Methodological Review of Malaysia’s Energy Security Measurement: A Systems Approach using Stakeholder Engagement

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Abstract. This study considers the analysis of Malaysia’s Energy Security (ES) using a mixed-method of inquiry. A combination of qualitative and quantitative methods known as the ‘triangulation of methods’ was used to build a solid understanding of ES from the standpoint of Malaysia within the Association of Southeast Asian Nations (ASEAN). Qualitative data were collected from 16 stakeholders and experts in the field of energy security and sustainability from Malaysia and the ASEAN region using semi-structured interviews (SSI). These data were coded using grounded theory (GT) that follows emerging coding techniques to allow for emerging ES themes to develop, hence creating our ES framework, used as the basis for a systems approach – quantitative research on ES. Quantitative data were collected from energy reports and statistics published by ministries, agencies, and relevant departments in Malaysia and ASEAN. The dimensional indicators identified from the ES framework are causally-linked using system dynamics (SD) modelling, underpinned by systems thinking, where SD models are designed and simulated to yield meaningful insights on Malaysia’s energy security for future policy recommendations. This mixed-method approach has enabled our futuring research through the modelling of scenarios to inform policy-making within the contexts of the problem space.

1. Introduction

This study aims to address how the combination of qualitative and quantitative data analysis can be used in ES research to utilize the best of both approaches in consolidating the concept of ES and its impact on any country as a whole. The combination of different methods to study the same concept is called ‘Triangulation’ of methods [1]. The combination of qualitative and quantitative data is actively debated [2] yet it is one of the most effective ways to validate the results generated using each method. The mixed-method approach has not been studied and practiced widely for energy research and ES specifically. ES is a complex phenomenon comprised of several dimensions. Hence, studying ES is not straightforward when it comes to a single method of research, either qualitative or quantitative solely. A combination of both methods gives the research an edge over single methods because...
qualitative data from stakeholder discusses the causal relation between ES dimensional indicators while quantitative analysis using system dynamics gives quantitative results in the graphical form of these dimensions to understand the extent to which they are affected. This is a combination of methods that have not been practiced widely in the field of ES hence giving a good opportunity to explore these methods followed in this research. The methods have been discussed in depth in this study and explained step by step to understand the flow in section 3. The advantages of this mixed-method should outweigh the limitations given that the researcher has ample time to carry out the research. This research approach has the scope of exploring similar fields of research for social studies and engineering research and is an example of how social research can blend in the field of energy engineering.

The study has been structured into 4 phases including, a literature review of ES (phase 1), interview and stakeholder engagement (qualitative data analysis, phase 2), SD modelling and simulation (quantitative data analysis, phase 3), and validation (phase 4). Phase 2 cannot be designed and conducted without prior knowledge of phase 1 and similarly, phase 3 cannot be designed unless the ES framework is established in phase 2. Qualitative data validate the quantitative model that has been built in phase 3, hence proving that triangulation is important for convergent validation [1].

2. Literature Review
This section of the study emphasizes understanding the two key aspects of the research i.e. ES and the mixed-method approach taken to quantify ES for Malaysia. A brief history of the mixed-methods and their origin alongside the different dimensional definitions of ES have been discussed here. It is important to understand them to be able to analyse ES in-depth and to learn the different approaches taken in order to do so.

2.1. Understanding Energy Security
ES is a phenomenon that can be drawn back to as early as the stone age roughly 2000 years ago where the need for flammable materials like wood was important to make a living. A stable and adequate supply of these would lead to a stable ES for the livelihood [3]. ES has been defined concerning its dimensions like affordability, acceptability, availability, accessibility, environmental sustainability, economic aspects, political aspects, and more. International Energy Agency (IEA) has defined ES as “the uninterrupted availability of energy sources at an affordable price” [4]. This is a simplified definition of what can be more complex like “continuity of energy supplies relative to demand” [5], “the continuity of specific commodity or service supplies, or the impact of supply discontinuities on the continuity of the economy” [5] and “feature (measure, situation, or status) in which a related system functions optimally and sustainably in all its dimensions, freely from any threats” [6]. The definitions in different research reflect upon the complexity of the term ES and hence the mixed-method approach in this study is recruited to breakdown the concept into smaller dimensions and understand them in depth.

2.2. Understanding the Mixed-method approach
Mixed-method approaches began as early as 1985 and are an Anglo-American invention primarily as popularised by writers like Greene from the USA and Bryman from England [7]. On the other hand, ‘Triangulation’ is the term defined by Denzin, 1978 as the combination of different methods to study the same phenomenon [1]. Denzin, 2012 in [8] have referred to triangulation as ‘looking through a crystal’ to perceive all the viewpoint of the data. Triangulation is considered to be beneficial compared to the singular method because it allows a more holistic and contextual portrayal of the phenomenon under study [1]. In this field of research, it helps to validate the results to ensure that the variance reflected that of the trait and not the methods as stated by [9] [1]. The key assumption made in triangulation is that the weaknesses of each of the single methods are compensated by the strengths of the other and vice versa [1]. Mixed method research with triangulation as the metaphor has been
proven to help researchers get clarity over theoretical propositions and to bridge the gap between theoretical and empirical findings and develop new theory according to study [2]. This study aims to motivate the practice of mixed-methods and triangulation in the ES research as it can be beneficial for policy suggestions by quantifying the variables of ES from the qualitative data for Malaysia and ASEAN countries. It is equally challenging to understand how to mix the methods to achieve the best out of each of the singular methods used. There are ‘convergent mixed method design’ which allows comparing the results of both databases enabling us to understand them better, while there is ‘explanatory sequential design’ where data is collected first using a certain instrument to understand it and then followed up by another method or instrument to further enhance the data collection [7]. This research has integrated the use of semi-structured interviews of qualitative data collection with the system dynamics approach of modelling these data using Vensim as the tool to quantify the dimensional indicators or the variables to quantify ES for Malaysia. This can fall in the category of ‘exploratory sequential design’ of mixed-method where qualitative data collection is done after analysing the literature followed by a quantitative method of system dynamics approach based on the qualitative data that generates the ES framework.

3. A detailed explanation of the mixed-method approach

The development of a framework based on the qualitative data analysis from stakeholder engagements and literature and creating a quantitative system dynamics model to quantify ES are two key research objectives that we are aiming to achieve using these mixed methods. A measurement system is to be established to quantify the current and future ES of Malaysia using its dimensional indicators. These dimensional indicators are identified using the ES framework created from the qualitative data from stakeholder engagement. Four phases have been planned out for this research which has been discussed in detail in this section of the paper.

3.1. Stakeholder Engagement

In this research, data collection plays a very crucial role in fulfilling the research objectives, and hence data collection is done with utmost importance and care. The data collection for this research follows the steps as shown below in Table 1.

| Sampling                  | Instrument/Tool                        | Data collection procedure                      |
|--------------------------|----------------------------------------|------------------------------------------------|
| Selection of Stakeholders and Interviewees from government organizations, private sector, and research institutes | Designing Semi-Structured Questions for Interview of stakeholder | Conducting Semi-Structured Interviews
- Face-to-face
- Video Call with researchers abroad |
|                          | Collecting quantitative data from energy reports and statistics of Malaysian ministries and energy agencies published online. | Transcribing the recorded interviews |

Table 1. Stages of Data Collection

Qualitative data is collected from stakeholders in the form of a semi-structured interview. The qualitative data collection is used to create the framework of ES which is based on the important dimensions and their respective indicators for ES of Malaysia. This framework lays the structure and base for the creation of the SD model which generates quantitative results. The quantitative data is solely collected for Malaysia and other ASEAN countries from energy reports published by the energy regulatory bodies. These data are used in the system dynamics model to generate quantitative results.
The qualitative approach allows us to understand the reasons, opinions, and motivations of ES of Malaysia and its impact. This understanding comes from Phase 1 of the research where qualitative research has been done on ES of Malaysia and researchers have shared their perspective of ES. A quantitative approach is important here because of the availability of historical data and documentation of the values of the energy security indicators. Further analysis of historical data tends to give an insight into how the future of these indicators might shape. Although, several external factors do not necessarily let the historical data to be repeated in the upcoming years. This is where analytical skills are needed to understand each indicator well and expert opinion becomes valuable. Interview of experts i.e. stakeholders as mentioned in phases 2 and 4 is of utmost importance to this research as it adds value and justification to the qualitative research done so far as well as verify and validate the quantitative research that has been done in this study.

The addition of Quantitative research to the existing work will quantify the problem with the addition of CLD’s, SFD’s, and numerical values and data. The numerical results are easier to analyse and give a clear concept of ES current and future scenarios for Malaysia. Once the quantitative data is collected alongside the qualitative data from stakeholder engagement, they are used in combination with phase 3 of the research where the SD model is created. Post simulation of the SFD’s, the results were validated and verified through a second meeting with the same set of stakeholders who have given their feedback on the ES framework and the SD model results that are generated.

The advantages of using both approaches are valuable for this research. There is methodological flexibility in this mixed-method as it combines the best of two approaches to collect high quality and more comprehensive data through the integration of the two [10]. The mixed-method also allows the participants to share their points of view and opinions that are recorded alongside the quantitative data. The stakeholder opinions and views in the current research add more insight into the historical data collected from documents and existing energy policies. Despite having these advantages, this approach does have a few drawbacks and limitations. This can be time-consuming as an integration of both approaches will require time and labour to bring all the resources together. It can be complex and requires systematic planning to select the sample and collect data from the stakeholders of this research. Quantifying a term like ES comes with its own challenges as there are several variables linked to each other with causal relation and factors like time delay and intervening factors that change from time to time.

### 3.1.1. Stakeholder Selection and Justification

The samples for the interview in this study is very selective and targeted towards the ministries, government agencies, research institutes, and private organization who work directly working with ES policies and dimensions. There is a certain limitation to the number of stakeholders that can be engaged due to the filtering process used as shown in Figure 1. Also, keeping in consideration that the entire process of data collection has been done by a single researcher[11] and facing time constraints, the selected number of stakeholders are considered sufficient to get emerging themes as outputs from the semi-structured interviews (SSI). The sample size in the Grounded Theory (GT) approach of coding also depends on data saturation. Data saturation is critical to qualitative results as failure to reach saturation can hamper the quality and validity of data [8]. There is no “one-size-fits-all” method to data saturation because of the differences in study design depending on whether it is ethnography, meta-analysis, or phenomenological study [8]. The uniqueness of each study requires the researchers to determine how much data is enough for analysis, depending on when no new theme, no new data, and the concept are generated from the data been collected. Data triangulation and data saturation are dependent on each other in the way that one ensures the other [8]. The triangulation of different methods ensures that data saturation is reached [8]. In this research, 16 stakeholders were interviewed in total. The first 10 stakeholder interviews led to generating new themes in higher frequency and number. After 10 interviews, lesser themes started to emerge out of the data coded using the GT approach. As the GT approach follows emergent coding,
every possible chance of finding new themes was explored in this study until no new themes could be found from the transcripts of SSI. Hence, a sample size of 16 is considered to be sufficient to do the thematic analysis of the qualitative data that is collected for designing the ES framework of Malaysia. Phase 2 and 4 of this research requires the strong engagement of the stakeholder for justifying the literature and data collected and at the same time to validate and verify the CLD’s and SFD’s that are created. There are few criteria to be fulfilled by the stakeholders for their successful selection as shown in Figure 1.

3.1.2. Designing the research instrument. Interviewing the stakeholder to gain further knowledge which is otherwise not available in literature adds value to the research beyond the literature. The purpose of the semi-structured questions is to know the opinion and their expert advice on the current ES scenario with ways to improve them and new policy suggestions. To understand the definition, the dimensions, and the key indicators that are involved in Malaysian ES it is important to blend the data of literature and the in-depth qualitative data collected from the SSI’s. The design of the SSI questions is based on current literature and as per the requirement of the research objectives. The questions are designed with the primary aim to answer the research questions and to work well with the proposed method of data analysis, in this case, a GT approach. According to the study of [12], there are important steps to be followed in designing the semi-structured interview questions. According to Charmaz in [13], it is very important to frame the correct questions and requires skills that a researcher can develop as he/she continues to carry out more interviews on different topics. The questions must explore the interview topic and fit the participant's experience [13]. Charmaz explains in-depth how questions are to be framed and how to conduct interviews to extract the best possible outputs from the participants [13] and these steps have been followed very closely to design this study. The questions used in stakeholder data collection are listed below in Table 2 but are not just limited to these questions. Follow up questions based on where the interviewee answers lead is very important. The questions designed for this research are flexible and allows the interviewee to answer them with their own perspective and, hence sharing their experience. According to Creswell in the book “Research
Design” the author has urged to ensure that the questions are designed to keep the interviewee on focus with the context of the question.

Table 2. Stakeholder Interview Questions

| Stakeholder interview questions |
|--------------------------------|
| 1 | How would you define Energy security? |
| 2 | Why is it important for us to address Energy Security challenges and their impacts? |
| 3 | Is there any specific energy policy that addresses the Energy Security of your country? What more can be added to the existing policies? |
| 4 | Socio-economy, Environmental Sustainability, and Energy Availability are listed as 3 key dimensions of Energy security in this research. Is there any other dimension that can be added and why? |
| 5 | Can you suggest ways to improve the Energy Security scenario and tackle the challenges of Malaysia and other ASEAN countries? |
| 6 | This research uses Systems thinking as an approach and System Dynamics as a tool to develop the causal relation of the indicators. What are your thoughts on this approach and what are your suggestions? |

3.1.3. Semi-Structured Interview (SSI). SSI is the qualitative method of data collection that has been adopted for this research through the use of semi-structured questions that have been tabulated in Table 2. These are open-ended questions with a designed structure that allows the interviewee to express their opinion within the context of it. This also gives the flexibility to the interviewer to ask questions that can be answered in several ways varying with different individuals and allows the interviewee to express his opinion more openly on the topic of discussion or phenomenon. SSI’s allows interviewers to be well prepared ahead of time and also allow the interviewer to express his opinions during the interview [14]. This method is used to extract rich descriptive data from personal experiences and to ascertain participants’ perspectives regarding an experience pertaining to the research topic [15]. The SSIs of this research are recorded with the consent of the participants to generate intelligent verbatim transcripts that are analysed using the software ‘Quirkos’ which gives a richer insight into the data that has been collected through these SSIs. Stakeholders abroad are contacted through video calls and SSI’s have been conducted over the video call [16]. This is an easier, cost-effective, and convenient option to conduct one-on-one interviews with the stakeholders who are not residing in Malaysia. The SSIs in this research aims to collect data from the stakeholders and experts on their opinion and thoughts on ES, ES issues and challenges, the current and future policies to address ES, and the causal relations between the dimensional indicators of ES for Malaysia. The stakeholders are expected to put forward their opinions and views on each of these questions which are to be analysed and compared with all the participants. The construction of SSI follows certain steps according to the research by [12] [15] which have been followed in this study to
maximize the output of these interviews. The systematic approach is as shown below adapted from the studies.

- Identifying the domain of the topic
- Identifying the categories
- Identifying the items
- Writing the question stems
- Piloting the interview schedule
- Testing

3.1.4. Grounded Theory Approach for Qualitative Data Analysis. Grounded theory (GT) is the approach taken in this research to understand and analyse the data that has been collected through the detailed process as explained in section 3.1.2 and 3.1.3. This is an inductive approach of concluding theories and frameworks from observations which in this case is from the data collected and recorded from the stakeholders through semi-structured interviews. The GT follows the inductive approach as shown by Charmaz in [17].

![Figure 2. The inductive approach of grounded theory](image)

Figure 2 summarises how the GT approach works from recording observation to finding patterns in the observation that leads to a tentative hypothesis and hence a theory which in this case is the framework created for ES of Malaysia using the hypothesis and theory formed. GT is considered to be inherently flexible yet a complex methodology to be carried out according to the study in [18].

![Figure 3. The process as explained by Charmaz [17]](image)

Figure 3 shows the iterative and simultaneous process of data collection and coding as explained by Charmaz. These steps are followed in the research to code the collected data through SSI and analyse them using grounded theory. In this research, the GT approach follows emergent coding where the
codes emerge as we read the text and also a bit of structural coding where there is a preconceived notion of what is absolutely necessary to code according to ES of Malaysia and ASEAN countries. This combination of emergent coding with structural coding makes it the best approach to analyse the SSI data collected. Once, the sample size is determined and data is collected the data preparation stage begins. In this stage, the data collected is transcribed using an intelligent verbatim transcription method and read through thoroughly before coding can begin. The constructivist approach of coding is followed by Charmaz [13]. The constructivist approach of the GT follows mostly two stages of coding: first is initial coding followed by focused coding. Initial coding is done by the following line by line coding and reading the fragments of the texts and coding them as we read through for the analytical import. Focused coding is where the most appropriate and relevant codes are picked from the initial code where data with data is compared and then data with codes. This is also known as the constant comparative analysis [18] where new concepts are generated through constant comparison of incidents in a category with other incidents and further categories with other categories.

3.1.5. Quantitative Data Collection. Quantitative data can be usually collected using multiple techniques such as questionnaire surveys with scales like nominal scales, interval scales, and ratio scales [14]. The quantitative data collection process is more structured than qualitative data collection and it only allows the participants to answer what is required. The quantitative data used in this study is collected from published energy reports and statistics by the ministry of energy and natural resources of Malaysia and other energy agencies like the energy commission, Sustainable energy development authority (SEDA), and International energy agency (IEA), ASEAN centre for energy (ACE) in publications like [19] [20] [21] [22] [23] [24]. These are secondary data that are readily available in the public domain and are easily accessible. The advantage of using secondary data from these sources is that they are highly validated as they are published by government bodies of Malaysia and ASEAN countries and data are available in large quantity and requires no cost to obtain them. Much of the background work of literature review, case studies, published texts, and statistics are already carried out in secondary data [14]. Hence, the collection of these secondary data is relatively an easier process for this study, and which does not require much time and effort. The only aspect to be taken care of is the reliability of the source from which the data is collected, which in this study is well taken care of since data comes from government agencies, ministries, and energy research institutes.

3.2. System Dynamics Modelling using Vensim

Systems thinking is used to provide us with a tool to better understand difficult problems [25]. System dynamics is a methodology of systems thinking which is used to understand and model complex systems [26]. The use of system dynamics is a key part of this research where causal loop diagrams (CLD’s) and stock and flow diagrams (SFD’s) are created through Vensim and they are simulated to quantify the dimensional indicators of ES for Malaysia as stated in the framework of ES created. CLD’s are created by understanding and developing a causal relationship between the dimensional indicators which are the variables. This understanding comes from the ES framework created using the qualitative and quantitative data collected.

3.2.1. Causal Loop Diagrams. Causal loop diagrams are visual aids that help understand how different variables in a system are interrelated. A positive sign represents a positive relation and vice versa for a negative sign. A positive relation means, an increase in one variable will lead to an increase in the next if they are related by ‘+’ sign or a decrease in the previous will lead to a decrease in the next variable. A ‘-’ sign indicates that there will be a change in the opposite direction compared to the previous variable. CLD’s can form closed cycles which form either a balancing loop or a reinforcing loop. In a balancing loop if a variable increase, the cycle will lead to a decrease in the same variable and vice versa. In a reinforcing loop, the increase in a variable would further lead to more increase in
the same variable as a result of the effect in the cycle. CLD’s also have ‘delays’ in their loops which is used in cases where time is consumed before the effect plays out.

3.2.2. Stock and Flow Diagrams. Stocks are fundamental to generate behaviour in the system. They determine the current state of the system [27]. Stocks can be measured at one instant at a time and can only be changed by flows in and out of the system. Flows are expressed per unit time which means it measures over a period. All the causal loop must involve at least one stock, without which the loop becomes instantaneous. Auxiliary variables influence stocks but adding or removing an auxiliary variable does not change the mathematical structure of the system [27]. An example of SFD from this research is shown below in Figure 4.

![Figure 4. SFD of production to reserve ratio, imported energy, and short-term ES](image)

3.2.3. Equations for Stocks and Flows. To quantitatively model any process there needs to be quantitative values and equations which define each of the variables and their flows. There are two assumptions according to the study of (Morecroft and Sterman 1994) which are; (1) flows within processes are continuous, and (2) flow do not have a random component [25]. Keeping these two assumptions in mind we can consider any stock and flow system to be like a ‘plumbing system’ where the stock is the tank and the flows are the valves that control the rate of flow in and out of the tank. The initial value of each stock and the equation of flow is needed to be set. These equations lead to the solving of the model in Vensim and hence generating a graphical representation of how the change takes place over time.

4. Discussion

4.1. Contribution to mixed-method studies and advantages of this approach

The triangulation of two or more methods has been rare in the field of ES research. It leaves a gap for researchers to fill because triangulation as discussed in sections 2 and 3 gives a wider scope to broaden the knowledge and dig deeper into the variables and reasonings that are directly or indirectly related to ES of Malaysia and ASEAN countries. The mixed-method approach taken in this study combines SSI’s for qualitative data collection and GT approach for analysis along with systems thinking and system dynamics approach to model these data to quantify them is unique on its own. This combination of methods to collect data and analyse them leaves a lesser gap in the knowledge in the field of ES as you can visualise data from different aspects and dimensions. This approach involves a lot of rigor in the field of research hence solidifying the dimensions and variables of ES and their causal relationship between each other. This set of methods gives the freedom to the researchers to model their qualitative data along with quantitative data collected. Modelling of these data using systems approach makes room for futuristic prediction of scenarios for ES of Malaysia in this study which may benefit the policymakers to take note of future policy design for ES. Previously, there have been either pure qualitative or quantitative analysis of ES of different countries or even regions of the world. Systems thinking adds depth to these qualitative and quantitative data by creating the links
between the dimensions and their variables of ES. There are benefits of using these methods individually but when combined the results generated for this study become more valuable and in-depth. The value lies in the fact that the ES framework followed by the ES model created in Vensim is validated by the qualitative data of the expert in phase 2. The phase 4 engagement of stakeholders work as the validation stage of the research. The results of this study validated by stakeholders give this kind of study the added value in terms of implementation in the future in its respective field. This study should encourage the use of this mixed-method approach widely in social science and engineering research as it possesses a lot of benefits in terms of quality and adding depth to the data has been analysed.

4.2. Limitations of this approach
Like any mixed-method research, this approach also has its limitations. Firstly, this research involves two stages of stakeholder engagement. Studies like this involving stakeholder engagement in two phases (phases 2 and 4) can be lengthy in duration and time-consuming. The process of selecting stakeholders, connecting to them, and getting approval to interview them can be time-consuming. The transcription of the recorded data and emergent coding using the GT approach can be time-consuming as well. Systems thinking and modelling involve creating a relation between the variables found from the qualitative data. This entire process can be tedious for an individual researcher and involves rigor. As it is an ‘exploratory sequential design’ study, it involves a systemic procedure to be followed and needs to go through the sequence which cannot be disrupted. There are limitations in the system dynamics approach of modelling these variables as these variables and their relationships with each other can take drastic turns depending on various factors like geopolitics, socio-economy, environmental disaster, or any form of a global pandemic affecting the economy, infrastructure, and environment as a whole. The process is dynamic, which changes with time and hence needs to be updated frequently to represent the ES scenarios that are relevant to date. Systems thinking also involves one’s perception of the qualitative data and how the researcher develops the connection between the variables. It does not necessarily have to be the same as any other researcher and can vary depending on the researcher’s perception of a certain ES scenario.

5. Conclusion
The contribution of this study is in encouraging the use of a mixed-method approach for analysing ES of Malaysia and neighbouring ASEAN countries. Triangulation of different methods is encouraged in this study to analyse ES, which is a complex problem transcending multiple disciplines. The advantages of this mixed-method outweigh its limitations as there is value to build a transdisciplinary team to work on a complex problem project like this as each person in the team contributes knowledge, skills and practices in curating a new way of working. Also, the fact that data coding using the GT method of emerging coding can be cross-verified between the researchers and to avoid bias towards certain data and negligence towards certain data too. The advantage of adopting the triangulation of methods from this study has been the fact that ES of Malaysia and ASEAN countries can be looked upon from different angles and perspectives as it involves secondary data from literature combined with more consolidated primary data from stakeholders. Collectively, these data are analysed using system dynamics which bridges the links between the variables and their dimensions overall. The simulation of the model gives a graphical representation of future results for respective variables which can be very handy in policy-making for ES of Malaysia. This method also enables the researchers to understand the crucial relationship between dimensions that would otherwise be neglected while analysing a tricky topic like ES. It gives us the confidence that this mixed-method approach is feasible to develop a critical relation between ES dimensions which otherwise is challenging. This mixed-method approach has the scope of exploring topics like this in the field of energy engineering in local community scale or larger scale in the country or a region.
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