange programmes, workshops, and technical cooperation projects with international organisations [1,2,38].

One expert from ASEANTOM participaing in the 2017 roundtable discussion provided concrete examples of these activities. ASEANTOM has been directly assisting Laos which does not have enough well-trained staff and regulatory infrastructure, especially for the regulation of radioactive materials, through the initiative of its neighbor Thailand. In 2017, ASEANTOM launched the *Lao PDR-Thailand Technical Cooperation Workshop on Strengthening Capacity-Building on Radiation Safety and Radioactive Measurement and Monitoring in the Environment*. It entails on-site training and expert missions by Thailand's regulatory body to help Laos establish its own regulatory infrastructure. ASEANTOM also organises annually the *Regional Workshop on Capacity-Building and Strengthening the Nuclear and Radiation Safety and Security Network in the ASEAN Region*, which includes 130 participants and experts from ASEAN member states, South Korea, Japan and Taiwan [1].

Furthermore, it was also underscored in the expert group discussions that global and regional institutions provide technical and funding assistance to ASEANTOM to capacitate the regional organisation to assist its members. For instance, ASEANTOM and the IAEA co-organise workshops, training courses, expert missions, and meetings under the *Technical Cooperation Project on Supporting Regional Nuclear Emergency Preparedness and Response in the Member States of ASEAN Region*. ASEANTOM and the European Union (EU) jointly manage a capacity-building project entitled *Enhancing Emergency Preparedness and Response in ASEAN: Technical Support for Decision Making*. These regional projects are aimed at enhancing the quality and coherence of decision-making within ASEAN following a radiological or nuclear emergency [1]. ASEANTOM's regional projects and initiatives can therefore help promote nuclear safety culture and security culture in Southeast Asian states.

4.4. Lack of COEs and training support centres

Apart from regional bodies such as the ASEANTOM, COEs and training support centres play a key role for global nuclear security and safety architecture. As demonstrated in Northeast Asian countries, COEs can provide the much needed human resource practical training and promoting nuclear security culture and safety culture. Southeast Asian states should emulate this good practice and increase the number of COEs in the region dedicated to safety-security cultures. In the context of security culture, however, only a few Southeast Asian countries such as Indonesia, Thailand and Malaysia have established nuclear security support centres of excellence that can provide holistic education and training for radiation workers, researchers, hospital staff and industrial workers, as pointed out in the 2017 expert group discussion [1]. Indonesia appears to have the most significant progress in the region in terms of promoting a nuclear security culture. Leading the promotion of a security culture is BATAN's Centre for Security Culture and Assessment which was established in 2014. The self-assessment pilot project of the Centre has yielded significant and tangible results for BATAN. It offered not only an assessment of the status of security culture at three research reactors, but also a learning experience for management and the workforce of BATAN to identify gaps and improve their security culture [40]. But one significant gap is the need to expand security culture self-assessment training to hospitals, industrial facilities, and other stakeholders that utilise radioactive material, apart from the government's research reactors.

Complementing the work of CSCA is the Indonesia- Centre of Excellence on Nuclear Security and Emergency Preparedness (I-CONSEP), serving as the nuclear security support and training center to facilitate the development of human resources and the provision of support services for nuclear security and emergency preparedness. One of its priority areas is the development of a nuclear safety culture and a security culture through its training, awareness and educational activities for frontline officers, emergency responders, security officials and border officers ([2,41]. These concrete examples of evidence accentuate that with the establishment of these two specialised centres, Indonesia recognises the importance of sustainable efforts to achieve an effective nuclear safety and security regime, with safety-security cultures as essential elements.

Another significant gap is the lack of nuclear training COEs in other Southeast Asian countries. As shown in Table 5, with the exception of Malaysia and Indonesia, there are no dedicated COEs for nuclear security in other ASEAN Member States. It would be more difficult to inculcate a security culture without a nuclear security support centre/COE. Table 6 enumerates COEs that have been established in the region and identifies their primary activities on nuclear security culture. It also contains COEs that are planned to be

Table 6
Centres of excellence on nuclear security in Southeast Asia.

Country	Centre of excellence	Supervising government bodies	Year of establishment	Primary activities
Indonesia	Centre for Security Culture and Assessment	National Nuclear Energy Agency (BATAN)	2014	Conducts nuclear security culture assessment, security trainings and exercises
	Indonesia Center of Excellence on Nuclear Security and Emergency Preparedness (I-CoNSEP)	Nuclear Energy Regulatory Agency (BAPETEN)	2014	Provides policy, technical and scientific support to nuclear security; facilitates nuclear emergency response coordination and capacity-building; promotes regional collaboration
Malaysia	Nuclear Security Support Centre (NSSC)	Atomic Energy Licensing Board	Recognised by the IAEA in 2012	Conducts trainings on nuclear security for law enforcers; shares Malaysia's experiences and best practices with countries in the region
The Philippines	Planned but not yet established	Philippine Nuclear Research Institute	N/A	N/A
Vietnam	Planned but not yet established	Vietnam Agency for Radiation and Nuclear Safety	N/A	N/A
Thailand	Under Consideration	Office of Atoms for Peace (OAP), International Law Enforcement Academy Bangkok (ILEA), in collaboration with Chulalongkorn University	N/A	N/A

Sources: [1,42]

created by selected Southeast Asian counties.

Majority of Southeast Asian countries should therefore consider setting up their national COEs that are mainly dedicated to fostering a safety culture and a security culture. Furthermore, a potential network of COEs in Southeast Asia can complement the work of ASEANTOM in terms of sharing good practices, resources, expertise and information. It would definitely help deepen cooperation on safety-security cultures in Southeast Asia and institutionalise collaboration with the COEs of Northeast Asia. COEs and nuclear training centres signify a bright future for nuclear security and safety education in East Asia, a region that will definitely need significant capacity building in the coming decades.

5. Conclusion

Promoting a nuclear security culture, together with a nuclear safety culture, is becoming more relevant in Southeast Asia in view of long-term plans by several Southeast Asian states to build NPPs and recent incidents of missing radioactive sources in the region. The development of robust nuclear security capabilities in Southeast Asia is critical to prevent malicious actors from getting access to nuclear facilities and radioactive materials. Despite the robust regional cooperation on nuclear security and safety, one evident shortcoming of nuclear energy governance in Southeast Asia is weak nuclear security culture and safety culture, highlighting the importance of human factors, such as attitudes, awareness and behaviours. Nuclear power and utilisation of radioactive material for non-power applications do not merely involve technological aspects. Human errors such as complacency and the lack of critical thinking play a role in most reported incidents, including cases of loss and theft of radioactive materials. In this regard, Southeast Asian states can learn valuable lessons from the experiences and best practices of China, Japan and South Korea on promoting and institutionalising a safety culture and a security culture. Three major policy frameworks from Northeast Asia can be emulated by Southeast Asia to foster strong safety-security cultures: (1) a comprehensive nuclear policy framework covering both technical and human factors; (2) a proactive and independent regulatory body; and the (3) establishment of nuclear training and support centres/COEs.

As seen from Southeast Asian countries, policy frameworks on safety-security cultures remain fragmented or non-existent. The establishment of more national security culture centres/COEs in

ASEAN member states should also be considered. Holistic nuclear education and training activities that include safety-security cultures are still lacking in many Southeast Asian states. It is recommended to complement regional technical training workshops with robust training activities on strengthening human factors–safety culture and security culture. With the transboundary risks of nuclear accidents, radiological emergencies or stolen radioactive materials ever present, it is glaringly urgent that Southeast Asian states apply the lessons from Northeast Asia by collectively building the necessary skills and mindsets that will discourage complacency and promote critical thinking in using nuclear energy.

Declaration of interest

None.

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